



**REPUBLIC OF KENYA**

**LEARNING GUIDE**

**FOR  
ELECTRICAL INSTALLATION**

**LEVEL 5**



**TVET CDACC  
P.O. BOX 15745-00100  
NAIROBI**

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**Council Secretary/CEO**  
**TVET Curriculum Development, Assessment and Certification Council**  
**P.O. Box 15745–00100**  
**Nairobi, Kenya**  
**Email: [info@tvetcdacc.go.ke](mailto:info@tvetcdacc.go.ke)**  
**Website: [www.tvetcdacc.go.ke](http://www.tvetcdacc.go.ke)**

easytvet.com

## **FOREWORD**

The provision of quality education and training is fundamental to the Government's overall strategy for social economic development. Quality education and training will contribute to achievement of Kenya's development blue print and sustainable development goals. Reforms in education are necessary to align the sector to the provisions of the Constitution of Kenya 2010. This triggered the formulation of the Policy Framework on "Reforming Education and Training in Kenya" (Sessional Paper No. 1 of 2019). A key provision of this policy is the radical change in the design, development and delivery of Technical and Vocational Education and Training (TVET) which is the key to unlocking the country's potential for industrialization. This policy requires that training in TVET be Competency Based, Curriculum development be industry led, certification be based on demonstration of competence and that mode of delivery allows for multiple entry and exit in TVET programs.

The State Department for Vocational and Technical Training (VTT) has a responsibility of facilitating the process of inculcating knowledge, skills and attitudes necessary for catapulting the nation to a globally competitive country, hence the paradigm shift to embrace Competency Based Education and Training (CBET) to address the mismatch between skills acquired through training and skills needed by industry as well as increase the global competitiveness of Kenyan labor force. The Technical and Vocational Education and Training Act No. 29 of 2013 and the Sessional Paper No. 1 of 2019 on Reforming Education and Training in Kenya, emphasizes the need to reform curriculum development, assessment and certification to respond to the unique needs of the industry.

This learning guide has been developed to support the implementation of CBET curriculum in Electrical Installation Level 5 and is intended to guide the trainee through the learning process. It is my conviction that this learning guide will play a critical role towards supporting the development of competent human resource for Engineering sector's growth and sustainable development.

**PRINCIPAL SECRETARY, VOCATIONAL AND TECHNICAL TRAINING  
MINISTRY OF EDUCATION**

## PREFACE

Kenya Vision 2030 is anticipated to transform the country into a newly industrializing, “middle-income country providing a high-quality life to all its citizens by the year 2030”. The Sustainable Development Goals (SDGs) number four that focuses on inclusive and equitable quality education and promotion of lifelong learning for all, further affirm that education and training is an important driver to economic development for any country. Kenya intends to create a globally competitive and adaptive human resource base to meet the requirements of a rapidly industrializing economy.

TVET CDACC has a responsibility of facilitating the process of inculcating knowledge, skills and attitudes necessary for catapulting the nation to a globally competitive country, hence the paradigm shift to embrace Competency Based Education and Training (CBET) to address the mismatch between skills acquired through training and skills needed by industry as well as increase the global competitiveness of Kenyan labor force. The Technical and Vocational Education and Training Act No. 29 of 2013 and the Sessional Paper No. 1 of 2019 on Reforming Education and Training in Kenya, emphasizes the need to reform curriculum development, assessment and certification to respond to the unique needs of the industry.

To effectively implement CBET curriculum in Electrical Installation Level 5 this learning guide has been designed and organized with clear interactive learning activities for each learning outcome of every unit of learning. The guide further provides information sheet, self-assessment items, tools, equipment, supplies, and materials necessary for the particular learning outcome. This is aimed at imparting the relevant knowledge, requisite skills and the right attitude for work.

I am grateful to the trainers involved in the development of this learning guide.

**Prof. CHARLES M. M. ONDIEKI, PhD, FIET (K), Con. Eng Tech.**  
**CHAIRMAN, TVET CDACC**

## **ACKNOWLEDGEMENT**

This learning guide has been designed and developed to support the implementation of Competency Based Education and Training (CBET) curricula in Kenya. The learning guide is intended to support learning by providing practical and theoretical learning activities, simplified content and self-assessment items to guide the trainee in the learning process.

I recognize with appreciation the critical role of trainers in developing this learning guide and ensuring its alignment with National Occupational Standards (OS) and CBET curriculum. I am convinced that this learning guide will support trainees' acquisition of knowledge, skills and right attitude needed for work in the Engineering sector.

**DR. LAWRENCE GUANTAI M'ITONGA, PhD**  
**COUNCIL SECRETARY/CEO**  
**TVET CDACC**

*easytvvet.com*

## ACRONYMNS AND ABBREVIATIONS

|         |  |
|---------|--|
| BS      | British standards  |
| CAD     | Computer Aided Design  |
| CBET    | Competency Based Education and Training                      |
| CCTV    | Closed Circuit Tele Vision                                   |
| CDACC   | Curriculum Development, Assessment and Certification Council |
| CEC     | County environmental committee                               |
| CPC     | Circuit protective conductors                                |
| EHS     | Environment Health and Safety                                |
| EIA     | Environmental impact assessment                              |
| EMCA    | Environment management and coordination Act                  |
| ERC     | Energy regulatory commission                                 |
| FEMA    | Forest conservation and management act                       |
| HVAC    | Heating Ventilation and Air Conditioning                     |
| IBMS    | Integrated Building Management System                        |
| IEE     | Institute of electrical engineers                            |
| IR      | Insulation resistance  |
| K.C.S.E | Kenya Certificate of Secondary Education                     |
| KEBS    | Kenya Bureau of Standards                                    |
| KNQA    | Kenya National Qualification Authority                       |
| NCA     | National Construction Authority                              |
| NEMA    | National Environment Management Authority                    |
| OSHA    | Occupational safety and health act                           |
| PPE     | Personal Protective Equipment                                |
| PV      | Photo Voltaic  |
| SELV    | Separated extra low voltage                                  |
| TVET    | Technical and Vocational Education and Training              |
| VT      | Visual Testing   |
| VTT     | Vocational and Technical Training                            |
| WIBA    | Work Injury Benefits Act                                     |
| WIBA    | Work injury benefits act                                     |

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## Background Information

This learning guide will enable the trainee to acquire competencies to undertake various processes in Electrical Installation. It provides practical and theoretical learning activities, simplified content, illustrations and self-assessment items to guide the trainee in the learning process. It also provides links and references for further reading.

## Layout of the Trainee Guide

**Performance standards:** These are obtained from the performance criteria statements in the related unit of competency of the Occupational Standards (OS).

**Information Sheet:** This section covers information relating to the specific learning outcome. This information should include but not limited to meaning of terms, methods, processes/ procedures/ guidelines, Illustrations (photographs, pictures, videos, charts, plans, digital content links, simulations links) and case studies. This section also provides additional information sources relevant to the learning outcome e.g., books, web links.

**Learning activities:** This section covers practical activities related to the Performance Criteria statements, Knowledge in relation to Performance Criteria as given under content in the curriculum Special instructions related to learning activities.

**Self-Assessment:** This section must be related to the Performance Criteria, Required Knowledge and Skills in the Occupational Standards. This section requires the trainee to evaluate their acquisition of skills, knowledge and attitude in relation to the learning outcome. A variety of assessment items such as written and practical tests which emphasizes on the application of knowledge, skills and attitude is recommended.

The self-assessment items should be valid, relevant and comprehensive to the level of qualification in the learning outcome.

**Tools, equipment, materials and supplies:** This section should provide for the requirements of the learning outcome in terms of tools, equipment, supplies and materials. The section should be adequate, relevant and comprehensive for the learning outcome.

**References:** Information sources should be quoted and presented as required in the APA format The units of learning covered in this learning guide are as presented in the table below:

**Table 1: Common Units of Learning**

| Unit Code           | Unit Title              |
|---------------------|-------------------------|
| ENG/CU/EI/CC/01/5/A | Engineering Mathematics |
|                     | Electrical Principles   |
| ENG/CU/EI/CC/02/5/A | Workshop Technology     |

|                     |                   |
|---------------------|-------------------|
| ENG/CU/EI/CC/03/5/A |                   |
| ENG/CU/EI/CC/04/5/A | Technical Drawing |

**Table 2: Core Units of Learning**

| <b>Unit Code</b>    | <b>Unit Title</b>                             |
|---------------------|---|
| ENG/CU/EI/CR/01/5/A | Electrical Installation Work Planning         |
| ENG/CU/EI/CR/02/5/A | Perform Electrical Installation               |
| ENG/CU/EI/CR/03/5/A | Testing of Electrical Installation            |
| ENG/CU/EI/CR/04/5/A | Electrical Installation Maintenance           |
| ENG/CU/EI/CR/05/5/A | Electrical Installation Breakdown Maintenance |

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## CHAPTER 1: ENGINEERING MATHEMATICS

Unit of learning code: ENG/CU/EI/CC/1/5

**Related Unit of Competency in Occupational Standard:** Apply Engineering Mathematics

### 1.1 Introduction to the unit of learning

This unit describes the competencies required by an automotive technician in order to apply engineering mathematics. It involves use concepts of arithmetic in solving work problems, applying algebra, applying trigonometry and hyperbolic functions, applying complex numbers, applying coordinate geometry, carrying out binomial expansion, applying calculus, solving ordinary differential equations, carrying out mensuration, applying power series, applying statistics, applying numerical methods, applying vector theory, applying matrix, solving partial differential equations, applying Laplace transforms and applying Fourier series.

### 1.2 Summary of Learning Outcomes

1. Use concepts of arithmetic in solving work problems
2. Use common formula and algebraic expressions for work
3. Use trigonometry to solve practical engineering problems
4. Perform estimations, measurements and calculations
5. Apply matrices in work
6. Apply vectors in work
7. Collect, organize and interpret statistical data
8. Apply concepts of probability for work
9. Perform commercial calculation

### Learning Outcome 1: Use Concepts of Arithmetic in Solving Work Problems

#### 1.2.1.1 Introduction to the Learning Outcome

This learning outcome covers algebra and the learner should be able to: carry out fundamental operations, addition, subtraction, multiplication and division of positive and negative numbers, fractions and decimals operations and conversions, indices, ratios and proportions,

#### 1.2.1.2 Performance Standard

- 1.2.1.2.1 Fundamental operations
- 1.2.1.2.2 Addition, subtraction, multiplication and division of positive and negative numbers
- 1.2.1.2.3 Fractions and decimals operations and conversions
- 1.2.1.2.4 Indices
- 1.2.1.2.5 Ratios and proportions
- 1.2.1.2.6 Meaning
- 1.2.1.2.7 Conversions into percentages
- 1.2.1.2.8 Direct and inverse proportions determination

### 1.2.1.2.9 Use of scientific calculator

#### 1.2.1.3 Information Sheet

##### Fundamental operations

Brackets and the precedence rules are used to remove ambiguity in a calculation. In any calculation involving all four arithmetic operations as we proceed follows:

- a. Working from the left evaluate divisions and multiplications as they are encountered

This leaves a calculation involving just addition and subtraction.

- b. Working from the left evaluate additions and subtraction as they are

The four basic arithmetic operations are: addition and subtraction, multiplication and division

The order of precedence of operations for problems containing fractions is the same as that for integers, i.e. remembered by BODMAS (Brackets, Of, Division, Multiplication, Addition and Subtraction).

##### Rules that govern basic laws of arithmetic:

###### 1. Commutativity

Two integers can be added or multiplied in either order without affecting the result. For example:

$$5 + 8 = 8 + 5 = 13 \text{ and } 5 \times 8 = 8 \times 5 = 40$$

Addition and multiplication are commutative operations, whereas subtraction and division are not commutative operations.

$$4 - 2 \neq 2 - 4 \text{ as } 4 - 2 = 2 \text{ and } 2 - 4 = -2$$

$$4 \div 2 \neq 2 \div 4 \text{ as } 4 \div 2 = 2 \text{ and } 2 \div 4 = 0.5$$

###### 2. Associativity

The way in which three or more integers are associated under addition or multiplication does not affect the result.

###### 3. Distributivity

Multiplication is distributed over addition and subtraction from both the right and left.

Division is distributed over addition and subtraction from the right but not from the left.

##### **Addition, subtraction, multiplication and division of positive and negative numbers**

Adding two numbers gives their sum and subtracting two numbers gives their difference. For example:

$$7 + 3 = 10$$

$$7 - 3 = 4$$



$$3 - 7 = -4$$

Adding a negative number is the same as subtracting its positive counterpart. For example:

$$7 + (-2) = 5$$

Subtracting a negative number is the same as adding its positive counterpart. For example:

$$7 - (-2) = 9$$

**Multiplication and division**

Multiplying two numbers gives their product while dividing two positive and negative numbers gives their quotient.

Multiplying and dividing two positive or two negative numbers gives a positive number.

$$12 \times 2 = 24 \text{ and } (-12) \times (-2) = 24$$

$$12 \div 2 = 6 \text{ and } (-12) \div (-2) = 6$$

Multiplying or dividing a positive number by a negative number gives a negative number.

$$12 \times (-2) = -24; 12 \div (-2) = -6$$

## Fractions and decimals operations and conversions

### Fractions

When 2 is divided by 3, it may be written as  $\frac{2}{3}$  is called a fraction. The number above the line, i.e. 2, is called the numerator and the number below the line, i.e. 3, is called the denominator. When the value of the numerator is less than the value of the denominator, the fraction is called a proper fraction; thus  $\frac{2}{3}$  is a proper fraction. When the value of the numerator is greater than the denominator, the fraction is called an improper fraction. Thus  $\frac{7}{3}$  is an improper fraction and can also be expressed as a mixed number, that is, an integer and a proper fraction. Thus the improper fraction  $\frac{7}{3}$  is equal to the mixed number  $2\frac{1}{3}$ .

When a fraction is simplified by dividing the numerator and denominator by the same number, the process is called cancelling. Cancelling by 0 is not permissible.

Simplify:  $\frac{1}{3} + \frac{2}{7}$

The lowest common multiple (i.e. LCM) of the two denominators is 3 d 7, i.e. 21

Expressing each fraction so that their denominators are 21, gives:

$$\frac{1}{3} + \frac{2}{7} = \frac{1}{3} \times \frac{7}{7} + \frac{2}{7} \times \frac{3}{3} = \frac{7}{21} + \frac{6}{21} = \frac{13}{21}$$

Simplify:  $\frac{1}{3} - \left(\frac{2}{5} + \frac{1}{4}\right) \div \left(\frac{3}{8} \times \frac{1}{3}\right)$

$$\text{Solution } \frac{1}{3} - \left(\frac{2}{5} + \frac{1}{4}\right) \div \left(\frac{3}{8} \times \frac{1}{3}\right) = \frac{1}{3} - \left(\frac{4 \times 2 + 1 \times 5}{20}\right) \div \left(\frac{3}{24}\right)$$

$$\frac{1}{3} - \frac{13}{20} \div \frac{1}{8} = \frac{1}{3} - \frac{13}{20} \times \frac{8}{1}$$

$$\frac{1}{3} - \frac{26}{5} = \frac{(1 \times 5) - (26 \times 3)}{15} = \frac{-73}{15} = -4 \frac{13}{15}$$

## Decimals

The decimal system of numbers is based on the digits 0 to 9. A number such as 53.17 is called a decimal fraction, a decimal point separating the integer part, i.e. 53, from the fractional part, i.e. 0.17

A number which can be expressed exactly as a decimal fraction is called a terminating decimal and those which cannot be expressed exactly as a decimal fraction are called non-terminating decimals. Thus,  $\frac{3}{2} = 1.5$  is a terminating decimal, but  $\frac{4}{3} = 1.3333$  is a non-terminating decimal. 1.33333... can be written as 1.P3, called 'one point three recurring'.

The answer to a non-terminating decimal may be expressed in two ways, depending on the accuracy required:

- (i) Correct to a number of significant figures, that is, figures which signify something, and
- (ii) Correct to a number of decimal places, that is, the number of figures after the decimal point.

The last digit in the answer is unaltered if the next digit on the right is in the group of numbers 0, 1, 2, 3 or 4, but is increased by 1 if the next digit on the right is in the group of numbers 5, 6, 7, 8 or 9.

Evaluate

$$42.7 + 3.04 + 8.7 + 0.06 = 54.50$$

## Indices

The lowest factors of 2000 are  $2 \times 2 \times 2 \times 2 \times 5 \times 5 \times 5$ . These factors are written as  $2^4 \times 5^3$ , where 2 and 5 are called bases and the numbers 4 and 3 are called indices.

When an index is an integer it is called a power. Thus,  $2^4$  is called 'two to the power of four', and has a base of 2 and an index of 4.

Special names may be used when the indices are 2 and 3, these being called 'squared' and 'cubed', respectively. Thus  $7^2$  is called 'seven squared' and  $9^3$  is called 'nine cubed'. When no index is shown, the power is 1, i.e. 2 means  $2^1$ .

### Reciprocal

The reciprocal of a number is when the index is -1 and its value is given by 1, divided by the base.

Thus the reciprocal of 2 is  $2^{-1}$  and its value is  $\frac{1}{2}$  or 0.5.

### Square root

The square root of a number is when the index is  $\frac{1}{2}$ , and the square root of 2 is written as  $2^{\frac{1}{2}}$  or  $\sqrt{2}$ .

There are always two answers when finding the square root of a number and this is shown by putting both a + and a - sign in front of the answer to a square root problem.

## Ratios and proportions

The ratio of one quantity to another is a fraction, and is the number of times one quantity is contained in another quantity of the same kind. If one quantity is directly proportional to another, then as one quantity doubles, the other quantity also doubles. When a quantity is inversely proportional to another, then as one quantity doubles, the other quantity is halved.

An alloy is made up of metals A and B in the ratio 2.5: 1 by mass. How much of A has to be added to 6 kg of B to make the alloy?

Ratio A: B: 2.5: 1 (i.e. A is to B as 2.5 is to 1) or  $\frac{A}{B} = \frac{2.5}{1} = 2.5$

When B = 6 kg,  $\frac{A}{6} = 2.5$  from which,

$$A = 6 \times 2.5 = 15kg$$

## Conversions into percentages

Percentages are used to give a common standard and are fractions having the number 100 as their denominators. For example, 25 per cent means  $\frac{25}{100}$  i.e.  $\frac{1}{4}$  and is written 25%.

A decimal fraction is converted to a percentage by multiplying by 100. Thus, 1.875 corresponds to  $1.875 \times 100\% = 187.5\%$

Direct and inverse proportions determination

Directly proportional: as one amount increases, another amount increases at the same rate. The symbol for “directly proportional” is  $\propto$

Inversely proportional: when one value decreases at the same rate the other increases.

## Use of scientific calculator

A scientific calculator is a special electronic calculator that aids the calculation involving problems in mathematics, engineering and science. It can be used in the following ways;

- Basic operations i.e. addition subtraction, multiplication and division.
- Calculation of exponents.
- Solving problems with an order of operations.
- Working out squares and square roots of numbers.
- Solving logarithmic problems.
- Solving of problems in statistics e.g. find the mean, variance, standard deviation etc.

Example: The “log” function in the calculator is the key that allows you to work with the logarithm.

The steps in using the log functions are;

- i. Type the number you are to work with in your scientific calculator.
- ii. Press the “log” button on the calculator.

- iii. From your screen, obtain the exponent from the original number you entered.
- iv. Check your results.

#### 1.2.1.4 Learning Activities

1. Create an instruction sheet with the following five fractions:  $\frac{1}{3}$ ,  $\frac{1}{8}$ ,  $\frac{2}{3}$ ,  $\frac{1}{4}$  and  $\frac{1}{5}$

Create a pizza (circular cut outs), using construction paper and decorate the toppings to represent each fraction.

For example, if they had a quarter (fourth), they should cover one-quarter of the pizza with a specific pattern.

2. Using your calculator check that you agree with the answers to the following problems:

Evaluate the following, correct to 4 significant figures:

- a.  $4.7826 + 0.02713 = 4.80973 = 4.810$
- b.  $21.93 \times 0.012981 = 0.2846733 = 0.2847$

Evaluate the following, correct to 3 decimal places:

- a.  $\sqrt{0.007328}$
- b.  $\sqrt{52.91} - \sqrt{31.76}$

#### 1.2.1.5 Self-Assessment

1. Place the appropriate symbol  $< or >$  between each of the following pairs of numbers:

- a.  $3 \_ 2$
- b.  $8 \_ -13$
- c.  $-25 \_ 0$

2. Find the value of each of the following:

- a.  $13 + 9 \div 3 - 2 \times 5$
- b.  $(13 + 9) \div (3 - 2) \times 5$

3. Complete the following:

- a.  $\frac{4}{5} =$
- b.  $48\% \text{ of } 50 =$

4. Write the following proportions as ratios:

- a.  $\frac{1}{2} \text{ of } A, \frac{1}{5} \text{ of } B, \frac{3}{10} \text{ of } C$

5. Reduce each of the following to their lowest form:

- a.  $\frac{12}{18}$
- b.  $\frac{144}{21}$

6. Round each of the following decimal numbers, first to 3 significant figures and to 2 decimal places:

- a. 21.355

b. 0.02456

### 1.2.1.6 Tools, Equipment, Supplies and Materials

- Calculator
- Paper and pencil
- Computer
- Ruler and graph paper
- Marker pen

### 1.2.1.7 References

Stroud K. A. (2001). Engineering Mathematics. Fifth Edition. North America: Industrial Press, Inc.

John Bird. (2003). Engineering Mathematics. Fourth Edition. London, UK: Newnes Elsevier Science

### 1.2.1.8 Answers to Self-Assessment

1. Place the appropriate symbol  $<$  or  $>$  between each of the following pairs of numbers:

- $3 > 2$
- $8 > -13$
- $-25 < 0$

2. Find the value of each of the following:

a.  $13 + 9 \div 3 - 2 \times 5$

$$13 + (9 \div 3) - (2 \times 5)$$

$$13 + 3 - 10 = (13 + 3) - 10 = 6$$

b.  $(13 + 9) \div (3 - 2) \times 5$

$$(13 + 9) \div (3 - 2) \times 5 = 22 \div 1 \times 5 = (22 \div 1) \times 5 = 110$$

3. Complete the following:

a.  $\frac{4}{5}$  as a % =

$$\frac{4}{5} \times 100 = 80\%$$

b. 48% of 50 =

$$\frac{48}{100} \times 50 = 24$$

4. Write the following proportions as ratios:

a.  $\frac{1}{2}$  of A,  $\frac{1}{5}$  of B,  $\frac{3}{10}$  of C

The LCM of the denominators 2, 5 and 10 is 10 then;

$$\frac{1}{2} \text{ of A is } \frac{1 \times 5}{2 \times 5} = \frac{5}{10}, \frac{1}{5} \text{ of B is } \frac{1 \times 2}{5 \times 2} = \frac{2}{10} \text{ and } \frac{3}{10} \text{ of C}$$

Hence: A: B: C = 5:2:3

5. Reduce each of the following to their lowest form:

a.  $\frac{12}{18}$

$$\frac{12}{18} = \frac{12 \div 6}{18 \div 6} = \frac{2}{3}$$

b.  $\frac{144}{21}$

$$\frac{144}{21} = \frac{144 \div 3}{21 \div 3} = \frac{48}{7} = 4\frac{6}{7}$$

6. Round each of the following decimal numbers, first to 3 significant figures and to 2 decimal places:

a. 21.355

21.4 3sf

21.36 2dp

b. 0.02456

0.025 2sf

0.03 2dp

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## 1.2.2 Learning Outcome 2: Use formulae and algebraic expressions for work

### 1.2.2.1 Introduction to the learning outcome

This learning outcome covers algebra and the learner should be able to: perform calculations involving Indices as per the concept; perform calculations involving Logarithms as per the concept; use scientific calculator is used mathematical problems in line with manufacturer's manual; perform simultaneous equations as per the rules. Algebra is used throughout engineering, but it is most commonly used in mechanical, electrical, and civil branches due to the variety of obstacles they face. Engineers need to find dimensions, slopes, and ways to efficiently create any structure or object.

### 1.2.2.2 Performance Standard

1.2.2.3 Algebraic linear equation

1.2.2.4 Simultaneous

1.2.2.5 Quadratic

1.2.2.6 Linear graphs

1. Plotting
2. Interpretation
3. Applications of linear graphs

4. Curves of first and second degree
5. Plotting
6. Interpretation
7. Applications

### 1.2.3 Information Sheet

#### 1.2.3.1 Definitions of terms

Algebra is the study of mathematical symbols and the rules for manipulating these symbols; it is a unifying thread of almost all of mathematics. It includes everything from elementary equation solving to the study of abstractions such as groups, rings, and fields.

Logarithms: This is the power to which a number must be raised in order to get some other number which means that logarithms is the inverse of the exponential.

Linear equations: A linear equation is any equation of the form  $a + bx=0$  where a and b are real numbers and  $x$  is a variable.

Quadratic equation: It is any equation of the form  $ax^2 + bx + c$ . It is any equation of the second degree meaning that one of its terms is a squared.

### Performance of calculations involving indices

The lowest factors of 2000 are  $2 \times 2 \times 2 \times 2 \times 5 \times 5 \times 5$ . These factors are written as  $2^4 \times 5^3$ , where 2 and 5 are called bases and the numbers 4 and 3 are called indices. When an index is an integer it is called a power. Thus,  $2^4$  is called ‘two to the power of four’, and has a base of 2 and an index of 4.

Given  $b^x$ , b is known as the base and x is known as the power or index to which b is raised. It can be interpreted as:

$$b^x = b \times b \times b \dots \dots \dots (x \text{ times})$$

$x$  Can be real number.

The reciprocal of a number is when the index is  $-1$  and its value is given by 1, divided by the base.

The square root of a number is when the index is  $\frac{1}{2}$ , and the square root of 2 is written as  $2^{\frac{1}{2}}$  or  $\sqrt{2}$ . The value of a square root is the value of the base which when multiplied by itself gives the number.

### Laws of indices

When simplifying calculations involving indices, certain basic rules or laws can be applied, called the laws of indices.

For any number  $x$  and  $y$  the following basic laws hold;

$$a^x a^y = a^{x+y}$$

$$\frac{a^x}{a^y} = a^{x-y}$$

$$(a^x)^y = a^{xy}$$

$$a^{\frac{x}{y}} = \sqrt[y]{a^x}$$

$$a^{-y} = \frac{1}{a^y}$$

$$a^0 = 1$$

Note: The above law only applies if bases are similar e.g.  $2^3 \cdot 2^4 = 2^7 = 128$

$$\frac{a^x}{a^y} = a^{x-y}$$

Example:

$$\frac{2^4}{2^3} = 2^{4-3} = 2^1 = 2. \text{ If } x \text{ and } y \text{ equals one, } x = 1, y = 1 \text{ then } \frac{a^1}{a^1} = a^{1-1} = a^0 = 1$$

$$(a^x)^y = a^{xy} = (a^y)^x \text{ jjh}$$

Example:

$$(a^3)^2 = a^6 = (a^2)^3$$

$$(ab)^x = a^x b^x$$

Example:

$$(ab)^4 = a^4 b^4$$

NB: The expression  $a^{-x}$  is equivalent to  $\frac{1}{a^x}$

$$\frac{1}{a^x} = \frac{a^0}{a^x} = a^{0-x} = a^{-x}$$

### Calculating the indicial equations

Given  $3(2^{2x}) + 12(2^x) - 96 = 0$ , solve for  $x$

Steps

Let  $2^x = p$

Substitute  $p$  in the equation



i. e  $3p^2 + 12p - 96 = 0$ , simplifying the equation, it becomes  $p^2 + 4p - 32 = 0$ .

Factorize  $p^2 + 4p - 32 = 0$

$$p^2 + 8p - 4p - 32 = 0$$

$$P(P + 8) - 4(P + 8) = 0$$

$$(P - 4)(p + 8) = 0$$

$$P = 4 \text{ or } p = -8$$

Since  $2^x = 2^2$   $x = 2$  then the other solution has no real roots

### Performance of calculations involving logarithms

Laws of logarithms

$$\log A + \log B = \log AB$$

Example

Solve  $\log_{10} 5 + \log_{10} 4$

$$\log_{10} 5 + \log_{10} 4 = \log_{10}(5 \times 4) = \log_{10} 20$$

$$\log A - \log B = \log \frac{A}{B}$$

Example:

Use the second law to simplify:

$$\log_{10} 6 - \log_{10} 3$$

$$\log_{10} 6 - \log_{10} 3 = \log_{10} \frac{6}{3} = \log_{10} 2$$

$$\log B^n = n \log B$$

Example:

Use the third law to write the alternative form of

$$3 \log_{10} 5 = \log_{10} 5^3 = \log_{10} 125$$

1.2.3.1.1 1.2.2.3.5 Solving logarithmic equations

Given  $\log_2(x + 4) + \log_2(6) = \log_2 54$ , Find x,

Steps

From laws of logarithms

Law 1,  $\log_2(x + 4) + \log_2(6) = \log_2 54$

$$\log_2((x + 4) \times (6)) = \log_2 54$$

Distribute  $(x + 4)(6) = 6x + 24$

$$\log_2(6x + 24) = \log_2 54$$

Drop the logs

$$6x + 24 = 54$$

Solve the linear equation

$$6x = 30$$

$$x = 5$$

### Use of scientific calculator in solving mathematical problems

A scientific calculator is a special electronic calculator that aids the calculation involving problems in mathematics, engineering and science. It can be used in the following ways;

- Basic operations i.e. addition subtraction, multiplication and division.
- Calculation of exponents.
- Solving problems with an order of operations.
- Working out squares and square roots of numbers.
- Solving logarithmic problems.
- Solving of problems in statistics e.g. find the mean, variance, standard deviation etc.

Example: The “log” function in the calculator is the key that allows you to work with the logarithm.

The steps in using the log functions are;

- v. Type the number you are to work with in your scientific calculator.
- vi. Press the “log” button on the calculator.
- vii. From your screen, obtain the exponent from the original number you entered.
- viii. Check your results.

### Obtainment of solution to system of linear equations involving three unknowns

This is how one should solve a system with three unknowns.

Steps

- i. Take a pair of the equation from the system.
- ii. Using addition/subtraction, eliminate the same variables from each pair.
- iii. Using additional/subtraction, solve the system of two new equations.

- iv. Substitute the solution back into one of the equations and solve for the third variable.
- v. Confirm your solution by the use of one of the equations.

Example:

Solve the following system of equations.

$$8x - 6y + 2z = -20$$

$$4x + 2y + 6z = 0$$

$$-2x + 4y - 10z = 34$$

Pick two pairs

$$8x - 6y + 2z = -20$$

$$4x + 2y + 6z = 0$$

*and*

$$4x + 2y + 6z = 0$$

$$-2x + 4y - 10z = 34$$

Eliminate the same variables from each system

$$8x - 6y + 2z = -20$$

$$4x + 2y + 6z = 0$$

Simplify

$$4x - 3y + z = -10$$

$$2x + y + 3z = 0$$

$$4x - 3y + z = -10$$

$$\underline{-4x - 2y - 6z = 0}$$

$$-5y - 5z = -10$$

$$4x + 2y + 6z = 0$$

$$-2x + 4y - 10z = 34$$

Simplify

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$$2x + y + 3z = 0$$

$$-x + 2y - 5z = 17$$

$$2x + y + 3z = 0$$

$$\underline{-2x + 4y - 10z = 34}$$

$$5y - 7z = 34$$

Solve the system of the equations.

$$-5y - 5z = -10$$

$$\underline{5y - 7z = 34}$$

$$-12z = 24$$

Thus  $z = -2$ , solving for  $y$ ,  $y = 4$

Substitute in the original to obtain  $x$

$$-2x + 4y - 10z = 17$$

$$-2 + 4(4) - 10(-2) = 17$$

$$-2x = -2 \quad x = 1$$

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### Performance of calculations involving Quadratic Equations

It is an equation of the form  $ax^2 + bx + c = 0$

Solving the quadratic equation

Quadratic equations can be solved by factorization.

Quadratic equation can be solved by the use of the quadratic formula.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Also, quadratic equations can be solved through the completing squares method.

By the use of the graphical method.

Example:

Solve using the quadratic formula;

$$x^2 + 2x + 1 = 0$$

Solution:

$$a = 1$$

$$b = 2$$

$$c = 1$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-2 \pm \sqrt{2^2 - 4 \times 1 \times 1}}{2 \times 1}$$

The discriminant is;

$$b^2 - 4ac = 2^2 - 4 \times 1 \times 1 = 0$$

$$x = \frac{-2 \pm \sqrt{0}}{2 \times 1}$$

$$= \frac{-2}{2 \times 1} = 1$$

### Calculations involving sequence and series are performed as per the concept

A sequence are numbers or functions arranged in a special order while series is the sum of sequence of terms.

Types of sequence in mathematics

- Arithmetic sequence: is a set of the numbers that follows a pattern formed by adding a common difference to the proceeding number.
- Geometric sequence: is a set of numbers that are multiplied (or divided) by a constant called the common ratio.

Types of series

Arithmetic series is the sum of the terms of arithmetic sequence while geometric series is the sum of the terms of the geometric sequence. The  $n^{th}$  term of the arithmetic sequence is given by  $a + (n - 1)d$  while the sum of terms in the series is given by  $\frac{n}{2} [2a + (n - 1)d]$ . The  $n^{th}$  term of a G.P is given by  $ar^{n-1}$ . The sum of the infinite terms of the series  $s_n = \frac{a^n}{1-r}$

Where  $0 < r < 1$

$a$  Is the first term.

$n$  Is the number of terms?

$d$  Is the common difference

$r$  Is the common ratio

### Example

Determine the type of the sequence

**1, 4, 7, 10, 13 ...** It is an arithmetic sequence with a common difference of 3.

**2, 4, 8, 16, 32 ...** Is a geometric sequence with a common ratio of 2

In the arithmetic sequence **1, 4, 7, 10, 13, ...** find the sum of the first 10 terms.

$$a = 1, \quad d = 3 \quad n = 10$$

Use the formula  $\frac{n}{2}[2a + (n - 1)d]$

$$\frac{10}{2}[2(1) + (10 - 1)3]$$

$$= 5(2 + 27) = 145$$

In the geometric sequence **2, 4, 8, 16, 32**. Find the sum of the first 10 terms.

#### 1.2.4 Learning Activities

1. In groups of two solve this hexagon puzzle as an algebra challenge. It involves rolling a dice to work out the value of an algebraic expression. Students take turns rolling the dice and the number rolled becomes the value of 'n'. The player then gets one chance to choose a hexagon and solve the equation using the assigned value of 'n'. At the end of the game, the student with the most number of solved hexagons wins.

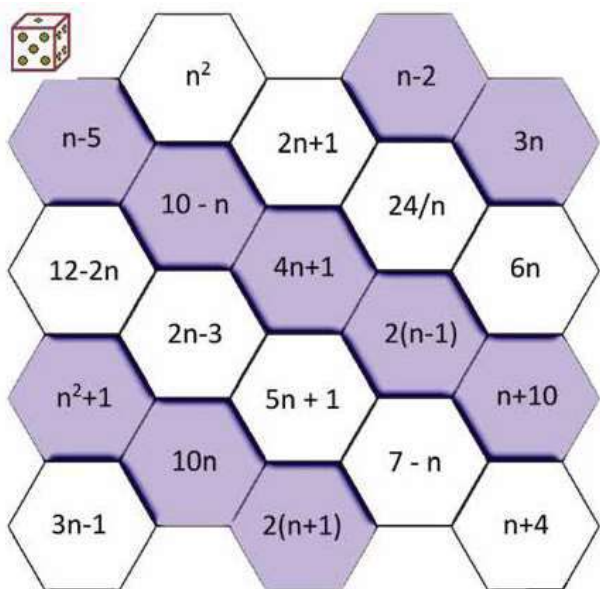


Figure 1: Hexagon Puzzle 1

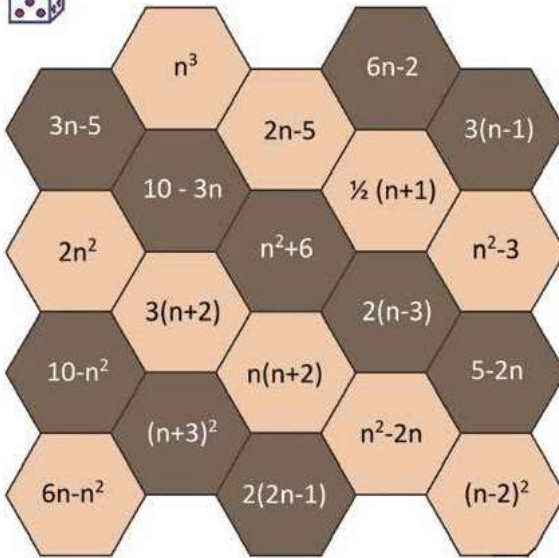


Figure 2: Hexagonal Puzzle 2

2. Perform a survey in your locality (in around 50 homesteads) and find out the total number of rabbits' population. It is believed that the population will increase by 2% every year. Predict the rabbit population after 3 years.

#### 1.2.5 Self-Assessment

1. Find the value of  $4p^2qr^3$ , given that  $p = 2$ ,  $q = \frac{1}{2}$  and  $r = 1\frac{1}{2}$
2. Find the sum of:  $5a - 2b$ ,  $2a + c$ ,  $4b - 5d$  and  $b - a + 3d - 4c$
3. Subtract  $2x + 3y - 4z$  from  $x - 2y + 5z$
4. Multiply  $3x - 2y^2 + 4xy$  by  $2x - 5y$
5. Simplify:  $2p \div 8pq$
6. Simplify:  $\frac{x^2y}{xy^2-xy}$
7. Simplify:  
 $(a^3\sqrt{b}\sqrt{c^5})(\sqrt{a^3}\sqrt{bc^3})$  And evaluate when  $a = \frac{1}{4}$ ,  $b = 6$  and  $c = 1$
8. Factorize:  $2ax - 3ay + 2bx - 3by$

#### 1.2.6 Tools, Equipment, Supplies and Materials

- Calculator
- Paper and pencil
- Computer
- Ruler and graph paper
- Dice

#### 1.2.7 References

- Anto H & Lolles, C (2013). Elementary Linear Algebra: Applications version
- Greub Werner H. (2012). Linear Algebra Vol 23 springer Science

1.2.8 Answers to the Self-Assessment

1. Find the value of  $4p^2qr^3$ , given that  $p = 2$ ,  $q = \frac{1}{2}$  and  $r = 1\frac{1}{2}$

Solution:

Replacing p, q and r with their numerical values gives:

$$4p^2qr^3 = 4(2) \times (2^2) \times \frac{1}{2} \times \left(\left(\frac{3}{2}\right)^3\right) = 27$$

2. Find the sum of:  $5a - 2b$ ,  $2a + c$ ,  $4b - 5d$  and  $b - a + 3d - 4c$

Solution:

The algebraic expressions may be tabulated as shown below, forming columns for a's, b's, c's and d's.

Thus:

$$\begin{aligned} 5a + (-2b) + 2a + c + 4b + (-5d) + b + (-a) + 3d + (-4c) \\ = 6a + 3b - 3c - 2d \end{aligned}$$

3. Subtract  $2x + 3y - 4z$  from  $x - 2y + 5z$

$$\begin{aligned} (x - 2y + 5z) - (2x + 3y - 4z) \\ = -x - 5y + 9z \end{aligned}$$

4. Multiply  $3x - 2y^2 + 4xy$  by  $2x - 5y$

$$\begin{aligned} 2x(3x - 2y^2 + 4xy) &= 6x^2 - 4xy^2 + 8xy^2 \\ -5y(3x - 2y^2 + 4xy) &= -15xy + 10y^3 - 20xy^2 \\ (6x^2 - 4xy^2 + 8xy^2) + (-15xy + 10y^3 - 20xy^2) \\ 6x^2 - 24xy^2 + 8xy^2 - 15xy + 10y^3 \end{aligned}$$

5. Simplify:  $2p \div 8pq$

$$\frac{2p}{8pq} = \frac{1}{4q}$$

6. Simplify:  $\frac{x^2y}{xy^2-xy}$

The highest common factor (HCF) of each of the three terms comprising the numerator and denominator is xy. Dividing each term by xy gives:

$$\frac{x^2y}{xy^2-xy} = \frac{\frac{x^2y}{xy}}{\frac{xy^2-xy}{xy}} = \frac{x}{y-1}$$

7. Simplify:

$$(a^3\sqrt{b}\sqrt{c^5})(\sqrt{a^3}\sqrt{bc^3}) \text{ And evaluate when } a = \frac{1}{4}, b = 6 \text{ and } c = 1$$

Using the fourth law of indices, the expression can be written as:

$$\left(a^3b^{\frac{1}{2}}c^{\frac{5}{2}}\right)\left(a^{\frac{1}{2}}b^{\frac{1}{2}}c^3\right)$$



Using the first law of indices gives:

$$a^{3+\frac{1}{2}}b^{\frac{1}{2}+\frac{2}{3}}c^{\frac{5}{2}+3} = a^{\frac{7}{2}}b^{\frac{7}{6}}c^{\frac{11}{2}}$$

It is usual to express the answer in the same form as the question. Hence:

$$a^{\frac{7}{2}}b^{\frac{7}{6}}c^{\frac{11}{2}} = \sqrt{a^7}\sqrt[6]{b^7}\sqrt{c^{11}} = \sqrt{\left(\frac{1}{4}\right)^7}({}^6\sqrt{6^7})(\sqrt{1^{11}})=1$$

8. Factorize:  $2ax - 3ay + 2bx - 3by$

a is a common factor of the first two terms and b a common factor of the last two terms

Thus:  $2ax - 3ay + 2bx - 3by = a(2x - 3y) + b(2x - 3y)$

$(2x - 3y)(a + b)$

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## 2 Learning Outcome 3: Use trigonometry to solve practical work problems

### 2.2.2 Introduction to the learning outcome

This learning outcome covers applications of trigonometric rules, identities the calculation of area, perimeter of shapes and solids .it also covers one to one relationships and calculation involving hyperbolic functions and identities.

### 2.2.3 Performance Standard

1. Meaning of trigonometry
2. Pythagoras theorem
3. Trigonometry ratios of angles
4. Trigonometric identities
5. Conversion of angles

### 2.2.4 Information Sheet

#### 2.2.4.1 Definition of Terms

Trigonometry rule: This is a rule aimed at expressing the relationship between the angles of a triangle and the side lengths.

Hyperbolic function: This is a function of an angle that is defined for the hyperbola, not on the circle.

One to one function: A function said to be one to one if different elements in **a** map different element in **b**.

**Performance of calculations are performed using trigonometric rules**

Consider a unit circle of radius 1

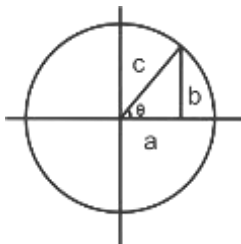


Figure 3: Circle

$$\sin\theta = \frac{b}{c}$$

$$\cos\theta = \frac{a}{c}$$

$$\tan = \frac{b}{a}$$

$$a^2 + b^2 = c^2$$

$$\frac{a^2}{c^2} + \frac{b^2}{c^2} = 1$$

Some of the trigonometric rules are;

$$(\cos^2 \theta) + (\sin^2 \theta) = 1$$

$$\cos^2 \theta + \sin^2 \theta = 1 \dots (1)$$

*dividing (1) by  $\sin^2 \theta$*

$$\cot^2 \theta + 1 = \operatorname{cosec}^2 \theta$$

$$\cot^2 \theta = \operatorname{cosec}^2 \theta - 1$$

Note:

$$\cot \theta = \frac{\cos \theta}{\sin \theta}$$

$$\operatorname{cosec} \theta = \frac{1}{\sin \theta}$$

$$\sec \theta = \frac{1}{\cos \theta}$$

$$\tan \theta = \frac{\sin \theta}{\cos \theta}$$

Dividing (i) by

$$\sin^2 \theta$$

$$1 + \tan^2 \theta = \sec^2 \theta - 1$$

$$\tan^2 \theta = \sec^2 \theta - 1$$

The double angle formula can then be given as  $\sin 2A = 2 \cos A \sin A$  +  $\cos 2A = \cos^2 A - \sin^2 A$

$$\sin 2A = 2 \cos A \sin A - \cos A \sin A$$

Note: If values are different, it becomes a factor theorem with  $2A=A+B$ .

From the above relationship, we derive the half angle formula; that is

$$\cos 2A = \cos^2 A - \sin^2 A$$

$$\cos 2A = 2 \cos^2 A - 1$$

$$\cos A = 2 \cos^2 \left(\frac{A}{2}\right) - 1$$

$$\cos A = 1 - 2 \sin^2 \left(\frac{A}{2}\right)$$

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Therefore,  $2\sin^2(A/2) = 1 - \cos B$

$$\cos(A/2) = \pm\sqrt{\frac{1+\cos A}{2}} \text{ and } \sin(A/2) = \pm\sqrt{\frac{1-\cos A}{2}}$$

Example

Without using calculator, find  $\cos 15^\circ$

Solution

$$\begin{aligned} \cos 15^\circ &= (\cos 45^\circ - \cos 30^\circ) \\ &= \cos 45 \cos 30 + \sin 45 \sin 30 \\ &= \sqrt{\frac{2}{2}} \cdot \sqrt{\frac{3}{2}} + \sqrt{\frac{2}{2}} \cdot \sqrt{\frac{1}{2}} \\ &= \sqrt{\frac{2}{4}}(\sqrt{3} + 1) \end{aligned}$$

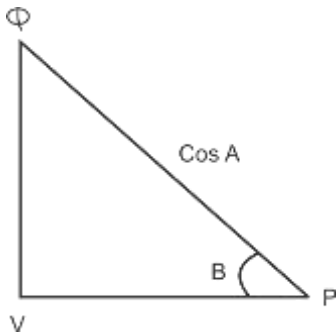


Figure 4: Triangle PQV

From triangle PQV

$$\sin B = \frac{QV}{PQ} = QV = \cos A \sin B$$

Therefore from (i) and (ii)

$$\sin(A + B) = \sin A \cos B + \cos A \sin B$$

Replacing B by (-B) in equation (i), we get:

$$\sin(A - B) = \sin A \cos(-B) + \cos A \sin(-B)$$

$$\sin(A - B) = \sin A \cos B - \cos A \sin B$$

Similarly;

$$\cos(A + B) = \cos A \cos B - \sin A \sin B$$

$$\cos(A - B) = \cos A \cos B + \sin A \sin B$$

### Performance of calculations are performed using hyperbolic functions

These functions are expressed as exponential functions and are generally expressed as hyperbolic sine or hyperbolic cosine, where other relationships can be derived.

### The hyperbolic identities

Hyperbolic identities are obtained from the hyperbolic trigonometric functions. i.e

$$\mathbf{Tanh\ } x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

$$\mathbf{Sech\ } x = \frac{2}{e^x + e^{-x}}$$

$$\mathbf{coth\ } x = \frac{e^x + e^{-x}}{e^x - e^{-x}}$$

$$\mathbf{cosech\ } x = \frac{2}{e^x - e^{-x}}$$

The derived hyperbole identities then become:

$$\mathbf{cosh^2 x - sinh^2 x = 1}$$

$$\mathbf{1 - tanh^2 x = sech^2 x}$$

$$\mathbf{coth^2 x - 1 = cosech^2 x}$$

$$\mathbf{\sinh(x \pm y) = \sinh x \cosh y \pm \cosh x \sinh y}$$

$$\mathbf{\cosh(x \pm y) = \cosh x \cosh y \pm \sinh x \sinh y}$$

$$\mathbf{\sinh(-x) = -\sinh x}$$

$$\mathbf{\cosh x = \cosh(-x)}$$

### Examples

Solve the following equation in terms of a natural logarithm.

$$\mathbf{4\cosh 2x + 20\sinh 2x = 10}$$

Solution

$$\mathbf{\cosh 2x = \frac{e^{2x} + e^{-2x}}{2}}$$

$$\sinh 2x = \frac{e^{2x} - e^{-2x}}{2}$$

$$\text{Therefore } 2e^{2x} + 2e^{-2x} + 10e^{2x} - 10e^{-2x} = 10$$

$$12e^{2x} - 8e^{-2x} = 10$$

$$6e^{4x} - 5e^{2x} - 4 = 0$$

$$(3e^{2x} - 4)(2e^{2x} + 1) = 0$$

$$e^{2x} = \frac{4}{3} \text{ or } e^{2x} = -\frac{1}{2}$$

$$x = \frac{1}{2} \ln \frac{4}{3} \text{ since the real solution occurs when } e^{2x} > 0$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

$$\sinh x = \frac{e^x - e^{-x}}{2}$$

Most of the properties are similar to properties of trigonometric functions. For example; cosh function is even while **sinh** function is odd. The only difference in properties is,

$$(\cosh x)^2 - (\sinh x)^2$$

*Examples*

Calculate **sinh 5** using exponential functions.

Solution

$$\sinh 5 = \frac{e^5 - e^{-5}}{2}$$

$$= 74.2.3 \text{ to } 3 \text{ d.p}$$

Calculate cosh 7 using the factor theorem.

$$\cosh 7 = \cosh(3 + 4) = \cosh 3 \cosh 4 - \sinh 3 \sinh 4$$

$$= (10.68)(27.308) - (10.018)(27.290)$$

$$= 1.543$$

Given the value of x, one is able to calculate inverse of the hyperbolic functions

### 2.2.5 Learning Activities

1. Prove the following hyperbolic identities, use the definition of  $\sinh x$  and  $\cosh x$  in terms of exponential functions

- $\cosh^2 x - \sinh^2 x = 1$
- $1 - \tanh^2 x = \operatorname{sech}^2 x$
- $\coth^2 x - 1 = \operatorname{cosech}^2 x$

2. On graph papers:

- Plot the graphs of  $\sinh x$  and  $\cosh x$
- Superimpose the graphs above, do the curves intersect?
- Predict the graphs of  $y = \coth x$ ,  $y = \operatorname{cosech} x$  and  $y = \operatorname{sech} x$

### 2.2.6 Self-Assessment

1) Solve the following equation in terms of a natural logarithm.

$$4\cosh^2 x + 20 \sinh^2 x = 10$$

2) Indicate the sign needed to make the following identity true.

a)  $\sinh^2 x ( ) \cosh^2 x = 1$

3) A tree casts a horizontal shadow  $8\sqrt{3} \text{ m}$ , if a line is drawn from the end of the shadow to the top of the tree an angle of  $60^\circ$ . What is the height of the tree?



4) Prove that:  $\frac{\sin A + \sin B}{\cos A + \cos B} = \tan \frac{A+B}{2}$

5) With an aid of an example, analyze when a function is said to be injective?

6) Justify the relationship between the hyperbolic and the trigonometric functions.

7) Given;

$a, b, c > 0$ , show that when  $a > b$ , then  $a \cosh x + b \sinh x$  can be written in the form  $R \cosh(x + \alpha)$ . Therefore determine a further condition for which the following equation has real solutions.

$$a \cosh x + b \sinh x = c$$

### 2.2.7 Tools, Equipment, Supplies and Materials

- Calculator

- SMP tables
- Measuring tables
- Graph Papers
- Pens and Pencils

### 2.2.8 References

Mikusinski J. (2014).Operational Calculus .Elsevier.

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### 2.2.9 Answers to Self-Assessment

1. Solve the following equation in terms of a natural logarithm.

$$4\cosh 2x + 20 \sinh 2x = 10$$

Solution

$$\cosh 2x = \frac{e^{2x} + e^{-2x}}{2}$$

$$\sinh 2x = \frac{e^{2x} - e^{-2x}}{2}$$

$$\text{Therefore } 2e^{2x} + 2e^{-2x} + 10e^{2x} - 10e^{-2x} = 10$$

$$12e^{2x} - 8e^{-2x} = 10$$

$$6e^{4x} - 5e^{2x} - 4 = 0$$

$$(3e^{2x} - 4)(2e^{2x} + 1) = 0$$

$$e^{2x} = \frac{4}{3} \text{ or } e^{2x} = -\frac{1}{2}$$

$$x = \frac{1}{2} \ln \frac{4}{3} \text{ since the real solution occurs when } e^{2x} > 0$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

$$\sinh x = \frac{e^x - e^{-x}}{2}$$

2. Indicate the sign needed to make the following identity true.

$$\sinh^2 x (+) \cosh^2 x = 1$$

3. A tree casts a horizontal shadow  $8\sqrt{3} \text{ m}$ , if a line is drawn from the end of the shadow to the top of the tree an angle of  $60^\circ$ . What is the height of the tree?





$$\tan 60^\circ = \frac{h}{8\sqrt{3}}$$

$$\tan 60^\circ = \frac{\text{height of tree}}{\text{length of shadow}}$$

$$h = 8\sqrt{3} \tan 60^\circ = 24\text{m}$$

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### 3 Learning Outcome 4: Perform estimations, measurements and calculations of quantities

#### 3.2.2 Introduction to the learning outcome

This topic covers the units of measurement and their symbols, conversion of units of measurement, mensuration, measuring tools and equipment and performing measurements and estimations of quantities.

#### 3.2.3 Performance Standard

- 1) Units of measurements and their symbols
- 2) Conversion of units of measurement
- 3) Calculation of length, width, height, perimeter, area and angles of figures
- 4) Measuring tools and equipment
- 5) Performing measurements and estimations of quantities

### 3.2.4 Information Sheet

#### 3.2.4.1 Definition of terms

#### Units of measurements and their symbols

There are seven base units in the SI system:

- the kilogram (kg), for mass
- the second (s), for time
- the kelvin (K), for temperature
- the ampere (A), for electric current
- the mole (mol), for the amount of a substance
- the candela (cd), for luminous intensity
- the meter (m), for distance

Table 1: SI Units

| QUANTITIES  | UNIT                     | SYMBOL   |
|-------------|--------------------------|----------|
| Length      | • Millimeter             | mm       |
|             | • Meter                  | m        |
|             | • Kilometer              | km       |
| Mass        | • Gram                   | g        |
|             | • Kilogram               | kg       |
|             | • Tonne                  |          |
| Time        | 1 Second                 | s        |
| Temperature | Degree Celsius           | °C       |
| Area        | Square kilometer         | $km^2$   |
| Volume      | Cubic Meter              | $m^3$    |
| Speed       | 2 Meter per second       | m/s      |
|             | 3 Kilometer per hour     | km/hr    |
| Density     | Kilogram per cubic meter | $kg/m^3$ |
| Force       | Newton                   | N        |

#### Conversion of units of measurement

Table 2: SI Prefix Symbols

| Prefix | Symbol | Ordinary Notation | Factor    |
|--------|--------|-------------------|-----------|
| Giga   | G      | 1000000000        | $10^9$    |
| Mega   | M      | 1000000           | $10^6$    |
| Kilo   | K      | 1000              | $10^3$    |
| Milli  | m      | 0.001             | $10^{-3}$ |
| Micro  | $\mu$  | 0.000001          | $10^{-6}$ |
| Nano   | N      | 0.000000001       | $10^{-9}$ |

Table 3: Conversions of SI Units

| QUANTITY | UNITY                | VALUE IN SI UNITS  |
|----------|----------------------|--|
| Length   | 3.2.4.1.1 Millimeter | 3.2.4.1.4 1000mm = 1m<br>3.2.4.1.5 100cm = 1m<br>3.2.4.1.6 1km = 1000m |
|          | 3.2.4.1.2 Centimeter |  |
|          | 3.2.4.1.3 Kilometer  |  |
|          |                      |  |
| Time     | 3.2.4.1.7 Minute     | 1minute = 60s  |
|          | 3.2.4.1.8 Hour       | 1hour = 60minute=3600s   |
|          | 3.2.4.1.9 Day        | 1day = 24hrs   |

### Calculation of length, width, height, perimeter, area and angles of figures

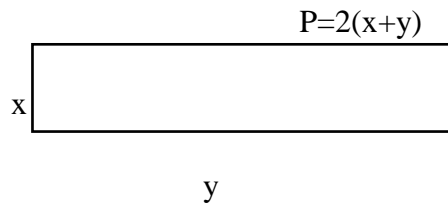
#### Perimeter

The perimeter is the length of the outline of a shape. To find the perimeter of a rectangle or square you have to add the lengths of all the four sides. X is in this case the length of the rectangle while y is the width of the rectangle.

The perimeter, P, is:

$$P = x + x + y + y$$

$$P = 2x + 2y$$



Find the perimeter of this rectangle



$$P = 7 + 7 + 4 + 4$$

$$P = 2 \cdot 7 + 2 \cdot 4$$

$$P = 2 \cdot (7 + 4)$$

$$P = 2 \cdot 11$$

$$P = 22\text{m}$$

*Area*

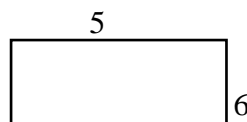
Area is the measurement of the surface of a shape. To find the area of a rectangle or a square you need to multiply the length and the width of a rectangle or a square.

Area,  $A$ , is  $x$  times  $y$ .

$$A = x \cdot y$$

Examples:

Find the area of this square.



$$A = x \cdot y$$

$$A = 5 \cdot 6$$

$$A = 30\text{m}^2$$

There are different units for perimeter and area. Perimeter has the same units as the length of the sides of rectangle or square whereas the area's unit is squared.

*Obtain volume and surface area of solids*

The surface area of a figure is defined as the sum of the areas of the exposed sides of an object.

The volume of an object is the amount of three-dimensional space an object takes up. It can be thought of as the number of cubes that are one unit by one unit by one unit that it takes to fill up an object.

Surface Area of a Rectangular Solid (Box)

$$SA = 2(lw + lh + wh)$$

**l = length of the base of the solid**

**w = width of the base of the solid**

**h = height of the solid**

Volume

Volume of a Solid with a Matching Base and Top

$$V = Ah$$

A = area of the base of the solid

h = height of the solid

Volume of a Rectangular Solid (specific type of solid with matching base and top)

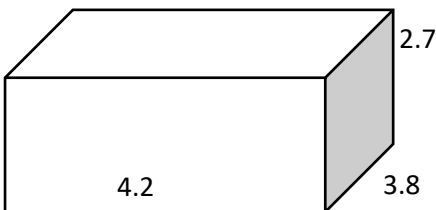
$$V = l \times w \times h$$

l = length of the base of the solid

w = width of the base of the solid

h = height of the solid

Example:



Based on the way our box is sitting, we can say that the length of the base is 4.2 m; the width of the base is 3.8 m; and the height of the solid is 2.7 m. Thus, we can quickly find the volume of the box to be:

$$V = lwh = 4.2 \times 3.8 \times 2.7 = 43.092m^3$$

A cylinder

A cylinder is an object with straight sides and circular ends of the same size. The volume of a cylinder can be found in the same way you find the volume of a solid with a matching base and top. The surface area of a cylinder can be easily found when you realize that you have to find the area of the circular base and top and add that to the area of the sides. If you slice the side of the cylinder in a straight line from top to bottom and open it up, you will see that it makes a rectangle. The base of the rectangle is the circumference of the circular base, and the height of the rectangle is the height of the cylinder.

Volume of a cylinder

$$V=Ah$$

A = the area of the base of the cylinder

h = the height of the cylinder

Surface Area of a Cylinder

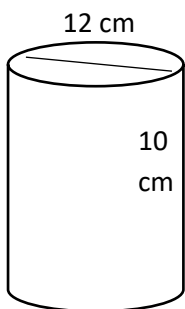
$$SA=2(\pi r^2)+2\pi rh$$

r = the radius of the circular base of the cylinder

h = the height of the cylinder

$\pi$  = the number that is approximated by 3.141593

Find the area of the cylinder



$$SA = 2(\pi r^2) + 2\pi rh$$

$$SA = 2(\pi \cdot 6^2) + 2\pi(6)(10) = 603.18579$$

## Measuring tools and equipment

### Vernier Caliper

Vernier Caliper is a widely used linear measurement instrument with a least count of 0.02 mm. It is used to measure linear dimensions like length, diameter and depth.

## Micrometer

External Micrometer is also known as Outside Micrometer or External Micrometer.

It is used to check outside diameter of circle by the means of accuracy of 0.01 mm or up to 0.001 mm.

## Steel Scale

Steel scale is single piece linear measuring instrument. Steel scale indicates two units that are cm and inches, cm division on one side and inches, on another side.

## Measuring tape.

## Ruler and Rule

Performing measurements and estimations of quantities

### 3.2.5 Learning Activities

1. In this particular activity, apples will be used to practice math skills of estimation and measurement of the circumference of an apple.

Materials you'll need:

- An apple
  - A ruler
  - Scissors
  - Thread
- a) You begin by placing the apple in front of your students. Let them hold the apple to ascertain its circumference. Encourage your students to cut the yarn to a length that they feel would properly wrap around the apple. This will require estimation on their part.
  - b) Use multiple apples of varying sizes, and have students estimate the amount of string that they'll need for each measurement.
  - c) Use the ruler to measure the string.
  - d) After determining whether they're too long or too short, have your students cut a second string to try to get closer to the circumference of the apple.

### 3.2.6 Self-Assessment

1. A rectangular tray is 820 mm long and 400 mm wide. Find its area in: (a)  $mm^2$  (b)  $m^2$  (c)  $cm^2$

2. Calculate the areas of the following sectors of circles having:

(a) Radius 6 cm with angle subtended at center  $50^\circ$

$$\text{Area of sector of a circle} = \frac{\theta^2}{360} (\pi r^2)$$

(b) Diameter 80 mm with angle subtended at center  $107^\circ 42'$

(c) Radius 8 cm with angle subtended at center 1.15 radians

3. A water tank is the shape of a rectangular prism having length 2 m, breadth 75 cm and height 50 cm.

Determine the capacity of the tank in (a)  $m^3$  (b)  $cm^3$  (c) litres

4. Find the volume and total surface area of a cylinder of length 15 cm and diameter 8 cm

### 3.2.7 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Dice
- Computers with internet connection
- Tape measure
- Thread
- Mathematical set

### 3.2.8 References

Hoyland, A., Rausand, and M. (1994), System Reliability Theory: Models and Statistical Methods, (New York).

Kaplan, W. (1984), Advanced Calculus, 3rd ed., Addison-Wesley (Cambridge, MA).

Kreyszig, E. (1999), Advanced Engineering Mathematics, 8th ed., (New York).

O'Neil, P.V. (1995), Advanced Engineering Mathematics, 4th ed., PWS-Kent Pub. (Boston).

### 3.2.9 Answers to Self-Assessment

1. A rectangular tray is 820 mm long and 400 mm wide. Find its area in: (a)  $mm^2$  (b)  $m^2$  (c)  $cm^2$

$$\text{Area} = \text{length} \times \text{width} = 820 \times 400 = 328000mm^2$$

Area D length ð width D 820 ð 400 D  
 $1cm^2 = 100mm^2$

$$\text{Hence: } 328000mm^2 = \frac{328000}{100} cm^2 = 3280cm^2$$

$$1m^2 = 10000cm^2$$

$$\text{Hence: } 3280cm^2 = \frac{3280}{10000} = 0.3280m^2$$

2. Calculate the areas of the following sectors of circles having:

(a) Radius 6 cm with angle subtended at center  $50^\circ$

$$\begin{aligned} \text{Area of sector of a circle} &= \frac{\theta}{360} (\pi r^2) \\ &= \frac{50}{360} (\pi 6^2) = \frac{50 \times \pi \times 36}{360} = 5\pi = 15.71cm^2 \end{aligned}$$

(b) Diameter 80 mm with angle subtended at center  $107^\circ 42'$

If the diameter = 80mm, then the radius,  $r = 40mm$

$$= \frac{107 \frac{42}{60}}{360} (\pi 40^2) = 1504mm$$

(c) Radius 8 cm with angle subtended at center 1.15 radians



3. A water tank is the shape of a rectangular prism having length 2 m, breadth 75 cm and height 50 cm.

Determine the capacity of the tank in (a)  $m^3$  (b)  $cm^3$  (c) litres

Volume of rectangular prism =  $l \times b \times h$

Volume of tank =  $2 \times 0.75 \times 0.5 = 0.75m^3$

$$1m^3 = 10^6cm^3$$

$$0.75m^3 = \frac{0.75}{10^6} = 750000cm^3$$

$$1 \text{ litre} = 1000cm^3$$

Hence:

$$750000cm^3 = \frac{750000}{1000} = 750litres$$

4. Find the volume and total surface area of a cylinder of length 15 cm and diameter 8 cm

Volume of cylinder =  $\pi r^2 h$

Since diameter = 8cm, then radius = 4cm

Hence:

$$Volume = \pi \times 4^2 \times 15 = 754cm^3$$

Total surface area =  $2\pi r h + 2\pi r^2 = 477.5cm^2$

#### 4 Learning Outcome 5: Apply Matrices in work

##### 4.2.2 Introduction to the learning outcome

This learning outcome covers: Matrix definition, types, matrix operations, compatibility and determination of inverse of a matrix, solving simultaneous equations with two and three and application of the matrices.

##### 4.2.3 Performance Standard

1. Meaning of matrix
2. Types of matrices
3. Matrix operations
4. Compatibility
5. Addition
6. Subtraction
7. Multiplication
8. Determination of inverse of a matrix
9. Solution of simultaneous equations with two and three unknowns
10. Applications of matrices

##### 4.2.4 Information Sheet

Matrix: This is a set of real or complex numbers arranged in rows and columns to form a rectangular array and it is always denoted by capital letters.

Order: A matrix of order of ( $m \times n$ )

Determinant: It is a physical quantity/value assigned to any square matrix.

E.g. given  $\begin{bmatrix} a & b \\ c & d \end{bmatrix} = ad - cd$

Inverse: The inverse of a matrix  $Q^{-1}$  is the matrix than when multiplied by the original matrix  $Q$  gives the identity matrix. i.e.  $Q Q^{-1}=I$ .

### Matrices

The numbers within a matrix are called an array and the coefficients forming the array are called the elements of the matrix. The number of rows in a matrix is usually specified by  $m$  and the number of columns by  $n$  and a matrix referred to as an ‘ $m$  by  $n$ ’ matrix. Thus,  $\begin{pmatrix} 2 & 3 & 6 \\ 4 & 5 & 7 \end{pmatrix}$  is a ‘2 by 3’ matrix?

### Type of matrix

The numbers within a matrix are called an **array** and the coefficients forming the array are called the **elements** of the matrix. The number of rows in a matrix is usually specified by  $m$  and the number of columns by  $n$  and a matrix referred to as an ‘ $m$  by  $n$ ’ matrix.

### Matrix Operations

To be added or subtracted matrices must be of the same order.

In describing the matrix, the number of rows the number of rows is stated first and the number of columns second. i.e.

$\begin{pmatrix} 6 & 3 \\ 2 & 4 \\ 5 & 1 \end{pmatrix}$  is a matrix of order of  $3 \times 2$

### Compatibility

A row matrix consists of 1 row only

A column matrix consists of 1 column only.

### Addition

Corresponding elements in two matrices may be added to form a single matrix.

Problem 1. Add the matrices

$$\begin{pmatrix} 2 & -1 \\ -7 & 4 \end{pmatrix} + \begin{pmatrix} -3 & 0 \\ 7 & -4 \end{pmatrix}$$
$$\begin{pmatrix} 2 + -3 & -1 + 0 \\ -7 + 7 & 4 + -4 \end{pmatrix}$$

$$= \begin{pmatrix} -1 & -1 \\ 0 & 0 \end{pmatrix}$$

### Subtraction

If A is a matrix and B is another matrix, then (A-B) is a single matrix formed by subtracting the elements of B from the corresponding elements of A.

Problem 2. Subtract

$$\begin{pmatrix} -3 & 0 \\ 7 & -4 \end{pmatrix} - \begin{pmatrix} 2 & -1 \\ -7 & 4 \end{pmatrix}$$

To find matrix A minus matrix B, the elements of B are taken from the corresponding elements of A.

Thus:

$$\begin{pmatrix} -3 & 0 \\ 7 & -4 \end{pmatrix} - \begin{pmatrix} 2 & -1 \\ -7 & 4 \end{pmatrix}$$

$$\begin{pmatrix} -3 - 2 & 0 - (-1) \\ 7 - (-7) & -4 - 4 \end{pmatrix}$$

$$\begin{pmatrix} -5 & 1 \\ 14 & -8 \end{pmatrix}$$

### Multiplication

When a matrix is multiplied by a number, called scalar multiplication, a single matrix results in which each element of the original matrix has been multiplied by the number.

Problem 4.

$$\text{If } A = \begin{pmatrix} -3 & 0 \\ -7 & -4 \end{pmatrix}, B = \begin{pmatrix} -2 & -1 \\ -7 & 4 \end{pmatrix} \text{ and } C = \begin{pmatrix} -1 & 0 \\ -2 & -4 \end{pmatrix}$$

Find

$$2A - 3B + 4C$$

For scalar multiplication, each element is multiplied by the scalar quantity, hence

$$2A = 2 \begin{pmatrix} -3 & 0 \\ -7 & -4 \end{pmatrix} = \begin{pmatrix} -6 & 0 \\ -14 & -8 \end{pmatrix}$$

$$3B = 3 \begin{pmatrix} -2 & -1 \\ -7 & 4 \end{pmatrix} = \begin{pmatrix} -6 & -3 \\ -21 & 12 \end{pmatrix}$$

$$4C = 4 \begin{pmatrix} -1 & 0 \\ -2 & -4 \end{pmatrix} = \begin{pmatrix} -4 & 0 \\ -8 & -16 \end{pmatrix}$$

Hence  $2A - 3B + 4C$

$$\begin{pmatrix} -6 & 0 \\ -14 & -8 \end{pmatrix} - \begin{pmatrix} -6 & -3 \\ -21 & 12 \end{pmatrix} + \begin{pmatrix} -4 & 0 \\ -8 & -16 \end{pmatrix}$$

When a matrix A is multiplied by another matrix B, a single matrix results in which elements are obtained from the sum of the products of the corresponding rows of A and the corresponding columns of B. Two matrices A and B may be multiplied together, provided the number of elements in the rows of matrix A are equal to the number of elements in the columns of matrix B. In general terms, when multiplying a matrix of dimensions (m by n) by a matrix of dimensions (n by r), the resulting matrix has

dimensions (m by r). Thus a 2 by 3 matrix multiplied by a 3 by 1 matrix gives a matrix of dimensions 2 by 1.

Problem 5. If  $A = \begin{pmatrix} -2 & 3 \\ 1 & -4 \end{pmatrix}$   $B = \begin{pmatrix} -5 & 7 \\ -3 & 4 \end{pmatrix}$

Find  $A \times B$ .

Let  $A \times B = C$  where  $C = \begin{pmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{pmatrix}$

$C_{11}$  is the sum of the products of the first row elements of A and the first column elements of B taken one at a time, i.e.  $C_{11} = (-2 \times -5) + (3 \times -3) = -19$

$C_{12}$  is the sum of the products of the first row elements of A and the second column elements of B, taken one at a time, i.e.  $C_{12} = (2 \times 7) + (3 \times 4) = 26$

$C_{21}$  is the sum of the products of the second row elements of A and the first column elements of B, taken one at a time, i.e.  $C_{21} = (1 \times -5) + (-4 \times -3) = 7$

Finally,  $C_{22}$  is the sum of the products of the second row elements of A and the second column elements of B, taken one at a time, i.e.  $C_{22} = (1 \times 7) + (-4 \times 4) = -9$

Thus,  $A \times B = \begin{pmatrix} -19 & 26 \\ 7 & -9 \end{pmatrix}$

### Determination of inverse of a matrix

The determinant of a 2 by 2 matrix

The determinant of a 2 by 2 matrix,  $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$  is defined as  $(ad - bc)$ .

The elements of the determinant of a matrix are written between vertical lines. Thus, the determinant of  $\begin{pmatrix} 3 & -4 \\ 1 & 6 \end{pmatrix}$  is written as  $\begin{vmatrix} 3 & -4 \\ 1 & 6 \end{vmatrix}$  and is equal to  $(3 \times 6) - (-4 \times 1) = 22$ . Hence the determinant of a matrix can be expressed as a single numerical value, i.e.  $\begin{vmatrix} 3 & -4 \\ 1 & 6 \end{vmatrix} = 22$

The inverse or reciprocal of a 2 by 2 matrix

The inverse of matrix A is  $A^{-1}$  such that  $A \times A^{-1} = \mathbf{1}$ , the unit matrix.

Let matrix A be  $\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$  and let the inverse matrix,  $A^{-1}$  be  $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$

Then, since  $A \times A^{-1} = \mathbf{1}$

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} \times \begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Multiplying the matrices on the left hand side, gives

$$\begin{pmatrix} a + 2c & b + 2d \\ 3a + 4c & 3b + 4d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Equating corresponding elements gives:

$$b + 2d = 0$$

$$b = -2d \text{ And } 3a + 4c = 0$$

$$a = -\frac{4}{3}c$$

Substituting for a and b gives:

$$\begin{pmatrix} -\frac{4}{3}c + 2c & -2d + 2d \\ 3\left(-\frac{4}{3}c\right) + 4c & 3(-2d) + 4d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} -\frac{2}{3}c & 0 \\ 0 & -2d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Showing that  $\frac{2}{3}c = 1, c = \frac{3}{2}$  and  $-2d = 1$  i.e.  $d = -\frac{1}{2}$

Since  $b = -2d, b = 1$  and since  $a = -\frac{4}{3}c, a = -2$

Thus the inverse of matrix  $\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$  is  $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$  that is  $\begin{pmatrix} -2 & 1 \\ \frac{3}{2} & -\frac{1}{2} \end{pmatrix}$

### Solution of simultaneous equations with two and three unknowns

The procedure for solving linear simultaneous equations in two unknowns using matrices is:

- (i) Write the equations in the form  $a_1x + b_1y = c_1, a_2x + b_2y = c_2$
- (ii) Write the matrix equation corresponding to these equations, i.e.  $\begin{pmatrix} a_1 & b_1 \\ a_2 & b_2 \end{pmatrix} \times \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix}$
- (iii) Determine the inverse matrix of  $\begin{pmatrix} a_1 & b_1 \\ a_2 & b_2 \end{pmatrix}$  i.e.  $\frac{1}{a_1b_2 - b_1a_2} \begin{pmatrix} b_2 & -b_1 \\ -a_2 & a_1 \end{pmatrix}$
- (iv) Multiply each side of (ii) by the inverse matrix
- (v) Solve for x and y by equating corresponding elements.

The procedure for solving linear simultaneous equations in three unknowns using matrices is:

- (i) Write the equations in the form

$$a_1x + b_1y + c_1z = d_1$$

$$a_2x + b_2y + c_2z = d_2$$

$$a_3x + b_3y + c_3z = d_3$$

- (ii) Write the matrix equation corresponding to these equations, i.e.

$$\begin{pmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{pmatrix} \times \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} d_1 \\ d_2 \\ d_3 \end{pmatrix}$$

- (iii) Determine the inverse matrix of

$$\begin{pmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{pmatrix}$$

- (iv) Multiply each side of (ii) by the inverse matrix
- (v) Solve for x, y and z by equating the corresponding elements.

## Applications of Matrices

- Cryptography

This is the process of hiding information for security purposes.

- Fourier analysis
- Gauss theorem
- Finding forces in the bridge
- Finding electric currents using matrix equation

### 4.2.5 Learning Activities

#### 1. Adding and Subtracting Matrices

Use this kinesthetic activity to help students add and subtract matrices by creating human matrices.

#### Materials

- Masking/painter's tape
- Copy paper
- Markers

#### Teacher Directions

- Show students examples of matrices and demonstrate how to add and subtract them. If possible, use matrices that reflect real-life data, such as population numbers for a specific continent.
- Give each student a piece of paper and marker.
- Have students write a number of their choice on the paper.
- Divide the classroom in half using a piece of masking/painter's tape.
- Create a matrix on both sides of the tape using students as the numbers. Have students stand in rows and columns holding their number signs on either side of the tape.
- Have students not involved in creating the matrices add or subtract them.
- Review the correct answers with the class.
- Have students rotate between serving as the numbers in the matrices and figuring out the sums or differences.

#### Discussion Questions

- What steps do you follow to add and subtract matrices?
- In what real-world situations might you need to add and subtract matrices?

### 4.2.6 Self-Assessment

#### 1. Add the matrices

$$\begin{pmatrix} 4 & -2 \\ -1 & 3 \end{pmatrix} + \begin{pmatrix} -3 & 5 \\ 7 & 6 \end{pmatrix}$$

2. Subtract

$$\begin{pmatrix} 3 & 1 & -4 \\ 4 & 3 & 1 \\ 1 & 4 & -3 \end{pmatrix} - \begin{pmatrix} 2 & 7 & -5 \\ -2 & 1 & 0 \\ 6 & 3 & 4 \end{pmatrix}$$

3. Determine the value of:

$$\begin{vmatrix} 3 & -2 \\ 7 & 4 \end{vmatrix}$$

4. If  $A = \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix}$  and  $B = \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix}$ , show that  $A \times B \neq B \times A$

#### 4.2.7 Tools, Equipment, Supplies and Materials

- Scientific calculator
- 15 cm ruler
- Pen, pencil
- Ruled and graph paper
- Mark Pens
- Cards

#### 4.2.8 References

Aitken, A.C (2017) Determinant and matrices Read Book Ltd.

Panju, M(2011) Iterative methods for computing eigen values and eigen vectors ar.xiv 11051185

Searle. S.R., & Khun, A.I. (2017) matrix algebra useful for statistics. John wiley & sons.

#### 4.2.9 Answers to Self-Assessment

1. Add the matrices

$$\begin{pmatrix} 4 & -2 \\ -1 & 3 \end{pmatrix} + \begin{pmatrix} -3 & 5 \\ 7 & 6 \end{pmatrix} = \begin{matrix} 4 + (-3) & -2 + 5 \\ -1 + 7 & 3 + 6 \end{matrix} = \begin{pmatrix} 1 & -3 \\ 6 & 9 \end{pmatrix}$$

2. Subtract

$$\begin{pmatrix} 3 & 1 & -4 \\ 4 & 3 & 1 \\ 1 & 4 & -3 \end{pmatrix} - \begin{pmatrix} 2 & 7 & -5 \\ -2 & 1 & 0 \\ 6 & 3 & 4 \end{pmatrix} = \begin{pmatrix} 3-2 & 1-7 & -4-(-5) \\ 4-(-2) & 3-1 & 1-0 \\ 1-6 & 4-3 & -3-4 \end{pmatrix} = \begin{pmatrix} 1 & -6 & 1 \\ 6 & 2 & 1 \\ -5 & 1 & -7 \end{pmatrix}$$

3. Determine the value of:

$$\begin{vmatrix} 3 & -2 \\ 7 & 4 \end{vmatrix} = (3 \times 4) - (-2 \times 7) = 26$$

4. If  $A = \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix}$  and  $B = \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix}$ , show that  $A \times B \neq B \times A$

$$\begin{aligned} A \times B &= \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix} \times \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} [(2 \times 2) + (3 \times 0)] & [(2 \times 3) + (3 \times 1)] \\ [(1 \times 2) + (0 \times 0)] & [(1 \times 3) + (0 \times 1)] \end{pmatrix} \\ &= \begin{pmatrix} 4 & 9 \\ 2 & 3 \end{pmatrix} \end{aligned}$$

$$\begin{aligned} B \times A &= \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix} \times \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix} = \begin{pmatrix} [(2 \times 2) + (3 \times 1)] & [(2 \times 3) + (3 \times 0)] \\ [(0 \times 2) + (1 \times 1)] & [(0 \times 3) + (1 \times 0)] \end{pmatrix} \\ &= \begin{pmatrix} 7 & 6 \\ 1 & 0 \end{pmatrix} \end{aligned}$$

Therefore  $A \times B \neq B \times A$

## 5 Learning Outcome 6: Apply Vectors in work

### 5.2.2 Introduction to the learning outcome

This learning outcome covers; derivation of vectors in two and three dimensions and performing various operations on vectors which includes obtaining vector position and performing resolution of vectors.

### 5.2.3 Performance Standard

1. Meaning of vector
2. Representations of vectors
3. Operations of vectors
4. Addition
5. Subtraction
6. Scalar and vector products
7. Determination of angles

### 5.2.4 Information Sheet

#### 5.2.4.1 Definition of terms

**Scalar:** These are quantities with magnitude but no direction.

**Vector:** These are quantities with both magnitude and direction.

**Position vector:** This is a vector that originates from the origin to a given point e.g. velocity and acceleration.

### Meaning of vector

A vector is a quantity having both magnitude and direction such as force, velocity etc. A vector is also defined as a tensor of order one. A scalar has only magnitude and is completely characterized by one number.



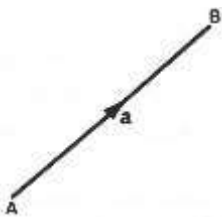
It is a tensor of order zero and temperature is an example of a scalar. A second order tensor, in a three-dimensional space, is represented by nine numbers (components).

### Representations of vectors

The vector quantity can be represented graphically by a line, drawn so that:

- i. The length of the line denotes the magnitude of the quantity according to the stated vector scale
- ii. The direction of the line denotes the direction in which the vector quantity acts. The sense of the direction is indicated by an arrowhead.

The vector quantity AB is referred to as  $\overline{AB}$  or a.



The magnitude of the vector quantity is written  $|\overline{AB}|$  or  $|a|$  or simply AB or a.

### Operations of vectors

To add or to subtract vectors, we add or subtract the respective corresponding components.

I.e. let  $\vec{P} = (a, b)$  and  $\vec{Q} = (c, d)$

$$\text{Then } \vec{p} + \vec{q} = (a + c, b + d)$$

Let  $\vec{r} = (r_1, r_2)$  and  $\vec{S} = (s_1, s_2)$

$$=(r_1 - s_1, r_2 - s_2)$$

Example: Find

( $\vec{P} + \vec{Q}$ )      B) ( $\vec{P} - \vec{Q}$ )      Given  $\vec{P} = (4, 5)$  And  $\vec{Q} = (6, -1)$

### Solution

$$\vec{P} + \vec{Q} = (p_1 + q_1, p_2 + q_2)$$

$$= (4 + 6, 5 + -1)$$

$$= (10, 4)$$

$$\text{ii) } \vec{P} - \vec{Q} = (p_1 - q_1, p_2 - q_2)$$

$$= (4 - 6, 5 - (-1))$$

$$= (-2, 6)$$

OR

Rewrite the difference  $\vec{P} - \vec{Q}$  as the sum  $\vec{P} + (-\vec{Q})$ . To determine  $-\vec{Q}$ , we do a scalar multiplication of -1 times  $\vec{Q}$

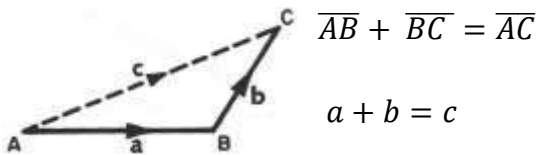
$$-\vec{q} = -1 (6, -1)$$

$$= (-6, 1)$$

$$\text{Hence } \vec{P} + \vec{Q} = (4 - 6, 5 + 1) = (-2, 6)$$

### Addition

The sum of two vectors,  $\vec{AB}$  and  $\vec{BC}$  is defined as the single equivalent or resultant vector  $\vec{AC}$ .



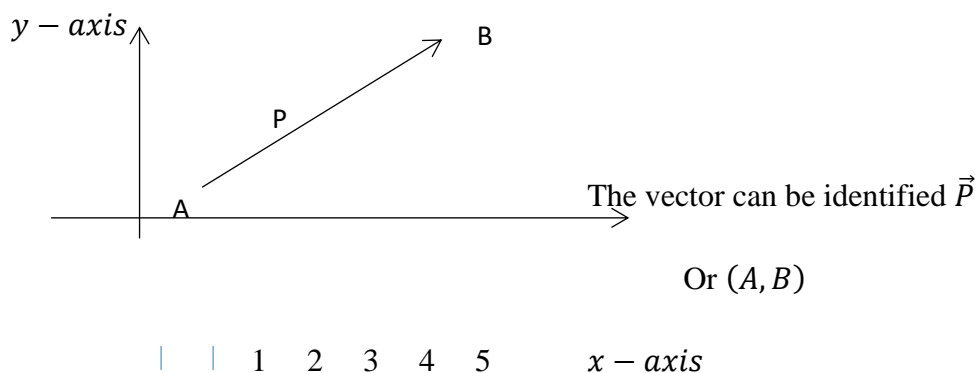
Example:

A force of 40N is acting in the direction due east represented by p and a force of 30N is acting in the direction due south represented as q, find the magnitude (r) of the vector of the two forces.

$$r^2 = p^2 + q^2 = \sqrt{(p^2 + q^2)} = \sqrt{(40^2 + 30^2)} = 50$$

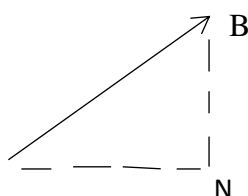
### Scalar and vector products

In the concept of two-dimensions, we can use the Cartesian planes to draw our vectors



Vector P is a 2-dimensional vector drawn with 3 units on the x-axis and 3 units on the y-axis.

The magnitude of vector P is simply the length of vector P which we can calculate using the basic Pythagoras theorem i.e. we can denote the vector components as  $NB = 3$  and  $AN = 3$

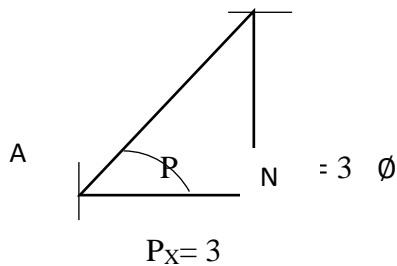


A

Magnitude of P (denoted as  $|P|$ )

$$|P| = \sqrt{3^2 + 3^2} = 4.24 \text{ units}$$

Direction of a vector normally we use degrees or radians from the horizontal in an anticlockwise direction to describe direction of a vector



Where AB – Hypotenuse side

BN - Adjacent side

NB – Opposite side to angle  $\theta$

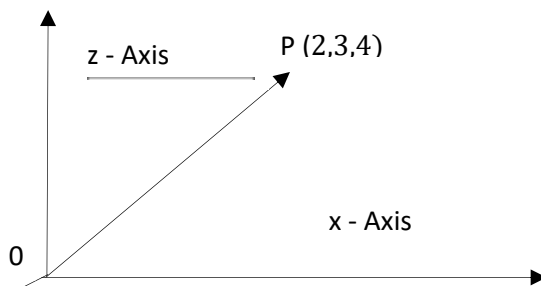
We first form a right-angled triangle by joining the ends of the vector then apply simple trigonometry.

So, we have:  $\tan \theta = \frac{3}{3} \left( \frac{\text{opposite}}{\text{adjacent}} \right) = 1$

$$\tan^{-1} 1 = 45^\circ = 0.785 \text{ radians}$$

Hence, we can describe our vector as having magnitude 4.24 units and direction  $45^\circ$  from the right horizontal axis. In three dimensional spaces, we construct three mutually perpendicular axes (commonly the x, y, z axis).

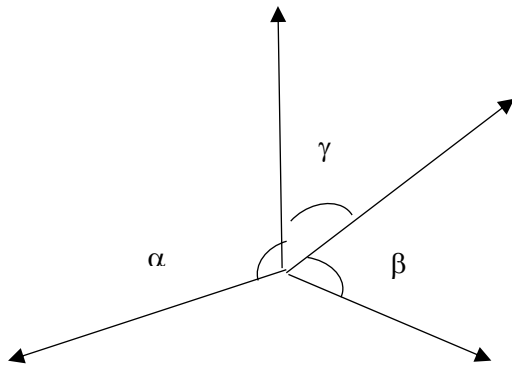
**Example:** Sketch point (2,3,4)



Just like y - Axis in 2 dimensional we can also denote three dimensional vectors using the standard unit vectors  $i, j, k$ ,  $i=(1, 0, 0)$ ,  $j=(0, 1, 0)$ ,  $k=(0, 0, 1)$  and then express the vector as sum of scalar multiples of these unit vectors i.e.  $P=(P_1 \ P_2 \ P_3)= P_{1i} + P_{2j} + P_{3k}$

For vector  $OP_1$

$$|OP| = \sqrt{2^2 + 3^2 + 4^2} = 5.385 \text{ units}$$



$\delta$ -Angle between P and x-axis

Use scalar products to get the direction cosines.

$$\text{I.e. } p_1 = P \cdot i = 1 \times 1 \times \cos \delta$$

$$p_2 = P \cdot j = 1 \times 1 \times \cos \beta$$

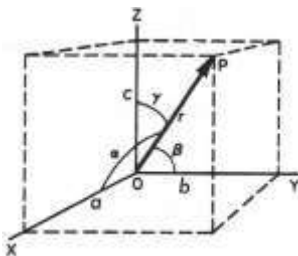
$$p_3 = P \cdot k = 1 \times 1 \times \cos \gamma$$

So, we can write a unit vector P as:

$$P = \cos \delta i + \cos \beta j + \cos \gamma k$$

### Determination of angles

The direction of a vector in three directions is determined in angles which the vector makes with the three axes of reference.



$$\text{Let } \overline{OP} = r = ai + bj + ck$$

$$\text{Then; } \frac{a}{r} = \cos \alpha \therefore a = r \cos \alpha$$

$$\frac{b}{r} = \cos \beta \therefore b = r \cos \beta$$

$$\frac{c}{r} = \cos \gamma \therefore c = r \cos \gamma$$

Figure 5: Directional Cosines

$$\text{Also } a^2 + b^2 + c^2 = r^2$$

$$r^2 \cos^2 \alpha + r^2 \cos^2 \beta + r^2 \cos^2 \gamma = r^2$$

$$\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = 1$$

Scalar (Dot) product of vectors

Product of two non-zero vectors  $\vec{a}$  and  $\vec{b}$  denoted by  $\vec{a} \cdot \vec{b} = |\vec{a}| |\vec{b}| \cos \theta$

Where  $\theta$  is the angle between  $\vec{a}$  and  $\vec{b}$ .

When either  $\vec{a} = 0$  or  $\vec{b} = 0$  then  $\theta$  is not defined and in this case,  $\vec{a} \cdot \vec{b} = 0$

If both  $\vec{a}$  and  $\vec{b}$  are non-zero and yet  $\vec{a} \cdot \vec{b} = 0$ , then this implies that  $\vec{a}$  and  $\vec{b}$  are perpendicular to each other. The angle between two non-zero vectors is given by;

$$\cos \theta = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}| |\vec{B}|}$$

$$\text{Or simply } \theta = \cos^{-1} \frac{\vec{A} \cdot \vec{B}}{|\vec{A}| |\vec{B}|}$$

If the  $\theta$  has not been given,

$$\vec{a} \cdot \vec{b} = (a_1 b_1 + a_2 b_2) = K \text{ (a constant).}$$

Example

Compute the product for each of the following.

$$\vec{p} = 4\mathbf{i} - 3\mathbf{j} \quad \vec{q} = 2\mathbf{i} + \mathbf{j}$$

*Solution*

$$\vec{p} \cdot \vec{q} = (4 \times 2) + (-3 \times 1)$$

$$= 8 - 3 = 5$$

$$\vec{p} = (8, 0, 3) \quad \vec{q} = (3, 2, 7)$$

*Solution*

$$\vec{p} \cdot \vec{q} = (8 \times 3) + (0 \times 2) + (3 \times 7)$$

$$= 6 + 0 + 21$$

$$= 27$$

Determine the angle between  $\vec{p} = (3, -4, -1)$  and  $(0, 5, 2)$

**Solution**

First, we need to calculate  $\vec{p} \cdot \vec{q}$  And then  $|\vec{p}|$  and  $|\vec{q}|$

$$\vec{p} \cdot \vec{q} = (3 \times 0) + (-4 \times 5) + (-1 \times 2)$$

$$= 0 + -20 - 2$$

$$= -22$$

$$|\vec{p}| = \sqrt{3^2 + (-4^2) + (-1^2)} = \sqrt{26}$$

$$|\vec{q}| = \sqrt{0^2 + 5^2 + 2^2} = \sqrt{29}$$

$$\cos \theta = \frac{\vec{p} \cdot \vec{q}}{|\vec{p}| |\vec{q}|} = \frac{-22}{\sqrt{26} \sqrt{29}} = -0.8011927 =$$

$$\cos^{-1}(-0.8011927) = 143.24^\circ \text{ (2.5 radians)}$$

$$\text{Let } \vec{P} = (p_1, p_2, p_3) \text{ and } \vec{Q} = (q_1, q_2, q_3)$$

$$\text{Then } \vec{P} \times \vec{Q} = (p_2 q_3 - p_3 q_2) \mathbf{i} - (p_1 q_3 - p_3 q_1) \mathbf{j} - (p_1 q_2 - p_2 q_1) \mathbf{k}$$

### Position of vectors

Definition: A position vector is a vector that starts from the origin i.e. its origin is (0, 0, 0)

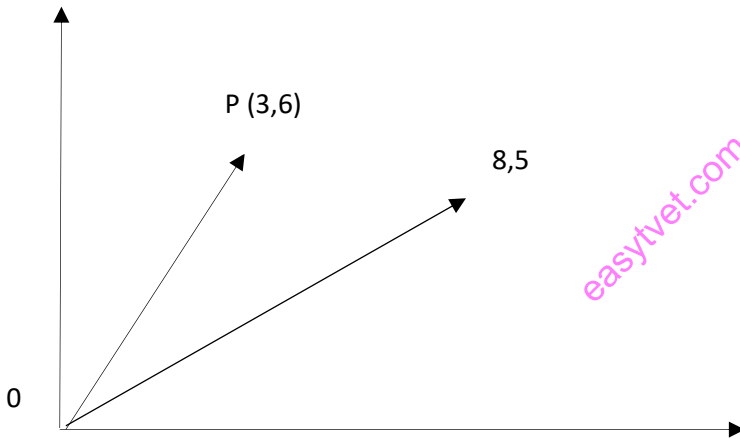


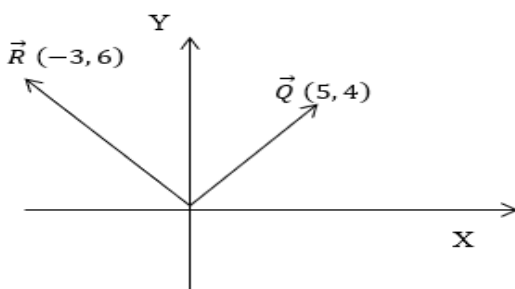
Figure 6: Position Vectors

The position vector of  $\vec{P}$  is  $\begin{pmatrix} 3 \\ 6 \end{pmatrix}$  and position vector of  $\vec{Q}$   $\begin{pmatrix} 8 \\ 5 \end{pmatrix}$

### Example 1

The position vector of  $\vec{Q}$  is  $\begin{pmatrix} 5 \\ 4 \end{pmatrix}$  and the position vector and the position vector of  $\vec{R}$   $\begin{pmatrix} -3 \\ 6 \end{pmatrix}$  is

Find the vector  $\vec{QR}$



Solution

$$\vec{QR} = \vec{QO} + \vec{OR}$$

NB:  $\vec{QO} = -\vec{OQ}$  (opposite direction)

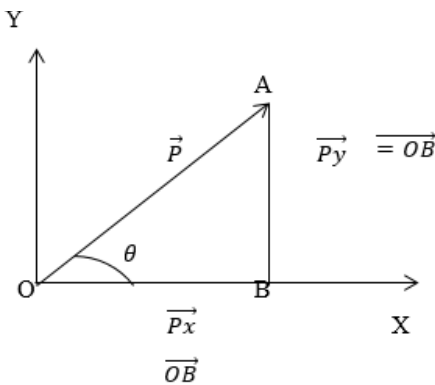
$$-\begin{pmatrix} 5 \\ 4 \end{pmatrix} + \begin{pmatrix} -3 \\ 6 \end{pmatrix} = \begin{pmatrix} -8 \\ 2 \end{pmatrix}$$

Generally,  $\vec{AB} = -a + b$  or simply  $b-a$  since from A to B, you must first move from A to the origin hence (-a) then from the origin to B.

### Performance of vector resolution

Definition: A vector resolution is the breaking down of one vector into two or more smaller vectors. In this regard, we only discuss the rectangular components of a vector (X-component and Y component).

Thus,



The rectangular components of  $\vec{P}$  are  $\vec{P}_x$  and  $\vec{P}_y$

$$\cos\theta = \frac{OB}{OA}$$

$$OB = \vec{P} \cos\theta$$

$$\text{Recall Cosine} = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\text{But } OB = P_x$$

Hence  $P_x = \vec{P} \cos\theta$  -The magnitude of horizontal component

$$\sin\theta = \frac{AB}{OA} \left[ \sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}} \right]$$

$$AB = OA \sin\theta \text{ (but } AB = P_y)$$

Hence  $P_y = \vec{P} \sin\theta$  is the magnitude of vertical component.

### 5.2.5 Learning Activities

#### 1. Activity 1

## Labeling Components

One of the first steps to understanding vectors is knowing what the different components are. Have your students work with partners for the first part of this activity. Each pair should create a graph that represents a vector. Their graphs should carefully represent the difference between a vector and a line, particularly because the graphs can have some similarities.

Then, have all students hang their graphs on a classroom wall, numbering each graph. Ask students to walk along the wall with their notebooks and notate the horizontal and vertical components of each of their classmates' vectors.

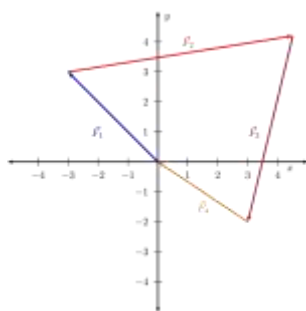
Once you have discussed their answers, ask each partnership to take their own graph and use colors and arrows to show how the horizontal and vertical components of their own vectors are determined.

## 2. Activity 2

To understand the principles of adding vectors by the graphical method and of adding vectors by component addition.

Two or more vectors can be added together to determine a vector sum or resultant. Two methods of adding vectors are the graphical or head-to-tail method and the trigonometric or component addition method. For each problem, vectors A, B and C are shown.

- i. Sketch the head-to-tail addition of  $F_1, F_2, F_3$  and  $F_4$  on the empty grid; label each vector.
- ii. Draw and label the resultant (R).
- iii. Record the magnitude and direction of each component; use a + to indicate East or North; use a – to indicate a West or South.
- iv. Sum the components to determine the components of the resultant.
- v. Use the Pythagorean theorem and SOH CAH TOA to determine the magnitude and direction of R



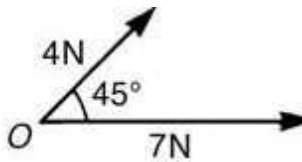
Magnitude of R =

Direction of R =

### 5.2.6 Self-Assessment

1. Calculate the resultant force of the two forces:

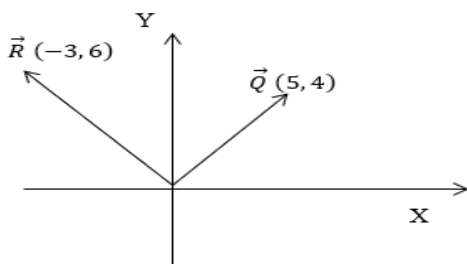




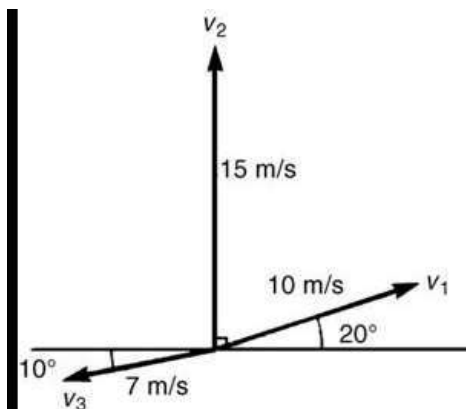
- i. The magnitude of the resultant of vector addition
- ii. The direction of the resultant of vector addition

1 The position vector of  $\vec{Q}$  is  $\begin{pmatrix} 5 \\ 4 \end{pmatrix}$  and the position vector and the position vector of  $\vec{R}$  is  $\begin{pmatrix} -3 \\ 6 \end{pmatrix}$

Find the vector  $\vec{QR}$



3. Use a graphical method to determine the magnitude and direction of the resultant of the three velocities



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### 5.2.7 Tools, Equipment, Supplies and Materials

- Calculator
- Ruler
- Black/white board
- Chalk/ board markers (Assorted)

### 5.2.8 References

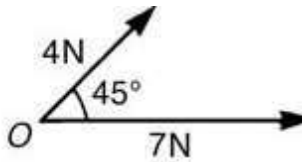
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Richard E. Johnson (2010). Vector Algebra Meerut: Krishna Prakashan Media (P) Ltd.

### 5.2.9 Answers to Self-Assessment

1. Calculate the resultant force of the two forces:



Horizontal component of force,

$$H = 7\cos 0^\circ + 4\cos 45^\circ$$

$$= 7 + 2.828 = 9.828\text{N}$$

Vertical component of force,

$$V = 7\sin 0^\circ + 4\sin 45^\circ = 0 + 2.828 = 2.828$$

The magnitude of the resultant of vector addition

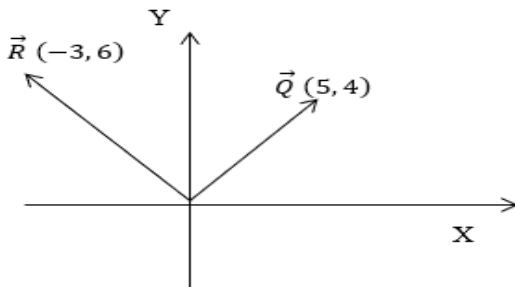
$$= \sqrt{H^2 + V^2} = \sqrt{9.828^2 + 2.828^2} = 10.23\text{N}$$

The direction of the resultant of vector addition

$$= \tan^{-1}\left(\frac{2.828}{9.828}\right) = 16.05^\circ$$

2. The position vector of  $\vec{Q}$  is  $\begin{pmatrix} 5 \\ 4 \end{pmatrix}$  and the position vector and the position vector of  $\vec{R}$   $\begin{pmatrix} -3 \\ 6 \end{pmatrix}$  is

Find the vector  $\vec{QR}$



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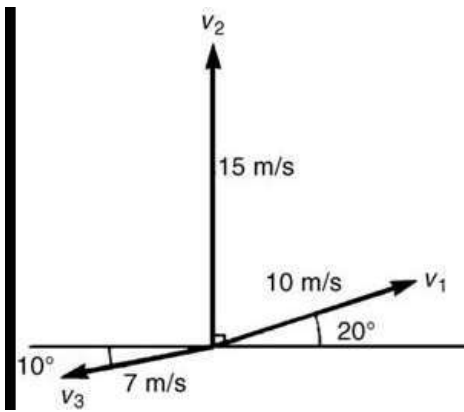
*Solution*

$$\vec{QR} = \vec{QO} + \vec{OR}$$

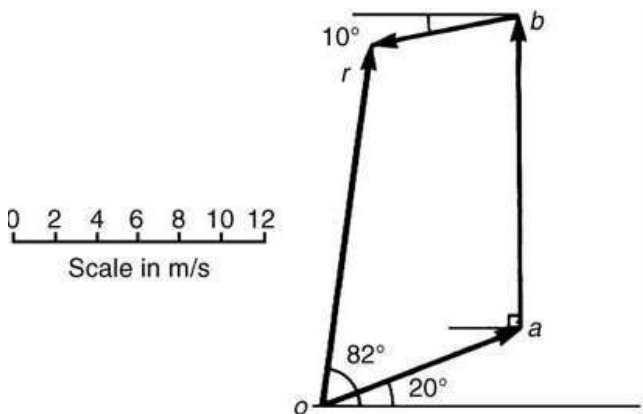
NB:  $\vec{QO} = -\vec{OQ}$  (opposite direction)

$$-\begin{pmatrix} 5 \\ 4 \end{pmatrix} + \begin{pmatrix} -3 \\ 6 \end{pmatrix} = \begin{pmatrix} -8 \\ 2 \end{pmatrix}$$

3. Use a graphical method to determine the magnitude and direction of the resultant of the three velocities



$$v_1 + v_2 + v_3 = 17.5 \text{ m/s at } 82^\circ \text{ to the horizontal}$$



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## 6 Learning Outcome 7: Collect, Organize and Interpret Statistical Data

### 6.2.2 Introduction to the learning outcome

This learning outcome covers obtainment of mean, median, mode and standard deviation from given data, performance of calculations based on laws of probability, performance of calculation involving probability distributions, mathematical expectation sampling distributions and application of sampling distribution methods in data analysis.

### 6.2.3 Performance Standard

1. Classification of data
  - a) Grouped data
  - b) Ungrouped data
2. Data collection
  - a) Tabulation of data
  - b) Class intervals
  - c) Class boundaries

- d) Frequency tables
- e) Cumulative frequency
- 3. Sampling
  - a) Importance of sampling
  - b) Errors in sampling
  - c) Types of sampling and their limitations
- 4. Diagrammatic and graphical presentation of data e.g.
  - a) Histograms
  - b) Frequency polygons
  - c) Bar charts
  - d) Pie charts
  - e) Cumulative frequency curves
- 5. Measures of central tendency
  - a) Measures
  - b) Properties
- 6. Calculation and interpretation of mean, mode and median, variance and standard deviation

#### 6.2.4 Information Sheet

##### 6.2.4.1 Definition of Terms

**Mode:** This is the number which is the most repeated in a series.

**Standard deviation:** This is the amount of variation of a set of numbers. It is the square root variance.

**Variance:** This is the mean of the squared differences of the number from the mean.

#### Classification of data

A variable may be of two kinds:

Discrete – a variable that can be counted, or for which there is a fixed set of values.

Continuous – a variable that can be measured on a continuous scale, the result depending on the precision of the measuring instrument or the accuracy of the observer.

*Ungrouped data* can be presented diagrammatically in several ways and these include:

- (a) Pictograms, in which pictorial symbols are used to represent quantities
- (b) Horizontal bar charts, having data represented by equally spaced horizontal rectangles
- (c) Vertical bar charts, in which data are represented by equally spaced vertical rectangles

Trends in ungrouped data over equal periods of time can be presented diagrammatically by a percentage component bar chart.

#### *Grouped data*

When the number of members in a set is small, say ten or less, the data can be represented diagrammatically without further analysis, by means of pictograms, bar charts, percentage components bar charts or pie diagrams.

For sets having more than ten members, those members having similar values are grouped together in classes to form a frequency distribution. To assist in accurately counting members in the various classes, a tally diagram is used.

A frequency distribution is merely a table showing classes and their corresponding frequencies.

The new set of values obtained by forming a frequency distribution is called grouped data.

### Data collection

We can use this example to define a number of terms, consider the class labelled 7.1 – 7.3

The class values stated in the table are the lower and upper limits of the class and their difference gives the class width.

The class boundaries are 0.05 below the lower class limit and 0.05 above the upper class limit.

The lower class boundary is  $7.1 - 0.05 = 7.05$

The upper class boundary is  $7.3 + 0.05 = 7.35$

The class interval is the difference between the upper and lower class boundaries.

Class interval = upper class boundary – lower class boundary  
 $= 7.35 - 7.05 = 0.30$

Where the classes are regular, the class interval can also be found by subtracting any lower class limit from the lower class limit of the following class.

The central value (mid value) of the class is the average of the upper and lower class boundaries.

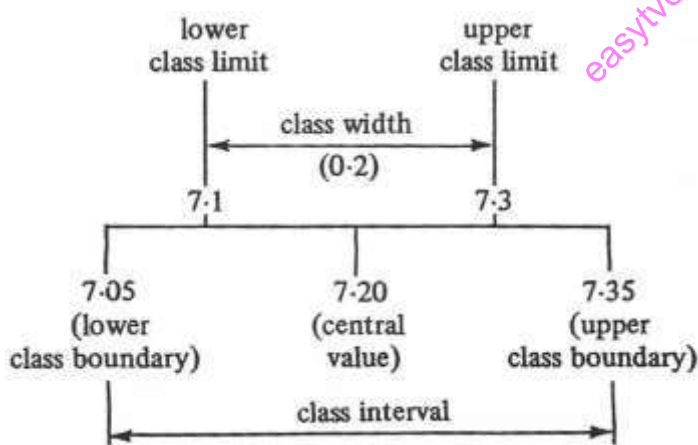


Figure 7: Class Boundaries

### Sampling

*Performance of calculations involving use of standard normal table, sampling distribution, t-distribution and estimation*

Standard normal table (known Z table)

$$Z = \frac{x - \mu}{\alpha}$$

$X = \text{raw score}$

$\mu = \text{mean}$

$\alpha = \text{standard deviation}$

A Z found on the both tables should be used on the table provided to know the percentile and therefore compare. Note; if it is a negative then a table for negative values is used.

### **Sampling distribution**

It is also known as probability distribution and the standard deviation of this topic is known as standard error. Sampling distribution mean is equal to the mean of the population.

$$\mu_x = \mu$$

Therefore, standard error is:

$$\sigma = \sqrt{\frac{\sum(x_j - \mu)^2}{n - 1}}$$

$$SE = \frac{\sigma}{\sqrt{n}}$$

SE Standard error

$\sigma$  = Standard deviation

$\mu$  = Size of population

n = size of sample

If  $fpc = 1$  from factor  $\sqrt{(N - n)/N - 1}$ , therefore standard error formula can be approximated by

$$\sqrt{(x - \mu)}/\sqrt{n}$$

### **Distribution**

It is a type of distribution similar with the normal distribution curve but with a bit shorter and fatter tail. Therefore distribution is used because small size is small.

$$t = \frac{x - \mu}{\left(\frac{s}{\sqrt{n}}\right)}$$

Where,

$\bar{x}$  is the sample mean

$\mu$  is the population mean

s is the standard deviation

n is the size of the sample given

### **Estimation**

This is the process of identifying a value by approximating due to a certain purpose. It can be done by rounding off to the nearest whole number.

Application of sampling distribution methods in data analysis

There are three main types;

- Normal distribution; commonly used in investing, finance, science and engineering. It fully based on its mean and standard deviation.
- Binomial distribution: It is discrete, as opposed to continuous, since 1 or 0 / yes or no is a valid response.
- Chi-squared distribution
- Poisson distribution

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### **DIAGRAMMATIC AND GRAPHICAL PRESENTATION OF DATA**

#### *Histograms*

#### *Frequency histogram*

A histogram is a graphical representation of a frequency distribution, in which vertical rectangular blocks are drawn so that:

- i. The centre of the base indicates the central value of the class
- ii. The area of the rectangle represents the class frequency

If the class intervals are regular, the frequency is then denoted by the height of the rectangle.

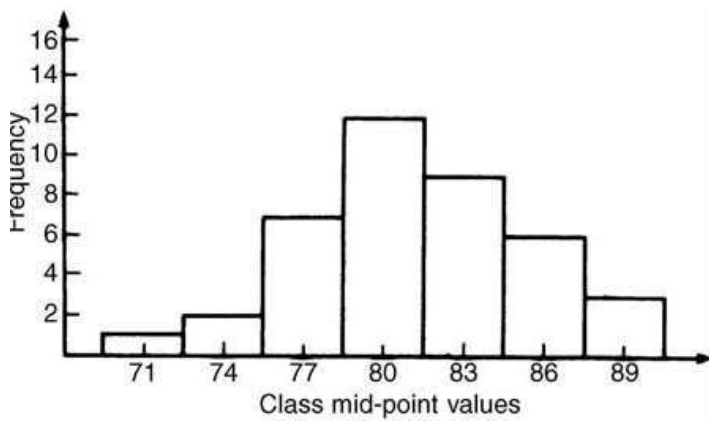


Figure 8: Histogram

### Frequency Polygon

Another method of presenting grouped data diagrammatically is by using a **frequency polygon**, which is the graph produced by plotting frequency against class mid-point values and joining the coordinates with straight lines.

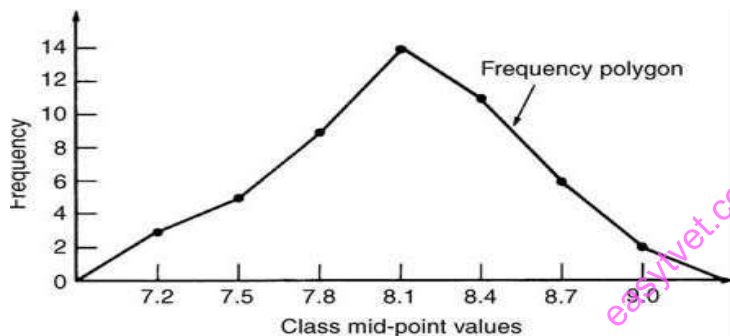


Figure 9: Frequency Polygon

A cumulative frequency distribution is a table showing the cumulative frequency for each value of upper class boundary. The cumulative frequency for a particular value of upper class boundary is obtained by adding the frequency of the class to the sum of the previous frequencies.

The curve obtained by joining the co-ordinates of cumulative frequency (vertically) against upper class boundary (horizontally) is called an **ogive** or a **cumulative frequency distribution curve**

## MEASURES OF CENTRAL TENDENCY

A single value, which is representative of a set of values, may be used to give an indication of the general size of the members in a set, the word '**average**' often being used to indicate the single value.

The statistical term used for 'average' is the arithmetic mean or just the **mean**.

Other measures of central tendency may be used and these include the **median** and the **modal** values.



## Obtainment of mean, median, mode and standard deviation from given data

A **set** is a group of data and an individual value within the set is called a **member** of the set. Some members selected at random from a population are called a **sample**.

**Mean:** It is also known as average therefore it is addition of the number divided by the number of the numbers.

$$\text{Mean} = \frac{\sum \text{of numbers}}{\text{no of numbers}}$$

**Median:** This is the number in the middle after being arranged from the lowest to the highest number; if they are two, find the mean.

**Mode:** This is the number which is the most repeated in a series.

**Variance:** This is the mean of the squared differences of the number from the mean.

$$\text{Variance} = \sum (x_i - \mu)^2 / n$$

**Standard deviation:** This is the amount of variation of a set of numbers known as square root variance.

Example:

Determine the mean, median and mode for the set:

{2, 3, 7, 5, 5, 13, 1, 7, 4, 8, 3, 4, 3}

Thus, **mean value**,

$$\bar{x} = \frac{2+3+7+5+5+13+1+7+4+8+3+4+3}{13} = \frac{65}{13} = 5$$

Median

To obtain the median value the set is ranked, that is, placed in ascending order of magnitude, and since the set contains an odd number of members the value of the middle member is the median value.

Ranking the set gives: [1,2,3,3,3,4,4,5,5,7,7,8,13]

{1, 2, 3, 3, 3, 4, 4, 5, 5, 7, 7, 8, 13}

The middle term is the seventh member, i.e. 4, thus the **median value is 4**.

Mode

The **modal value** is the value of the most commonly occurring member and is **3**, which occurs three times, all other members on occurring once or twice.

### 6.2.5 Learning Activities

1. As the teacher ask your students to collect 25 bottle tops and start making a histogram of their dates they forward the bottle tops. Each student has collected 25 bottle tops over the past few days. The students come to place the pennies in groups above a number line on the floor, according to the years in which the pennies were minted.

- i. Construct a histogram of the dates of return within a week.
- ii. Ask the class to estimate the mean and standard deviation of the distribution

### 6.2.6 Self-Assessment

1. The data given below refer to the gain of each of a batch of 40 transistors, expressed correct to the nearest whole number.

Form a frequency distribution for these data having seven classes.

81 83 87 74 76 89 82 84

86 76 77 71 86 85 87 88

84 81 80 81 73 89 82 79

81 79 78 80 85 77 84 78

83 79 80 83 82 79 80 77

- Calculate the range
- Calculate the range
- Construct the frequency distribution
- Construct the histogram

3. The frequency distribution for the value of resistance in ohms of 48 resistors is as shown.

Determine the mean value of resistance.

20.5–20.9: 3, 21.0–21.4: 10, 21.5–21.9: 11,

22.0–22.4: 13, 22.5–22.9: 9, 23.0–23.4: 2

4. Determine the standard deviation from the mean of the set of numbers: (5, 6, 8, 4, 10, 3) correct to 4 significant figures.

### 6.2.7 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Computers with an internet connection

### 6.2.8 References

K. A. Stroud, (2001). Engineering Mathematics, 5<sup>th</sup> Ed. Industrial Press Inc, New York.

John Bird, (2003). Engineering Mathematics, Fourth Edition. Elsevier Science, Oxford, UK

### 6.2.9 Answers to Self-Assessment

1. The data given below refer to the gain of each of a batch of 40 transistors, expressed correct to the nearest whole number.

Form a frequency distribution for these data having seven classes.

81 83 87 74 76 89 82 84

86 76 77 71 86 85 87 88  
 84 81 80 81 73 89 82 79  
 81 79 78 80 85 77 84 78  
 83 79 80 83 82 79 80 77

a) Calculate the range

The value obtained by taking the value of the smallest member from that of the largest member.

Inspection of the set of data shows that, range=89-71=18

b) Construct a tally diagram

This is obtained by listing the classes in the left-hand column, and then inspecting each of the 40 members of the set in turn and allocating them to the appropriate classes by putting '1s' in the appropriate rows. Every fifth '1' allocated to the particular row is shown as an oblique line crossing the four previous '1s', to help with final counting.

| Class | Tally |
|-------|-------|
| 70-72 | 1     |
| 73-75 | 11    |
| 76-78 | 11    |
| 79-81 | 11    |
| 82-84 | 1111  |
| 85-87 | 1     |
| 88-90 | 111   |

Figure 10: Tally Diagram

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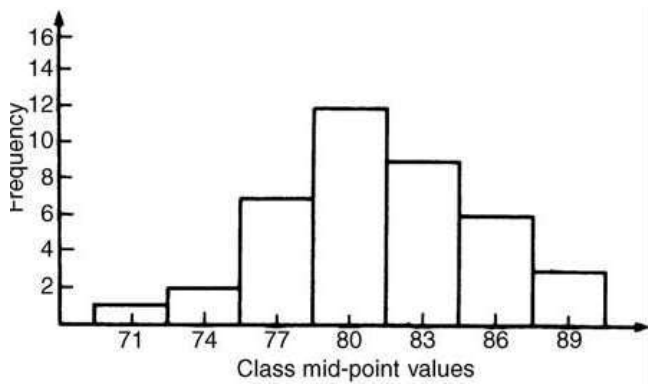
c) Construct the frequency distribution

| Class   | Class mid-point | Frequency |
|---------|-----------------|-----------|
| 70 - 72 | 71              | 1         |
| 73 - 75 | 74              | 2         |
| 76 - 78 | 77              | 7         |
| 79 - 81 | 80              | 12        |
| 82 - 84 | 83              | 9         |
| 85 - 87 | 86              | 6         |
| 88 - 90 | 89              | 3         |

Figure 11: Frequency Distribution

d) Construct the histogram

The width of the rectangles correspond to the upper class boundary values minus the lower class boundary values and the heights of the rectangles correspond to the class frequencies. The easiest way to draw a histogram is to mark the class mid-point values on the horizontal scale and draw the rectangles symmetrically about the appropriate class mid-point values and touching one another.



5. The frequency distribution for the value of resistance in ohms of 48 resistors is as shown.

Determine the mean value of resistance.

20.5–20.9: 3, 21.0–21.4: 10, 21.5–21.9: 11,

22.0–22.4: 13, 22.5–22.9: 9, 23.0–23.4: 2

The class mid-point/frequency values are:

20.7 - 3, 21.2 - 10, 21.7 - 11, 22.2 - 13, 22.7 - 9 and 23.2 - 2

For grouped data, the mean value is given by:

$$\bar{x} = \frac{\sum(fx)}{\sum f} = \frac{(20.7 \times 3) + (21.2 \times 10) + (21.7 \times 11) + (22.2 \times 13) + (22.7 \times 9) + (23.2 \times 2)}{48}$$

$$= 21.9$$

6. Determine the standard deviation from the mean of the set of numbers: (5, 6, 8, 4, 10, 3) correct to 4 significant figures.

$$\text{The arithmetic mean } \bar{x} = \frac{\sum x}{n} = \frac{5+6+8+4+10+3}{6} = 6$$

$$\text{Standard deviation } \sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

The  $(x - \bar{x})^2$  values are  $(5 - 6)^2, (6 - 6)^2, (8 - 6)^2, (4 - 6)^2, (10 - 6)^2, (3 - 6)^2$

The sum of the  $(x - \bar{x})^2$  values, i.e.

$$\sum (x - \bar{x})^2 = 1 + 0 + 4 + 4 + 16 + 9 = 34$$

$$= \frac{\sum(x - \bar{x})^2}{n} = \frac{34}{6} = 5.6$$

Since, there are 6 members in the set.

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n}} = \sqrt{5.6} = 2.38$$

## 7 Learning Outcome 8: Apply Concepts of probability for Work

### 7.2.2 Introduction to the learning outcome

This learning outcome covers: Probability, Types of probability events, Laws of probability, Counting techniques, Permutation, Combination, Tree diagrams and Venn diagrams.

### 7.2.3 Performance Standard

1. Probability
2. Types of probability events
  - Dependent
  - Independent
  - Mutually exclusive
3. Laws of probability
4. Counting techniques
5. Permutation
6. Combination
7. Tree diagrams
8. Venn diagrams

### 7.2.4 Information Sheet

#### 7.2.4.1 Definition of terms

#### **Probability**

Probability of something happening is the likelihood or chance of it happening. Values of probability lie between 0 and 1, where 0 represents an absolute impossibility and 1 represents an absolute certainty.

The probability of an event happening usually lies somewhere between these two extreme values and is expressed either as a proper or decimal fraction.

If  $p$  is the probability of an event happening and  $q$  is the probability of the same event not happening, then the total probability is  $p + q$  and is equal to unity, since it is an absolute certainty that the event either does or does not occur, i.e.  $p + q = 1$

The expectation,  $E$ , of an event happening is defined in general terms as the product of the probability  $p$  of an event happening and the number of attempts made,  $n$ , i.e.  $E = pn$ .

#### **TYPES OF PROBABILITY EVENTS**

##### ***Dependent event***

A dependent event is one in which the probability of an event happening affects the probability of another ever happening.

##### ***Independent event***

An independent event is one in which the probability of an event happening does not affect the probability of another event happening.

### **Conditional probability**

Conditional probability is concerned with the probability of say event B occurring, given that event A has already taken place. If A and B are independent events, then the fact that event A has already occurred will not affect the probability of event B. If A and B are dependent events, then event A having occurred will affect the probability of event B.

### **Mutually exclusive event**

Two events are known as mutually exclusive, when the occurrence of one of them excludes the occurrence of the other. I.e. in tossing of a coin the outcomes are either head or tail.

## **Laws of probability**

### **The addition law of probability**

The addition law of probability is recognized by the word ‘**or**’ joining the probabilities. If  $P_A$  is the probability of event A happening and  $P_B$  is the probability of event B happening, the probability of **event A or event B** happening is given by  $P_A + P_B$  (provided events A and B are **mutually exclusive**, i.e. A and B are events which cannot occur together).

Similarly, the probability of events **A or B or C or . . . N** happening is given by

$$P_A + P_B + P_C \dots \dots \dots P_N$$

### **The multiplication law of probability**

The multiplication law of probability is recognized by the word ‘**and**’ joining the probabilities. If  $P_A$  is the probability of event A happening and  $P_B$  is the probability of event B happening, the probability of **event A and event B** happening is given by  $P_A \times P_B$ .

Similarly, the probability of events **A and B and C and . . . N** happening is given by:

$$P_A \times P_B \times P_C \dots \dots \dots P_N$$

### **Not Mutually Exclusive Events**

Consider the case where two events A and B are not mutually exclusive. The probability of that event that either A or B or both occur is given as

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

## **Permutations**

If n different objects are available, they can be arranged in different orders of selection. Each different ordered arrangement is called a **permutation**.

For example, permutations of the three letters X, Y and Z taken together are:

XYZ, XZY, YXZ, YZX, ZXY and ZYX

This can be expressed as  ${}^3P_3 = 6$ , the upper 3 denoting the number of items from which the arrangements are made, and the lower 3 indicating the number of items used in each arrangement.

In general,  ${}^nP_r = n(n-1)(n-2) \dots \dots \dots (n-r+1)$  or  $= \frac{n!}{(n-r)!}$

### Combinations

Using three letters A, B, C we now make selections without regard to the order of the letters in each group i.e. AB is now the same as BA, etc. Each group is called a combination and  ${}^nC_r$ , where n is the total number of items and r is the number in each selection, gives the number of possible combinations. Note that AB and BA are different permutations, but are not different combinations.

### Tree Diagram

A **probability tree diagram** shows all the possible events. The first event is represented by a dot. From the dot, branches are drawn to represent all possible outcomes of the event. The probability of each outcome is written on its branch.

### Venn Diagram

A set is a collection of things. A Venn diagram uses overlapping circles or other shapes to illustrate the logical relationships between two or more sets of items. Often, they serve to graphically organize things, highlighting how the items are similar and different.

Each friend is an "element" (or "member") of the set. It is normal to use **lowercase letters** for them.

Now let's say that alex, casey, drew and hunter play **Soccer**:

$$\text{Soccer} = \{\text{alex, casey, drew, hunter}\}$$

*(It says the Set "Soccer" is made up of the elements alex, casey, drew and hunter.)*

And casey, drew and jade play **Tennis**:

$$\text{Tennis} = \{\text{casey, drew, jade}\}$$

We can put their names in two separate circles:

You can now list your friends that play **Soccer OR Tennis**.

This is called a "Union" of sets and has the special symbol **U**:

$$\text{Soccer } \mathbf{U} \text{ Tennis} = \{\text{alex, casey, drew, hunter, jade}\}$$

Not everyone is in that set ... only your friends that play Soccer or Tennis (or both).

In other words we combine the elements of the two sets.

"Intersection" is when you must be in BOTH sets.

In our case that means **they play both Soccer AND Tennis** ... which is Casey and Drew.

The special symbol for Intersection is an upside down "U" like this:  $\cap$

And this is how we write it:

$$\text{Soccer} \cap \text{Tennis} = \{\text{Casey, Drew}\}$$

### ***Difference***

You can also "subtract" one set from another.

For example, taking Soccer and subtracting Tennis means people that **play Soccer but NOT Tennis** ... which is Alex and Hunter.

And this is how we write it:

$$\text{Soccer} - \text{Tennis} = \{\text{Alex, Hunter}\}$$

### 7.2.5 Learning Activities

1. In groups of 2 have the students play the Rock, Paper and Scissors game. Play the first round:

- i. What is the probability that your friend will throw a rock?
- ii. What is the probability that your friend will not throw a paper?

Now get a paper and pen and play 20 times and record your data.

- i. How many times was rock thrown by the partner?
- ii. What was the probability of it being thrown?
- iii. How many times was paper thrown by the partner?
- iv. What was the probability?
- v. How many times was scissors thrown by the partner?
- vi. What was the probability?

### 7.2.6 Self-Assessment

1. Determine the probabilities of selecting at random (a) a man, and (b) a woman from a crowd containing 20 men and 33 women.
2. Find the expectation of obtaining a 4 upwards with 3 throws of a fair dice.



3. The probability of a component failing in one year due to excessive temperature is  $\frac{1}{20}$ , due to excessive vibration is  $\frac{1}{25}$  and due to excessive humidity is  $\frac{1}{50}$ . Determine the probabilities that during a one-year period component: (a) fails due to excessive temperature and excessive vibration, (b) fails due to excessive vibration or excessive humidity, and (c) will not fail because of both excessive temperature and excessive humidity.

#### 7.2.7 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Computers with an internet connection

#### 7.2.8 References

K. A. Stroud, (2001). Engineering Mathematics, 5<sup>th</sup> Ed. Industrial Press Inc, New York.

John Bird, (2003). Engineering Mathematics, Fourth Edition. Elsevier Science, Oxford, UK

#### 7.2.9 Answers to Self-Assessment

1. Determine the probabilities of selecting at random (a) a man, and (b) a woman from a crowd containing 20 men and 33 women.

Solution

- a. The probability of selecting at random a man,  $p$ , is given by the ratio =  $\frac{\text{number of men}}{\text{number of crowd}}$

$$P = \frac{20}{20 + 33} = \frac{20}{53} = 0.3774$$

- b. The probability of selecting at random women,  $q$ , is given by the ratio =  $\frac{\text{number of women}}{\text{number of crowd}}$

$$Q = \frac{33}{20 + 33} = \frac{33}{53} = 0.6226$$

2. Find the expectation of obtaining 4 upwards with 3 throws of a fair dice.
3. The probability of a component failing in one year due to excessive temperature is  $\frac{1}{20}$ , due to excessive vibration is  $\frac{1}{25}$  and due to excessive humidity is  $\frac{1}{50}$ . Determine the probabilities that during a one-year period component: (a) fails due to excessive temperature and excessive vibration, (b) fails due to excessive vibration or excessive humidity, and (c) will not fail because of both excessive temperature and excessive humidity.

Solution

Let  $PA$  be the probability of failure due to excessive temperature, then

$$PA = \frac{1}{20} \text{ and } \overline{PA} = \frac{19}{20}$$

$\overline{PA}$  The probability of not failing.

Let  $PB$  be the probability of failure due to excessive vibration, then

$$PB = \frac{1}{25} \text{ and } \overline{PB} = \frac{24}{25}$$

Let  $PC$  be the probability of failure due to excessive humidity, then

$$PC = \frac{1}{50} \text{ and } \overline{PC} = \frac{49}{50}$$

- a. The probability of a component failing due to excessive temperature **and** excessive vibration is given by:

$$PA \times PB = \frac{1}{20} \times \frac{1}{25} = \frac{1}{500} = 0.002$$

- b. The probability of a component failing due to excessive vibration **or** excessive humidity is:

$$PB + PC = \frac{1}{25} + \frac{1}{50} = \frac{3}{50} = 0.06$$

- c. The probability that a component will not fail due to excessive temperature **and** will not fail due to excess humidity is:

$$\overline{PA} \times \overline{PC} = \frac{19}{20} \times \frac{49}{50} = \frac{931}{1000} = 0.931$$

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## 8 Learning Outcome 9: Perform Commercial Calculation

### 8.2.2 Introduction to the learning outcome

The learning outcome covers: Product pricing, Average sales determination, Stock turnover, Calculation of incomes, Profit and Loss calculations, Salaries,

### 8.2.3 Performance Standard

1. Product pricing
2. Average sales determination
3. Stock turnover
4. Calculation of incomes
5. Profit and loss calculations
6. Salaries
  - Gross
  - Net
7. Wages
  - Time rate
  - Flat rate
  - Overtime
  - Piece rate
  - Commission
  - Percentage
  - Bonus
8. Exchange rates calculation
  - Devaluation
  - Revaluation

### 8.2.4 Information Sheet

#### 8.2.4.1 Definition of terms

#### **Product pricing**

Price is the money that customers must pay for a product or service. In other words, price is an offer to sell for a certain amount of currency.

Pricing is the art of translating into quantitative terms the value of a product to customers at a point of time.

There are three components to the overall pricing strategy:

- Choice of a **Pricing Principle**: *Cost-Plus, Competitive, Value-Based*
- Choice of a **Price Positioning**: *Market Skimming, Neutral, Penetration*
- Choice of a **Pricing Structure**: *Unit Pricing, Tiered Pricing, Bundled Pricing, Subscriptions etc.*

#### **Average sales determination**

The selling price formula is:

$$\text{Selling Price} = \text{Cost Price} + \text{Profit Margin}$$

Cost price is the price a retailer paid for the product. And the profit margin is a percentage of the cost price.

- **Cost Price:** The price a retailer paid for the product
- **Profit Margin:** A percentage of the cost price.

How to Calculate Selling Price per Unit

1. Determine the total cost of all units purchased.
2. Divide the total cost by the number of units purchased to get the cost price.
3. Use the selling price formula to calculate the final price:  $\text{Selling Price} = \text{Cost Price} + \text{Profit Margin}$

### **Stock turnover**

Inventory turnover is a ratio showing how many times a company has sold and replaced inventory during a given period. A company can then divide the days in the period by the inventory turnover formula to calculate the days it takes to sell the inventory on hand.

Inventory Turnover = Sales / Average Inventory

### **Where:**

Average Inventory = (Beginning Inventory + Ending Inventory) / 2

Companies calculate inventory turnover by:

- Calculating the average inventory, which is done by dividing the sum of beginning inventory and ending inventory by two.
- Dividing sales by average inventory.

### **Profit and loss calculations**

Cost price (C.P.): This is the price at which an article is purchased.

Selling price (S.P.): This is the price at which an article is sold.

Profit or Gain: If the selling price is more than the cost price, the difference between them is the profit incurred.

$$\text{Formula: Profit or Gain} = \text{S.P.} - \text{C.P.}$$

Loss: If the selling price is less than the cost price, the difference between them is the loss incurred.

$$\text{Formula: Loss} = \text{Cost price (C.P.)} - \text{Selling Price (S.P.)}$$

Profit or Loss is always calculated on the cost price.

Marked price: This is the price marked as the selling price on an article, also known as the listed price.

Discount or Rebate: This is the reduction in price offered on the marked or listed price.

Below is the list of some basic formulas used in solving questions on profit and loss:

- $\text{Gain \%} = (\text{Gain} / \text{CP}) * 100$
- $\text{Loss \%} = (\text{Loss} / \text{CP}) * 100$
- $\text{SP} = [(100 + \text{Gain\%}) / 100] * \text{CP}$
- $\text{SP} = [(100 - \text{Loss \%}) / 100] * \text{CP}$

### **Salaries**

A salary is a form of payment from an employer to an employee, which may be specified in an employment contract. It is contrasted with piece wages, where each job, hour, or other unit is paid separately, rather than on a periodic basis.

#### *Gross Pay*

Gross income for an individual—also known as gross pay when it's on a paycheck—is the individual's total pay from his or her employer before taxes or other deductions. This includes income from all sources and is not limited to income received in cash; it also includes property or services received. Gross annual income is the amount of money a person earns in one year before taxes and includes income from all sources.

#### *Net Pay*

Net pay refers to the amount an employee takes home, not the amount it costs to employ them.

### **Wages**

- Time rate
- Flat rate
- Overtime
- Piece rate
- Commission
- Percentage
- Bonus

### **Exchange rates calculation**

The exchange rate is defined as the rate on the basis of which two countries involved in trade exchange marketable items or commodities. It is basically the cost of exchanging one currency for another currency.

Exchange rates fluctuate constantly throughout the week as currencies are actively traded. This pushes the price up and down, similar to other assets such as gold or stocks. Therefore, the exchange rate can be calculated as per the below-mentioned relationship: –

Exchange Rate = Money in Foreign Currency / Money in Domestic Currency

Additionally, it can also be determined as per the below-mentioned relationship: –

Exchange Rate = Money in After Exchange / Money before Exchange

### *Devaluation*

Devaluation is the deliberate downward adjustment of the value of a country's money relative to another currency, group of currencies, or currency standard. Countries that have a fixed exchange rate or semi-fixed exchange rate use this monetary policy tool. It is often confused with depreciation and is the opposite of revaluation, which refers to the readjustment of a currency's exchange rate.

Given two exchange rates in terms of a Base Currency and a Quote Currency we can calculate appreciation and depreciation between them using the percentage change calculation. Letting  $V_1$  be the starting rate and  $V_2$  the final rate.

The percentage change of the Quote Currency relative to the Base Currency is

$$\%change = \frac{(V_1 - V_2)}{V_2} \times 100$$

The percentage change of the Base Currency relative to the Quote Currency is

$$\%change = \frac{(V_2 - V_1)}{V_1} \times 100$$

A positive change is appreciation and a negative change is depreciation.

- Revaluation

A revaluation is a calculated upward adjustment to a country's official exchange rate relative to a chosen baseline. The baseline can include wage rates, the price of gold, or a foreign currency.

Revaluation is the opposite of devaluation, which is a downward adjustment of a country's official exchange rate.

### 8.2.5 Learning Activities

#### Activity 1

The activity below is to enhance knowledge on taxes.

Materials:

- computer/internet
- W-2 form (pre-filled)
- 1040 tax form

Guiding Questions:

- What types of taxes do people in your community pay?
- What is the tax rate for each type of tax?
- How much of your income will go to taxes?

Procedures:

- Divide students into pairs or small groups.
- Have students determine their annual income if they work 40 hours a week 52 weeks a year at the current minimum wage rate.
- Have students fill out a 1040 tax form using a prepared W-2.
- Have students determine their income tax rate for federal and state taxes.
- Have students research what other taxes apply to their personal situation and figure out the amount.
- Have students create a slide presentation that explains the difference between their annual salary and the actual amount they are able to count as part of their budget after paying taxes.

#### Activity 2

In groups of 4, have the students buy 20 biro pens at wholesale price of KShs. 10 per pen, they will spend a total cost of KShs. 2.50 per pen to advertise and on labor. If they made a total of profit of KShs. 120 from sale of the 20pens Using the template below let them fill the results.

Cost of the pen?

Profit per pen?

Selling price?

### 8.2.6 Self-Assessment

1. The market oriented pricing, there are three pricing ways, outline them?
2. Hot Pie's Bakery Supply needs to calculate the selling price for its product line of bread machines. The business purchased 20 bread machines for \$3,000.

a. Calculate the cost price

b. The cost price for each bread machine is \$150, and the business hopes to earn a 40% profit margin.

Calculate the selling price?

3. In a transaction, the profit percentage is 80% of the cost. If the cost further increases by 20% but the selling price remains the same, how much is the decrease in profit percentage?
4. A man bought two bicycles for Rs. 2500 each. If he sells one at a profit of 5%, then how much should he sell the other so that he makes a profit of 20% on the whole?
5. **A trader wants to make an investment in the exchange-traded funds traded in US markets. However, the trader lives in India and 1 INR corresponds to 0.014 USD. The trader has INR 10,000 to invest in the exchange-traded funds traded in the offshore market.**

**Help the trader determine the value of INR investment in terms of US currency.**

### 8.2.7 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Computers with an internet connection

### 8.2.8 References

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### 8.2.9 Answers to Self-Assessment

1. In market oriented pricing, there are three pricing ways, outline them.
  - **Price above market:** Consciously pricing your product above the competition to brand yourself as having a higher-quality or better-performing item
  - **Copy market:** Selling your item at the same price as your competition to maximize profit while staying competitive
  - **Price below market:** Using data as a benchmark and consciously pricing a product below competitors, to lure customers into your store over theirs



2. Hot Pie's Bakery Supply needs to calculate the selling price for its product line of bread machines. The business purchased 20 bread machines for \$3,000.

a. Calculate the cost price

**Total cost of units purchased:** \$3,000

**Number of units purchased:** 20

$$\text{Cost price:} = \frac{\$3,000}{20} = \$150$$

b. The cost price for each bread machine is \$150, and the business hopes to earn a 40% profit margin. Calculate the selling price?

$$\text{Selling Price} = \$150 + (40\% \times \$150)$$

$$\text{Selling Price} = \$150 + (0.4 \times \$150)$$

$$\text{Selling Price} = \$150 + \$60$$

$$\text{Selling Price} = \$210$$

3. In a transaction, the profit percentage is 80% of the cost. If the cost further increases by 20% but the selling price remains the same, how much is the decrease in profit percentage?

**Solution:**

Let us assume CP = Rs. 100.

Then Profit = Rs. 80 and selling price = Rs. 180.

The cost increases by 20% → New CP = Rs. 120, SP = Rs. 180.

$$\text{Profit \%} = \frac{60}{120} \times 100 = 50\%.$$

Therefore, Profit decreases by 30%.

4. A man bought two bicycles for Rs. 2500 each. If he sells one at a profit of 5%, then how much should he sell the other so that he makes a profit of 20% on the whole?

**Solution:**

Before we start, it's important to note here that it is not 15% to be added to 5% to make it a total of 20%.

Let the other profit percent be  $x$ .

Then, our equation looks like this.

$$105/100 * 2500 + [(100+x)/100] * 2500 = 120/100 * 5000 \rightarrow x= 35.$$

Hence, if he makes a profit of 35% on the second, it comes to a total of 20% profit on the whole.

- 5. A trader wants to make an investment in the exchange-traded funds traded in US markets. However, the trader lives in India and 1 INR corresponds to 0.014 USD. The trader has INR 10,000 to invest in the exchange-traded funds traded in the offshore market.**

**Help the trader determine the value of INR investment in terms of US currency.**

Determine the value of exchange in terms of US dollars.

$$\text{Money in after exchange} = \text{Exchange rate} \times \text{Money before exchange}$$

The value of exchange in terms of US dollars =  $0.014 \times 10000$

**Money in After Exchange = \$140**

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**Nairobi, Kenya**

**Email: [info@tvetcdacc.go.ke](mailto:info@tvetcdacc.go.ke)**

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## **CHAPTER 2: ELECTRICAL PRINCIPLES**

### **Unit of learning code ENG/CU/EI/CC/02/5**

#### **Relationship to Occupational Standards**

This unit addresses the unit of competency: Apply Electrical Principles

#### **2.1 Introduction**

This unit describes the competencies required by a Solar PV installation technician in order to apply a wide range of Electrical principles in their work. Which includes; Use of the concept of basic Electrical quantities, use of the concepts of D.C and A.C circuits in electrical installation, use of basic electrical machine, demonstrating the understanding of three phase power supply systems, use of power factor in electrical installation, use of earthing in Electrical installations, apply lightning protection measures and apply Electromagnetic field theory

#### **2.2 Summary of Learning Outcomes**

1. Use the concept of basic Electrical quantities
2. Use the concepts of D.C and A.C circuits in electrical installation
3. Use of basic electrical machine
4. Demonstrate understanding of three phase power supply
5. Use of power factor in electrical installation
6. Use of earthing in Electrical installations
7. Apply lightning protection measures
8. Apply Electromagnetic field theory

##### **2.2.1 Learning outcome 1: use the concept of basic electrical quantities**

###### **2.2.1.1 Introduction**

To use the concept of basic electrical quantities, the learner need to identify basic SI units in electrical such as quantities of charge, force, work and power, perform calculations involving Ohm's law i.e. current, resistance and voltage and other various electrical quantities and identify electrical quantities measuring instruments.

###### **2.2.1.2 Performance Standard**

- 2.2.1.2.1 Identify basic SI units in electrical systems
- 2.2.1.2.2 Identify quantities of charge, force, work and power
- 2.2.1.2.3 Perform calculations involving Ohm's law i.e. current, resistance and voltage
- 2.2.1.2.4 Perform calculations involving various electrical quantities
- 2.2.1.2.5 Identify electrical quantities measuring instruments

### 2.2.1.3 Information Sheet

#### SI units

The system of units used in engineering and science is the System International unites (International system of units), usually abbreviated to SI units, and is based on the metric system. This was introduced in 1960 and is now adopted by the majority of countries as the official system of measurement. The basic units in the SI system are listed in table 1 with their symbols.

| S/no. | Quantity                  | unit          |
|-------|---------------------------|---------------|
| 1.    | Length                    | Metre (m)     |
| 2.    | Mass                      | Kilogram (kg) |
| 3.    | Time                      | Second(s)     |
| 4.    | Electric current          | Ampere (A)    |
| 5.    | Thermodynamic temperature | Kelvin (K)    |
| 6.    | Luminous intensity        | Candela (cd)  |
| 7.    | Amount of substance       | Mole (mol)    |

Table 1 SI system and their symbols

Derived SI units use combinations of basic units and there are many of them. Two examples are:

- a) Velocity – metres per second (m/s)
- b) Acceleration – metres per second squared ( $m/s^2$ )

SI units may be made larger or smaller by using prefixes which denote multiplication or division by a particular amount. The six most common multiples, with their meaning, are listed in table 2

| S/No. | Prefix | Name  | Meaning   |
|-------|--------|-------|---|
| 1.    | M      | mega  | Multiply by 1,000,000 (i.e. $\times 10^6$ )           |
| 2.    | k      | kilo  | Multiply by 1,000 (i.e. $\times 10^3$ )               |
| 3.    | m      | milli | divide by 1,000 (i.e. $\times 10^{-3}$ )              |
| 4.    | $\mu$  | micro | divide by 1,000,000 (i.e. $\times 10^{-6}$ )          |
| 5.    | n      | nano  | divide by 1,000,000,000 (i.e. $\times 10^{-9}$ )      |
| 6.    | p      | pico  | divide by 1,000,000,000,000 (i.e. $\times 10^{-12}$ ) |

Table 2 Multiples and sub multiples of units

#### Standard electrical units of measure

The standard electrical units of measure are shown in table 3

Table 3 Standard units of measure

| S/No. | Electrical Parameter | Measuring unit | Symbol             | Description  |
|-------|----------------------|----------------|--------------------|--|
| 1.    | Voltage              | Volt           | V or E             | Unit of Electrical Potential ( $V = I \times R$ )    |
| 2.    | Current              | Ampere         | I or i             | Unit of Electrical Current ( $I = V \div R$ )        |
| 3.    | Resistance           | Ohm            | R or $\Omega$      | Unit of DC Resistance ( $R = V \div I$ )             |
| 4.    | Conductance          | Siemen         | G or $\mathcal{O}$ | Reciprocal of Resistance ( $G = 1 \div R$ )          |
| 5.    | Capacitance          | Farad          | C                  | Unit of Capacitance ( $C = Q \div V$ )               |
| 6.    | Charge               | Coulomb        | Q                  | Unit of Electrical Charge ( $Q = C \times V$ )       |
| 7.    | Inductance           | Henry          | L or H             | Unit of Inductance ( $V_L = -L(di/dt)$ )             |
| 8.    | Power                | Watts          | W                  | Unit of Power ( $P = V \times I$ or $I^2 \times R$ ) |
| 9.    | Impedance            | Ohm            | Z                  | Unit of AC Resistance ( $Z^2 = R^2 + X^2$ )          |
| 10.   | Frequency            | Hertz          | Hz                 | Unit of Frequency ( $f = 1 \div T$ )                 |

### Ohms law

Ohm's law states that the current flowing in a circuits is directly proportional to the applied voltage V and inversely proportional to the resistance R, provided the temperature remains constant. Thus,

$$I = \frac{V}{R} \text{ or } V = IR \text{ or } R = \frac{V}{I}$$

### Question 1

The current flowing through a resistor is 0.8 A when a p.d. of 20 V is applied. Determine the value of the resistance.

From ohms law,

$$\text{Resistance } R = \frac{V}{I} = \frac{20}{0.8} = 25\Omega$$

### Question 2.

Determine the p.d. which must be applied to a 2 K $\Omega$  resistor in order that a current of 10 mA may flow.

$$\text{Resistance } R = 2K\Omega = 2 \times 10^3 = 2000\Omega$$

$$\text{Current } I = 10 \text{ mA} = 10 \times 10^{-3} \text{ A}$$

### Question 3

A 100 V battery is connected across resistor and causes a current of 5 mA to flow. Determine the resistance of the resistor. If the voltage is now reduced to 25 V, what will be the new value of the current flowing?

$$\text{Resistance } R = \frac{V}{I} = \frac{100}{5 \times 10^{-3}} = 20 \times 10^3 = 20K\Omega$$

#### Question 4

A 100 W electric light bulb is connected to a 250 V supply. Determine

- a) the current flowing in the bulb, and
- b) the resistance of the bulb.

Power  $P = V \times I$ , from which, current  $I = PV$

- a) Current  $I = \frac{100}{250} = 0.4 \text{ A}$
- b) Resistance  $R = \frac{V}{I} = \frac{250}{0.4} = 625\Omega$

#### Question 5

Calculate the power dissipated when a current of 4 mA flows through a resistance of 5k $\Omega$ .

$$\begin{aligned} \text{Power } P &= I^2 R = 4 \times 10^{-3} \times 5 \times 10^3 = 80 \times 10^{-3} \\ &= 0.80W \text{ or } 80mW \end{aligned}$$

### Electrical Measurement & Instrument

Basically, measurement is an essential act to determine the electrical measuring unit. It performs from the comparing unknown quantity's unit and standard unit of an electronic device.

#### Definition:

A measuring devices which use to measure or compare unknown quantity with standard quantity is called as 'Measuring Instrument'

In simple words, sometimes, the measuring instrument called as '**Meter**'.

Ammeter, Voltmeter, Ohmmeter, and wattmeter are the example of the electrical measuring instrument.

These instruments calculate or measure the value of electrical quantities (current, voltage, resistance, electric power.

#### Classification of Electrical Measuring Instrument

The classification of an electrical measuring instrument is based on the nature of the operation, function, purpose, uses and many other terms. Generally, it is classified into two categories.

- a) Direct Measuring Instrument
- b) Comparison Measuring Instrument

A direct measuring instrument measures the electrical unit by reading and deflection. Ammeter, voltmeter, wattmeter are types of direct measuring instruments.

It is mostly used in engineering practical study especially electrical and electronics stream. It is simple and inexpensive as compared to the comparison instrument. It is also classified into two different parts like,

- i. Absolute Instrument
- ii. Secondary Instrument

You can easily understand the classification of an instrument through the block chart shown in figure

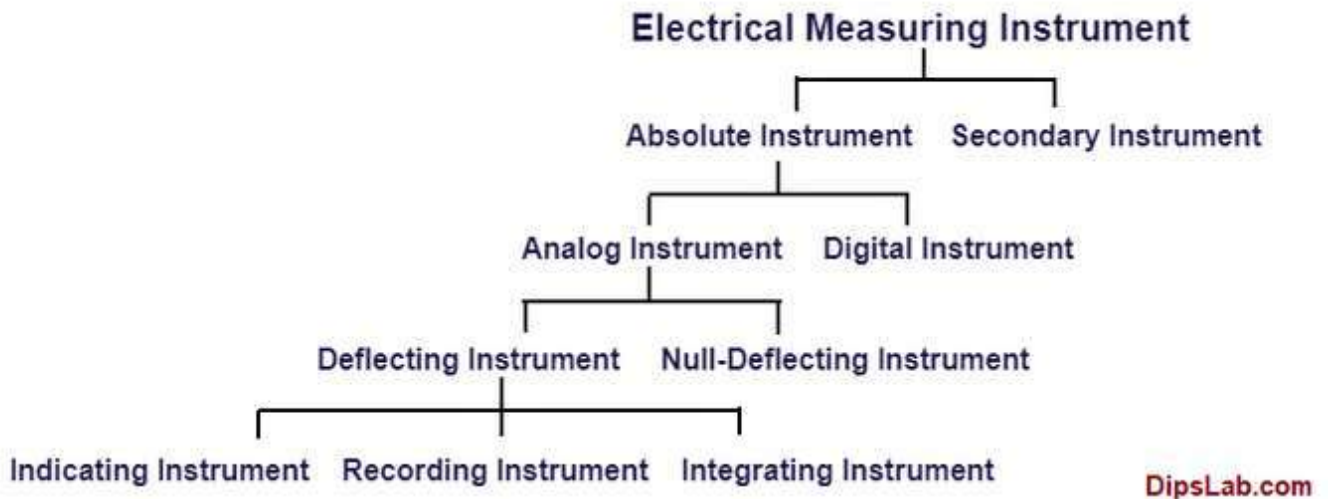


Figure 12: Classification of instruments

### Multimeter

Multi-meters can be used to make various electrical measurements, they can be used to measure AC and DC voltage, AC and DC current, and resistance. It is known as multi-meter because it can do the functions of various meters such as voltmeter, ammeter, and ohm-meter. Multi-meters can also be used to check the continuity. **Multimeter** are a popular type of electrical measuring instrument. Like its name, it works like an ammeter, voltmeter, and ohmmeter to measure current, voltage, and resistance, respectively

The multimeter is available into two different forms, like-

- i. Analog type Multimeter
- ii. Digital type Multimeter

In this advanced technology, both types of meter are needed as per requirement. A signal Multimeter performs all standard analog and digital meters measurement units or functions for AC and DC.

### Advantages of Digital Multimeter over the Analog Multimeter

- a) The analog type of multimeter shows the continuous signal. It detects and displays the electrical reading by using the moving pointer. Whereas, digital type of multimeter shows the discrete signal. And it measures and displays the numeric measuring unit or value. So, digital multimeter (DMM) gives a more accurate, fast response and readable digital output over analog multimeter.
- b) Digital meter is also called as '**Smart Meters**' or '**Advance Meters**'. With this single smart meter, you can measure multiple units. Instead of buying separate meters to measure current, voltage, resistance, and so on, you buy digital a multimeter.



## **Ammeter**

An ammeter is an instrument which is used to measure the electric current in amperes in a branch of an electric circuit. In order to measure the current it must flow through the ammeter, so the ammeter must be placed in series with the measured branch and it must have very low resistance so that the alteration of the current can be avoided which is measured. Instruments which is used to measure smaller currents are micro-ammeter. The ammeter is connected in series to the device which is to be measured because objects in series have the same current.

## **Types of ammeter**

### **Moving iron ammeter**

In a moving iron, ammeter can measure the AC and DC, it has an iron piece instead of the spring and pointer system of the galvanometer. The iron will act by the magnetic field created in the coil.

### **Zero center ammeter**

Zero center ammeters are used where the voltage needs to be monitored in two directions and they are used along with a battery. In this the charging of battery deflects the needle in one direction and discharging of the battery deflects the battery in the other.

### **Galvanometer**

Galvanometer was the first type of ammeter; it is used to detect and measure electric current. It is an analog electromechanical transducer which makes a rotary deflection in response to the electric current flowing through the coil. A galvanometer can read direct current flow, the magnetic field created as current flows through a coil acts on a spring, which will move the needle indicator.

### **Shunt**

A shunt can be used in ammeters to measure large currents, shunt acts as a resistor the known quantity of resistance is used to obtain an accurate reading. Digital ammeters use analog to digital converter to measure the current across the shunt.

### **Clamp meter**

Clamp meters are used to measure the current flowing through a conductor, AC clamp meters have a current transformer in it. With the help of the current transformer the reading will be taken. There are two types of clamp meters AC clamp meter which is used to measure the AC and the DC clamp meter which is used to measure the DC.

### **Voltmeter**

The voltmeter can be considered as a kind of galvanometer, which can be used to measure the voltage potential of an electrical circuit or the potential difference between two points. A voltmeter can also be considered as an ammeter they also measure the current, voltage is only measured when the current is transmitted in a circuit through resistance. Voltmeters are capable to measure the current, voltage and resistance. Voltmeters are also termed as high resistance ammeters they can also measure DC and AC. A

voltmeter can measure the change in voltage by two points in an electrical circuit and they are connected in parallel with the portion of the circuit on which the measurement is made. Voltmeters must have high resistance so that it won't have any effect on the current or voltage associated with the circuit.

## **Types of voltmeter**

### **Digital voltmeter**

Digital voltmeters can measure the AC and DC voltages and it displays the result in converted digital form with decimal point and polarity. It can provide accurate details about the current draw and current continuity and this will help the users to troubleshoot erratic loads.

### **What are the advantages of digital voltmeter?**

- a. Outputs are accurate without any error
- b. Readings are taken quickly
- c. Versatile and accurate
- d. Less power consumption
- e. Portable instrument

### **Electrostatic voltmeter**

These voltmeters are instruments that can accurately measure the voltage without any charge transfer. Whereas conventional voltmeter needs charge transfer to the voltmeter and it will lead to loading and adjustment of the source voltage. The main advantage of an electrostatic voltmeter is that it can do the surface potential measurement on any type of material without any physical contact.

### **Ohmmeter**

An ohmmeter is an instrument that is used to measure the resistance and they can measure the value of resistance accurately. According to their measurement and construction, these instruments are classified into the series type and shunt type ohmmeter. It can be used to check the continuity of the electrical circuits and components. Series type ohmmeters are used to measure the high resistance values while the shunt type is used to measure low resistance values.

### **Potentiometer**

Potentiometers are instruments that can be used to measure the unknown voltage. The known voltage will be supplied from a standard cell or any other known voltage reference source. Potentiometer measurement has high accuracy because the measurement is done by the comparison method and the obtained result is not by the deflection of the pointer. Potentiometers can be used to compare the E.M.F of the two cells, it can be used to determine the E.M.F of a cell, it can be used to determine the internal resistance of a cell and to calibrate the voltmeter and ammeter.

## Wattmeter

Watt-meters are used to measure power, these instruments are similar in design and construction of an ammeter. It can be used to measure the average electric power in watts. Wattmeter has two coils they are current and pressure coil. Wattmeter can be used to measure the gain in amplifiers, bandwidth in filters.

### Necessity or Uses of Electrical Measuring Instruments

The main functions of the measurement system are indicating, recording, detecting, controlling and testing the electrical units. Apart from that, here are some important used.

- i. It helps to control and monitoring the operation in an electrical system.
- ii. You can find out the error in the measuring unit with the help of standard values.
- iii. In generating power stations, instruments are used for data recording, measuring the value, fault detecting and many more purpose.
- iv. It helps to detect and protect from hazard conditions.
- v. Measuring instrument uses for the analysis of experimental data in an electrical system.
- vi. It is essential for displaying accurate numerical values. Digital multimeter is one of them.
- vii. Mostly, it utilizes in testing in the lab, industrial environment, science, and engineering study, building an electrical and electronics project, etc.

### 3.1.1.3. Learning Activities

#### Project/workshop

| Practical activity  | Knowledge             | Special instruction   |
|---|-----------------------|---|
| 1. Identification of basic SI units in electrical systems         | SI units              | Write down the SI units of electrical systems               |
| 2. Identification of quantities of charge, force, work and power. | Quantities            | Write the units for measuring charge, force, work and power |
| 3. Measure current, Voltage and resistance                        |                       | Perform calculations using the measured quantities.         |
| 4. Measure various electrical quantities                          |                       | Perform calculations using the measured quantities.         |
| 5. Identify electrical quantities measuring instruments           | Measuring instruments | Record the measured readings                                |

### 3.1.1.4. Self-Assessment Questions

- 1) What does 'SI units' mean? (3 Marks)
- 2) Which electrical instrument would you use to measure current in an electric circuit? (2 Marks)

- 3) A charge of 240 Coulombs is transferred in 2 minutes in an electric circuit, what is the amount of current flowing through it? **(2 Marks)**
- 4) What is Ohms law? **(3 Marks)**
- 5) What is the power dissipated by a resistor of 10  $\Omega$  when a current of 2 A passes through it? **(2 Marks)**
- 6) A current of 2 A flows for 10 h through a 100 resistor. What is the energy consumed by the resistor? **(3 Marks)**

### 3.1.1.5.Tools, Equipment and Materials

#### Recommended Resources

| Tools and equipment   | Materials and supplies   |
|---|--|
| <ul style="list-style-type: none"> <li>i. Cable Strippers</li> <li>ii. Pliers</li> <li>iii. Screw drivers</li> <li>iv. Hammers</li> <li>v. Chisels</li> <li>vi. Allen keys</li> <li>vii. Electrician knives</li> <li>viii. Crimping tools</li> <li>ix. Bending springs</li> <li>x. Bending machine</li> <li>xi. Steel tapes</li> <li>xii. Draw wires</li> <li>xiii. Hack saws</li> <li>xiv. Drilling tools</li> <li>xv. Stock and die</li> <li>xvi. Bench vice</li> <li>xvii. Machine vice</li> <li>xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul> | <ul style="list-style-type: none"> <li>i. Stationery</li> <li>ii. Cables</li> <li>iii. Light fittings</li> <li>iv. Accessories</li> <li>v. Conduits and fittings</li> <li>vi. Cable trays</li> <li>vii. Cable ducts</li> <li>viii. Trunkings</li> <li>ix. Computers</li> <li>x. Drawing instruments</li> <li>xi. Screws</li> </ul> |

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### 3.1.1.7. Model answers to self-assessment Questions

1. **'SI units' mean** **(3 Marks)**

The system of units used in engineering and science, which is based on the metric system. This was introduced in 1960 and is now adopted by the majority of countries as the official system of measurement.

2. **Electrical instrument used to measure current in an electric circuit** **(2 Marks)**
  - a) An ammeter
  - b) Clamp metre

3. **The amount of current flowing through the electric circuit in which a charge of 240 Coulombs is transferred in 2 minutes** **(2 Marks)**

$$Q = It \quad I = \frac{Q}{t}$$

$$I = \frac{240C}{2 \times 60 \text{ sec}} \\ = 2 \text{ Amperes}$$

4. **Ohms law** **(3 Marks)**

Ohms law states that the current I flowing through a conductor in a circuit is directly proportional to the applied voltage V provided that temperature and other physical condition are kept constant

5. **The power dissipated by a resistor of 10  $\Omega$  when a current of 2 A passes through it.** **(2 Marks)**

$$P = I^2 R$$

$$2^2 \times 10 = 40 \text{ Watts}$$

6. **The energy consumed by a 100  $\Omega$  resistor when a current of 2 A flows for 10 h through.**

**(3 Marks)**

$$\begin{aligned} \text{Energy} &= \text{Power} \times \text{time} \\ &= I^2 R \times 10 \text{ hours} \\ &= 2^2 \times 100 \times 10 \text{ hours} \\ &= 4000 \text{ watts} \end{aligned}$$

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### 3.1.2. Use the concepts of D.C and A.C circuits in electrical installation

#### 3.1. Introduction

To use the concepts of D.C and A.C circuits in Electrical installation, the learner should perform calculations involving parallel and series circuits, perform calculations involving Network theorems e.g. Kirchhoff's laws, superposition, Thevenin's, Norton's ; identify photovoltaic solar system and perform AC to Dc and DC to AC conversion.

#### 3.1.2.1. Performance Standard

1. Perform calculations involving parallel and series circuits
2. Perform calculations involving Network theorems e.g. Kirchhoff's laws, Superposition, Thevenin's, Norton's etc.
3. Identify Photovoltaic solar system
4. Perform AC to DC and DC to AC conversion

#### 3.1.2.2. Information Sheet

##### Definition of terms

**Resistance:** - opposition to current flow.

**Inductive reactance ( $X_L$ ):**- the opposition to an *a. c.* current in an inductive circuit.

**Capacitive reactance ( $X_C$ ):** - the opposition to an *a.c.* current in a capacitive circuit.

**Impedance ( $Z$ ):**-the total opposition to current flow in an *a. c.* circuit

**A phasor:** -straight line, having definite length and direction, which represents to scale the magnitude and direction of a quantity such as a current, voltage or impedance

**Circuit:** – a circuit is a closed loop conducting path in which an electrical current flows.

**Path:** – a single line of connecting elements or sources.

**Node** – a node is a junction, connection or terminal within a circuit where two or more circuit elements are connected or joined together giving a connection point between two or more branches. A node is indicated by a dot.

**Branch** – a branch is a single or group of components such as resistors or a source which are connected between two nodes.

**Loop** – a loop is a simple closed path in a circuit in which no circuit element or node is encountered more than once.

**Mesh** – a mesh is a single closed loop series path that does not contain any other paths. There are no loops inside a mesh.

#### Series and parallel networks

##### Series networks

Figure 2 shows three resistors  $R_1$ ,  $R_2$  and  $R_3$  connected end to end, i.e., in series, with a battery source of  $V$  volts.

Since the circuit is closed a current,  $I$  will flow and the *p. d.* across each resistor may be determined from the voltmeter readings  $V_1$ ,  $V_2$  and  $V_3$ .

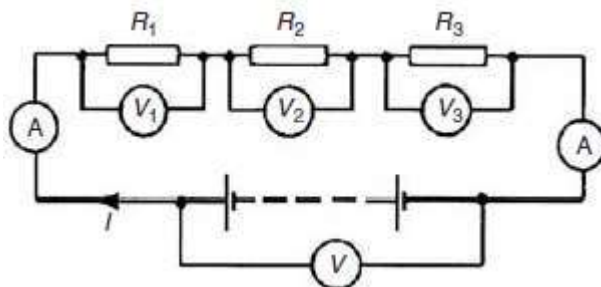


Figure 13: series circuit

### In a series circuit

- the current  $I$  is the same in all parts of the circuit and hence the same reading is found on each of the ammeters shown, and
- the sum of the voltages  $V_1$ ,  $V_2$  and  $V_3$  is equal to the total applied voltage,  $V$ ,

$$\text{i.e. } V = V_1 + V_2 + V_3$$

From Ohm's law:  $V_1 = IR_1$ ,  $V_2 = IR_2$ ,  $V_3 = IR_3$  and

$V = IR$  where  $R$  is the total circuit resistance. Since

$V = V_1 + V_2 + V_3$  then  $IR = IR_1 + IR_2 + IR_3$ . Dividing throughout by  $I$  gives

$$R = R_1 + R_2 + R_3$$

Thus, for a series circuit, the total resistance is obtained by adding together the values of the separate resistance's.

### Potential divider

The voltage distribution for the circuit shown in Fig. 3 is given by:

$$V_1 = \left( \frac{R_1}{R_1 + R_2} \right) V \text{ and } V_2 = \left( \frac{R_2}{R_1 + R_2} \right) V$$

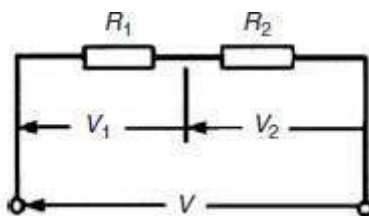


Figure 14: Voltage distribution circuit



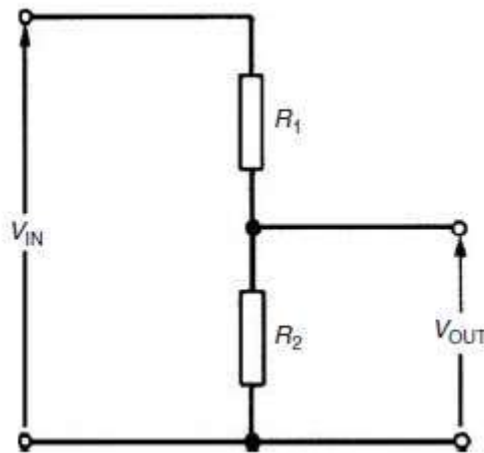


Figure 15: Potential divider

The circuit shown in Fig. 4 is often referred to as a **potential divider** circuit. Such a circuit can consist of a number of similar elements in series connected across a voltage source, voltages being taken from connections

$$V_{OUT} = \left( \frac{R_2}{R_1 + R_2} \right) V_{IN}$$

A potential divider is the simplest way of producing a source of lower *e.m.f.* from a source of higher e.m.f., and is the basic operating mechanism of the **potentiometer**, a measuring device for accurately measuring potential differences.

### Parallel networks

Figure 5 shows three resistors,  $R_1$ ,  $R_2$  and  $R_3$  connected across each other, i.e. in parallel, across a battery source of  $V$  volts.

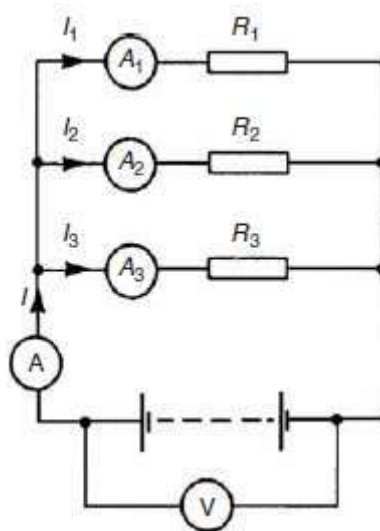


Figure 16: Resistors connected in parallel

### In a parallel circuit:

- The sum of the currents  $I_1$ ,  $I_2$  and  $I_3$  is equal to the total circuit current,  $I$ , i.e.  $I = I_1 + I_2 + I_3$  and
- The source *p.d.*,  $V$  volts, is the same across each of the resistors.

From Ohm's law:

$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3} \text{ and } I = \frac{V}{R}$$

Where  $R$  is the total circuit resistance. Since  $I = I_1 + I_2 + I_3$  then  $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

Dividing throughout by  $V$  gives:  $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

This equation must be used when finding the total resistance  $R$  of a parallel circuit. For the special case of **two resistors in parallel**

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 R_2}$$

$$\text{Hence } R = \frac{R_1 R_2}{R_1 + R_2} \left( i. e. \frac{\text{Product}}{\text{sum}} \right)$$

### Current division

For the circuit shown in Fig. 6, the total circuit resistance,  $R_T$  is given by  $R_T = \frac{R_1 R_2}{R_1 + R_2}$

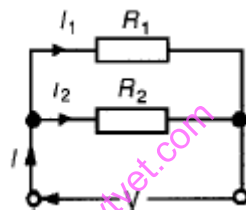


Figure 17: Current division circuit

### Alternating current theory

Commercial quantities of electricity for industry, commerce and domestic use are generated as a.c. in large Power Stations and distributed around the United Kingdom on the National Grid to the end user. The D.C. electricity has many applications where portability or an emergency stand-by supply is important but for large quantities of power it has to be an a.c. supply because it is so easy to change the voltage levels using a transformer. Rotating a simple loop of wire or coils of wire between the poles of a mag-net such as that shown simplified in Fig. 7 will cut the north south lines of magnetic flux and induce an a.c. voltage in the loop or coils of wire as shown by the display on a cathode ray oscilloscope. This is an a.c. supply, an alternating current supply. The basic principle of the a.c. supply generated in a Power Station is exactly

the same as shown in Figure 7 except that powerful electromagnets are used and the power for rotation comes from a steam turbine.

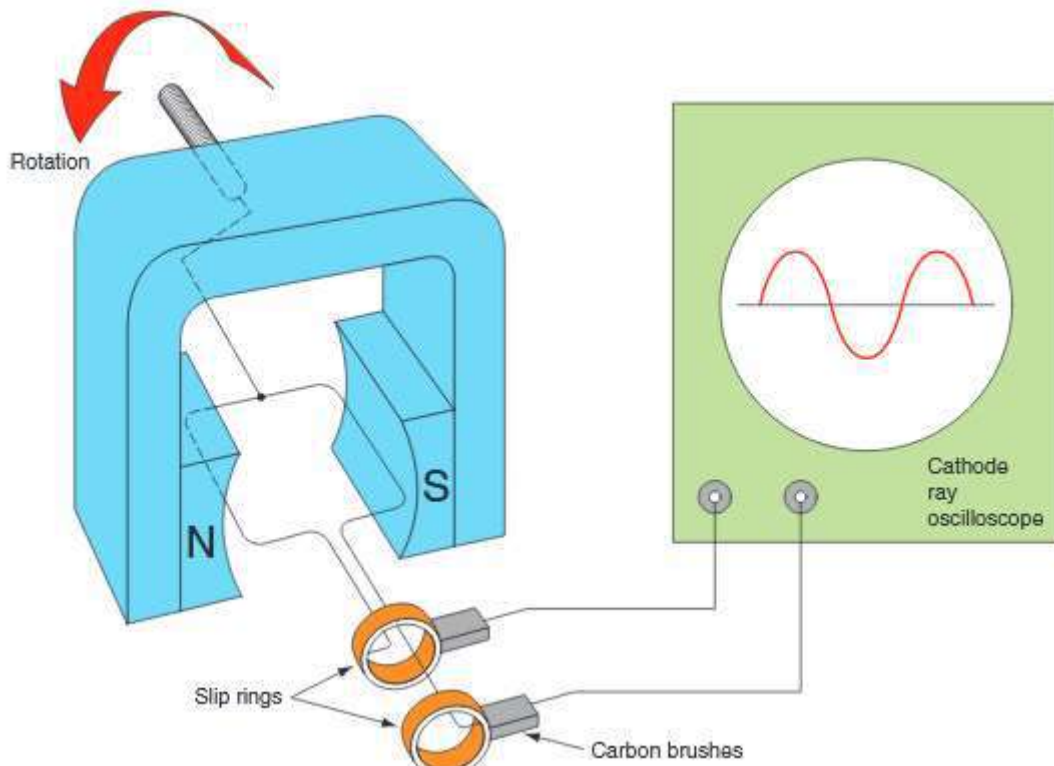


Figure 18: Simple generator/alternator

### Resistance

From Ohm's law:

$$R = \frac{V_R}{I_R} (\Omega)$$

However, in an *a. c.* circuit, resistance is only part of the opposition to current flow. The inductance and capacitance of an *a. c.* circuit also cause an opposition to current flow, which we call reactance.

### Inductive reactance ( $X_L$ )

It causes the current in the circuit to lag behind the applied voltage, as shown in Fig. 8. It is given by the formula:

$$X_L = 2\pi fL (\Omega)$$

where

$\pi = 3.142$  a constant

$f$  = the frequency of the supply

$L$  = the inductance of the circuit or by

$$X_L = \frac{V_L}{I_L}$$

### Capacitive reactance ( $X_C$ )

It causes the current in the circuit to lead ahead of the voltage, as shown in Fig. 8. It is given by the formula:

$$X_C = \frac{1}{2\pi fC} \text{ } (\Omega)$$

Where  $\pi$  and  $f$  are defined as before and  $C$  is the capacitance of the circuit. It can also be expressed as:

$$X_C = \frac{V_C}{I_C}$$

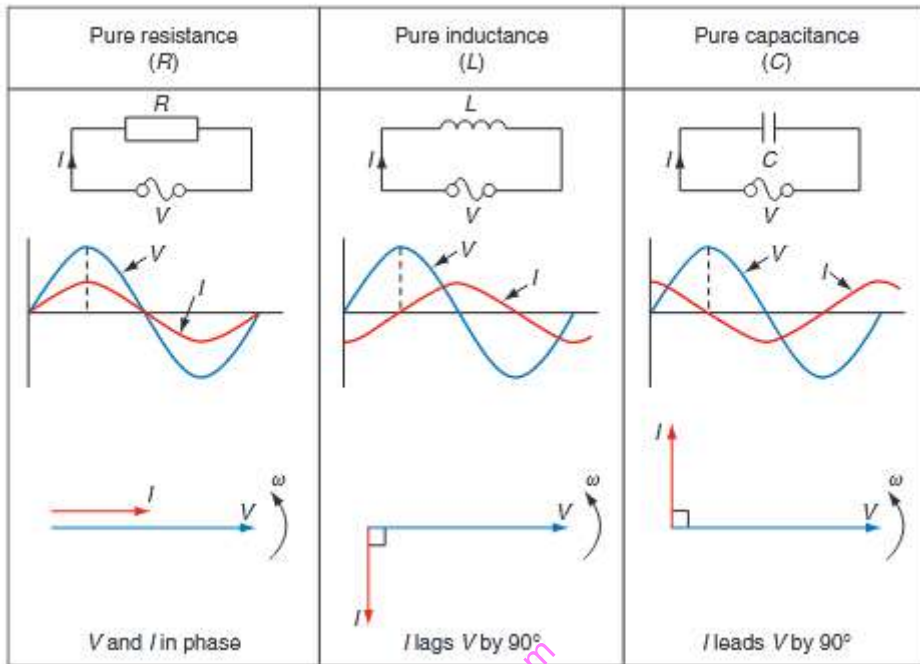


Figure 19: Voltage and current relationships in resistive, capacitive and inductive circuits

### Impedance (Z)

Impedance is the combined opposition to current flow of the resistance, inductive reactance and capacitive reactance of the circuit and can be calculated from the formula:

$$Z = \sqrt{R^2 + X^2} \text{ } (\Omega)$$

OR

$$Z = \frac{V_T}{I_T}$$

### Resistance, inductance and capacitance in an a.c. circuit

When a resistor only is connected to an a.c. circuit the current and voltage waveforms remain together, starting and finishing at the same time. We say that the waveforms are in phase. When a pure inductor is connected to an a.c. circuit the current lags behind the voltage waveform by an angle of 90°. We say that the current lags the voltage by 90°. When a pure capacitor is connected to an a.c. circuit the current leads the voltage by an angle of 90°. These various effects can be observed on an oscilloscope, but the circuit diagram, waveform diagram and phasor diagram for each circuit are shown in Fig. 8.

### Phasor diagrams

Phasor diagrams and a.c. circuits are an inseparable combination. Phasor diagrams allow us to produce a model or picture of the circuit under consideration which helps us to understand the circuit.

To find the combined effect of two quantities we combine their phasors by adding the beginning of the second phasor to the end of the first. The combined effect of the two quantities is shown by the resultant phasor, which is measured from the original zero position to the end of the last phasor. The figure 9 shows phasor addition of currents A and B.

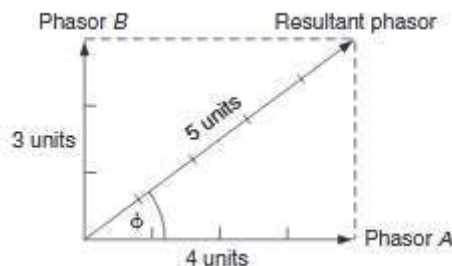


Figure 20: The Phasor addition of currents A and B

### Phase angle $\phi$

In an a.c. circuit containing resistance only, such as a heating circuit, the voltage and current are in phase, which means that they reach their peak and zero values together, as shown in Fig. 10. In an a.c. circuit containing inductance, such as a motor or discharge lighting circuit, the current often reaches its maximum value after the voltage, which means that the current and voltage are out of phase with each other, as shown in Fig. 10. The phase difference, measured in degrees between the current and voltage, is called the phase angle of the circuit, and is denoted by the symbol  $\phi$ , the lower-case Greek letter phi. When circuits contain two or more separate elements, such as RL, RC or RLC, the phase angle between the total voltage and total current will be neither  $0^\circ$  nor  $90^\circ$  but will be determined by the relative values of resistance and reactance in the circuit. In Fig. 11 the phase angle between applied voltage and current is some angle  $\phi$ .

### Alternating current series circuits

In a circuit containing a resistor and inductor connected in series as shown in Fig. 11, the current  $I$  will flow through the resistor and the inductor causing the voltage  $V_R$  to be dropped across the resistor and  $V_L$  to be dropped across the inductor. The sum of these voltages will be equal to the total voltage  $V_T$  but because this is an a.c. circuit the voltages must be added by phasor addition. The result is shown in Fig. 11, where  $V_R$  is drawn to scale and in phase with the current and  $V_L$  is drawn to scale and leading the current by  $90^\circ$ . The phasor addition of these two voltages gives us the magnitude and direction of  $V_T$ , which leads the current by some angle  $\phi$ . In a circuit containing a resistor and capacitor connected in series as shown in Fig. 12, the current  $I$  will flow through the resistor and capacitor causing voltage drops  $V_R$  and  $V_C$ . The voltage  $V_R$  will be in phase with the current and  $V_C$  will lag the current by  $90^\circ$ . The phasor addition of these voltages is equal to the total voltage  $V_T$  which, as can be seen in Fig. 12, is lagging the current by some angle  $\phi$ .

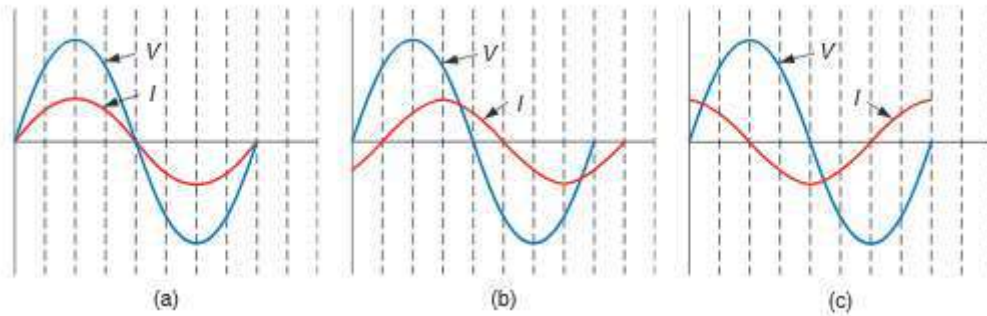


Figure 21: phase relationship of ac waveform

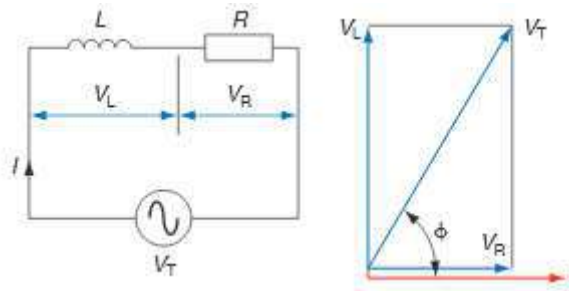


Figure 22: Series RL circuit and phasor diagram

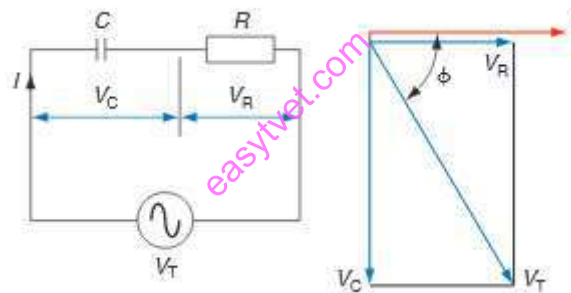


Figure 23: Series RC and phasor diagram

### The impedance triangle

We have now established the general shape of the phasor diagram for a series a.c. circuit. Figures 10.5 and 10.6 show the voltage phasors, but we know that  $V_R = IR$ ,  $V_L = IX_L$ ,  $V_C = IX_C$ , and  $V_T = IZ$  therefore the phasor diagrams (a) and (b) of Fig. 13 must be equal. From Fig. 13(b), by the theorem of Pythagoras, we have:

$$(IZ)^2 = (IR)^2 + (IX)^2$$

$$I^2 Z^2 = I^2 R^2 + I^2 X^2$$

If we now divide throughout by  $I^2$  we have:

$$Z^2 = R^2 + X^2$$

$$\text{or } Z = \sqrt{R^2 + X^2} \Omega$$

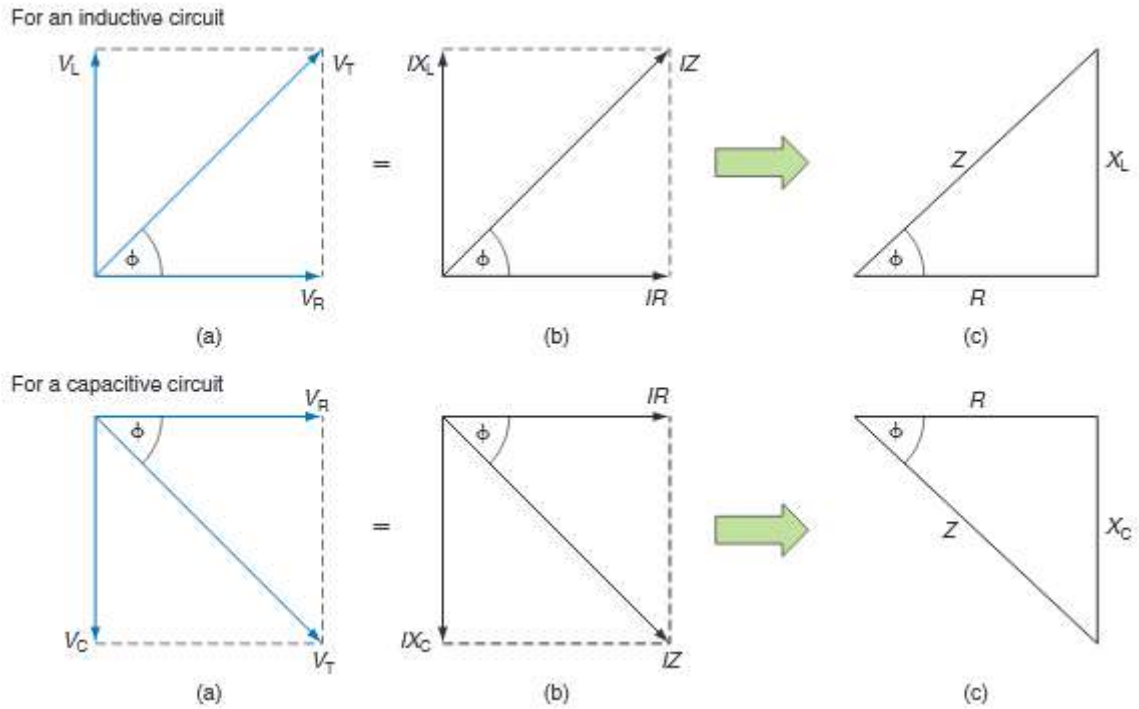


Figure 24: Phasor diagram and impedance triangle

## Network Theorems

### Thevenin's theorem and Norton theorem

The Thévenin and Norton networks shown in Fig. 19 are equivalent to each other. The resistance 'looking-in' at terminals AB is the same in each of the networks, i.e.  $r$

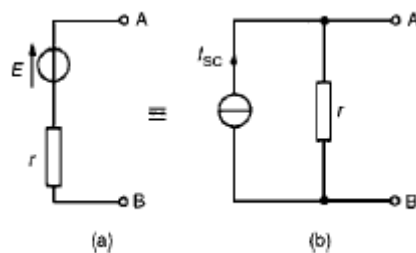


Figure 25: Norton's and Thevenin's networks

If terminals AB in Fig. 19(a) are short-circuited, the short-circuit current is given by  $E/r$ . If terminals AB in Fig. 19(b) are short-circuited, the short-circuit current is  $I_{SC}$ . For the circuit shown in Fig. 19(a) to be equivalent to the circuit in Fig. 19(b) the same short-circuit current must flow. Thus  $I_{SC} = E/r$ . Figure 20 shows a source of *e. m. f.*  $E$  in series with a resistance  $r$  feeding a load resistance  $R$

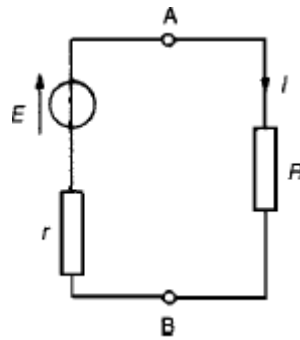


Figure 15: Source of *e.m.f* in series with resistance

From Fig. 20,

$$I = \frac{E}{r+R} = \frac{E/r}{(r+R)/r} = \left( \frac{r}{r+R} \right) \frac{E}{r}$$

i.e.  $I = \left( \frac{r}{r+R} \right) I_{SC}$

From Fig. 21 it can be seen that, when viewed from the load, the source appears as a source of current  $I_{SC}$  which is divided between  $r$  and  $R$  connected in parallel

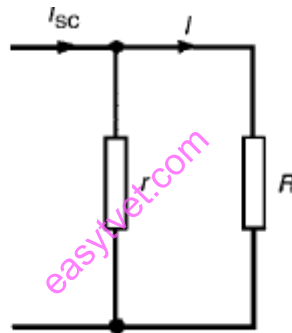


Figure 26: Source current divided

Thus the two representations shown in Fig. 20 are equivalent.

### Superposition Theorem

Superposition states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltage across (or currents through) that element due to EACH independent source acting alone.-The principle of superposition helps us to analyze a linear circuit with more than one independent source by calculating the contribution of each independent source separately.-Steps to Apply Superposition Principle:

1. Turn off all independent sources except one source. Find the output ( $v$  or  $i$ ) due to that active source.
2. Repeat Step 1 for each of the other independent sources.
3. Find Total contribution by adding all contributions from independent sources.

**Note:** In Step 1, this implies that we replace every voltage source by 0 V (or a short circuit), and every current source by 0 A (or an open circuit). Dependent sources are left intact because they are controlled by others.



## Kirchhoff's Circuit Law

Kirchhoff's Circuit Laws allow us to solve complex circuit problems by defining a set of basic network laws and theorems for the voltages and currents around a circuit a single equivalent resistance, ( $R_T$ ) can be found when two or more resistors are connected together in either series, parallel or combinations of both, and that these circuits obey Ohm's Law. However, sometimes in complex circuits such as bridge or T networks, we cannot simply use Ohm's Law alone to find the voltages or currents circulating within the circuit. For these types of calculations, we need certain rules which allow us to obtain the circuit equations and for this we can use Kirchhoff's Circuit Law. In 1845, a German physicist, Gustav Kirchhoff developed a pair or set of rules or laws which deal with the conservation of current and energy within electrical circuits. These two rules are commonly known as: Kirchhoff's Circuit Laws with one of Kirchhoff's laws dealing with the current flowing around a closed circuit, Kirchhoff's Current Law, (KCL) while the other law deals with the voltage sources present in a closed circuit, Kirchhoff's Voltage Law, (KVL).

### Kirchhoff's First Law – The Current Law, (KCL)

Kirchhoff's Current Law or KCL, states that the "total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero,  $I_{(\text{exiting})} + I_{(\text{entering})} = 0$ . This idea by Kirchhoff is commonly known as the Conservation of Charge. The figure 22 illustrates the Kirchhoff's current law.

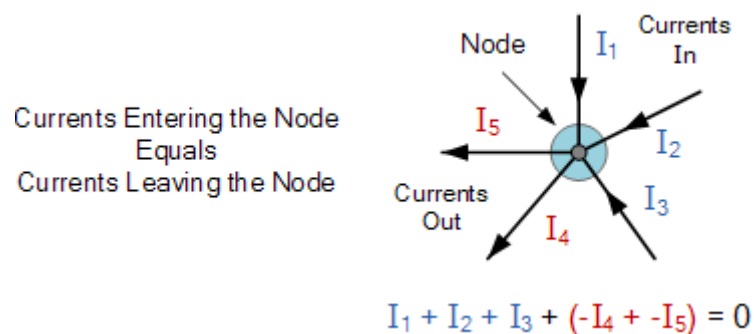


Figure 277: Kirchhoff's current law

Here, the three currents entering the node,  $I_1$ ,  $I_2$ ,  $I_3$  are all positive in value and the two currents leaving the node,  $I_4$  and  $I_5$  are negative in value. Then this means we can also rewrite the equation as;

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

The term Node in an electrical circuit generally refers to a connection or junction of two or more current carrying paths or elements such as cables and components. Also for current to flow either in or out of a node a closed circuit path must exist. We can use Kirchhoff's current law when analyzing parallel circuits.

### Kirchhoff's Second Law – The Voltage Law, (KVL)

Kirchhoff's Voltage Law or KVL, states that "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the Conservation of Energy.

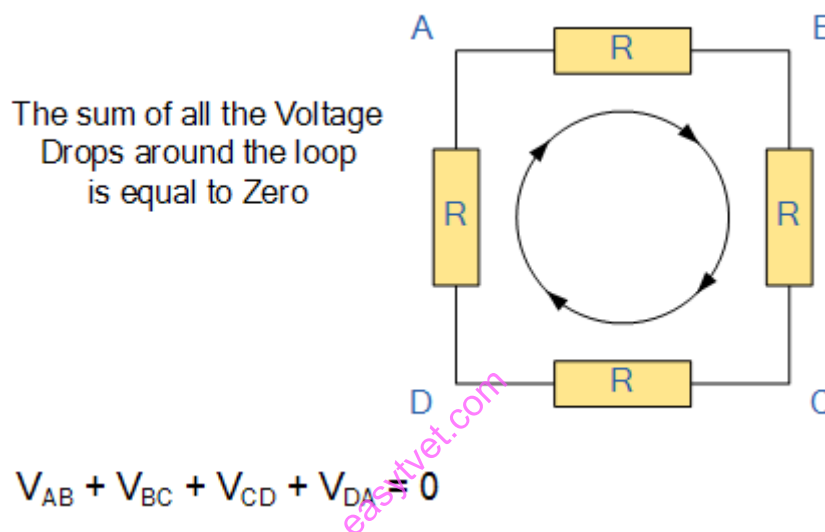


Figure 18: Kirchhoff's voltage law

Starting at any point in the loop continue in the same direction noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero. We can use Kirchhoff's voltage law when analyzing series circuits.

When analyzing either DC circuits or AC circuits using Kirchhoff's Circuit Laws a number of definitions and terminologies are used to describe the parts of the circuit being analyzed such as: node, paths, branches, loops and meshes. These terms are used frequently in circuit analysis so it is important to understand them.

### Norton theorem

Norton's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source  $I_N$  in parallel with a resistor  $R_N$ , where  $I_N$  is the short-circuit current through the terminals and  $R_N$  is the input or equivalent resistance at the terminals when the independent sources are turned off.

Thus, the circuit in Fig.(a) can be replaced by the one in Fig. (b)

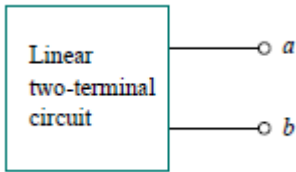


Figure 19. (a) Original circuit

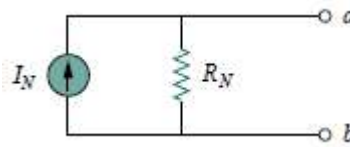


Figure 19. (b) Norton equivalent circuit

We find  $R_N$  in the same way we find  $R_{Th}$ . In fact, from what we know about source transformation, the Thevenin and Norton resistances are equal; that is,

$$R_N = R_{Th}.$$

To find the Norton current  $I_N$ , we determine the short-circuit current flowing from terminal  $a$  to  $b$  in both circuits in Fig. 4.37. It is evident that the short-circuit current in Fig. (b) is  $I_N$ . This must be the same short-circuit current from terminal  $a$  to  $b$  in Fig. (a), since the two circuits are equivalent. Thus,

$$I_N = i_{SC}$$

As shown in the fig below.

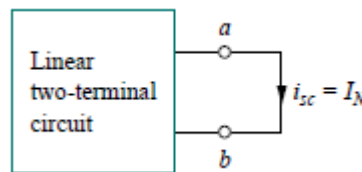


Figure 20: Finding Norton current  $I_N$

Dependent and independent sources are treated the same way as in Thevenin's theorem.

Observe the close relationship between Norton's and Thevenin's

theorems:  $R_N = R_{Th}$  and  $I_N = \frac{V_{Th}}{R_{Th}}$

This is essentially source transformation. For this reason, source transformation is often called Thevenin-Norton transformation. Since  $V_{Th}$ ,  $I_N$ , and  $R_{Th}$  are related; to determine the Thevenin or Norton equivalent circuit requires that we find:

- The open-circuit voltage  $v_{oc}$  across terminals  $a$  and  $b$ .
- The short-circuit current  $i_{sc}$  at terminals  $a$  and  $b$ .
- The equivalent or input resistance  $R_{in}$  at terminals  $a$  and  $b$  when all independent sources are turned off.

We can calculate any two of the three using the method that takes the least effort and use them to get the third using Ohm's law. Since,

$$\begin{aligned} V_{Th} &= v_{oc} \\ I_N &= i_{SC} \\ R_{Th} &= \frac{V_{oc}}{i_{SC}} = R_N \end{aligned}$$

## AC to DC conversion

The process of obtaining unidirectional currents and voltages from alternating currents and voltages is called rectification. Automatic switching in circuits is achieved using diodes. Half-wave rectification using a single diode,  $D$ , as shown in figure 19, half-wave rectification is obtained. When  $P$  is sufficiently positive with respect to  $Q$ , diode  $D$  is switched on and current  $i$  flows. When  $P$  is negative with respect to  $Q$  diode  $D$  is switched off. Transformer  $T$  isolates the equipment from direct connection with the mains supply and enables the mains voltage to be changed. Thus, an alternating, sinusoidal waveform applied to the transformer primary is rectified into a unidirectional waveform. Unfortunately, the output waveform shown in Figure 19 is not constant (i.e. steady), and as such, would be unsuitable as a *d. c.* power supply

for electronic equipment. It would, however, be satisfactory as a battery charger. Full-wave rectification using a centre-tapped transformer two diodes may be used as shown in Figure 20 to obtain full-wave rectification where a centre-tapped transformer T is used. When P is sufficiently positive with respect to Q, diode D1 conducts and current flows (shown by the broken line in Figure 20). When S is positive with respect to Q, diode D2 conducts and current flows (shown by the continuous line in figure 20)

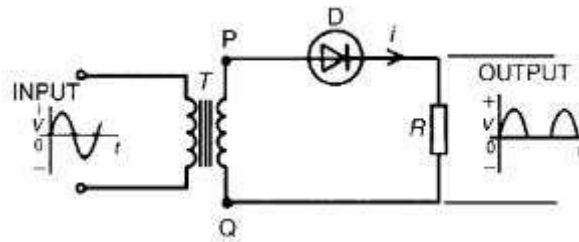


Figure 21: half wave rectification

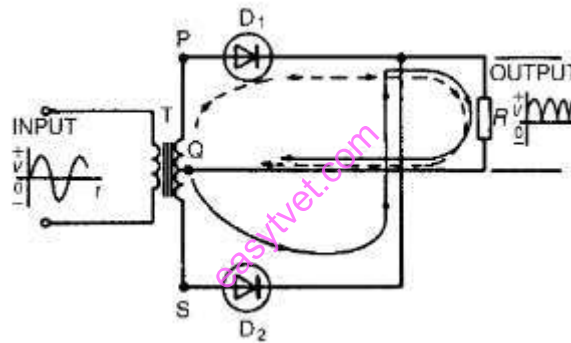


Figure 22: Full wave rectifier

The current flowing in the load R is in the same direction for both half-cycles of the input. The output waveform is thus as shown in figure 20. The output is unidirectional, but is not constant; however, it is better than the output waveform produced with a half-wave rectifier. A disadvantage of this type of rectifier is that centre-tapped transformers are expensive. Full-wave bridge rectification four diodes may be used in a bridge rectifier circuit, as shown in Figure 21 to obtain full-wave rectification. (Note, the term ‘bridge’ means a network of four elements connected to form a square, the input being applied to two opposite corners and the output being taken from the remaining two corners). As for the rectifier shown in Figure. 20 the current flowing in load R is in the same direction for both half cycles of the input giving the output waveform shown. Following the broken line in figure 21:

When P is positive with respect to Q, current flows from the transformer to point E, through diode D4 to point F, then through load R to point H, through D2 to point G, and back to the transformer. Following the full line in figure 27: When Q is positive with respect to P, current flows from the transformer to point G, through diode D3to point F, then through load R to point H, through D1to point E, and back to the

transformer. The output waveform is not steady and needs improving; a method of smoothing is explained in the next section.

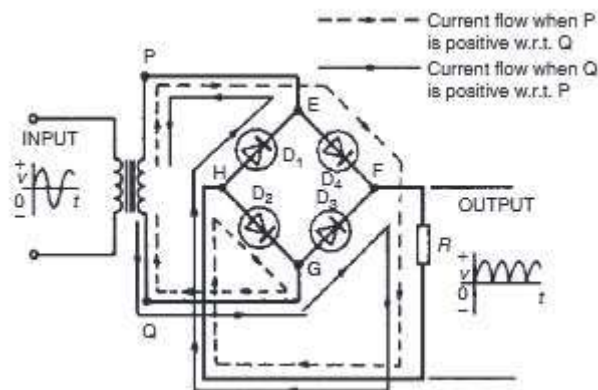


Figure 23: Bridge rectifier

### DC to AC Converters

Converts DC to AC power by switching the DC input voltage (or current) in a pre-determined sequence so as to generate AC voltage (or current) output. The figure 27 show the image and the block representation of DC to AC inverters

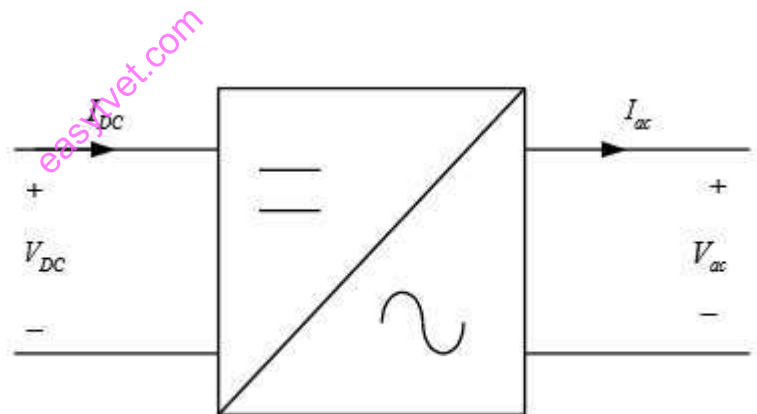


Figure 24: Dc to Ac inverters

#### 3.1.2.2. Self-Assessment Questions

1. State the Norton's Theorem
2. What is the difference between power and energy?
3. An EMF of 50 v is applied in turn to the following resistors: 22 Ω, 820 Ω, 330 Ω and 27 MΩ calculate the current flow in each case
4. What are the four major components of a solar PV system?

### 3.1.2.3. Tools, Equipment and Materials

These includes;

|   |   |
|---|---|
| <p><b>Tools and equipment</b></p> <ol style="list-style-type: none"> <li>i. Cable Strippers</li> <li>ii. Pliers</li> <li>iii. Screw drivers</li> <li>iv. Hammers</li> <li>v. Chisels</li> <li>vi. Allen keys</li> <li>vii. Electrician knives</li> <li>viii. Crimping tools</li> <li>ix. Bending springs</li> <li>x. Bending machine</li> <li>xi. Steel tapes</li> <li>xii. Draw wires</li> <li>xiii. Hack saws</li> <li>xiv. Drilling tools</li> <li>xv. Stock and die</li> <li>xvi. Bench vice</li> <li>xvii. Machine vice</li> <li>xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ol> | <p><b>Materials and supplies</b></p> <ol style="list-style-type: none"> <li>i. Stationery</li> <li>ii. Cables</li> <li>iii. Light fittings</li> <li>iv. Accessories</li> <li>v. Conduits and fittings</li> <li>vi. Cable trays</li> <li>vii. Cable ducts</li> <li>viii. Trunkings</li> <li>ix. Computers</li> <li>x. Drawing instruments</li> <li>xi. Screws</li> </ol> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>• IEE regulations</li> <li>• Occupational safety and health act (OSHA)</li> <li>• Work injury benefits act (WIBA)</li> <li>• Manufacturers’ catalogues</li> <li>• British standards</li> <li>• KEBS standards</li> </ul>   |   |

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### 3.1.2.5. Model Answers to self-assessment Questions

1. Norton's theorem states: The current that flows in any branch of a network is the same as that which would flow in the branch if it were connected across a source of electrical energy, the short-circuit current of which is equal to the current that would flow in a short-circuit across the branch, and the internal resistance of which is equal to the resistance which appears across the open-circuited branch terminals
2. Energy is the ability to do work while power is the rate of doing work
3.  $50/22=2.27\text{ A}$ , (b)  $5/82=0.06\text{ A}$  (c)  $50/(330 \times 1000)=0.0002\text{ A}$
4. What are the four major components of a solar PV system?
  - Solar module
  - Solar battery
  - Charge controller
  - Inverter



## Use of basic electrical machine

### 3.1.1.0.Introduction

In order to use basic electrical machine, identify various electrical machines, perform operations involving single phase and three phase AC and DC motors, perform operations involving single phase and three phase transformers, perform operations involving single phase and three phase generators and apply AC and DC machines. .

#### 3.1.1.1.Performance Standards

1. Identify types of various electrical machines
2. Perform operations involving single phase and three phase AC and DC motors
3. Perform calculations involving single phase AC and DC transformers.
4. Perform operations involving single and three phase generators
5. Apply AC and DC machines are as per their functions

#### 3.1.1.2.Information Sheet

##### Direct current motors

All electric motors work on the principle that when a current carrying conductor is placed in a magnetic field it will experience a force. An electric motor uses this magnetic force to turn the shaft of the electric motor. If a current carrying conductor is placed into the field of a permanent magnet as shown in Figure 50(c) a force  $F$  will be exerted on the conductor to push it out of the magnetic field.

Figure 50(a) shows the magnetic field due to the current carrying conductor only. Figure 50(b) shows the magnetic field due to the permanent magnet in which is placed the conductor carrying no current. Figure 50(c) shows the effect of the combined magnetic fields which are distorted and, because lines of magnetic flux never cross, but behave like stretched elastic bands, always trying to find the shorter distance between a north and south pole, the force  $F$  is exerted on the conductor, pushing it out of the permanent magnetic field.

This is the basic motor principle, and the force  $F$  is dependent upon the strength of the magnetic field  $B$ , the current  $I$  in the conductor and the length of conductor within the magnetic field  $l$ .

The following equation expresses this relationship:

$F = BIL(N)$  Where  $B$  is in tesla,  $l$  is in metres,  $I$  is in amperes and  $F$  is in Newtons.

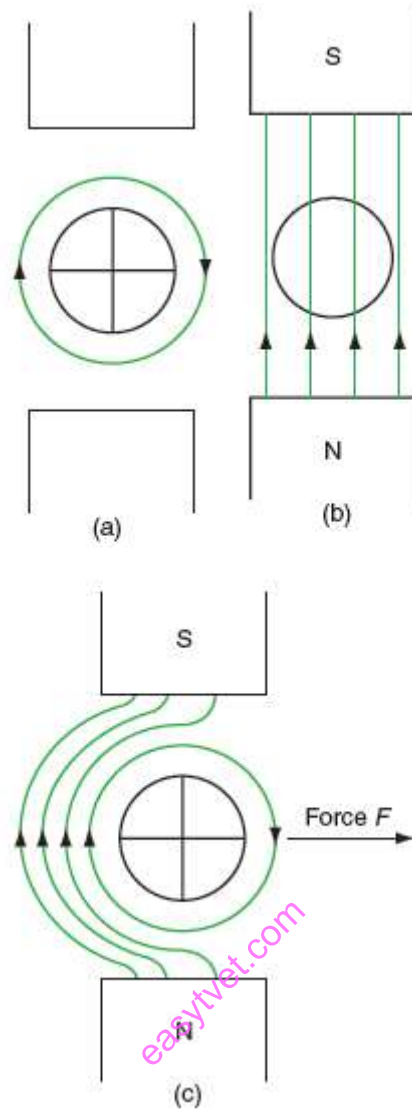


Figure 25: Magnetic fields

### DC generators

D.C. generators are classified according to the method of their field excitation. These groupings are:

- i. Separately-excited generators, where the field winding is connected to a source of supply other than the armature of its own machine.
- ii. Self-excited generators, where the field winding receives its supply from the armature of its own machine, and which are sub-divided into
  - I. shunt,
  - II. series, and
  - III. compound wound generators

### Practical *d. c.* motors

Practical motors are constructed as shown in Figure 51 all d.c. motors contain a field winding wound on pole pieces attached to a steel yoke. The armature winding rotates between the poles and is connected to the commutator. Contact with the external circuit is made through carbon brushes rubbing on the

commutator segments. Direct current motors are classified by the way in which the field and armature windings are connected, which may be in series or in parallel.

### Series motor

The field and armature windings are connected in series and consequently share the same current. The series motor has the characteristics of a high starting torque but a speed which varies with load. Figure 52 shows series motor connections and characteristics. For this reason the motor is only suitable for direct coupling to a load, except in very small motors, such as vacuum cleaners and hand drills, and is ideally suited for applications where the machine must start on load, such as electric trains, cranes and hoists.

Reversal of rotation may be achieved by reversing the connections of either the field or armature windings but not both. This characteristic means that the machine will run on both a.c. or d.c. and is, therefore, sometimes referred to as a 'universal' motor.

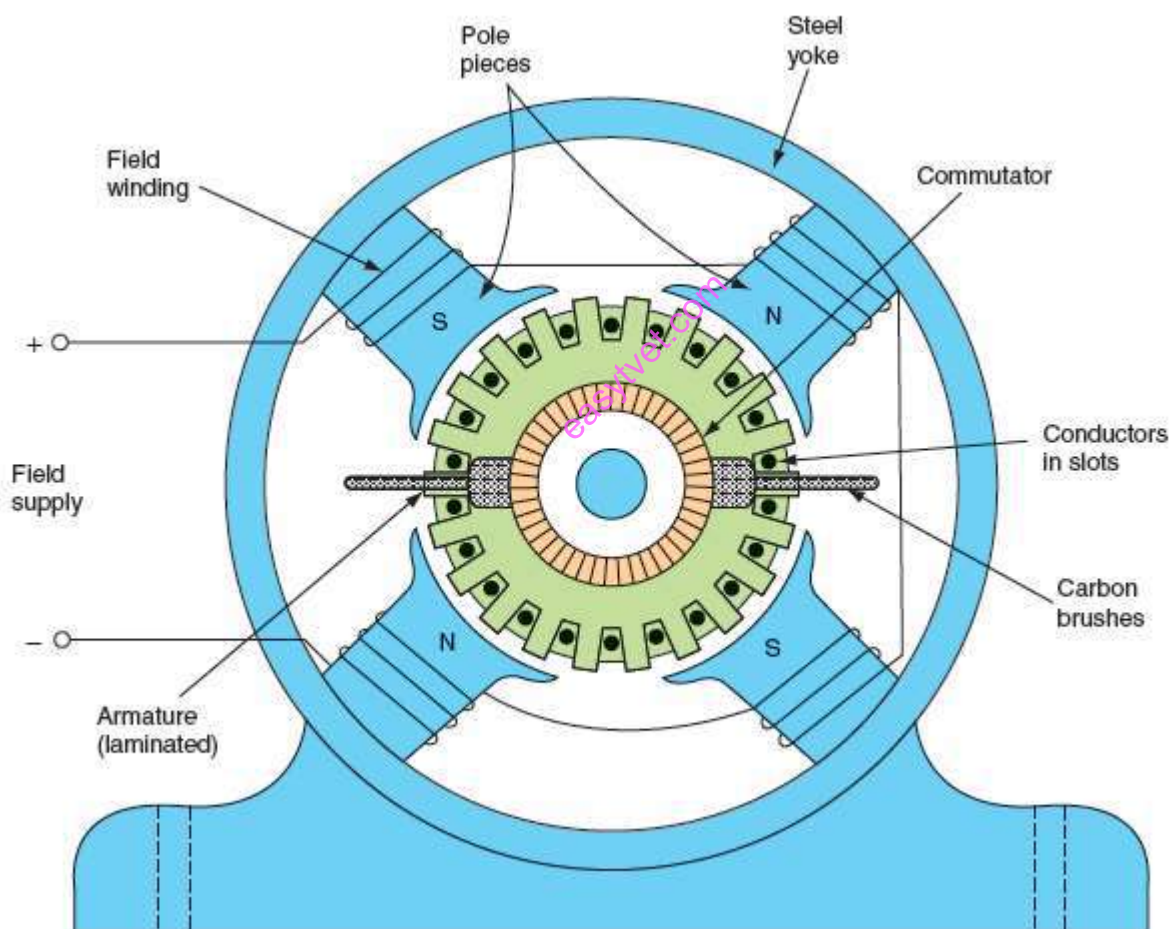


Figure 26: Practical motors

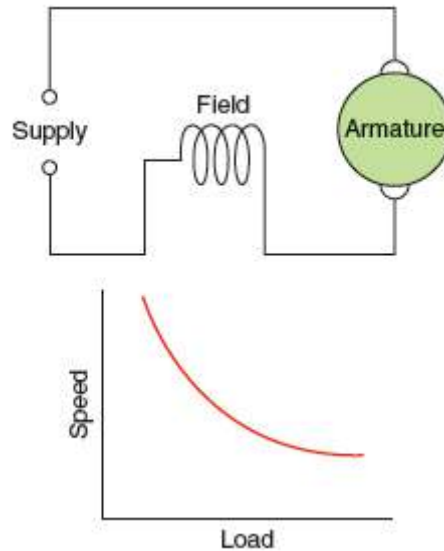


Figure 27: Series motor connection and characteristics

### Single-phase *a. c.* motors

A single-phase *a. c.* supply produces a pulsating magnetic field, not the rotating magnetic field produced by a three-phase supply. All *a. c.* motors require a rotating field to start. Therefore, single-phase *a. c.* motors have two windings which are electrically separated by about  $90^\circ$ . The two windings are known as the start and run windings. The magnetic fields produced by currents flowing through these out-of-phase windings create the rotating field and turning force required to start the motor. Once rotation is established, the pulsating field in the run winding is sufficient to maintain rotation and the start winding is disconnected by a centrifugal switch which operates when the motor has reached about 80% of the full load speed.

A cage rotor is used on single-phase *a. c.* motors, the turning force being produced in the way described previously for three-phase induction motors and shown in figure 53 because both windings carry currents which are out of phase with each other, the motor is known as a 'split-phase' motor. The phase displacement between the currents in the windings is achieved in one of two ways:

- by connecting a capacitor in series with the start winding, as shown in figure 53(a), which gives a  $90^\circ$  phase difference between the currents in the start and run windings;
- by designing the start winding to have a high resistance and the run winding a high inductance, once again creating a  $90^\circ$  phase shift between the currents in each winding, as shown in Figure 53(b).

When the motor is first switched on, the centrifugal switch is closed and the magnetic fields from the two coils produce the turning force required to run the rotor up to full speed. When the motor reaches about 80% of full speed, the centrifugal switch clicks open and the machine continues to run on the magnetic flux created by the run winding only.

Split-phase motors are constant speed machines with a low starting torque and are used on light loads such as fans, pumps, refrigerators and washing machines. Reversal of rotation may be achieved by reversing the connections to the start or run windings, but not both.

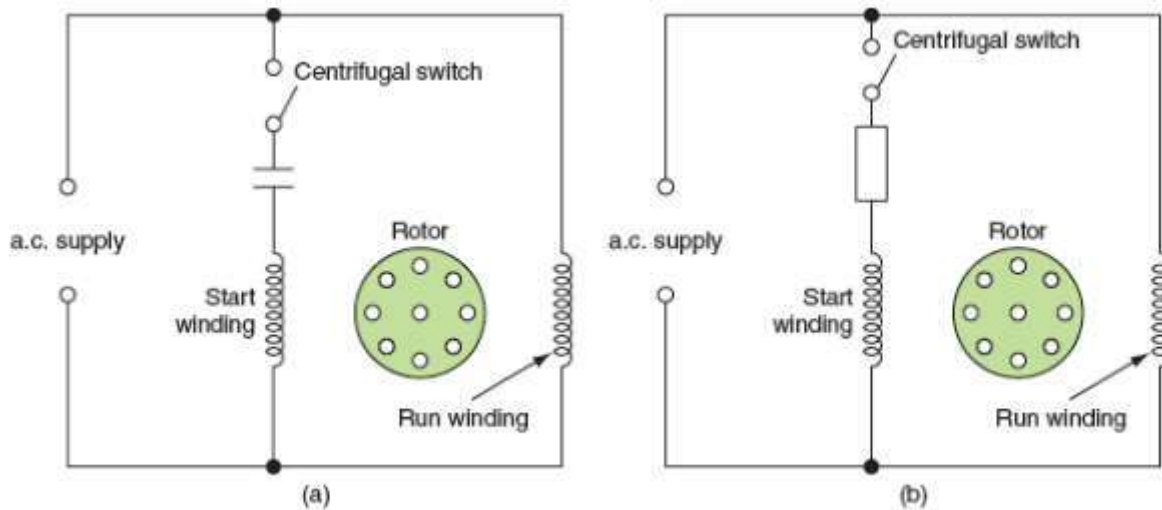


Figure 28: circuit diagram of : (a) capacitor split phase motors and (b) Resistance split phase motors

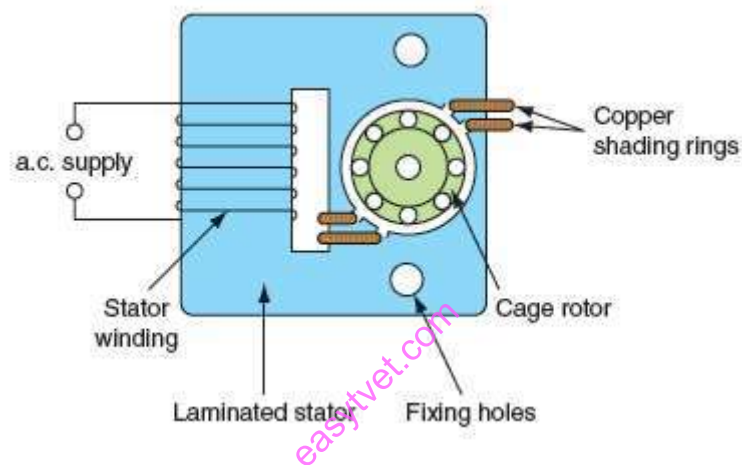


Figure 29: Shaded pole motor

### Shaded pole motors

The shaded pole motor is a simple, robust single-phase motor, which is suitable for very small machines with a rating of less than about 50 W. Figure 54 shows a shaded pole motor. It has a cage rotor and the moving field is produced by enclosing one side of each stator pole in a solid copper or brass ring, called a shading ring, which displaces the magnetic field and creates an artificial phase shift.

Shaded pole motors are constant speed machines with a very low starting torque and are used on very light loads such as oven fans, record turntable motors and electric fan heaters. Reversal of rotation is theoretically possible by moving the shading rings to the opposite side of the stator pole face. However, in practice this is often not a simple process, but the motors are symmetrical and it is sometimes easier to reverse the rotor by removing the fixing bolts and reversing the whole motor.

There are more motors operating from single-phase supplies than all other types of motor added together. Most of them operate as very small motors in domestic and business machines where single-phase supplies are most common.

### Transformers

A transformer is an electrical machine which is used to change the value of an alternating voltage. They vary in size from miniature units used in electronics to huge power transformers used in power stations. A transformer will only work when an alternating voltage is connected. It will not normally work from a *d. c.* supply such as a battery.

A transformer, as shown in Fig. 55, consists of two coils, called the primary and secondary coils, or windings, which are insulated from each other and wound on to the same steel or iron core. An alternating voltage applied to the primary winding produces an alternating current, which sets up an alternating magnetic flux throughout the core.

This magnetic flux induces an *e. m. f* in the secondary winding, as described by Faraday’s law, which says that when a conductor is cut by a magnetic field, an *e. m. f* is induced in that conductor. Since both windings are linked by the same magnetic flux, the induced *e. m. f* per turn will be the same for both windings. Therefore, the *e. m. f* in both windings is proportional to the number of turns. In symbols

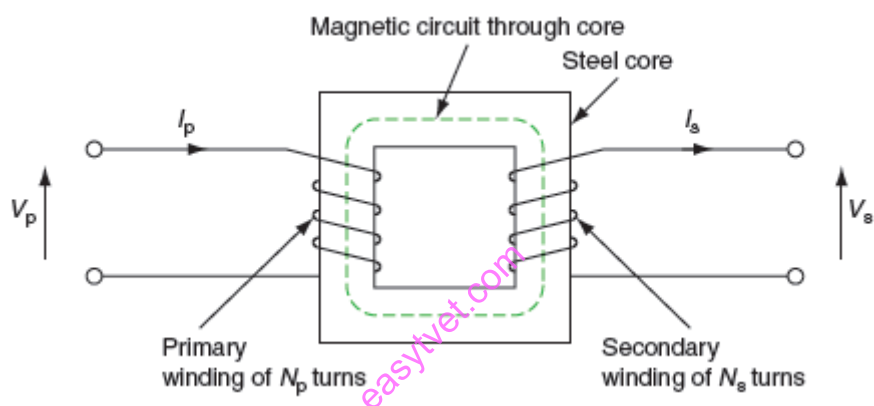


Figure 30: Simple transformer

$$\frac{V_p}{N_p} = \frac{V_s}{N_s}$$

Where  $V_p$  = the primary voltage

$V_s$  = the secondary voltage

$N_p$  = the number of primary turns

$N_s$  = the number of secondary turns

Moving the terms around, we have a general expression for a transformer:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

## Types of transformer

Step down Transformers are used to reduce the output voltage, often for safety reasons. Figure 10.22 shows a step down transformer where the primary winding has twice as many turns as the secondary winding. The turns ratio is 2:1 and, therefore, the secondary voltage is halved.

Step up Transformers are used to increase the output voltage. The electricity generated in a power station is stepped up for distribution on the National Grid Network. Figure 56 shows a step up transformer where the primary winding has only half the number of turns as the secondary winding.

The turns ratio is 1:2 and, therefore, the secondary voltage is doubled.

Instrument Transformers are used in industry and commerce so that large currents and voltage can be measured by small electrical instruments.

A Current Transformer (or CT) has the large load currents connected to the primary winding of the transformer and the ammeter connected to the secondary winding. The ammeter is calibrated to take account of the turns ratio of the transformer, so that the ammeter displays the actual current being taken by the load when the ammeter is actually only taking a small proportion of the load current.

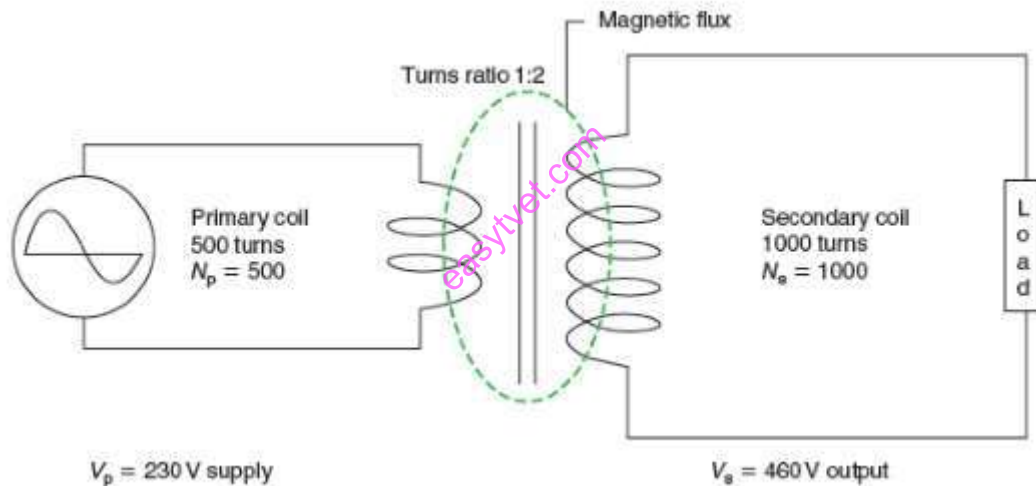


Figure 31: Step up transformer

A Voltage Transformer (or VT) has the main supply voltage connected to the primary winding of the transformer and the voltmeter connected to the secondary winding. The voltmeter is calibrated to take account of the turns ratio of the transformer, so that the voltmeter displays the actual supply voltage.

Separated Extra-low Voltage (SELV) Transformers If the primary winding and the secondary winding of a double wound transformer have a separate connection to earth, then the output of the transformer is effectively isolated from the input since the only connection between the primary and secondary windings is the magnetic flux in the transformer core. Such a transformer would give a very safe electrical supply which might be suitable for bathroom equipment such as shaver sockets and construction site 110 V tools, providing that all other considerations are satisfied, such as water ingress, humidity, IP protection and robust construction.

## Electrical machines

Electrical machines are energy converters. If the machine input is mechanical energy and the output electrical energy then that machine is a generator, as shown in Fig. 56(a). Alternatively, if the machine input is electrical energy and the output mechanical energy then the machine is a motor, as shown in Fig. 56(b). An electrical machine may be used as a motor or a generator, although in practice the machine will operate more efficiently when operated in the mode for which it was designed.

### Simple *a. c.* generator or alternator

If a simple loop of wire is rotated between the poles of a permanent magnet, as shown in Fig. 57, the loop of wire will cut the lines of magnetic flux between the north and south poles. This flux cutting will induce an *e. m. f* in the wire by Faraday's law which states that when a conductor cuts or is cut by a magnetic field, an *e. m. f* is induced in that conductor. If the generated *e. m. f* is collected by carbon brushes at the slip rings and displayed on the screen of a cathode ray oscilloscope, the waveform will be seen to be approximately sinusoidal. Alternately changing, first positive and then negative, then positive again, giving an alternating output. This simple arrangement produces a very bumpy *d. c.* output. In a practical machine, the commutator would contain many segments and many windings to produce a smoother *d. c.* output. Similar to the unidirectional battery supply shown in Fig. 58.

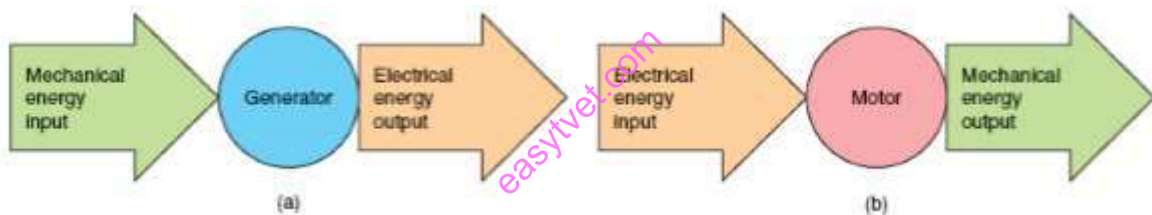


Figure 32: Electrical machines as energy converters

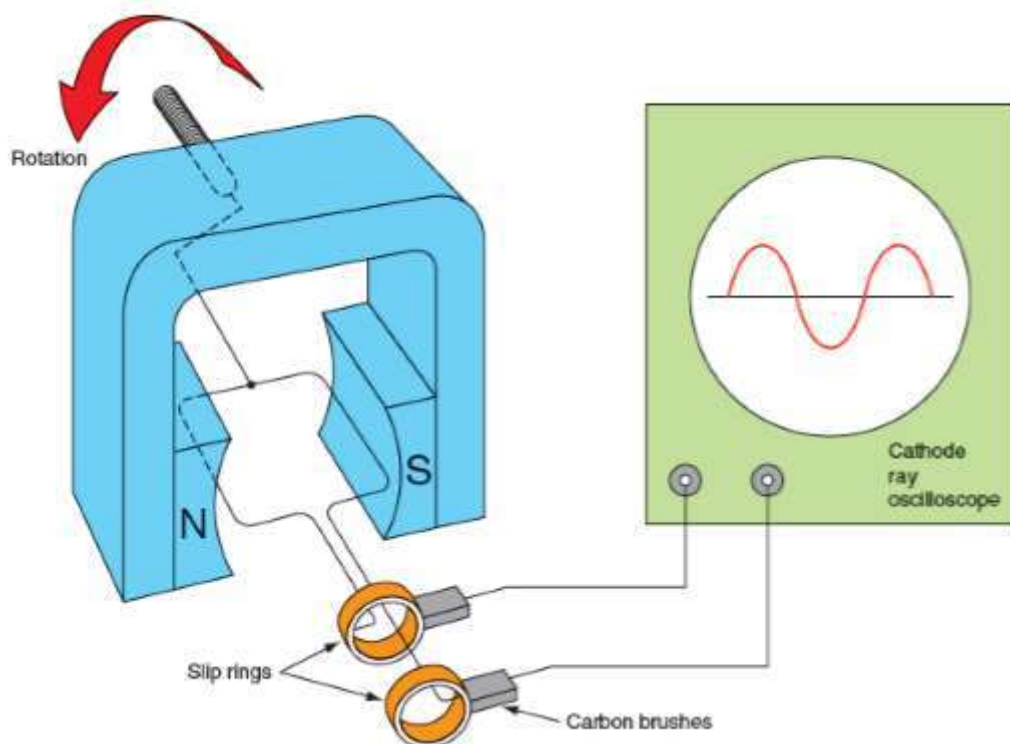


Figure 33: Simple AC generator or alternator



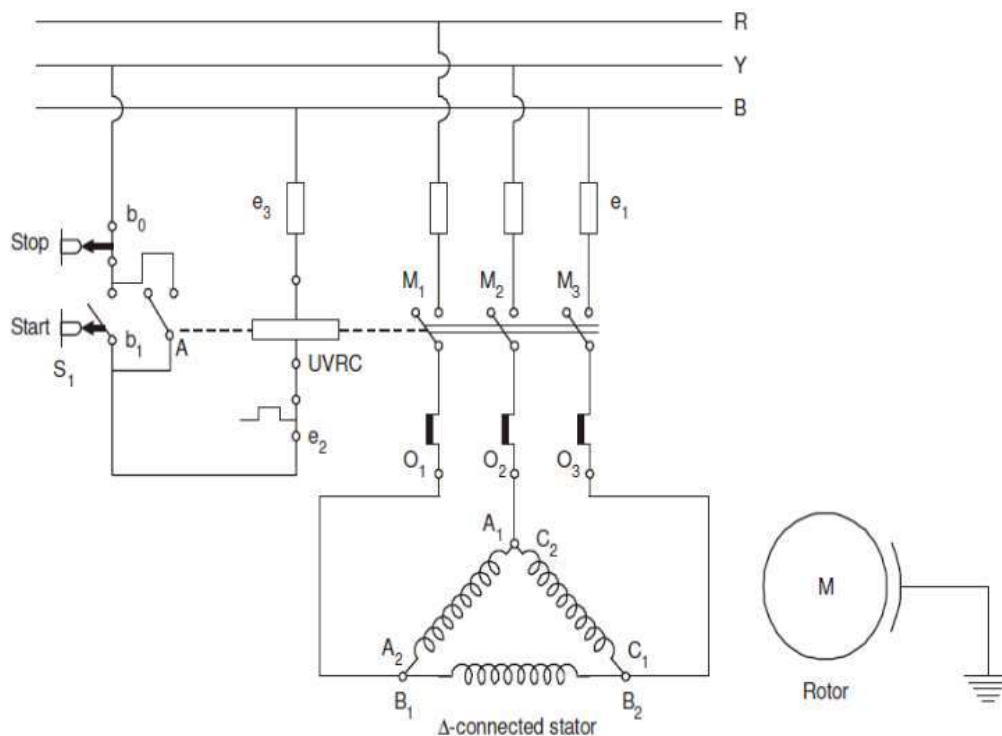
### Starting methods of three phase induction motors

An induction motor is similar to a poly-phase transformer whose secondary is short circuited. Thus, at normal supply voltage, like in transformers, the initial current taken by the primary is very large for a short while. Unlike in DC motors, large current at starting is due to the absence of back e.m.f. If an induction motor is directly switched on from the supply, it takes 5 to 7 times its full load current and develops a torque which is only 1.5 to 2.5 times the full load torque. This large starting current produces a large voltage drop in the line, which may affect the operation of other devices connected to the same line. Hence, it is not advisable to start induction motors of higher ratings (generally above 25kW) directly from the mains supply. Various starting methods of induction motors are described below.

#### Direct-on-line (DOL) starters

Small three phase induction motors can be started direct-on-line, which means that the rated supply is directly applied to the motor. But, as mentioned above, here, the starting current would be very large, usually 5 to 7 times the rated current. The starting torque is likely to be 1.5 to 2.5 times the full load torque. Induction motors can be started directly on-line using a DOL starter which generally consists of a contactor and a motor protection equipment such as a circuit breaker. A DOL starter consists of a coil operated contactor which can be controlled by start and stop push buttons. When the start push button is pressed, the contactor gets energized and it closes all the three phases of the motor to the supply phases at a time. The stop push button de-energizes the contactor and disconnects all the three phases to stop the motor. In order to avoid excessive voltage drop in the supply line due to large starting current, a DOL starter is generally used for motors that are rated below 5kW. The figure 59 shows a direct online starters

Figure 34: Direct online starters



### a) Auto-transformers:

Auto-transformers are also known as auto-starters. They can be used for both star connected and delta connected squirrel cage motors. It is basically a three phase step down transformer with different taps provided that permit the user to start the motor at, say, 50%, 65% or 80% of line voltage. With auto-transformer starting, the current drawn from supply line is always less than the motor current by an amount equal to the transformation ratio. For example, when a motor is started on a 65% tap, the applied voltage to the motor will be 65% of the line voltage and the applied current will be 65% of the line voltage starting value, while the line current will be 65% of 65% (i.e. 42%) of the line voltage starting value. This difference between the line current and the motor current is due to transformer action. The internal connections of an auto-starter are as shown in the figure. At starting, switch is at "start" position, and a reduced voltage (which is selected using a tap) is applied across the stator. When the motor gathers an appropriate speed, say up to 80% of its rated speed, the auto-transformer automatically gets disconnected from the circuit as the switch goes to "run" position. The switch changing the connection from start to run position may be air-break (small motors) or oil-immersed (large motors) type. There are also provisions for no-voltage and overload, with time delay circuits on an autostarter.

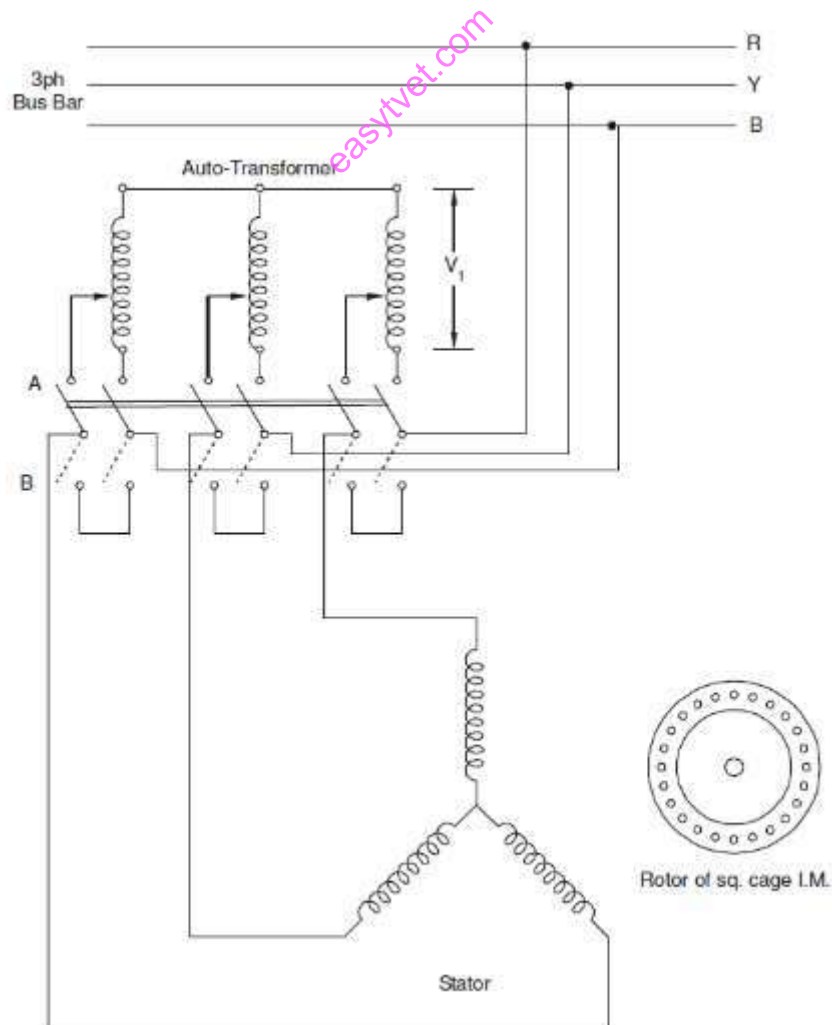


Figure 35: Autotransformer starting method

## b) Star-delta starter

The stator winding of the motor is designed for delta operation and is connected in star during the starting period. When the machine is up to speed, the connections are changed to delta. The circuit arrangement for star-delta starting is shown in Fig. The six leads of the stator windings are connected to the changeover switch as shown. At the instant of starting, the changeover switch is thrown to —Start position which connects the stator windings in star. Therefore, each stator phase gets  $V/\sqrt{3}$  volts where  $V$  is the line voltage. This reduces the starting current. When the motor picks up speed, the changeover switch is thrown to —Run position which connects the stator windings in delta. Now each stator phase gets full line voltage  $V$ .

The disadvantages of this method are:

- i. With star-connection during starting, stator phase voltage is  $1/\sqrt{3}$  times the line voltage. Consequently, starting torque is  $(1/\sqrt{3})^2$  or  $1/3$  times the value it would have with D-connection. This is rather a large reduction in starting torque.
- ii. The reduction in voltage is fixed. This method of starting is used for medium-size machines (up to about 25 H.P.).

Figure 61 shows star delta starter. Figure 62 shows the star and delta connections

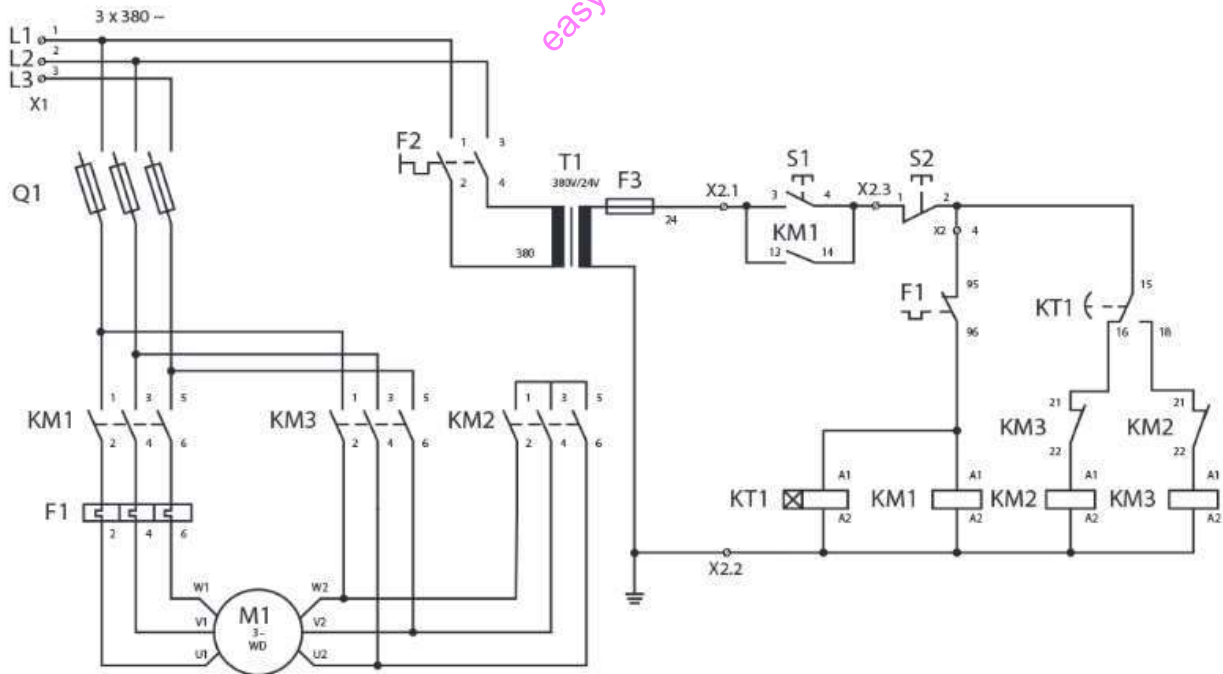


Figure 36: Star delta starter

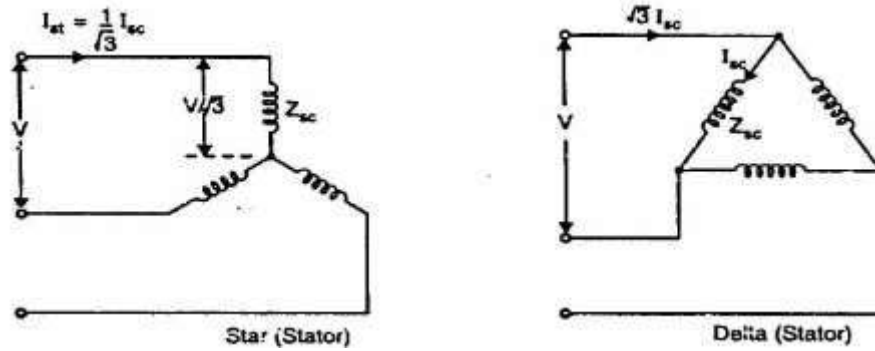


Figure 37: star and delta connections

### 3.1.3.3. Learning Activities

#### Workshop Practice

| Practical activities  | Knowledge | Special instruction |
|---|-----------|---------------------|
| 1. Identify types of various electrical machines                                      |           |                     |
| 2. Perform operations involving single phase and three phase AC and DC motors         |           |                     |
| 3. Perform calculations involving single phase and three phase AC and DC transformers |           |                     |
| 4. Perform operations involving single and three phase generators.                    |           |                     |
| 5. Apply AC and DC machines as per their functions                                    |           |                     |

### 3.1.3.4. Self-Assessment Questions

1. One application for an *a. c.* induction motor is:
  - A. an electric train
  - B. a microwave oven
  - C. a central heating pump
  - D. an electric drill.

2. One application for a shaded pole a.c. motor is:
- an electric train.
  - a microwave oven.
  - a central heating pump
  - an electric drill.
3. A step down transformer has 1000 turns on the primary winding and 500 turns on the secondary winding. If the input voltage was 230 V the output voltage will be:
- 11V
  - 115 V
  - 200 V
  - 460 V.
4. An electromagnetic switch operated by a solenoid is one definition of: a.
- a transformer
  - an a.c. motor
  - an relay
  - an inductive coil.

### 3.1.3.5. Tools, Equipment and Materials

#### Recommended Resources

| Tools and equipment   | Materials and supplies  |
|---|---|
| <ol style="list-style-type: none"> <li>Cable Strippers</li> <li>Pliers</li> <li>Screw drivers</li> <li>Hammers</li> <li>Chisels</li> <li>Allen keys</li> <li>Electrician knives</li> <li>Crimping tools</li> <li>Bending springs</li> <li>Bending machine</li> <li>Steel tapes</li> <li>Draw wires</li> <li>Hack saws</li> <li>Drilling tools</li> <li>Stock and die</li> <li>Bench vice</li> </ol> | <ol style="list-style-type: none"> <li>Stationery</li> <li>Cables</li> <li>Light fittings</li> <li>Accessories</li> <li>Conduits and fittings</li> <li>Cable trays</li> <li>Cable ducts</li> <li>Trunkings</li> <li>Computers</li> <li>Drawing instruments</li> <li>Screws</li> </ol> |

|  |  |
|--|--|
| xvii. Machine vice   |  |
| xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots |  |
| <b>Reference materials</b>   |  |
| I. IEE regulations   |  |
| II. Occupational safety and health act (OSHA)  |  |
| III. Work injury benefits act (WIBA)   |  |
| IV. Manufacturers' catalogues  |  |
| V. British standards   |  |
| VI. KEBS standards   |  |

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### 3.1.3.6. Model Answers to self-assessment Question

1. One application for an a.c. induction motor is:
  - A. An electric train
  - B. A microwave oven
  - C. A central heating pump**
  - D. An electric drill.
  
2. One application for a shaded pole a.c. motor is:
  - A. An Electric Train.
  - B. A Microwave Oven.**
  - C. A Central Heating Pump
  - D. An Electric Drill.
  
3. A step down transformer has 1000 turns on the primary winding and 500 turns on the secondary winding. If the input voltage was 230 V the output voltage will be:
  - A. 11V
  - B. 115 V**
  - C. 200 V
  - D. 460 V.
  
4. An electromagnetic switch operated by a solenoid is one definition of: a.
  - A. A Transformer
  - B. An A.C. Motor
  - C. An Relay**
  - D. An Inductive Coil.



## Demonstrate understanding of three phase power supply

### 3.1.2.0. Introduction

To demonstrate understanding of three phase power supply, perform connections of three phase power supply as per the standard operating procedure, perform calculations involving three phase power supply, perform measurements of three phase power supply and perform interconnections of three phase power supply as per the nature of load.

#### 3.1.2.1. Performance Standards

1. Perform connections of three phase power supply as per the standard operating procedure,
2. perform calculations involving three phase power supply
3. Perform measurements of three phase power supply
4. Perform interconnections of three phase power supply as per the nature of load.

### Information Sheet

#### Star and delta connections

The three-phase windings of an *a. c.* generator may be star connected or delta connected as shown in Fig. 63 The important relationship between phase and line currents and voltages is also shown. The square root of 3 is simply a constant for three-phase circuits, and has a value of 1.732. The delta connection is used for electrical power transmission because only three conductors are required. Delta connection is also used to connect the windings of most three-phase motors because the phase windings are perfectly balanced and, therefore, do not require a neutral connection. Making a star connection at the local sub-station has the advantage that two voltages become available – a line voltage of 400 V between any two phases, and a phase voltage of 230 V between line and neutral which is connected to the star point. In any star-connected system currents flow along the lines (IL), through the load and return by the neutral conductor connected to the star point. In a balanced three-phase system all currents have the same value and when they are added up by phasor addition, we find the resultant current is zero. Therefore, no current flows in the neutral and the star point is at zero volts. The star point of the distribution transformer is earthed because earth is also at zero potential. A star-connected system is also called a three-phase four-wire system and allows us to connect single-phase loads to a three-phase system.

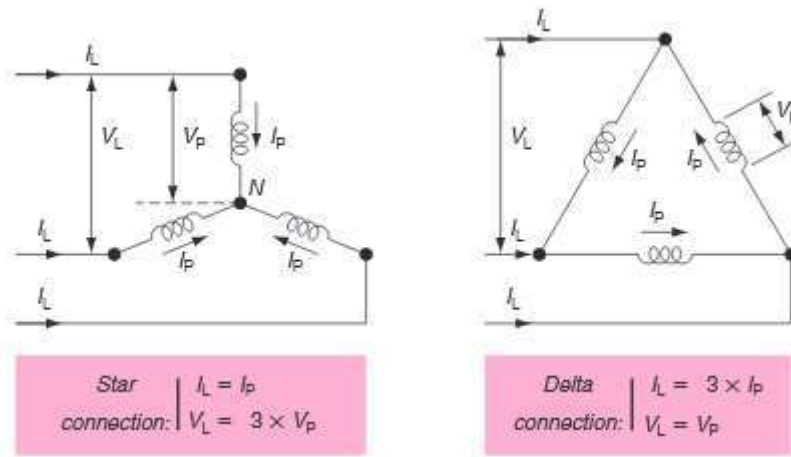


Figure 38: Star and delta connections

Three-phase power We know from our single-phase alternating current theory in Chapter 10 that power can be found from the following formula:  $P = VI \cos \phi$  In any balanced three-phase system, the total power is equal to three times the power in any one-phase.

### Voltage, current and power calculation

Three similar coils, each having resistance of  $8\Omega$  and an inductive reactance of  $8\Omega$  are connected

- In star and
- In delta, across a 415V, 3-phase supply. Calculate for each connection the readings on each of two wattmeters connected to measure the power by the two-wattmeter method.

(a) **Star connection:**  $V_L = \sqrt{3} V_p$  and  $I_L = I_p$

$$\text{Phase voltage, } V_p = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}}$$

and phase impedance,

$$Z_p = \sqrt{R_p^2 + X_L^2} = \sqrt{8^2 + 8^2} = 11.31 \Omega$$

Hence phase current,

$$I_p = \frac{V_p}{Z_p} = \frac{\frac{415}{\sqrt{3}}}{11.31} = 21.18 \text{ A}$$

Total power,

$$P = 3I_p^2 R_p = 3(21.18)^2(8) = 10\,766 \text{ W}$$

If wattmeter readings are  $P_1$  and  $P_2$  then:

$$P_1 + P_2 = 10\,766 \quad (1)$$

Since  $R_p = 8 \Omega$  and  $X_L = 8 \Omega$ , then phase angle  $\phi = 45^\circ$  (from impedance triangle).

$$\tan \phi = \sqrt{3} \left( \frac{P_1 - P_2}{P_1 + P_2} \right)$$

$$\text{hence } \tan 45^\circ = \frac{\sqrt{3}(P_1 - P_2)}{10\,766}$$

from which

$$P_1 - P_2 = \frac{(10\,766)(1)}{\sqrt{3}} = 6216 \text{ W} \quad (2)$$

Adding Equations (1) and (2) gives:

$$2P_1 = 10\,766 + 6216 = 16\,982 \text{ W}$$

Hence  $P_1 = 8491 \text{ W}$

From Equation (1),  $P_2 = 10\,766 - 8491 = 2275 \text{ W}$ .

**When the coils are star-connected the wattmeter readings are thus 8.491 kW and 2.275 kW**

(b) **Delta connection:**  $V_L = V_p$  and  $I_L = \sqrt{3} I_p$

$$\text{Phase current, } I_p = \frac{V_p}{Z_p} = \frac{415}{11.31} = 36.69 \text{ A.}$$

Total power,

$$P = 3I_p^2 R_p = 3(36.69)^2(8) = 32\,310 \text{ W}$$

$$\text{Hence } P_1 + P_2 = 32\,310 \text{ W} \quad (3)$$

$$\tan \phi = \sqrt{3} \left( \frac{P_1 - P_2}{P_1 + P_2} \right) \text{ thus } 1 = \frac{\sqrt{3}(P_1 - P_2)}{32\,310}$$

from which,

$$P_1 - P_2 = \frac{32\,310}{\sqrt{3}} = 18\,650 \text{ W} \quad (4)$$

Adding Equations (3) and (4) gives:

$$2P_1 = 50\,960 \text{ from which } P_1 = 25\,480 \text{ W.}$$

$$\text{From Equation (3), } P_2 = 32\,310 - 25\,480 = 6830 \text{ W}$$

**When the coils are delta-connected the wattmeter readings are thus 25.48 kW and 6.83 kW**

## Measurement of power in three phase systems

Power in three-phase loads may be measured by the following methods:

### a) One-wattmeter method for a balanced load

Wattmeter connections for both star and delta are shown in Fig. 64

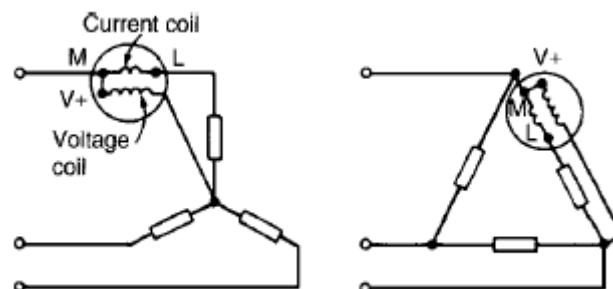


Figure 39: One wattmeter method

Total power = 3Xwattmeter reading

**b) Two-wattmeter method for balanced or unbalanced loads**

A connection diagram for this method is shown in Fig. 65 for a star-connected load. Similar connections are made for a delta-connected load.

**Total power = sum of wattmeter readings**

$$=P_1 + P_2$$

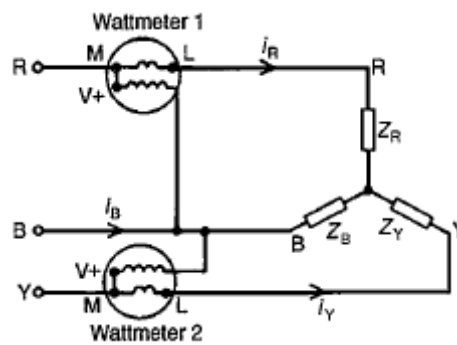


Figure 40: Two wattmeter method

The power factor may be determined from:  $\tan \phi = \sqrt{3} \left( \frac{P_1 - P_2}{P_1 + P_2} \right)$

It is possible, depending on the load power factor, for one wattmeter to have to be ‘reversed’ to obtain a reading. In this case it is taken as a negative reading

**c) Three-wattmeter method for a three-phase, 4- wire system for balanced and unbalanced loads**

$$\text{Total Power} = P_1 + P_2 + P_3$$

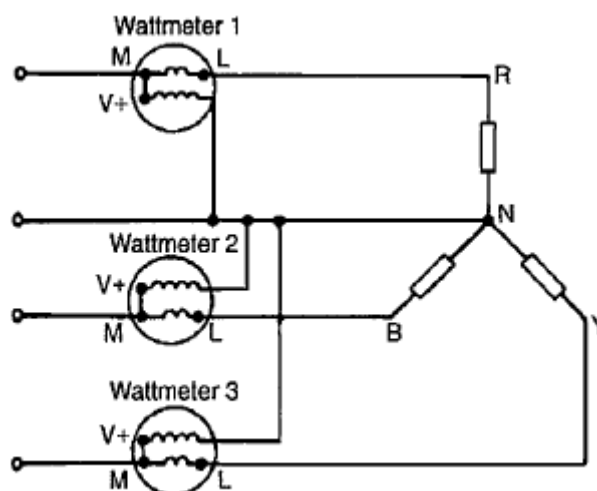


Figure 41: Three wattmeter method

### 3.1.2.2. Learning Activities

#### Industrial attachment/workshop practice/project

| Practical activities  | knowledge                                   | Special instructions |
|---|---|----------------------|
| 1. Performed connections of three phase power supply as per the standard operating procedure. | Connections of 3 phase power supplies       |                      |
| 2. Performed calculations involving three phase power supply connections                      | Three phase power calculations              |                      |
| 3. Performed measurements of three phase power supply   | Measurements of three phase power supply    |                      |
| 4. Performed interconnections of three phase power supply                                     | Interconnection of three phase power supply |                      |

### 3.1.2.3. Self-Assessment Questions

1. Which are the ways in which phases of a three-phase supply can be interconnected to reduce the number of conductors used compared with three single-phase systems?
2. State the relationships between line and phase currents and line and phase voltages or a star-connected system
3. By what methods may power be measured in a three-phase system?
4. State the national standard phase sequence for a three-phase supply

### 3.1.3.0. Tools, Equipment and Materials

#### Recommended Tools, Equipment and Materials

| Tools and equipment   | Materials and supplies   |
|---|--|
| <ol style="list-style-type: none"> <li>i. Cable Strippers</li> <li>ii. Pliers</li> <li>iii. Screw drivers</li> <li>iv. Hammers</li> <li>v. Chisels</li> <li>vi. Allen keys</li> <li>vii. Electrician knives</li> <li>viii. Crimping tools</li> <li>ix. Bending springs</li> <li>x. Bending machine</li> </ol> | <ol style="list-style-type: none"> <li>i. Stationery</li> <li>ii. Cables</li> <li>iii. Light fittings</li> <li>iv. Accessories</li> <li>v. Conduits and fittings</li> <li>vi. Cable trays</li> <li>vii. Cable ducts</li> <li>viii. Trunkings</li> <li>ix. Computers</li> <li>x. Drawing instruments</li> </ol> |

|  |  |
|--|--|
| <ul style="list-style-type: none"> <li>xi. Steel tapes</li> <li>xii. Draw wires</li> <li>xiii. Hack saws</li> <li>xiv. Drilling tools</li> <li>xv. Stock and die</li> <li>xvi. Bench vice</li> <li>xvii. Machine vice</li> <li>xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul> | <ul style="list-style-type: none"> <li>xi. Screws</li> </ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>a) IEE regulations</li> <li>b) Occupational safety and health act (OSHA)</li> <li>c) Work injury benefits act (WIBA)</li> <li>d) Manufacturers’ catalogues</li> <li>e) British standards</li> <li>f) KEBS standards</li> </ul>                          |  |

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### 3.1.3.1. Model Answer to self-assessment Questions

1. Ways in which phases of a three phase supply can be interconnected to reduce the number of conductors used compared with three single-phase systems
  - i. **Star**
  - ii. **Delta**
2. **Relationships between line and phase currents and line and phase voltages or a star-connected system**

$$V_L = \sqrt{3} V_p$$

$$I_L = I_p$$

3. **Methods in which power may be measured in a three-phase system**
  - a) One wattpower method
  - b) Two wattpower method
  - c) Three wattpower method
4. **National standard phase sequence for a three-phase supply**  
**RYBN**

### 3.1.5. USE OF POWER FACTOR IN ELECTRICAL INSTALLATION

#### Introduction

#### Performance Standard

1. Identify power triangle i.e. active, apparent and reactive power
2. Perform use of power factor
3. Perform calculations involving power factor correction
4. Apply methods of power factor correction

#### Information Sheet

#### Power and power factor

**Power factor** ( $p.f.$ ) is defined as the cosine of the phase angle between the current and voltage:

$$p.f. = \cos \phi$$

If the current lags the voltage as shown in Fig. 10.5, we say that the  $p.f.$  is lagging, and if the current leads the voltage as shown in Fig. 10.6, the  $p.f.$  is said to be leading. From the trigonometry of the impedance triangle shown in Fig. 10.7,  $p.f.$  is also equal to:

$$p.f. = \cos \phi = \frac{R}{Z} = \frac{V_R}{V_T}$$

The electrical power in a circuit is the product of the instantaneous values of the voltage and current. Figure 67 shows the voltage and current waveform for a pure inductor and pure capacitor. The power waveform is obtained from the product of  $V$  and  $I$  at every instant in the cycle. It can be seen that the power waveform reverses every quarter cycle, indicating that energy is alternately being fed into and taken out of the inductor and capacitor. When considered over one complete cycle, the positive and negative portions are equal, showing that the average power consumed by a pure inductor or capacitor is zero. This shows that inductors and capacitors store energy during one part of the voltage cycle and feed it back into the supply later in the cycle. Inductors store energy as a magnetic field and capacitors as an electric field. In an electric circuit more power is taken from the supply than is fed back into it, since some power is dissipated by the resistance of the circuit, and therefore:

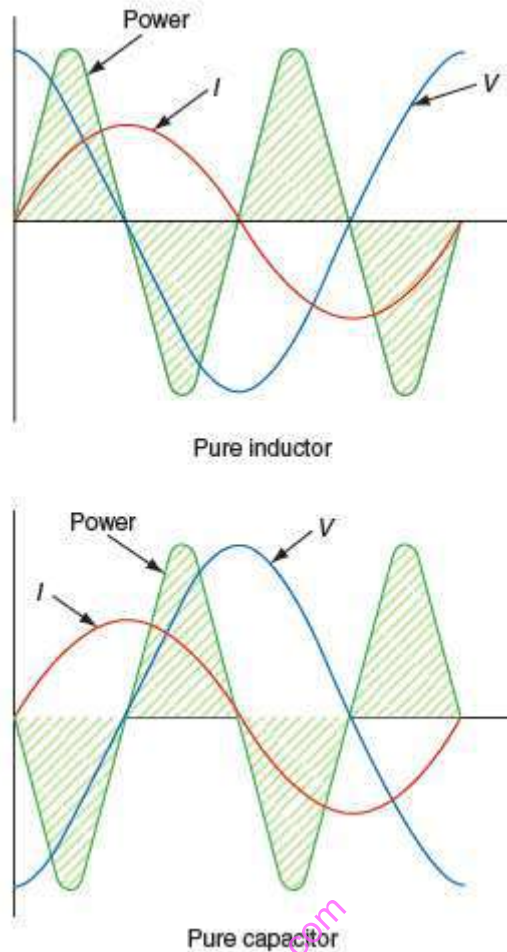


Figure 42: waveform for the ac power in purely inductive and purely capacitive circuit

$$P = I^2 R \text{ (W)}$$

In any *d. c.* circuit the power consumed is given by the product of the voltage and current, because in a *d. c.* circuit voltage and current are in phase. In an *a. c.* circuit the power consumed is given by the product of the current and that part of the voltage which is in phase with the current. The in-phase component of the voltage is given by  $V \cos \phi$ , and so power can also be given by the equation:

The power factor of most industrial loads is lagging because the machines and discharge lighting used in industry are mostly inductive. This causes an additional magnetizing current to be drawn from the supply, which does not produce power, but does need to be supplied, making supply cables larger.

### Power Triangle

Power Triangle is the representation of a right angle triangle showing the relation between active power, reactive power and apparent power. When each component of the current that is the active component ( $I \cos \phi$ ) or the reactive component ( $I \sin \phi$ ) is then multiplied by the voltage  $V$ , a power triangle is obtained shown in the figure 68.

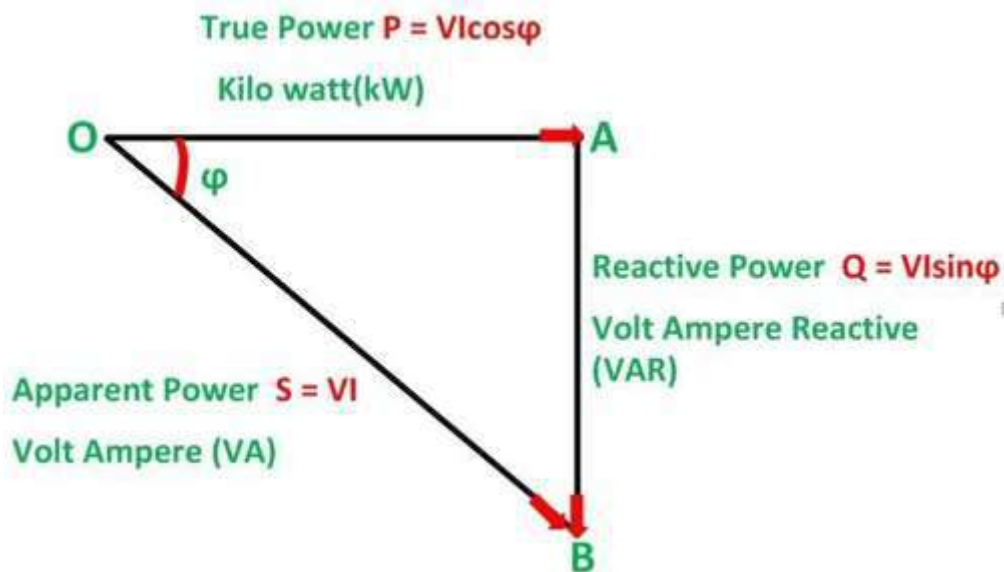


Figure 43: Power triangle

The power which is actually consumed or utilized in an AC Circuit is called True power or Active Power or real power. It is measured in kilowatt (kW) or MW. The power which flows back and forth that means it moves in both the direction in the circuit or reacts upon it, is called Reactive Power. The reactive power is measured in kilovolt-ampere reactive (kVAR) or MVAR. The product of root means square (RMS) value of voltage and current is known as Apparent Power. This power is measured in KVA or MVA.

The following point shows the relationship between the following quantities and is explained by graphical representation called Power Triangle shown above.

- i. When an active component of current is multiplied by the circuit voltage V, it results in active power. It is this power which produces torque in the motor, heat in the heater, etc. This power is measured by the wattmeter.
- ii. When the reactive component of the current is multiplied by the circuit voltage, it gives reactive power. This power determines the power factor, and it flows back and froths in the circuit.
- iii. When the circuit current is multiplied by the circuit voltage, it results in the apparent power.
- iv. From the power triangle shown above the power, the factor may be determined by taking the ratio of true power to the apparent power.

$$\text{Power factor } (\cos \varphi) = \frac{\text{Active Power}}{\text{Apparent Power}} = \frac{\text{kW}}{\text{kVA}}$$

As we know simply power means the product of voltage and current but in AC circuit except for pure resistive circuit, there is usually a phase difference between voltage and current and thus  $VI$  does not give real or true power in the circuit

### Power factor correction

Most installations have a low or bad power factor because of the inductive nature of the load. A capacitor has the opposite effect of an inductor, and so it seems reasonable to add a capacitor to a load which is known to have a lower or bad power factor, for example, a motor.

Figure 69(a) shows an industrial load with a low power factor. If a capacitor is connected in parallel with the load, the capacitor current  $I_C$  leads the applied voltage by  $90^\circ$ . When this capacitor current is added to the load current as shown in Fig 69(b) the resultant load current has a much improved power factor. However, using a slightly bigger capacitor, the load current can be pushed up until it is 'in phase' with the voltage as can be seen in Fig. 69(c). Capacitors may be connected across the main busbars of industrial loads in order to provide power factor improvement, but smaller capacitors may also be connected across an individual piece of equipment, as is the case for fluorescent light fittings.

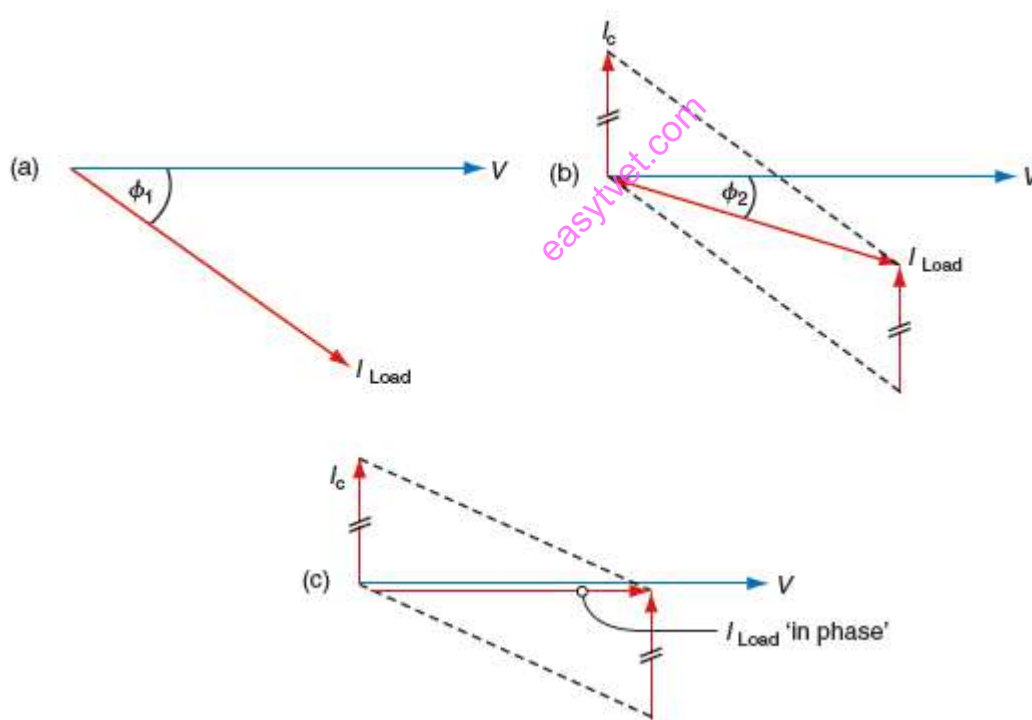


Figure 44: Power factor improvement using capacitors

### Causes of low power factor

- Most of the *a. c* motors are induction type which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0.2 to 0.3) and rises to 0.8 to 0.9 at full load
- Arc lamps, electric discharge lamps and industrial heating furnaces operate at low power factor.

- c) The load on the power system is varying; being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetization current thus decreased power factor.

### Ways of improving a low power factor

- i. Use of static capacitor-capacitor is connected in parallel with the equipment operating at a lagging power factor. The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of load current and thus raises power factor
- ii. Synchronous condenser-takes a leading current when overexcited and thus behaves like a capacitor. An overexcited synchronous motor running on no load is known as synchronous condenser. When connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of the load hence improving the power factor.
- iii. Phase Advancers-This provides exciting current from another ac source since the low power factor is as a result of stator winding drawing exciting current which lags behind the supply voltage by  $90^\circ$ .

### Calculation involving power factor correction

A Three phase motor connected to 400V, 50Hz takes 31.7A at a power factor of 0.7 lagging. Calculate the capacitance required in parallel with the motor to raise the power factor to 0.9 lagging.

#### Solution:

The circuit and phasor diagrams are shown in Figs. 6.8 and 6.9 respectively. Here

Motor  $M$  is taking a current  $IM$  of 31.7A. The current  $IC$  taken by the capacitor must be such that when combined with  $IM$ , the resultant current  $I$  lags the voltage by an angle  $\phi$  where  $\cos \phi = 0.9$ .

Referring to the phasor diagram in

$$\text{Active component of } IM = IM \cos \phi = 31.7 \times 0.7 = 22.19A$$

$$\text{Active component of } I = I \cos \phi = I \times 0.9$$

These components are represented in the phasor diagram

$$I = \frac{22.19}{0.9} = 24.65A$$

$$\text{Reactive component of } IM = IM \sin \phi = 31.7 \times 0.714^* = 22.6A$$

$$\text{Reactive component of } I = I \sin \phi = 24.65 \sqrt{1 - (0.9)^2}$$

$$= 24.65 \times 0.436 = 10.75 A$$

It is clear from the phasor diagram:

$$IC = \text{Reactive component of } IM - \text{Reactive component of } I$$

$$= 22.6 - 10.75 = 11.85A$$

$$\text{But } I_C = \frac{V}{X_c} = VX2\pi fc$$

$$\text{or } 11.85 = 400 \times 2\pi \times 50 \times C$$

$$\therefore C = 94.3 \times 10^{-6} \text{ F} = \mathbf{94.3 \mu F}$$

$$\begin{aligned} \Rightarrow \sin \phi_m &= \sqrt{1 - \cos^2 \phi_m} \\ &= \sqrt{1 - 0.7^2} \\ &= \mathbf{0.714} \end{aligned}$$

### 3.1.5.3. Learning Activities

#### Industrial attachment

| Practical activities   | Knowledge | Special instruction |
|--|-----------|---------------------|
| 1. Identify power triangle i.e. active apparent d reactive power |           |                     |
| 2. Perform the use of power factor                               |           |                     |
| 3. Perform calculations involving power factor correction        |           |                     |
| 4. Apply methods of power factor correction                      |           |                     |

#### Self-Assessment Questions

1. What does the term power factor mean? **(2 Marks)**
2. What are the causes of low power factors? **(4 Marks)**
3. Which are the ways used to improve the power factor of a system? **(4 Marks)**
4. A 230 V supply feeds three 1.84 kW loads with power factors of 1, 0.8 and 0.4. Calculate the current at each power factor. **(5 Marks)**

### 3.1.5.5. Tools, Equipment and Materials

#### Recommended Resources

| Tools and equipment  | Materials and supplies   |
|--|--|
| <ol style="list-style-type: none"> <li>Cable Strippers</li> <li>Pliers</li> <li>Screw drivers</li> <li>Hammers</li> <li>Chisels</li> </ol> | <ol style="list-style-type: none"> <li>Stationery</li> <li>Cables</li> <li>Light fittings</li> <li>Accessories</li> <li>Conduits and fittings</li> </ol> |

|  |   |
|--|---|
| <ul style="list-style-type: none"> <li>vi. Allen keys</li> <li>vii. Electrician knives</li> <li>viii. Crimping tools</li> <li>ix. Bending springs</li> <li>x. Bending machine</li> <li>xi. Steel tapes</li> <li>xii. Draw wires</li> <li>xiii. Hack saws</li> <li>xiv. Drilling tools</li> <li>xv. Stock and die</li> <li>xvi. Bench vice</li> <li>xvii. Machine vice</li> <li>xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul> | <ul style="list-style-type: none"> <li>vi. Cable trays</li> <li>vii. Cable ducts</li> <li>viii. Trunkings</li> <li>ix. Computers</li> <li>x. Drawing instruments</li> <li>xi. Screws</li> </ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>i. IEE regulations</li> <li>ii. Occupational safety and health act (OSHA)</li> <li>iii. Work injury benefits act (WIBA)</li> <li>iv. Manufacturers' catalogues</li> <li>v. British standards</li> <li>vi. KEBS standards</li> </ul>   |   |

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### 3.1.5.7. Response to self-assessment

#### 1. Power factor

(2 Marks)

Power factor ( $p.f.$ ) is defined as the cosine of the phase angle between the current and voltage:

$$p.f. = \cos \phi$$

#### 2. Causes of low power factors

(4 Marks)

- (a) Most of the *a. c* motors are induction type which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0.2 to 0.3) and rises to 0.8 to 0.9 at full load
- (b) Arc lamps, electric discharge lamps and industrial heating furnaces operate at low power factor.
- (c) The load on the power system is varying; being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetization current thus decreased power factor.

#### 3. Ways used to improve the power factor of a system

(4 Marks)

- a. Use of static capacitor-capacitor is connected in parallel with the equipment operating at a lagging power factor. The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of load current and thus raises power factor

- b. Synchronous condenser-takes a leading current when overexcited and thus behaves like a capacitor. An overexcited synchronous motor running on no load is known as synchronous condenser. When connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of the load hence improving the power factor.
- c. Phase Advancers-This provides exciting current from another ac source since the low power factor is as a result of stator winding drawing exciting current which lags behind the supply voltage by  $90^\circ$ .

4. A 230 V supply feeds three 1.84 kW loads with power factors of 1, 0.8 and 0.4. (5 Marks)

i. Current at 1.0 power factor.

The current is given by:  $I = \frac{P}{V \cos \phi}$

Where  $P = 1.84 \text{ kW} = 1840 \text{ W}$  and  $V = 230 \text{ V}$

$\therefore$  Current at 1.0 power factor,  $I = \frac{1840 \text{ W}}{230\text{V} \times 1} = 8.0 \text{ A}$

ii. Current at 0.8 power factor.

$$I = \frac{1840 \text{ W}}{230\text{V} \times 0.8} = 10.0 \text{ A}$$

iii. Current at 0.4 power factor.

$$I = \frac{1840 \text{ W}}{230\text{V} \times 0.4} = 20.0 \text{ A}$$

It can be seen from these calculations that a 1.84 kW load supplied at a power factor of 0.4 would require a 20 A cable, while the same load at unity power factor could be supplied with an 8 A cable. There may also be the problem of higher voltage drops in the supply cables. As a result, the supply companies encourage installation engineers to improve their power factor to a value close to unity (1.0) and sometimes charge penalties if the power factor falls below predetermined value, say 0.8

### 3.1.6. Use of earthing in electrical installation

#### 3.1.6.0. Introduction

To use earthing in electrical installations, one need to identify the earthing types, identify earthing points in electrical installation, perform calculation involved in determining the earthing type and perform test on earthing system in line with IEE regulations.

#### 3.1.6.1. Performance Standard

1. Identify the earthing types,
2. Identify earthing points in electrical installation,
3. Perform calculation involved in determining the earthing type and
4. Perform test on earthing system in line with IEE regulations

## Information Sheet

### Earthing system

#### Terms in earthing

**Current rating of a fuse** – it is the current the fuse will carry continuously without blowing or deteriorating.

**Rated minimum fusing current** – it is the minimum current at which the fuse will blow at a specified time. This may vary between 1.25 - 2.5 the current rating of the fuse.

**Fusing factor** – The relationship between the rated minimum fusing current and the current rating is called the fusing factor.

**Overcurrent** – Any current beyond the current rating of a fuse

**Discrimination** – relate to the time current characteristic of protection devices sustained. This is the ability of a fuse to distinguish between a transient and high current e.g. motor starting current and continuous fault current

#### Reasons for earthing

- (a) To maintain the potential of any part of an electrical system at a definite value with respect to earth.
- (b) To allow fault current to flow to earth in the event of an earth fault so that the protective gears operates to isolate the faulty circuit.
- (c) So that in the event of a fault, apparatus normally 'dead' cannot reach a dangerous potential with respect to earth.

#### Methods used to achieve earthing of an installation

- i. Connection to the metal sheath of armoring of supply authority underground cable (concentric earthing system)
- ii. Connection to the continuous earth wire provided by Supply authority where the distribution of energy is by overhead lines.
- iii. Connection to the earth electrode sunk into the ground for the purpose
- iv. Installation of automatic earth fault protection device e.g. ELCB

#### Fuses.

A fuse element consists essentially of a piece of copper or tin-lead alloy wire which will melt when carrying a predetermined current. This element with contact carrier, and base is called a fuse. It is placed in series with the circuit or sub-circuit to be protected, and automatically breaks the circuit when overloaded. In general, the regulations regarding fuses require that fuses shall be accessible, and shall be

fitted either on the front of a switch board or in a protecting case. In most cases in installation work the fuses are fitted in a distribution board.

The current rating or normal current-carrying capacity of a fuse should not exceed the current rating of the smallest conductor in the circuit protected by the fuse, account being taken of the class of excess-current protection provided by the fuse, coarse or close. For electric motors, a higher fuse rating is allowable. The fusing values of normal duty fuses vary from 160 to 200 percent of the carrying capacity.

### **Types of fuses**

#### **a. Rewireable fuses.**

In this type, fuse wire is placed in a removable fuse link. The fuse link may be of porcelain or other suitable insulating materials, it is so constructed that there is no danger to the operator in removing the fuse link. The fuse wire is connected between two terminals and passes through an asbestos tube or is in intimate contact with a sheet of asbestos. The fuse link is push-fitted into the fuse base to make the connection through suitable contacts. Although the material cost of replacing a blown fuse wire in a Rewirable fuse is negligible, nevertheless this fuse had disadvantages, the chief being the deterioration of the fuse wire over a period, and another the possibility of renewal by the wrong size of fuse wire.

#### **b. Cartridge fuses**

The cartridge fuse consists of a sealed tube with metal end caps. The fuse wire passes through the tube from cap to cap and is welded or soldered to the inside of the cap. There is sometimes a blowout device in the side of the tube to indicate when the fuse is blown. When the fuse is blown the whole cartridge must be replaced. Cartridge fuses only are used in fused plugs, such as the common ring-circuit 13 –A plug.

#### **c. High breaking and High rupturing capacity fuses.**

The H.B.C fuse consists of a ceramic tube with metal end caps and fixing tags. The fuse is a silver strip of special shape with a low melting point rivet in the centre. The strip is entirely surrounded by chemically purified silica. When an overload occurs breaking the fuse element, the silica prevents the formation of an arc, thus preventing overheating of the fuse and its surroundings.



*Figure 28 HRC fuses*

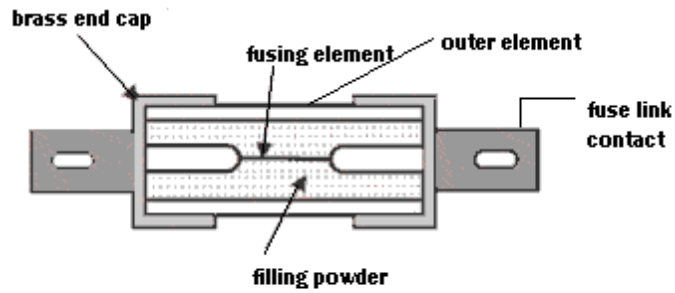


Figure 45: Construction of HRC fuse

### Distribution boards.

By definition, the distribution board is an assemblage of parts, including one or more fuses or circuit-breakers arranged for the distribution of electrical energy to final sub-circuits or to other distribution boards.

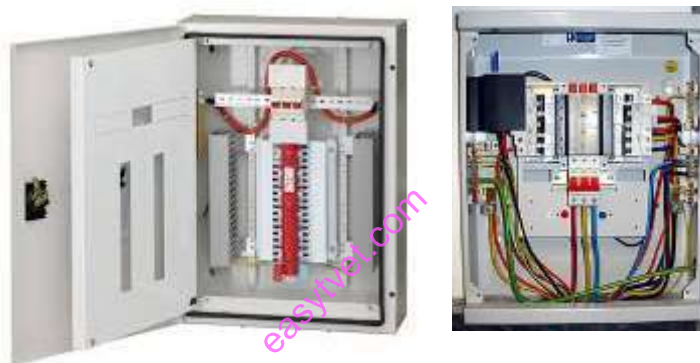


Figure 46: Distribution board

The boards are usually metal-cased in sheet steel, or hardwood- cased in oak, teak, or mahogany. The doors may be solid or glazed, and the case if fitted with an earthing terminal. Figure 1.38 shows a 1-pole and neutral, 6-way, distribution board with sheet steel body, fitted with Rewirable or H.B.C fuses. There is one fuse bank only, on the live side. One end of each of the six fuses is rigidly connected to a busbar, and the other end is arranged for connection to the circuit wire. The neutral wire of the circuit is connected to the neutral bar.

The regulations require that the neutral conductors for the different sub- circuits shall be connected in the same order as the live conductors to the fuses. Some distribution boards are designed to contain circuit – breakers instead of fuses. These however are more expensive than the equivalent Rewirable or H.B.C fuses.

### Miniature circuit- breakers

These are being increasingly used to provide *close excess - current* protection in single phase, 250 V circuits.

The circuit- breaker is essentially a switch which may be:

- i. Opened and closed by hand

- ii. Opened automatically when overloaded

The tripping action may be either magnetic or thermal. In general both these actions are used in this type of circuit-breaker. Protection against sustained over current is given by the bending of a bi-metal strip with its time-lag affect, while high speed protection against a short- circuit is given by magnetic operation.

The circuit-breaker replaces both switch and fuses in the various circuits in which it is used. It can be obtained with plug-in contacts for insertion into a fuse base in a distribution board in place of a plug-in fuse carrier.

### Main switch and fuses

The consumer's main switch and fuses may be combined in one case. With this type of switch and fuse gear, the switch cannot be operated when the case is open, nor can the case be opened while the switch is closed.

### Consumer's control unit

In a single-phase installation whose current rating is not greater than 60A, the consumer's main switch and fuse may be combined with the distribution board as one combined unit. The unit comprises a 60A 2-pole main switch and up to 12 single-pole circuit fuses ( 12 way consumer unit). The fuses vary in size, e.g 5A, 15 A and 30 A.

Obviously the maximum current to be taken from the unit at any one time must not exceed 60 A. either cartridge or Rewirable fuses may be employed. In addition to the fuses a neutral bar and an earthing bar are fitted. The whole is fitted in a suitable sheet steel case, or in a moulded case; figure 1.39 shows a connection diagram for this unit.

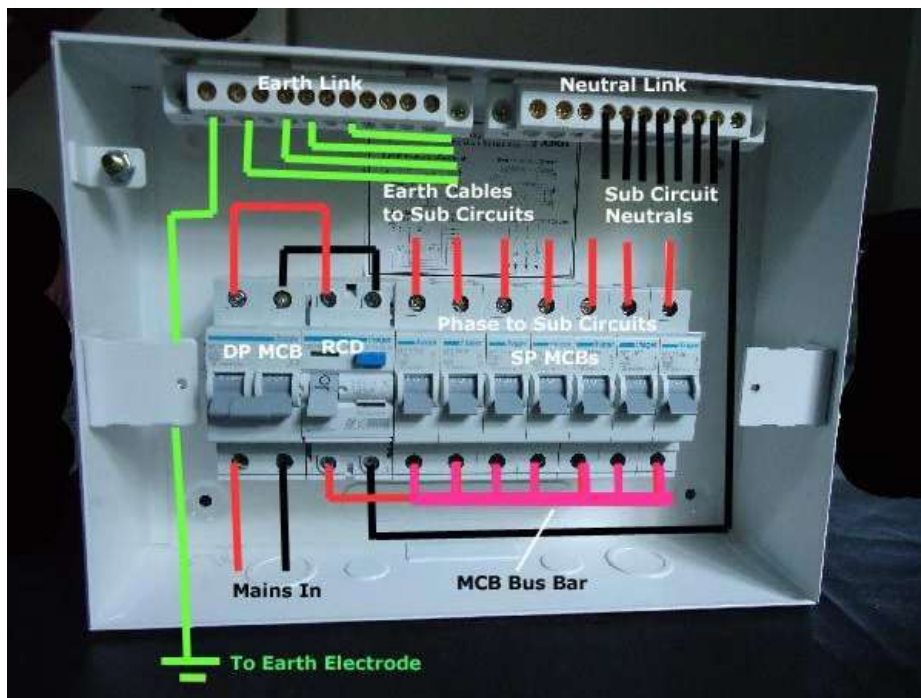


Figure 47: Consumer control unit

### Effectiveness of earthing tests

The purpose of this test is:-

- a) To measure the resistance of the earth continuity conductor.
- b) To check that the earth continuity heavy leakage currents.
- c) To ensure that the earth electrode is effectively connected to the general mass of earth.

### Earth Continuity

Earth continuity is making sure that should there be an electrical fault, all exposed metalwork in a building is bonded together and connected to the earth block in the consumer unit, leaving the current to earth and automatically disconnecting the supply. An earth continuity test will verify that exposed metalwork in a building is bonded together and connected to the earthing block in the consumer unit.

The ohmmeter leads are connected between the points being tested, between simultaneously accessible conductive parts e.g. pipe works, sinks etc. This test will verify that the conductor is sound.

### Earth fault loop test

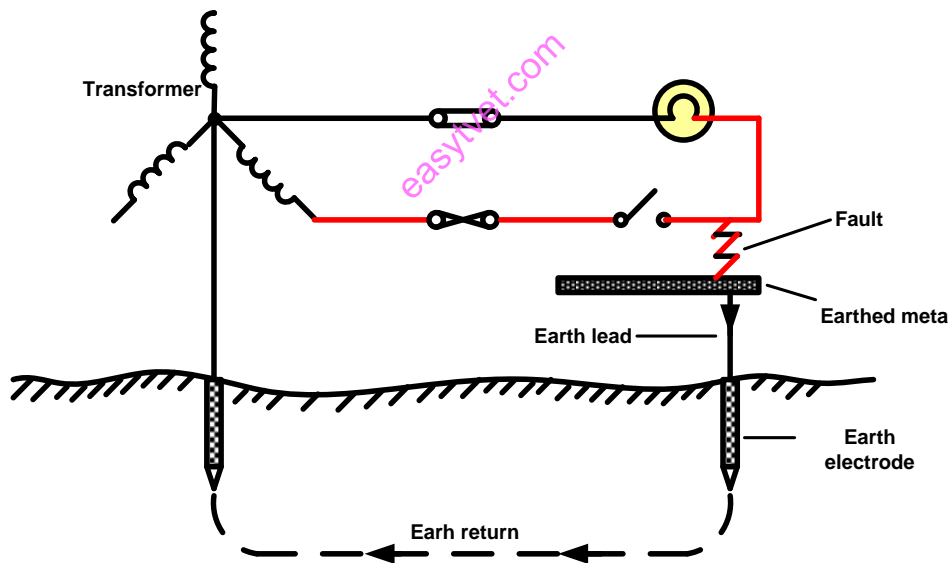


Figure 48: Earth loop test

The earth fault loop is the path which the leakage current will take back to the supply transformer when there is an earth leakage in an installation. The path is as shown below.

The test must be carried out on a new or largely modified installations where earth-leakage protection relies on the operation of fuses or excess current circuit – breakers.

- a) The leakage current flows from the faulty conductor into the earth continuity conductor.
- b) It then flows along the earth continuity conductor to the earthing lead.
- c) The earthing lead carries the current to the earth electrode.
- d) The leakage current now takes the shortest path back to the earthed neutral of the supply transformer.



The purpose of this test is to show that the earth fault loop is capable of carrying heavy leakage currents so that the protective gear (e.g. fuses) will operate when leakages occur between the line conductor and the earthed metalwork of the installation.

Apparatus: Line-earth loop tester (Megger).

### Method

The Line-earth loop tester, operating on full mains voltage, passes a short duration current of approximately 20A from the line conductor, through the consumer's earth continuity conductor and the earth return path to the neutral of the supply transformer. This instrument measures the value of the loop in Ohms.

### Readings

The minimum permissible reading depends on the operating conditions but the two main factors are:-

Operating current of fuse or circuit breaker protecting circuit.

Supply voltage.

### Example

If the circuit fuse operated at 50A and the supply voltage is 240V then the resistance of the earth fault loop must not be more than  $\frac{240 V}{60 A} = 4 \Omega$  . If the resistance is higher than this value the fuse will not open under serious fault conditions.

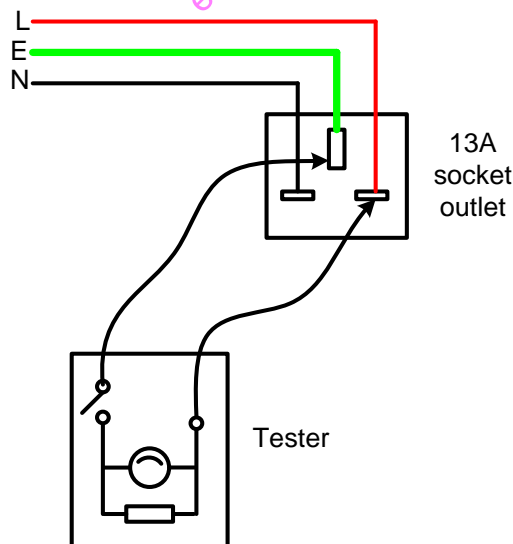


Figure 49: circuit of megger line-earth loop tester

Factors determining resistance of earth fault loop are as follows.

- i. The continuity of the metallic circuit up to the earth electrode (the earth continuity conductor and the earthing lead).
- ii. The resistance of the body of earth surrounding the earth electrode.

**Earthing Lead** – The minimum size of copper earthing lead is  $1\text{mm}^2$ . The earthing lead connecting an earth-leakage circuit-breaker to an earth electrode need not exceed  $2.5\text{mm}^2$ . The earthing lead should be

protected against mechanical damage and corrosion and the clamp used for connecting the earth lead to the earth electrode should be non-ferrous and should be accessible for inspection.

The resistance area is the name given to the resistance of the body of earth surrounding the earth electrode.

**The resistance area is measured using**

- i. An alternating current (at a maximum pressure of 40V) is connected between the main earth electrode A and an auxiliary electrode B, placed about 30m from A. An ammeter is placed in series with the supply to measure the current through the circuit.
- ii. A second auxiliary electrode C is placed between A and B and the voltage (potential difference) is measured between A and C. the resistance of the resistance area is found by taking various readings from point A towards point B. Outside the resistance area the resistance is constant .

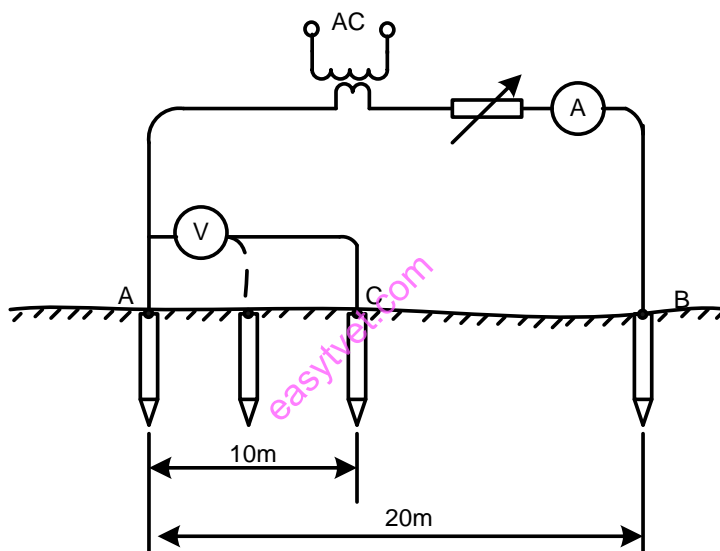


Figure 50: Earth electrode resistance test

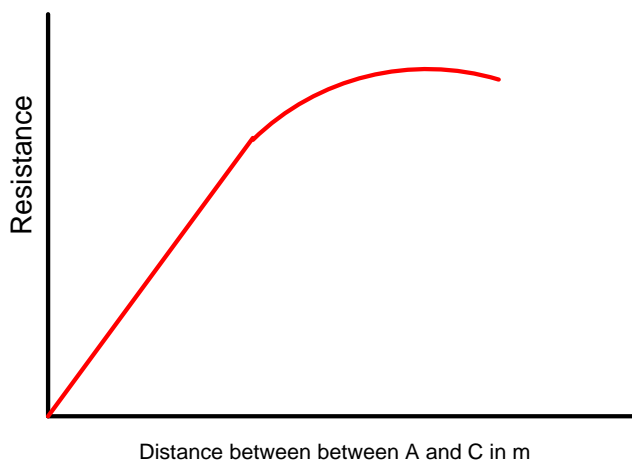


Figure 51: resistance area measurement

$$R = \frac{\text{Voltage between A and C}}{\text{Current}}$$

### 3.1.6.2. Learning Activities

#### Industrial attachment/workshop Practice

| Practical activities   | knowledge | Special instruction |
|--|-----------|---------------------|
| 1. Identify earthing types                                       |           |                     |
| 2. Identify earthing points in electrical installation           |           |                     |
| 3. Perform calculation involved in determining the earthing type |           |                     |
| 4. Perform test on earthing system in line with IEE regulations  |           |                     |

### 3.1.6.3. Self-Assessment Questions

1. What is the meaning of the following terms with reference to earthing:- (10 Marks)
  - i. Current rating of a fuse?
  - ii. Rated minimum fusing current?
  - iii. Fusing factor?
  - iv. Overcurrent?
  - v. Discrimination?
2. What are the reasons for earthing? (6 Marks)
3. Which methods can be used to achieve earthing of an installation? (6 Marks)
4. Which tests related to earthing should be carried out in a completed electrical installation? (3 Marks)

### 3.1.6.4. Tools, Equipment and Material

#### Recommended Resources

| Tools and equipment | Materials and supplies |
|---------------------|------------------------|
| i. Cable Strippers  | i. Stationery          |

|   |   |
|---|---|
| <ul style="list-style-type: none"> <li>ii. Pliers</li> <li>iii. Screw drivers</li> <li>iv. Hammers</li> <li>v. Chisels</li> <li>vi. Allen keys</li> <li>vii. Electrician knives</li> <li>viii. Crimping tools</li> <li>ix. Bending springs</li> <li>x. Bending machine</li> <li>xi. Steel tapes</li> <li>xii. Draw wires</li> <li>xiii. Hack saws</li> <li>xiv. Drilling tools</li> <li>xv. Stock and die</li> <li>xvi. Bench vice</li> <li>xvii. Machine vice</li> <li>xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul> | <ul style="list-style-type: none"> <li>ii. Cables</li> <li>iii. Light fittings</li> <li>iv. Accessories</li> <li>v. Conduits and fittings</li> <li>vi. Cable trays</li> <li>vii. Cable ducts</li> <li>viii. Trunkings</li> <li>ix. Computers</li> <li>x. Drawing instruments</li> <li>xi. Screws</li> </ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>I. IEE regulations</li> <li>II. Occupational safety and health act (OSHA)</li> <li>III. Work injury benefits act (WIBA)</li> <li>IV. Manufacturers’ catalogues</li> <li>V. British standards</li> <li>VI. KEBS standards</li> </ul>  |   |

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### 3.1.6.6. Model Answers to self-assessment Questions

(10 Marks)

1. What is the meaning of the following terms with reference to earthing
  - i. **Current rating of a fuse:** – it is the current the fuse will carry continuously without blowing or deteriorating.
  - ii. **Rated minimum fusing current:** – it is the minimum current at which the fuse will blow at a specified time. This may vary between 1.25 – 2.5 the current rating of the fuse.

- iii. **Fusing factor:** –The relationship between the rated minimum fusing current and the current rating is called the fusing factor.
- iv. **Overcurrent:** – Any current beyond the current rating of a fuse
- v. **Discrimination:** – relate to the time current characteristic of protection devices sustained. This is the ability of a fuse to distinguish between a transient and high current e.g. motor starting current and continuous fault current.

2. **Reasons for earthing**

**(6 Marks)**

- a) To maintain the potential of any part of an electrical system at a definite value with respect to earth.
- b) To allow fault current to flow to earth in the event of an earth fault so that the protective gears operates to isolate the faulty circuit.
- c) So that in the event of a fault, apparatus normally ‘dead’ cannot reach a dangerous potential with respect to earth.

3. **Methods used to achieve earthing of an installation**

**(6 Marks)**

- i. Connection to the metal sheath of armoring of supply authority underground cable (concentric earthing system)
- ii. Connection to the continuous earth wire provided by Supply authority where the distribution of energy is by overhead lines.
- iii. Connection to the earth electrode sunk into the ground for the purpose
- iv. Installation of automatic earth fault protection device e.g. ELCB

4. **Tests related to earthing which should be carried out in a completed electrical installation**

**(3 Marks)**

- a. Earth electrode resistance test
- b. Earth continuity conductor test
- c. Earth loop impedance test

### **3.1.7. Apply lightning protection measures**

#### **3.1.7.0. Introduction**

To apply lightning protection measures, identify types of lightning strokes, identify components of lightning protection system, establish tests to be carried out in lightning protection system and determine application of lightning protection system.

#### **Performance Standard**

1. Identify types of lightning strokes.
2. Identify components of lightning protection system.
3. Establish tests to be carried out in lightning protection system.
4. Determine application of lightning protection system.

#### **Information Sheet**

#### **Lightning protection**

Lightning is a sudden electrostatic discharge that occurs during a thunderstorm. This discharge occurs between electrically charged regions of a cloud (called intra-cloud lightning or IC), between two clouds (CC lightning), or between a cloud and the ground (CG lightning).

#### **Types of strikes and lightning**

- i. Different types of strikes
- ii. Cloud to cloud
- iii. Ground to cloud
- iv. Cloud to cloud

#### **Types of lightning**

- a. Normal lightning
- b. Sheet lightning
- c. Heat lightning
- d. Ball lightning
- e. Red sprite
- f. Blue jet

#### **Colors of lightning**



- a) Blue lightning within a cloud indicates the presence of hail
- b) Red lightning within a cloud indicates the presence of rain
- c) Yellow/orange lightning occurs when there is a large concentration of dust in the air
- d) White lightning is a sign of low humidity, white is the colour of lightning that most often ignites forest fires

### **Effects of lightning**

- i. Physical damage - Fire, explosion, mechanical destruction
- ii. Injuries/death to living being

### **Lightning protection components**

#### **a. Air termination or termination network**

- I. For a spire or chimney, this will consist of one or more vertical conductors positioned just above the highest point.
- II. For a small building, this will consist of a single horizontal conductor along the ridge of the roof.
- III. For roofs of larger dimensions this will consist of a system of horizontal conductors

#### **NB**

No part of the roof should be more than 9m from the nearest horizontal conductor and all metallic projections such as vent pipes, railing gutters etc., on or above the roof of the main building should be bonded to the conductor to form part of air termination.

#### **b. Down conductors**

The number of down conductors required is determined by the area covered by the structure. A structure with a base area not exceeding 100m<sup>2</sup> needs only one down conductor. Base areas greater than 100m<sup>2</sup> require one for every additional 300m<sup>2</sup> or part thereof.

#### ***Test joints***

These are provided in down conductors so that resistance measurements of sections can be made.

#### **c. Earth termination or termination network**

This is the part of the lightning protection system intended to discharge current into general mass of earth. All points below the lowest test point in a down conductor are included in this term. Figure x shows the components of a lightning protection system.

#### **d. Earth electrode**

This is the part of the earth termination which makes electrical contact with earth.

## NB

Roof and down conductors are generally annealed copper strips, as are any interconnections. Down conductors are secured to the building by 'holdfast' fixings made from gunmetal. Earth electrodes can be copper rods or copper plates.

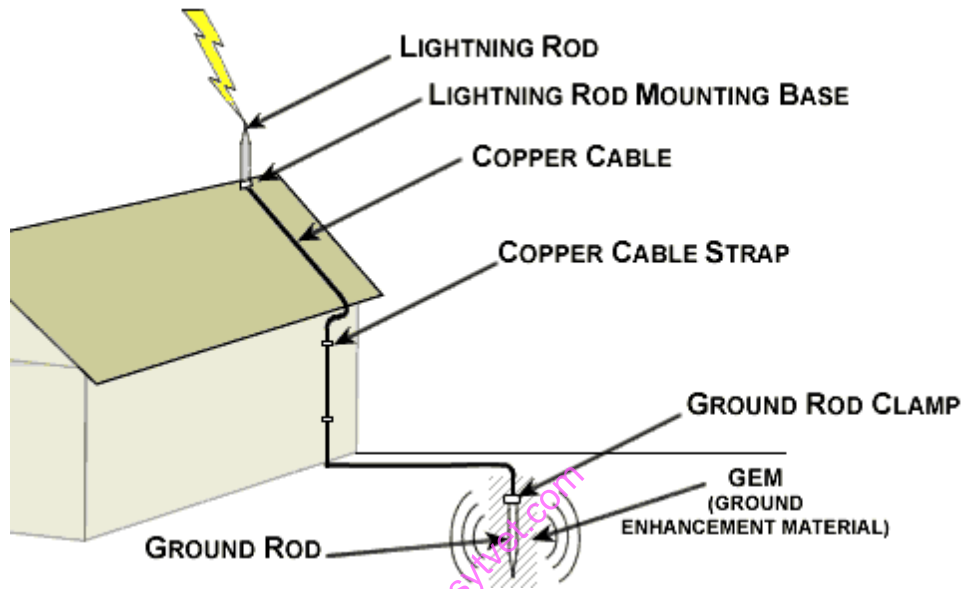


Figure 52: Lightning protection components

## Testing

All lightning protection systems should be inspected and tested after completion and at intervals of twelve months (six months if explosives are stored in the building) the tests should verify electrical continuity of the system and the resistance to the general mass of earth. This must not exceed 10 ohms using the electrode testing method.

Record test should be kept on site by the person responsible for maintaining the installation.

## Lightning rod maintenance

Lightning rods must undergo periodic inspections and maintenance, as indicated by national and international regulations (UNE21186, NF-C 17 102, IEC EN 62305). These periodic inspections of the lightning rod allow the detection of deviations from the reference standards or anomalies in the installation caused by environmental conditions such as corrosion, incorrect handling such as sectioning or robberies, or other circumstances such as expansions of the building where the lightning rod is located.

The inspection of the lightning protection system must be part of the maintenance routine of the buildings and the annual action plans.

### **Why is maintenance of lightning rods necessary?**

All lightning protection systems should have routine maintenance and monitoring carried out. If the lightning rod is not properly maintained, there is a risk that lightning strikes are not controlled nor their current conducted and dispersed in a safe manner. The different elements of the lightning protection system can be deteriorated over time, reducing safety levels of the system if they are not properly maintained.

For a lightning protection system to work optimally each and every part needs to be in good condition:

- a. The lightning rods, or air terminals must work correctly. In the case of the early streamer emission (ESE), the element that emits the upward leader should be fully operational in order to maintain the time of advance of the ESE air terminal that has been measured in the laboratory.
- b. Down conductors must maintain continuity at all times and be well fixed to avoid sparks and breakage.
- c. Ground resistance must remain below 10 ohms so the lightning current dissipates quickly, minimizing the return currents and the contact voltages, which that can be very dangerous for people.

### **How is the lightning rod revision carried out?**

The procedure for the lightning rod maintenance consists of two types of verifications:

Visual inspection in the maintenance of lightning protection systems

Check that:

- i. There is no damage due to lightning strikes.
- ii. The lightning rod keeps all its elements in good state.
- iii. The continuity of the conductors is correct.
- iv. The fixings are in good condition.
- v. There are no parts damaged by corrosion.
- vi. The state of the equipotential bonding is correct.

Complete verification in the maintenance of the lightning protection system. The complete verification includes the visual inspections described above as well as other measures. It is necessary to verify the

electrical continuity of the down conductors and the correct performance of the lightning rod according to the specifications indicated by the manufacturer.

In the case of ESEs, the correct operation of the air terminals must also be checked. The lightning rods are installed at the highest point of the structure, always two meters above any element to be protected and usually on a six-meter mast. Therefore, in most cases it is difficult to have access these air terminals and puts the operator is put in danger when carrying these inspections.

To make this maintenance task easier, a remote tester has been incorporated to the ESE terminal DAT CONTROLER REMOTE. By doing so, it is not necessary to physically access the air terminal, since it has a system that daily checks its state and sends the result to a web application where the updated data can be consulted at any time.

Regarding the earthing system, it is essential to measure the earth resistance, as it could vary with time. It is also important to ensure that it remains below 10  $\Omega$ . It is recommended to check the earthing annually. In fact, in many countries there is a regulation that requires this. If high earth values are recorded, it will be necessary to use a ground enhancing product such as Conductor Plus or adapt the system to include more earth rods.

Likewise, the inspection must verify that the electrical lines which require protection against overvoltages are protected with adequate surge protection devices.

After having carried out the inspections described and when deterioration or anomalies in the system are detected, it is essential to repair or carry out the necessary corrective measures in the shortest time possible to ensure optimum protection.

In both periodic inspection (visual and complete) the person in charge of the maintenance actions must elaborate a report which informs the inspections that have been carried out, providing data and photographs.



*Figure 53: Lightning rod image*

### **When should we carry out an inspection of a lightning rod?**

According to the standards, lightning protection systems must undergo an inspection whenever the structure of the building is modified or repaired and also when the structure has been struck by lightning. Therefore, it is very useful to have a lightning event counter that informs about the number of lightning strikes on the structure. For more information about the functioning of the lightning event counter check the technical data sheet for the ATLOGGER, a device which also records the information of the day and time of the strike.

Even if these situations do not occur, the inspection of the lightning protection system should be made periodically. As part of the maintenance protocol, the following types of verifications are carried out:

- a. Visual verification: Annual revision for levels of protection I and II. For levels III and IV, the visual verification needs to be done at least every two years.
- b. Complete verification: For levels of protection I and II, the complete verification will be done at least every two years. For protection levels III and IV, the verification will be done at least every 4 years.
- c. Complete verification of the critical systems: This verification needs to be done at least once a year for all of the protection levels.

In some countries where the rainy season has high rates of precipitation and is concentrated in a very short period of the year. In these cases, it is very important to carry out the maintenance of lightning rods before the beginning of this period of the year. Contact a specialist to perform necessary lightning protection system inspection and receive appropriate advice.

### 3.1.7.3. Learning Activities

#### Industrial attachment/workshop Practice

| Practical activities   | knowledge | Special instruction |
|--|-----------|---------------------|
| 1. Identify types of lightning strokes.                              |           |                     |
| 2. Identify components of lightning protection system.               |           |                     |
| 3. Establish tests to be carried out in lightning protection system. |           |                     |
| 4. Determine application of lightning protection system.             |           |                     |

### 3.1.7.4. Self-Assessment Questions

1. What is the meaning of the term lightning?
2. Which types lightning strokes do you know?
3. What are the structures of air termination or termination network used in buildings?
4. What are the components of lightning protection system?

### 3.1.7.5. Tools, Equipment and Material

#### Recommended Resources

|   |  |
|---|--|
| <b>Tools and equipment</b> <ol style="list-style-type: none"><li>i. Cable Strippers</li><li>ii. Pliers</li><li>iii. Screw drivers</li><li>iv. Hammers</li><li>v. Chisels</li><li>vi. Allen keys</li><li>vii. Electrician knives</li><li>viii. Crimping tools</li><li>ix. Bending springs</li><li>x. Bending machine</li><li>xi. Steel tapes</li><li>xii. Draw wires</li><li>xiii. Hack saws</li><li>xiv. Drilling tools</li><li>xv. Stock and die</li><li>xvi. Bench vice</li><li>xvii. Machine vice</li><li>xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li></ol> | <b>Materials and supplies</b> <ol style="list-style-type: none"><li>i. Stationery</li><li>ii. Cables</li><li>iii. Light fittings</li><li>iv. Accessories</li><li>v. Conduits and fittings</li><li>vi. Cable trays</li><li>vii. Cable ducts</li><li>viii. Trunkings</li><li>ix. Computers</li><li>x. Drawing instruments</li><li>xi. Screws</li></ol> |
| <b>Reference materials</b> <ol style="list-style-type: none"><li>i. IEE regulations</li></ol>   |  |

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| <ul style="list-style-type: none"><li>ii. Occupational safety and health act (OSHA)</li><li>iii. Work injury benefits act (WIBA)</li><li>iv. Manufacturers' catalogues</li><li>v. British standards</li><li>vi. KEBS standards</li></ul> |  |
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### 3.1.7.7. Model Answers to Self-Assessment Questions

#### 1. Lightning (2 Marks)

Lightning is a sudden electrostatic discharge that occurs during a thunderstorm. This discharge occurs between electrically charged regions of a cloud (called intra-cloud lightning or IC), between two clouds (CC lightning), or between a cloud and the ground (CG lightning).

#### 2. Lightning strokes (3 Marks)

- i. Different types of strikes
- ii. Cloud to cloud
- iii. Ground to cloud
- iv. Cloud to cloud

#### 3. The structures of air termination or termination network used in buildings

- (a) For a spire or chimney, this will consist of one or more vertical conductors positioned just above the highest point.
- (b) For a small building, this will consist of a single horizontal conductor along the ridge of the roof.
- (c) For roofs of larger dimensions this will consist of a system of horizontal conductors (6 Marks)

#### 4. The components of lightning protection system (4 Marks)

- a. Air termination or termination network
- b. Down conductors
- c. Earth termination or termination network
- d. Earth electrode

### 3.1.8. Apply electromagnetic field theory

#### 3.1.8.0. Introduction

Apply electromagnetic field theory, identify electromagnetic radiation sources, determine detectors of electromagnetic radiations, apply electromagnetic waves, identify electromagnetic laws and establish behaviours and effects of electromagnetic waves.

#### 3.1.1.1. Performance Standard

1. Apply electromagnetic field theory,
2. Identify electromagnetic radiation sources

3. Determine detectors of electromagnetic radiations,
4. Apply electromagnetic waves,
5. Identify electromagnetic laws and establish behaviours and effects of electromagnetic waves.

### 3.1.1.2. Information Sheet

#### Electromagnetic field

A property of space caused by the motion of an electric charge. A stationary charge will produce only an electric field in the surrounding space. If the charge is moving, a magnetic field is also produced. An electric field can be produced also by a changing magnetic field. The mutual interaction of electric and magnetic fields produces an electromagnetic field, which is considered as having its own existence in space apart from the charges or currents (a stream of moving charges) with which it may be related. Under certain circumstances, this electromagnetic field can be described as a wave transporting electromagnetic energy. Figure 80 shows frequency ranges of electromagnetic fields.



*Figure 54: Frequency ranges of electromagnetic fields*

Electromagnetic fields are a combination of invisible electric and magnetic fields of force. They are generated by natural phenomena like the Earth’s magnetic field but also by human activities, mainly through the use of electricity.

Mobile phones, power lines and computer screens are examples of equipment that generates electromagnetic fields.

Most man-made electromagnetic fields reverse their direction at regular intervals of time, ranging from high radio frequencies (mobile phones) through intermediate frequencies (computer screens) to extremely low frequencies (power lines).

The term static refers to fields that do not vary with time (i.e. with a frequency of 0 Hz). Static magnetic fields are used in medical imaging and generated by appliances using direct current.

### Typical sources of electromagnetic fields

| Frequency range                 | Frequencies       | Some examples of exposure sources   |
|---------------------------------|-------------------|---|
| Static                          | 0 Hz              | video display units; MRI (medical imaging) and other diagnostic or scientific instrumentation; industrial electrolysis; welding devices     |
| ELF [Extremely Low Frequencies] | 0-300 Hz          | power lines; domestic distribution lines; domestic appliances; electric engines in cars, trains and tramways; welding devices               |
| IF [Intermediate Frequencies]   | 300 Hz - 100 kHz  | video display units; anti-theft devices in shops; hands-free access control systems, card readers and metal detectors; MRI; welding devices |
| RF [Radio Frequencies]          | 100 kHz - 300 GHz | mobile telephones; broadcasting and TV; microwave ovens; radar and radio transceivers; portable radios; MRI                                 |
| THz technologies                | 300 GHz – 20 THz  | Applications are still in development, but currently mostly telecommunication applications and body scanners are considered.                |

### Detectors/sensors for Electromagnetic Radiation:

Radio waves, microwaves, infra-red, visible light, ultraviolet, X- and  $\gamma$ -rays are all examples of electromagnetic radiation. They are waves with electric and magnetic components which travel at the speed of light in a vacuum, approximately 300 million m/s. The electric and magnetic fields oscillate at right angles to each other and combined waves move in a direction perpendicular to both of the electric and magnetic field oscillations. Like all waves, they have a frequency, which is the number of crests per second, and a wavelength, which is the distance between successive crests. These values are used to

categorize the radiation into the types shown above. The examples here are given in order of increasing frequency and decreasing wavelength. FM radio, for instance, is transmitted at frequencies around 100 MHz, have wavelengths of 3 m and can be detected by an aerial. The eye can detect wavelengths in the region of 380-750 nm, less than a thousandth of a millimetre. Electromagnetic radiation, with even higher frequencies, and therefore smaller wavelengths, is ionizing, which means that a large enough exposure can damage DNA and cause cancer. The frequency of UV radiation is around ten million times higher than that of FM radio.

A variety of sensors are required for detecting the different ranges of electromagnetic radiation. Aerials are suitable for detecting radio waves and microwave transmissions as used by Wi-Fi and Bluetooth devices for example. Optical sensors such as photodiodes and charge-coupled devices are used for the infra-red and visible wavelengths. Geiger-Müller tubes use the ionizing properties of the higher frequencies to produce a current pulse which can be used to generate an audible click. Scintillators fluoresce when they detect ionizing radiation. Microwave sensors are recently proven successfully over the range of 1-300 GHz to suit various industrial applications including non-invasive real-time monitoring of the oil and water pipe line constituents, passive radiometer and radar applications for mapping, imaging and tomography. Recent and future development of such sensors having high accuracy and reliability in health care applications including detection of tumours, alcohol, drugs and sugar in the blood stream. A new development has emerged in the use of optical imaging in radiotherapy that by measuring the patient movements very accurately which will have a tremendous potential for the health care industry. Future sensors will emerge in the form of nanoscale with hybrid multi-functionality sensors meeting the demands of many challenging applications.

## **Applications of electromagnetic waves**

### **(a) Microwave oven**

Microwave oven is most familiar as the energy source for cooking food. It generate microwave radiation of appropriate frequency in the working space of the oven where food is kept. The energy is not wasted in heating up the vessel as in conventional method. The energy is directly delivered to water molecules which are shared by the entire food.

### **(b) Radar**

**Radar** is acronym for Radio Detection And Ranging. Radar is an electromagnetic system, used for sensing, detecting, and locating the object present in the ambience. Used to detect direction, speed,

velocity, range, altitude of an object with the help of radio waves. Radar find applications in various systems such as air traffic control to track planes both on and off the grounds it is also used to track satellites.

### (c) **Wireless Communication**

Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor. The term is commonly used in the telecommunications industry to refer to telecommunications systems (e.g., radio transmitters and receivers, remote controls, etc.) that use some form of energy (e.g., radio waves, acoustic energy, etc.) to transfer information without the use of wires. Information is transferred in this manner over both short and long distances. Wireless operations permit services, such as long-range communications, that are otherwise impossible (or impractical) to implement with the use of wires e.g from earlier technologies such as GSM, CDMA and GPRS, to 3G networks such as W-CDMA, EDGE or CDMA2000, another popular supporting technology is Wi-Fi, a wireless local area network that enables portable computing devices to connect easily to the Internet.

## **Electromagnetic laws**

### **i. Faraday's law**

Faraday's law of induction states that the emf induced in a circuit is equal to the rate of change of magnetic flux through the circuit:

$$\mathcal{E} = -\frac{d\Phi_B}{dt}.$$

$$\mathcal{E} = -N\frac{d\Phi_B}{dt}.$$

### **ii. Lenz's law**

The minus sign in Faraday's law gives the direction of the induced *e.m.f*: A current produced by an induced *e.m.f* moves in a direction so that the magnetic field it produces tends to restore the changed field or: An induced *e.m.f* is always in a direction that opposes the original change in flux that caused it.

$$\mathcal{E} = -N\frac{d\Phi_B}{dt}.$$

### iii. Fleming's laws

#### a) Right hand rule

The Right Hand Rule, illustrated at left, simply shows how a current-carrying wire generates a magnetic field. If you point your thumb in the direction of the current, as shown, and let your fingers assume a curved position, the magnetic field circling around those wires flows in the direction in which your four fingers point.



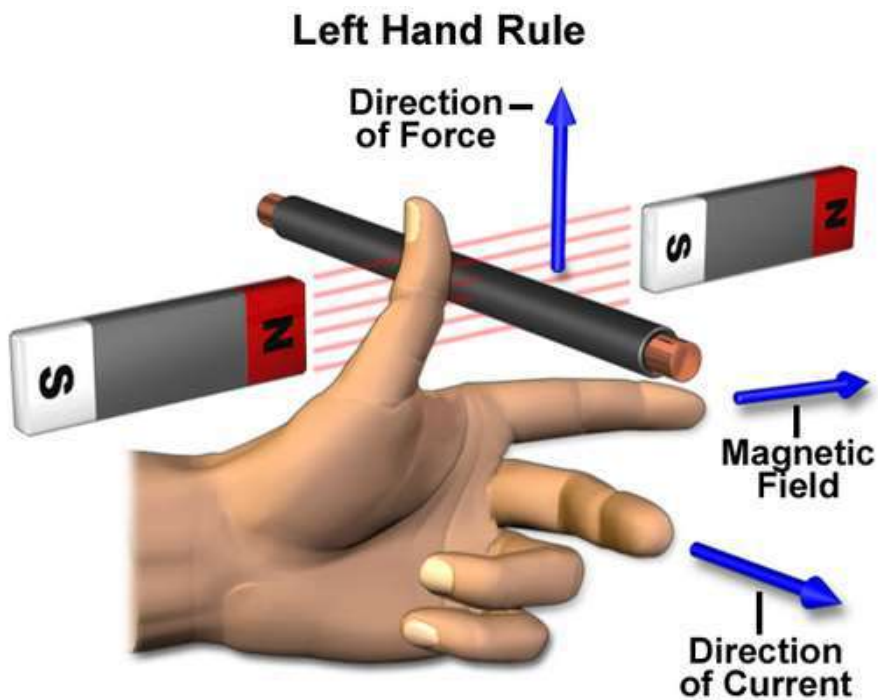
Right hand rule.

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#### Left hand rule

The Left Hand Rule shows what happens when an electrical current enters a magnetic field. You need to contort your hand in an unnatural position for this rule, illustrated below. As you can see, if your index finger points in the direction of a magnetic field, and your middle finger, at a 90 degree angle to your index, points in the direction of the current, then your extended thumb (forming an L with your index) points in the direction of the force exerted upon that particle. This rule is also called Fleming's Left Hand Rule, after English electronics pioneer John Ambrose Fleming, who came up with it.





### Common properties

Electromagnetic waves are members of a family of waves with **common properties** called the electromagnetic spectrum.

All electromagnetic waves:

- i. are transverse waves;
- ii. can travel through a vacuum;
- iii. Travel at exactly the same speed in a vacuum, the speed of light, 300,000,000 m/s.

Like all waves, electromagnetic waves:

- a. transfer energy from one place to another;
- b. can be reflected;
- c. Can be refracted.

### Differences

Each type of wave in the electromagnetic spectrum has different:

- a. wavelength;
- b. Frequency.

**Characteristics of Waves:**

All waves share certain characteristics:

**Amplitude**

- The maximum distance the molecules are displaced from their starting place
- As energy ↑, amplitude ↑

**Wavelength**

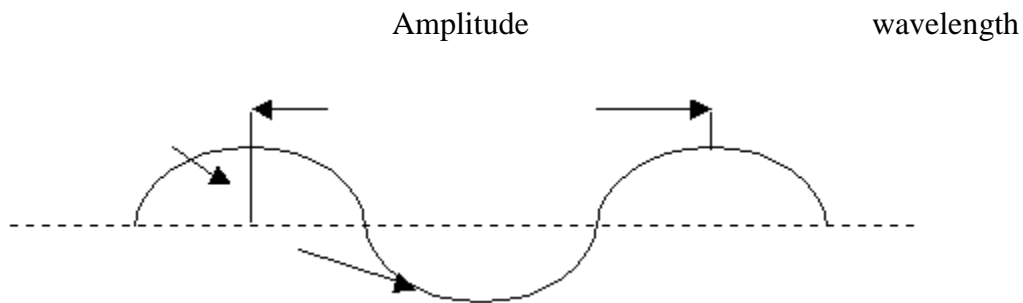
The distance between 2 consecutive crests or troughs

**Frequency**

The number of cycles per unit time

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- Transverse – crests (troughs)/second
- Compression – compressions (rarefactions)/second
- Unit is the hertz (Hz)                      1Hz = 1wave/second



**Speed of Waves:**

The speed of a wave is determined by the number of waves passing a point per second and the length of the wave.

- Speed in any given medium is constant.
- Speed = frequency  $\times$  wavelength ( $f \times \lambda$ )
  - If  $f \uparrow, \lambda \downarrow$  or  $f \downarrow, \lambda \uparrow$

### **Electromagnetic shielding**

Electromagnetic shielding is the practice of reducing the electromagnetic field in a space by blocking the field with barriers made of conductive or magnetic materials. Shielding is typically applied to enclosures to isolate electrical devices from their surroundings, and to cables to isolate wires from the environment through which the cable runs. Electromagnetic shielding that blocks radio frequency (RF) electromagnetic radiation is also known as RF shielding.

The shielding can reduce the coupling of radio waves, electromagnetic fields, and electrostatic fields. A conductive enclosure used to block electrostatic fields is also known as a Faraday cage. The amount of reduction depends very much upon the material used, its thickness, the size of the shielded volume and the frequency of the fields of interest and the size, shape and orientation of holes in a shield to an incident electromagnetic field.

### **Materials used**

Typical materials used for electromagnetic shielding include sheet metal, metal screen, and metal foam. Common sheet metals for shielding include copper, brass, nickel, silver, steel, and tin. Shielding effectiveness, that is how well a shield reflects or absorbs/suppresses electromagnetic radiation, is affected by the physical properties of the metal. These may include conductivity, solderability, permeability, thickness, and weight. A metal's properties are an important consideration in material selection. For example, electrically dominant waves are reflected by highly conductive metals like copper, silver, and brass, while magnetically dominant waves are absorbed/suppressed by a less conductive metal such as steel or stainless steel. Further, any holes in the shield or mesh must be significantly smaller than the wavelength of the radiation that is being kept out, or the enclosure will not effectively approximate an unbroken conducting surface.

Another commonly used shielding method, especially with electronic goods housed in plastic enclosures, is to coat the inside of the enclosure with a metallic ink or similar material. The ink consists of a carrier material loaded with a suitable metal, typically copper or nickel, in the form of very small particulates. It is sprayed on to the enclosure and, once dry, produces a continuous conductive layer of metal, which can be electrically connected to the chassis ground of the equipment, thus providing effective shielding.

Electromagnetic shielding is the process of lowering the electromagnetic field in an area by barricading it with conductive or magnetic material. Copper is used for radio frequency (RF) shielding because it absorbs radio and other electromagnetic waves. Properly designed and constructed RF shielding enclosures satisfy most RF shielding needs, from computer and electrical switching rooms to hospital CAT-scan and MRI facilities

### **Skin effect**

Skin effect is the tendency of an alternating electric current (AC) to become distributed within a conductor such that the current density is largest near the surface of the conductor and decreases exponentially with greater depths in the conductor. The electric current flows mainly at the "skin" of the conductor, between the outer surface and a level called the skin depth. Skin depth depends on the frequency of the alternating current; as frequency increases, current flow moves to the surface, resulting in less skin depth. Skin effect reduces the effective cross-section of the conductor and thus increases its effective resistance. Skin effect is caused by opposing eddy currents induced by the changing magnetic field resulting from the alternating current. At 60 Hz in copper, the skin depth is about 8.5 mm. At high frequencies the skin depth becomes much smaller.

Increased AC resistance caused by the skin effect can be mitigated by using specially woven litz wire. Because the interior of a large conductor carries so little of the current, tubular conductors such as pipe can be used to save weight and cost. The skin effect has practical consequences in the analysis and design of radio-frequency and microwave circuits, transmission lines (or waveguides), and antennas. It is also important at mains frequencies (50–60 Hz) in AC electrical power transmission and distribution systems. It is one of the reasons for preferring high-voltage direct current for long distance power transmission.

### **Causes of skin effect**

Conductors, typically in the form of wires, may be used to transmit electrical energy or signals using an alternating current flowing through that conductor. The charge carriers constituting that current, usually electrons, are driven by an electric field due to the source of electrical energy. A current in a conductor produces a magnetic field in and around the conductor. When the intensity of current in a conductor changes, the magnetic field also changes. The change in the magnetic field, in turn, creates an electric field which opposes the change in current intensity. This opposing electric field is called “counter-electromotive force” (back EMF). The back EMF is strongest at the center of the conductor, and forces the conducting electrons to the outside of the conductor.

Regardless of the driving force, the current density is found to be greatest at the conductor's surface, with a reduced magnitude deeper in the conductor. That decline in current density is known as the *skin effect* and the *skin depth* is a measure of the depth at which the current density falls to 1/e of its value near the surface. Over 98% of the current will flow within a layer 4 times the skin depth from the surface. This behavior is distinct from that of direct current which usually will be distributed evenly over the cross-section of the wire.

An alternating current may also be *induced* in a conductor due to an alternating magnetic field according to the law of induction. An electromagnetic wave impinging on a conductor will therefore generally produce such a current; this explains the reflection of electromagnetic waves from metals. Although the term "skin effect" is most often associated with applications involving transmission of electric currents, the skin depth also describes the exponential decay of the electric and magnetic fields, as well as the density of induced currents, inside a bulk material when a plane wave impinges on it at normal incidence

### 3.1.1.3. Learning Activities

#### Industrial attachment/workshop Practice

| Practical activities                   | knowledge | Special instruction |
|--|-----------|---------------------|
| 1. Apply electromagnetic field theory, |           |                     |

|  |  |  |
|--|--|--|
| 2. Identify electromagnetic radiation sources  |  |  |
| 3. Determine detectors of electromagnetic radiations,  |  |  |
| 4. Apply electromagnetic waves,  |  |  |
| 5. Identify electromagnetic laws and establish behaviours and effects of electromagnetic waves |  |  |

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### 3.1.1.4. Self-Assessment Questions

1. What are the sources of electromagnetic fields? **(4 Marks)**
2. Which detectors can be used to sense electromagnetic waves? **(4 Marks)**
3. What are the applications of Electromagnetic waves? **(3 Marks)**
4. What are the properties of Electromagnetic waves? **(4 Marks)**

### 3.1.1.5. Tools, Equipment and Material

These includes:

| Tools and equipment   | Materials and supplies   |
|---|--|
| <ul style="list-style-type: none"> <li>i. Cable Strippers</li> <li>ii. Pliers</li> <li>iii. Screw drivers</li> <li>iv. Hammers</li> <li>v. Chisels</li> <li>vi. Allen keys</li> <li>vii. Electrician knives</li> <li>viii. Crimping tools</li> <li>ix. Bending springs</li> <li>x. Bending machine</li> <li>xi. Steel tapes</li> <li>xii. Draw wires</li> <li>xiii. Hack saws</li> <li>xiv. Drilling tools</li> <li>xv. Stock and die</li> <li>xvi. Bench vice</li> <li>xvii. Machine vice</li> <li>xviii. PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul> | <ul style="list-style-type: none"> <li>i. Stationery</li> <li>ii. Cables</li> <li>iii. Light fittings</li> <li>iv. Accessories</li> <li>v. Conduits and fittings</li> <li>vi. Cable trays</li> <li>vii. Cable ducts</li> <li>viii. Trunkings</li> <li>ix. Computers</li> <li>x. Drawing instruments</li> <li>xi. Screws</li> </ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>a) IEE regulations</li> </ul>  |  |

|   |  |
|---|--|
| <ul style="list-style-type: none"><li>b) Occupational safety and health act (OSHA)</li><li>c) Work injury benefits act (WIBA)</li><li>d) Manufacturers' catalogues</li><li>e) British standards</li><li>f) KEBS standards</li></ul> |  |
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### 3.1.1.7. Model Answers to self-assessment Questions

#### 1. Sources of electromagnetic fields

(4 Marks)

- a) Static
- b) ELF (extremely low frequencies)
- c) IF(intermediate frequencies)

d) RF (radio frequencies)

**2. Detectors which can be used to sense electromagnetic waves (4 Marks)**

(a) Optical sensors

(b) Photodiodes

(c) IR

(d) Microwave sensors

**3. Applications of Electromagnetic waves (3 Marks)**

i. Microwave oven

ii. Radar

iii. Wireless communication

**4. Properties of Electromagnetic waves (4 Marks)**

i. Transverse

ii. Travel through a vacuum

iii. Can be reflected

iv. can be refracted

**CHAPTER 1 ENGINEERING MATHEMATICS**

**Unit of learning code:** ENG/AUT/CC/1/5

**Related Unit of Competency in Occupational Standard:** Apply Engineering Mathematics

**1.1 Introduction to the unit of learning**

This unit describes the competencies required by an automotive technician in order to apply engineering mathematics. It involves use concepts of arithmetic in solving work problems, applying algebra, applying trigonometry and hyperbolic functions, applying complex numbers, applying coordinate geometry, carrying out binomial expansion, applying calculus, solving ordinary differential equations, carrying out mensuration, applying power series, applying statistics, applying numerical methods, applying vector theory, applying matrix, solving partial differential equations, applying Laplace transforms and applying Fourier series.

**1.2 Summary of Learning Outcomes**

10. Use concepts of arithmetic in solving work problems

11. Use common formula and algebraic expressions for work

12. Use trigonometry to solve practical engineering problems

13. Perform estimations, measurements and calculations
14. Apply matrices in work
15. Apply vectors in work
16. Collect, organize and interpret statistical data
17. Apply concepts of probability for work
18. Perform commercial calculation

## **1.2.1 Learning Outcome 1: Use Concepts of Arithmetic in Solving Work Problems**

### **1.2.1.1 Introduction to the Learning Outcome**

This learning outcome covers algebra and the learner should be able to: carry out fundamental operations, addition, subtraction, multiplication and division of positive and negative numbers, fractions and decimals operations and conversions, indices, ratios and proportions,

### **1.2.1.2 Performance Standard**

- 2.2.1.2.6 Calculations involving Indices are performed as per the concept
- 2.2.1.2.7 Calculations involving Logarithms are performed as per the concept
- 2.2.1.2.8 Scientific calculator is used in solving mathematical problems in line with manufacturer's manual
- 2.2.1.2.9 Simultaneous equations are performed as per the rules
- 2.2.1.2.10 Quadratic equations are calculated as per the concept

### **1.2.1.3 Information Sheet**

#### **Fundamental operations**

Brackets and the precedence rules are used to remove ambiguity in a calculation. In any calculation involving all four arithmetic operations as we proceed follows:

- c. Working from the left evaluate divisions and multiplications as they are encountered

This leaves a calculation involving just addition and subtraction.

- d. Working from the left evaluate additions and subtraction as they are

The four basic arithmetic operations are: addition and subtraction, multiplication and division

The order of precedence of operations for problems containing fractions is the same as that for integers, i.e. remembered by BODMAS (Brackets, Of, Division, Multiplication, Addition and Subtraction).

Rules that govern basic laws of arithmetic:

#### 4. Commutativity

Two integers can be added or multiplied in either order without affecting the result. For example:

$$5 + 8 = 8 + 5 = 13 \text{ and } 5 \times 8 = 8 \times 5 = 40$$

Addition and multiplication are commutative operations, whereas subtraction and division are not commutative operations.

$$4 - 2 \neq 2 - 4 \text{ as } 4 - 2 = 2 \text{ and } 2 - 4 = -2$$

$$4 \div 2 \neq 2 \div 4 \text{ as } 4 \div 2 = 2 \text{ and } 2 \div 4 = 0.5$$

#### 5. Associativity

The way in which three or more integers are associated under addition or multiplication does not affect the result.

#### 6. Distributivity

Multiplication is distributed over addition and subtraction from both the right and left.

Division is distributed over addition and subtraction from the right but not from the left.

### **Addition, subtraction, multiplication and division of positive and negative numbers**

Adding two numbers gives their sum and subtracting two numbers gives their difference. For example:

$$7 + 3 = 10$$

$$7 - 3 = 4$$

$$3 - 7 = -4$$

Adding a negative number is the same as subtracting its positive counterpart. For example:

$$7 + (-2) = 5$$

Subtracting a negative number is the same as adding its positive counterpart. For example:

$$7 - (-2) = 9$$

Multiplication and division

Multiplying two numbers gives their product while dividing two positive and negative numbers gives their quotient.

Multiplying and dividing two positive or two negative numbers gives a positive number.

$$12 \times 2 = 24 \text{ and } (-12) \times (-2) = 24$$

$$12 \div 2 = 6 \text{ and } (-12) \div (-2) = 6$$

Multiplying or dividing a positive number by a negative number gives a negative number.

$$12 \times (-2) = -24; 12 \div (-2) = -6$$

## Fractions and decimals operations and conversions

### Fractions

When 2 is divided by 3, it may be written as  $\frac{2}{3}$  is called a fraction. The number above the line, i.e. 2, is called the numerator and the number below the line, i.e. 3, is called the denominator. When the value of the numerator is less than the value of the denominator, the fraction is called a proper fraction; thus  $\frac{2}{3}$  is a proper fraction. When the value of the numerator is greater than the denominator, the fraction is called an improper fraction. Thus  $\frac{7}{3}$  is an improper fraction and can also be expressed as a mixed number, that is, an integer and a proper fraction. Thus the improper fraction  $\frac{7}{3}$  is equal to the mixed number  $2\frac{1}{3}$ .

When a fraction is simplified by dividing the numerator and denominator by the same number, the process is called cancelling. Cancelling by 0 is not permissible.

Simplify:  $\frac{1}{3} + \frac{2}{7}$

The lowest common multiple (i.e. LCM) of the two denominators is 3 d 7, i.e. 21

Expressing each fraction so that their denominators are 21, gives:

$$\frac{1}{3} + \frac{2}{7} = \frac{1}{3} \times \frac{7}{7} + \frac{2}{7} \times \frac{3}{3} = \frac{7}{21} + \frac{6}{21} = \frac{13}{21}$$

Simplify:  $\frac{1}{3} - \left(\frac{2}{5} + \frac{1}{4}\right) \div \left(\frac{3}{8} \times \frac{1}{3}\right)$

Solution  $\frac{1}{3} - \left(\frac{2}{5} + \frac{1}{4}\right) \div \left(\frac{3}{8} \times \frac{1}{3}\right) = \frac{1}{3} - \left(\frac{4 \times 2 + 1 \times 5}{20}\right) \div \left(\frac{3}{24}\right)$

$$\frac{1}{3} - \frac{13}{20} \div \frac{1}{8} = \frac{1}{3} - \frac{13}{20} \times \frac{8}{1}$$

$$\frac{1}{3} - \frac{26}{5} = \frac{(1 \times 5) - (26 \times 3)}{15} = \frac{-73}{15} = -4\frac{13}{15}$$

## Decimals

The decimal system of numbers is based on the digits 0 to 9. A number such as 53.17 is called a decimal fraction, a decimal point separating the integer part, i.e. 53, from the fractional part, i.e. 0.17

A number which can be expressed exactly as a decimal fraction is called a terminating decimal and those which cannot be expressed exactly as a decimal fraction are called non-terminating decimals.

Thus,  $\frac{3}{2} = 1.5$  is a terminating decimal, but  $\frac{4}{3} = 1.3333$  is a non-terminating decimal.  $1.33333\dots$  can be written as 1.P3, called 'one point three recurring'.

The answer to a non-terminating decimal may be expressed in two ways, depending on the accuracy required:

- (i) Correct to a number of significant figures, that is, figures which signify something, and
- (ii) Correct to a number of decimal places, that is, the number of figures after the decimal point.

The last digit in the answer is unaltered if the next digit on the right is in the group of numbers 0, 1, 2, 3 or 4, but is increased by 1 if the next digit on the right is in the group of numbers 5, 6, 7, 8 or 9.

Evaluate

$$42.7 + 3.04 + 8.7 + 0.06 = 54.50$$

## Indices

The lowest factors of 2000 are  $2 \times 2 \times 2 \times 2 \times 5 \times 5 \times 5$ . These factors are written as  $2^4 \times 5^3$ , where 2 and 5 are called bases and the numbers 4 and 3 are called indices.

When an index is an integer it is called a power. Thus,  $2^4$  is called 'two to the power of four', and has a base of 2 and an index of 4.

Special names may be used when the indices are 2 and 3, these being called 'squared' and 'cubed', respectively. Thus  $7^2$  is called 'seven squared' and  $9^3$  is called 'nine cubed'. When no index is shown, the power is 1, i.e. 2 means  $2^1$ .

Reciprocal

The reciprocal of a number is when the index is -1 and its value is given by 1, divided by the base.

Thus the reciprocal of 2 is  $2^{-1}$  and its value is  $\frac{1}{2}$  or 0.5.

Square root

The square root of a number is when the index is  $\frac{1}{2}$ , and the square root of 2 is written as  $2^{\frac{1}{2}}$  or  $\sqrt{2}$ .

There are always two answers when finding the square root of a number and this is shown by putting both a + and a - sign in front of the answer to a square root problem.

### **Ratios and proportions**

The ratio of one quantity to another is a fraction, and is the number of times one quantity is contained in another quantity of the same kind. If one quantity is directly proportional to another, then as one quantity doubles, the other quantity also doubles. When a quantity is inversely proportional to another, then as one quantity doubles, the other quantity is halved.

An alloy is made up of metals A and B in the ratio 2.5: 1 by mass. How much of A has to be added to 6 kg of B to make the alloy?

Ratio A: B: 2.5: 1 (i.e. A is to B as 2.5 is to 1) or  $\frac{A}{B} = \frac{2.5}{1} = 2.5$

When B = 6 kg,  $\frac{A}{6} = 2.5$  from which,

$$A = 6 \times 2.5 = 15kg$$

### **Conversions into percentages**

Percentages are used to give a common standard and are fractions having the number 100 as their denominators. For example, 25 per cent means  $\frac{25}{100}$  i.e.  $\frac{1}{4}$  and is written 25%.

A decimal fraction is converted to a percentage by multiplying by 100. Thus, 1.875 corresponds to  $1.875 \times 100\% = 187.5\%$

Direct and inverse proportions determination

Directly proportional: as one amount increases, another amount increases at the same rate. The symbol for “directly proportional” is  $\propto$

Inversely proportional: when one value decreases at the same rate the other increases.

### **Use of scientific calculator**

A scientific calculator is a special electronic calculator that aids the calculation involving problems in mathematics, engineering and science. It can be used in the following ways;

- Basic operations i.e. addition subtraction, multiplication and division.
- Calculation of exponents.
- Solving problems with an order of operations.
- Working out squares and square roots of numbers.



- Solving logarithmic problems.
- Solving of problems in statistics e.g. find the mean, variance, standard deviation etc.

Example: The “log” function in the calculator is the key that allows you to work with the logarithm.

The steps in using the log functions are;

- Type the number you are to work with in your scientific calculator.
- Press the “log” button on the calculator.
- From your screen, obtain the exponent from the original number you entered.
- Check your results.

### 1. Learning Activities

- Create an instruction sheet with the following five fractions:  $\frac{1}{3}$ ,  $\frac{1}{8}$ ,  $\frac{2}{3}$ ,  $\frac{1}{4}$  and  $\frac{1}{5}$

Create a pizza (circular cut outs), using construction paper and decorate the toppings to represent each fraction.

For example, if they had a quarter (fourth), they should cover one-quarter of the pizza with a specific pattern.

- Using your calculator check that you agree with the answers to the following problems:

Evaluate the following, correct to 4 significant figures:

- $4.7826 + 0.02713 = 4.80973 = 4.810$
- $21.93 \times 0.012981 = 0.2846733 = 0.2847$

Evaluate the following, correct to 3 decimal places:

- $\sqrt{0.007328}$
- $\sqrt{52.91} - \sqrt{31.76}$

### 1. Self-Assessment

- Place the appropriate symbol  $<$  or  $>$  between each of the following pairs of numbers:

- $3 \_ 2$
- $8 \_ -13$
- $-25 \_ 0$

- Find the value of each of the following:

- $13 + 9 \div 3 - 2 \times 5$
- $(13 + 9) \div (3 - 2) \times 5$

9. Complete the following:

c.  $\frac{4}{5} =$

d. **48% of 50 =**

10. Write the following proportions as ratios:

b.  $\frac{1}{2}$  of A,  $\frac{1}{5}$  of B,  $\frac{3}{10}$  of C

11. Reduce each of the following to their lowest form:

c.  $\frac{12}{18}$

d.  $\frac{144}{21}$

12. Round each of the following decimal numbers, first to 3 significant figures and to 2 decimal places:

c. 21.355

d. 0.02456

#### **1.2.1.6 Tools, Equipment, Supplies and Materials**

- Calculator
- Paper and pencil
- Computer
- Ruler and graph paper
- Marker pen

#### **1.2.1.7 References**

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#### **6.2.1.8 Answers to Self-Assessment**

7. Place the appropriate symbol *< or >* between each of the following pairs of numbers:

d.  $3 > 2$

e.  $8 > -13$

f.  $-25 < 0$

8. Find the value of each of the following:

c.  $13 + 9 \div 3 - 2 \times 5$

$$13 + (9 \div 3) - (2 \times 5)$$
$$13 + 3 - 10 = (13 + 3) - 10 = 6$$

d.  $(13 + 9) \div (3 - 2) \times 5$

$$(13 + 9) \div (3 - 2) \times 5 = 22 \div 1 \times 5 = (22 \div 1) \times 5 = 110$$

9. Complete the following:

c.  $\frac{4}{5}$  as a % =

$$\frac{4}{5} \times 100 = 80\%$$

d. 48% of 50 =

$$\frac{48}{100} \times 50 = 24$$

10. Write the following proportions as ratios:

b.  $\frac{1}{2}$  of A,  $\frac{1}{5}$  of B,  $\frac{3}{10}$  of C

The LCM of the denominators 2, 5 and 10 is 10 then;

$$\frac{1}{2} \text{ of A is } \frac{1 \times 5}{2 \times 5} = \frac{5}{10}, \frac{1}{5} \text{ of B is } \frac{1 \times 2}{5 \times 2} = \frac{2}{10} \text{ and } \frac{3}{10} \text{ of C}$$

Hence: A : B : C = 5 : 2 : 3

11. Reduce each of the following to their lowest form:

c.  $\frac{12}{18}$

$$\frac{12}{18} = \frac{12 \div 6}{18 \div 6} = \frac{2}{3}$$

d.  $\frac{144}{21}$

$$\frac{144}{21} = \frac{144 \div 3}{21 \div 3} = \frac{48}{7} = 4\frac{6}{7}$$

12. Round each of the following decimal numbers, first to 3 significant figures and to 2 decimal places:

c. 21.355

21.4 3sf

21.36 2dp

d. 0.02456

0.025 2sf

0.03 2dp

## **1.2.2 Learning Outcome 2: Use formulae and algebraic expressions for work**

### **1.2.2.1 Introduction to the learning outcome**

This learning outcome covers algebra and the learner should be able to: perform calculations involving Indices as per the concept; perform calculations involving Logarithms as per the concept; use scientific calculator is used mathematical problems in line with manufacturer's manual; perform simultaneous equations as per the rules. Algebra is used throughout engineering, but it is most commonly used in mechanical, electrical, and civil branches due to the variety of obstacles they face. Engineers need to find dimensions, slopes, and ways to efficiently create any structure or object.

### **2.2.1.3 Performance Standard**

8. Algebraic linear equations
9. Simultaneous
10. Quadratic
11. Linear graphs
12. Plotting
13. Interpretation
14. Applications of linear graphs
15. Curves of first and second degree
16. Plotting
17. Interpretation
18. Applications

## **2.2.2 Information Sheet**

### **2.2.2.2 Definitions of terms**

Algebra is the study of mathematical symbols and the rules for manipulating these symbols; it is a unifying thread of almost all of mathematics. It includes everything from elementary equation solving to the study of abstractions such as groups, rings, and fields.

Logarithms: This is the power to which a number must be raised in order to get some other number which means that logarithms is the inverse of the exponential.

Linear equations: A linear equation is any equation of the form  $a + bx=0$  where a and b are real numbers and  $x$  is a variable.

Quadratic equation: It is any equation of the form  $ax^2 + bx + c$ . It is any equation of the second degree meaning that one of its terms is a squared.

### Performance of calculations involving indices

The lowest factors of 2000 are  $2 \times 2 \times 2 \times 2 \times 5 \times 5 \times 5$ . These factors are written as  $2^4 \times 5^3$ , where 2 and 5 are called bases and the numbers 4 and 3 are called indices. When an index is an integer it is called a power. Thus,  $2^4$  is called ‘two to the power of four’, and has a base of 2 and an index of 4.

Given  $b^x$ , b is known as the base and x is known as the power or index to which b is raised. It can be interpreted as:

$$b^x = b \times b \times b \dots \dots \dots (x \text{ times})$$

$x$  Can be real number.

The reciprocal of a number is when the index is  $-1$  and its value is given by 1, divided by the base.

The square root of a number is when the index is  $\frac{1}{2}$ , and the square root of 2 is written as  $2^{\frac{1}{2}}$  or  $\sqrt{2}$ . The value of a square root is the value of the base which when multiplied by itself gives the number.

### Laws of indices

When simplifying calculations involving indices, certain basic rules or laws can be applied, called the laws of indices.

For any number  $x$  and  $y$  the following basic laws hold;

$$a^x a^y = a^{x+y}$$

$$\frac{a^x}{a^y} = a^{x-y}$$

$$(a^x)^y = a^{xy}$$

$$a^{\frac{x}{y}} = \sqrt[y]{a^x}$$

$$a^{-y} = \frac{1}{a^y}$$

$$a^0 = 1$$

Note: The above law only applies if bases are similar e.g.  $2^3 \cdot 2^4 = 2^7 = 128$

$$\frac{a^x}{a^y} = a^{x-y}$$

Example:

$$\frac{2^4}{2^3} = 2^{4-3} = 2^1 = 2. \text{ If } x \text{ and } y \text{ equals one, } x = 1, y = 1 \text{ then } \frac{a^1}{a^1} = a^{1-1} = a^0 = 1$$

$$(a^x)^y = a^{xy} = (a^y)^x \text{ ljh}$$

Example:

$$(a^3)^2 = a^6 = (a^2)^3$$

$$(ab)^x = a^x a^x$$

Example:

$$(ab)^4 = a^4 b^4$$

NB: The expression  $a^{-x}$  is equivalent to  $\frac{1}{a^x}$

$$\frac{1}{a^x} = \frac{a^0}{a^x} = a^{0-x} = a^{-x}$$

### Calculating the indicial equations

Given  $3(2^{2x}) + 12(2^x) - 96 = 0$ , solve for  $x$

Steps

Let  $2^x = p$

Substitute p in the equation

*i. e*  $3p^2 + 12p - 96 = 0$ , simplifying the equation, it becomes  $p^2 + 4p - 32 = 0$ .

Factorize  $p^2 + 4p - 32 = 0$

$$p^2 + 8p - 4p - 32 = 0$$

$$P(P + 8) - 4(P + 8) = 0$$

$$(P - 4)(p + 8) = 0$$

$$P = 4 \text{ or } p = -8$$

Since  $2^x = 2^2$   $x = 2$  then the other solution has no real roots

### Performance of calculations involving logarithms

Laws of logarithms

$$\log A + \log B = \log AB$$

Example

Solve  $\log_{10} 5 + \log_{10} 4$

$$\log_{10} 5 + \log_{10} 4 = \log_{10} (5 \times 4) = \log_{10} 20$$

$$\log A - \log B = \log \frac{A}{B}$$

Example:

Use the second law to simplify:

$$\log_{10} 6 - \log_{10} 3$$

$$\log_{10} 6 - \log_{10} 3 = \log_{10} \frac{6}{3} = \log_{10} 2$$

$$\log B^n = n \log B$$

Example:

Use the third law to write the alternative form of

$$3 \log_{10} 5 = \log_{10} 5^3 = \log_{10} 125$$

2.2.2.2.1 1.2.2.3.5 Solving logarithmic equations

Given  $\log_2(x + 4) + \log_2(6) = \log_2 54$ , Find  $x$ ,

Steps

From laws of logarithms

$$\text{Law 1, } \log_2(x + 4) + \log_2(6) = \log_2 54$$

$$\log_2((x + 4) \times (6)) = \log_2 54$$

Distribute  $(x + 4)(6) = 6x + 24$

$$\log_2(6x + 24) = \log_2 54$$

Drop the logs

$$6x + 24 = 54$$

Solve the linear equation

$$6x = 30$$

$$x = 5$$

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### Use of scientific calculator in solving mathematical problems

A scientific calculator is a special electronic calculator that aids the calculation involving problems in mathematics, engineering and science. It can be used in the following ways;

- Basic operations i.e. addition subtraction, multiplication and division.
- Calculation of exponents.
- Solving problems with an order of operations.
- Working out squares and square roots of numbers.
- Solving logarithmic problems.
- Solving of problems in statistics e.g. find the mean, variance, standard deviation etc.

Example: The “log” function in the calculator is the key that allows you to work with the logarithm.



The steps in using the log functions are;

- xiii. Type the number you are to work with in your scientific calculator.
- xiv. Press the “log” button on the calculator.
- xv. From your screen, obtain the exponent from the original number you entered.
- xvi. Check your results.

### **Obtainment of solution to system of linear equations involving three unknowns**

This is how one should solve a system with three unknowns.

Steps

- vi. Take a pair of the equation from the system.
- vii. Using addition/subtraction, eliminate the same variables from each pair.
- viii. Using additional/subtraction, solve the system of two new equations.
- ix. Substitute the solution back into one of the equations and solve for the third variable.
- x. Confirm your solution by the use of one of the equations.

Example:

Solve the following system of equations.

$$8x - 6y + 2z = -20$$

$$4x + 2y + 6z = 0$$

$$-2x + 4y - 10z = 34$$

Pick two pairs

$$8x - 6y + 2z = -20$$

$$4x + 2y + 6z = 0$$

*and*

$$4x + 2y + 6z = 0$$

$$-2x + 4y - 10z = 34$$

Eliminate the same variables from each system

$$8x - 6y + 2z = -20$$

$$4x + 2y + 6z = 0$$

Simplify

$$4x - 3y + z = -10$$

$$2x + y + 3z = 0$$

$$4x - 3y + z = -10$$

$$\underline{-4x - 2y - 6z = 0}$$

$$-5y - 5z = -10$$

$$4x + 2y + 6z = 0$$

$$-2x + 4y - 10z = 34$$

Simplify

$$2x + y + 3z = 0$$

$$-x + 2y - 5z = 17$$

$$2x + y + 3z = 0$$

$$\underline{-2x + 4y - 10z = 34}$$

$$5y - 7z = 34$$

Solve the system of the equations.

$$-5y - 5z = -10$$

$$\underline{5y - 7z = 34}$$

$$-12z = 24$$

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Thus  $z = -2$ , solving for  $y, y = 4$

Substitute in the original to obtain  $x$

$$-2x + 4y - 10z = 17$$

$$-2 + 4(4) - 10(-2) = 17$$

$$-2x = -2 \quad x = 1$$

### Performance of calculations involving Quadratic Equations

It is an equation of the form  $ax^2 + bx + c = 0$

Solving the quadratic equation

Quadratic equations can be solved by factorization.

Quadratic equation can be solved by the use of the quadratic formula.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Also, quadratic equations can be solved through the completing squares method.

By the use of the graphical method.

Example:

Solve using the quadratic formula;

$$x^2 + 2x + 1 = 0$$

Solution:

$$a = 1$$

$$b = 2$$

$$c = 1$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-2 \pm \sqrt{2^2 - 4 \times 1 \times 1}}{2 \times 1}$$

The discriminant is;

$$b^2 - 4ac = 2^2 - 4 \times 1 \times 1 = 0$$

$$x = \frac{-2 \pm \sqrt{0}}{2 \times 1}$$

$$= \frac{-2}{2 \times 1} = 1$$

### Calculations involving sequence and series are performed as per the concept

A sequence are numbers or functions arranged in a special order while series is the sum of sequence of terms.

Types of sequence in mathematics

- Arithmetic sequence: is a set of the numbers that follows a pattern formed by adding a common difference to the proceeding number.
- Geometric sequence: is a set of numbers that are multiplied (or divided) by a constant called the common ratio.

Types of series

Arithmetic series is the sum of the terms of arithmetic sequence while geometric series is the sum of the terms of the geometric sequence. The  $n^{th}$  term of the arithmetic sequence is given by  $a + (n - 1)d$  while the sum of terms in the series is given by  $\frac{n}{2}[2a + (n - 1)d]$ . The  $n^{th}$  term of a G.P is given by  $ar^{n-1}$ . The sum of the infinite terms of the series  $s_n = \frac{a^n}{1-r}$

Where  $0 < r < 1$

$a$  Is the first term.

$n$  Is the number of terms?

$d$  Is the common difference

$r$  Is the common ratio

Example

Determine the type of the sequence

**1, 4, 7, 10, 13 ...** It is an arithmetic sequence with a common difference of 3.

**2, 4, 8, 16, 32 ...** Is a geometric sequence with a common ratio of 2

In the arithmetic sequence **1, 4, 7, 10, 13, ...** find the sum of the first 10 terms.

$$a = 1, \quad d = 3 \quad n = 10$$

Use the formula  $\frac{n}{2}[2a + (n - 1)d]$

$$\frac{10}{2}[2(1) + (10 - 1)3]$$

$$= 5(2 + 27) = 145$$

In the geometric sequence **2, 4, 8, 16, 32.** Find the sum of the first 10 terms.

### 2.2.3 Learning Activities

1. In groups of two solve this hexagon puzzle as an algebra challenge. It involves rolling a dice to work out the value of an algebraic expression. Students take turns rolling the dice and the number rolled becomes the value of 'n'. The player then gets one chance to choose a hexagon and solve the equation using the assigned value of 'n'. At the end of the game, the student with the most number of solved hexagons wins.

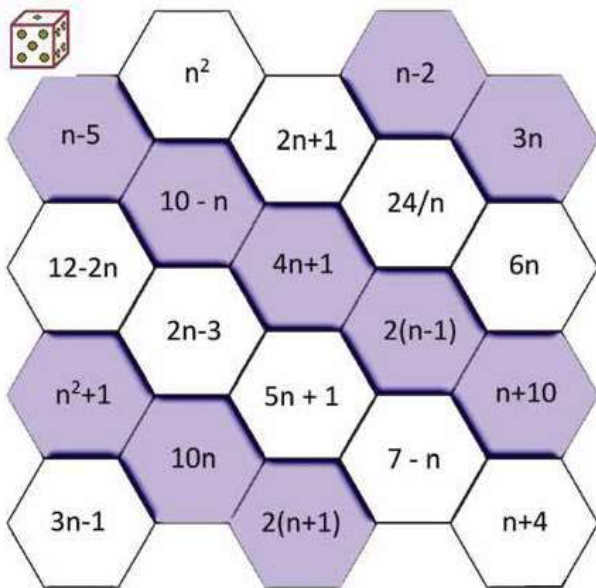


Figure 29: Hexagon Puzzle 1

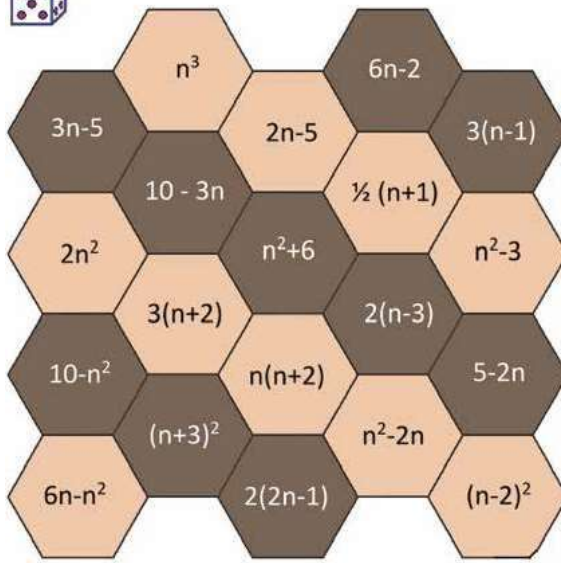


Figure 30: Hexagonal Puzzle 2

2. Perform a survey in your locality (in around 50 homesteads) and find out the total number of rabbits' population. It is believed that the population will increase by 2% every year. Predict the rabbit population after 3 years.

#### 2.2.4 Self-Assessment

1. Find the value of  $4p^2qr^3$ , given that  $p = 2$ ,  $q = \frac{1}{2}$  and  $r = 1\frac{1}{2}$
2. Find the sum of:  $5a - 2b$ ,  $2a + c$ ,  $4b - 5d$  and  $b - a + 3d - 4c$
3. Subtract  $2x + 3y - 4z$  from  $x - 2y + 5z$
4. Multiply  $3x - 2y^2 + 4xy$  by  $2x - 5y$
9. Simplify:  $2p \div 8pq$
10. Simplify:  $\frac{x^2y}{xy^2-xy}$
11. Simplify:  
 $(a^3\sqrt{b}\sqrt{c^5})(\sqrt{a^3}\sqrt{bc^3})$  And evaluate when  $a = \frac{1}{4}$ ,  $b = 6$  and  $c = 1$
12. Factorize:  $2ax - 3ay + 2bx - 3by$

#### 2.2.5 Tools, Equipment, Supplies and Materials

- Calculator
- Paper and pencil
- Computer

- Ruler and graph paper
- Dice

### 2.2.6 References

Anto H & Lolles, C (2013). Elementary Linear Algebra: Applications version

Greub Werner H. (2012). Linear Algebra Vol 23 springer Science

John Bird, (2003). Engineering Mathematics, Fourth Edition

Wilkinson, J.H Beur F.l& Reisch, (2013) Linear Algebra (Vol 12) Springer.

### 2.2.7 Answers to the Self-Assessment

1. Find the value of  $4p^2qr^3$ , given that  $p = 2, q = \frac{1}{2}$  and  $r = 1\frac{1}{2}$

Solution:

Replacing p, q and r with their numerical values gives:

$$4p^2qr^3 = 4(2) \times (2^2) \times \frac{1}{2} \times \left(\frac{3}{2}\right)^3 = 27$$

2. Find the sum of:  $5a - 2b, 2a + c, 4b - 5d$  and  $b - a + 3d - 4c$

Solution:

The algebraic expressions may be tabulated as shown below, forming columns for a's, b's, c's and d's.

Thus:

$$\begin{aligned} 5a + (-2b) + 2a + c + 4b + (-5d) + b + (-a) + 3d + (-4c) \\ = 6a + 3b - 3c - 2d \end{aligned}$$

3. Subtract  $2x + 3y - 4z$  from  $x - 2y + 5z$

$$\begin{aligned} (x - 2y + 5z) - (2x + 3y - 4z) \\ = -x - 5y + 9z \end{aligned}$$

4. Multiply  $3x - 2y^2 + 4xy$  by  $2x - 5y$

$$\begin{aligned} 2x(3x - 2y^2 + 4xy) &= 6x^2 - 4xy^2 + 8xy^2 \\ -5y(3x - 2y^2 + 4xy) &= -15xy + 10y^3 - 20xy^2 \\ (6x^2 - 4xy^2 + 8xy^2) + (-15xy + 10y^3 - 20xy^2) \\ 6x^2 - 24xy^2 + 8xy^2 - 15xy + 10y^3 \end{aligned}$$

9. Simplify:  $2p \div 8pq$

$$\frac{2p}{8pq} = \frac{1}{4q}$$

10. Simplify:  $\frac{x^2y}{xy^2-xy}$

The highest common factor (HCF) of each of the three terms comprising the numerator and denominator is  $xy$ . Dividing each term by  $xy$  gives:

$$\frac{x^2y}{xy^2-xy} = \frac{\frac{x^2y}{xy}}{\frac{x}{xy} \frac{xy}{xy}} = \frac{x}{y-1}$$

11. Simplify:

$(a^3\sqrt{b}\sqrt{c^5})(\sqrt{a^3}\sqrt{bc^3})$  And evaluate when  $a = \frac{1}{4}$ ,  $b = 6$  and  $c = 1$

Using the fourth law of indices, the expression can be written as:

$$(a^3b^{\frac{1}{2}}c^{\frac{5}{2}})(a^{\frac{3}{2}}b^{\frac{1}{2}}c^3)$$

Using the first law of indices gives:

$$a^{3+\frac{3}{2}}b^{\frac{1}{2}+\frac{1}{2}}c^{\frac{5}{2}+3} = a^{\frac{7}{2}}b^1c^{\frac{11}{2}}$$

It is usual to express the answer in the same form as the question. Hence:

$$a^{\frac{7}{2}}b^1c^{\frac{11}{2}} = \sqrt{a^7}\sqrt{b^2}\sqrt{c^{11}} = \sqrt{\left(\frac{1}{4}\right)^7} (\sqrt[6]{6^7})(\sqrt{1^{11}}) = 1$$

12. Factorize:  $2ax - 3ay + 2bx - 3by$

$a$  is a common factor of the first two terms and  $b$  a common factor of the last two terms

Thus:  $2ax - 3ay + 2bx - 3by = a(2x - 3y) + b(2x - 3y)$

$$(2x - 3y)(a + b)$$



### **Learning Outcome 3: Use trigonometry to solve practical work problems**

#### 2.2.8 Introduction to the learning outcome

This learning outcome covers applications of trigonometric rules, identities the calculation of area, perimeter of shapes and solids .it also covers one to one relationships and calculation involving hyperbolic functions and identities.

#### 2.2.9 Performance Standard

6. Meaning of trigonometry
7. Pythagoras theorem
8. Trigonometry ratios of angles
9. Trigonometric identities
10. Conversion of angles

#### 2.2.10 Information Sheet

##### 2.2.10.2 *Definition of Terms*

Trigonometry rule: This is a rule aimed at expressing the relationship between the angles of a triangle and the side lengths.

Hyperbolic function: This is a function of an angle that is defined for the hyperbola, not on the circle.

One to one function: A function said to be one to one if different elements in **a** map different element in **b**.

**Performance of calculations are performed using trigonometric rules**

Consider a unit circle of radius 1

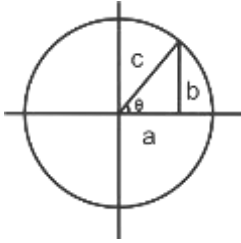


Figure 31: Circle

$$\sin\theta = \frac{b}{c}$$

$$\cos\theta = \frac{a}{c}$$

$$\tan = \frac{b}{a}$$

$$a^2 + b^2 = c^2$$

$$\frac{a^2}{c^2} + \frac{b^2}{c^2} = 1$$

Some of the trigonometric rules are;

$$(\cos^2\theta) + (\sin^2\theta) = 1$$

$$\cos^2\theta + \sin^2\theta = 1 \dots (1)$$

*dividing (1) by  $\sin^2\theta$*

$$\cot^2\theta + 1 = \operatorname{cosec}^2\theta$$

$$\cot^2\theta = \operatorname{cosec}^2\theta - 1$$

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Note:

$$\cot\theta = \frac{\cos\theta}{\sin\theta}$$

$$\operatorname{cosec}\theta = \frac{1}{\sin\theta}$$

$$\sec\theta = \frac{1}{\cos\theta}$$

$$\tan\theta = \frac{\sin\theta}{\cos\theta}$$

Dividing (i) by

$$\sin^2\theta$$

$$1 + \tan^2\theta = \sec^2\theta - 1$$

$$\tan^2\theta = \sec^2\theta - 1$$

The double angle formula can then be given as  $\sin 2A = 2 \cos A \sin A$  and  $\cos 2A = \cos^2 A - \sin^2 A$

$$\sin 2A = 2 \cos A \sin A - \sin A \sin A$$

Note: If values are different, it becomes a factor theorem with  $2A=A+B$ .

From the above relationship, we derive the half angle formula; that is

$$\cos 2A = \cos^2 A - \sin^2 A$$

$$\cos 2A = 2 \cos^2 A - 1$$

$$\cos A = 2 \cos^2\left(\frac{A}{2}\right) - 1$$

$$\cos A = 1 - 2\sin^2\left(\frac{A}{2}\right)$$

Therefore,  $2\sin^2\left(\frac{A}{2}\right) = 1 - \cos A$

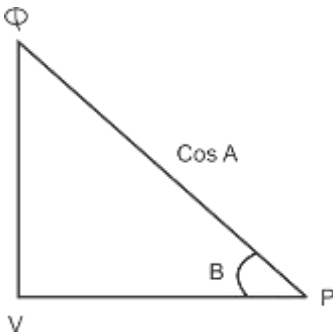
$$\cos\left(\frac{A}{2}\right) = \pm\sqrt{\frac{1+\cos A}{2}} \text{ and } \sin\left(\frac{A}{2}\right) = \pm\sqrt{\frac{1-\cos A}{2}}$$

Example

Without using calculator, find  $\cos 15^\circ$

Solution

$$\begin{aligned}\cos 15^\circ &= (\cos 45^\circ - \cos 30^\circ) \\ &= \cos 45 \cos 30 + \sin 45 \sin 30 \\ &= \sqrt{\frac{2}{2}} \cdot \sqrt{\frac{3}{2}} + \sqrt{\frac{2}{2}} \cdot \sqrt{\frac{1}{2}} \\ &= \sqrt{\frac{2}{4}} (\sqrt{3} + 1)\end{aligned}$$



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Figure 32: Triangle PQV

From triangle PQV

$$\sin B = \frac{QV}{\cos A} = QV = \cos A \sin B$$

Therefore from (i) and (ii)

$$\sin(A + B) = \sin A \cos B + \cos A \sin B$$

Replacing B by (-B) in equation (i), we get:

$$\sin(A - B) = \sin A \cos(-B) + \cos A \sin(-B)$$

$$\sin(A - B) = \sin A \cos B - \cos A \sin B$$

Similarly;

$$\cos(A + B) = \cos A \cos B - \sin A \sin B$$

$$\cos(A - B) = \cos A \cos B + \sin A \sin B$$

### Performance of calculations are performed using hyperbolic functions

These functions are expressed as exponential functions and are generally expressed as hyperbolic sine or hyperbolic cosine, where other relationships can be derived.

### The hyperbolic identities

Hyperbolic identities are obtained from the hyperbolic trigonometric functions. i.e

$$\mathbf{Tanh\ } x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

$$\mathbf{Sech\ } x = \frac{2}{e^x + e^{-x}}$$

$$\mathbf{coth\ } x = \frac{e^x + e^{-x}}{e^x - e^{-x}}$$

$$\mathbf{cosech\ } x = \frac{2}{e^x - e^{-x}}$$

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The derived hyperbole identities then become:

$$\mathbf{cosh^2 x - sinh^2 x = 1}$$

$$\mathbf{1 - tanh^2 x = sech^2 x}$$

$$\mathbf{coth^2 x - 1 = cosech^2 x}$$

$$\mathbf{\sinh(x \pm y) = \sinh x \cosh y \pm \cosh x \sinh y}$$

$$\mathbf{\cosh(x \pm y) = \cosh x \cosh y \pm \sinh x \sinh y}$$

$$\mathbf{\sinh(-x) = -\sinh x}$$

$$\mathbf{\cosh x = \cosh(-x)}$$

*Examples*

Solve the following equation in terms of a natural logarithm.

$$4\cosh 2x + 20 \sinh 2x = 10$$

Solution

$$\cosh 2x = \frac{e^{2x} + e^{-2x}}{2}$$

$$\sinh 2x = \frac{e^{2x} - e^{-2x}}{2}$$

$$\text{Therefore } 2e^{2x} + 2e^{-2x} + 10e^{2x} - 10e^{-2x} = 10$$

$$12e^{2x} - 8e^{-2x} = 10$$

$$6e^{4x} - 5e^{2x} - 4 = 0$$

$$(3e^{2x} - 4)(2e^{2x} + 1) = 0$$

$$e^{2x} = \frac{4}{3} \text{ or } e^{2x} = -\frac{1}{2}$$

$$x = \frac{1}{2} \ln \frac{4}{3} \text{ since the real solution occurs when } e^{2x} > 0$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

$$\sinh x = \frac{e^x - e^{-x}}{2}$$

Most of the properties are similar to properties of trigonometric functions. For example; cosh function is even while **sinh** function is odd. The only difference in properties is,

$$(\cosh x)^2 - (\sinh x)^2$$

*Examples*

Calculate **sinh 5** using exponential functions.

Solution

$$\sinh 5 = \frac{e^5 - e^{-5}}{2}$$

$$= 74.2.3 \text{ to } 3 \text{ d.p}$$

Calculate  $\cosh 7$  using the factor theorem.

$$\cosh 7 = \cosh(3 + 4) = \cosh 3 \cosh 4 - \sinh 3 \sinh 4$$

$$= (10.68)(27.308) - (10.018)(27.290)$$

$$= 1.543$$

Given the value of  $x$ , one is able to calculate inverse of the hyperbolic functions

### 2.2.11 Learning Activities

1. Prove the following hyperbolic identities, use the definition of  $\sinh x$  and  $\cosh x$  in terms of exponential functions

d)  $\cosh^2 x - \sinh^2 x = 1$

e)  $1 - \tanh^2 x = \operatorname{sech}^2 x$

f)  $\coth^2 x - 1 = \operatorname{cosech}^2 x$

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2. On graph papers:

d) Plot the graphs of  $\sinh x$  and  $\cosh x$

e) Superimpose the graphs above, do the curves intersect?

f) Predict the graphs of  $y = \coth x$ ,  $y = \operatorname{cosech} x$  and  $y = \operatorname{sech} x$

### 2.2.12 Self-Assessment

8) Solve the following equation in terms of a natural logarithm.

$$4\cosh^2 x + 20\sinh^2 x = 10$$

9) Indicate the sign needed to make the following identity true.

b)  $\sinh^2 x ( ) \cosh^2 x = 1$

10) A tree casts a horizontal shadow  $8\sqrt{3} \text{ m}$ , if a line is drawn from the end of the shadow to the top of the tree an angle of  $60^\circ$ . What is the height of the tree?



11) Prove that:  $\frac{\sin A + \sin B}{\cos A + \cos B} = \tan \frac{A+B}{2}$

12) With an aid of an example, analyze when a function is said to be injective?

13) Justify the relationship between the hyperbolic and the trigonometric functions.

14) Given;

$a, b, c > 0$ , show that when  $a > b$ , then  $a \cosh x + b \sinh x$  can be written in the form  $R \cosh(x + \alpha)$ . Therefore determine a further condition for which the following equation has real solutions.

$$a \cosh x + b \sinh x = c$$

#### 2.2.13 Tools, Equipment, Supplies and Materials

- Calculator
- SMP tables
- Measuring tables
- Graph Papers
- Pens and Pencils

#### 2.2.14 References

Mikusinski J. (2014). Operational Calculus .Elsevier.

Milne, W.E (2015) Numerical Calculus .Princeton University Press.

Zill D. & Dewar, J (2011). Algebra And Trigonometry, ones & Bartlett Publishers.

#### 2.2.15 Answers to Self-Assessment

4. Solve the following equation in terms of a natural logarithm.

$$4 \cosh 2x + 20 \sinh 2x = 10$$

Solution



$$\cosh 2x = \frac{e^{2x} + e^{-2x}}{2}$$

$$\sinh 2x = \frac{e^{2x} - e^{-2x}}{2}$$

Therefore  $2e^{2x} + 2e^{-2x} + 10e^{2x} - 10e^{-2x} = 10$

$$12e^{2x} - 8e^{-2x} = 10$$

$$6e^{4x} - 5e^{2x} - 4 = 0$$

$$(3e^{2x} - 4)(2e^{2x} + 1) = 0$$

$$e^{2x} = \frac{4}{3} \text{ or } e^{2x} = -\frac{1}{2}$$

$$x = \frac{1}{2} \ln \frac{4}{3} \text{ since the real solution occurs when } e^{2x} > 0$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

$$\sinh x = \frac{e^x - e^{-x}}{2}$$

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5. Indicate the sign needed to make the following identity true.

$$\sinh^2 x (+) \cosh^2 x = 1$$

6. A tree casts a horizontal shadow  $8\sqrt{3}m$ , if a line is drawn from the end of the shadow to the top of the tree an angle of  $60^\circ$ . What is the height of the tree?



$$\tan 60^\circ = \frac{h}{8\sqrt{3}}$$

$$\tan 60^\circ = \frac{\text{height of tree}}{\text{length of shadow}}$$

$$h = 8\sqrt{3} \tan 60^\circ = 24m$$

#### **Learning Outcome 4: Perform estimations, measurements and calculations of quantities**

##### 2.2.16 Introduction to the learning outcome

This topic covers the units of measurement and their symbols, conversion of units of measurement, mensuration, measuring tools and equipment and performing measurements and estimations of quantities.

##### 2.2.17 Performance Standard

- 6) Units of measurements and their symbols
- 7) Conversion of units of measurement
- 8) Calculation of length, width, height, perimeter, area and angles of figures
- 9) Measuring tools and equipment
- 10) Performing measurements and estimations of quantities

##### 2.2.18 Information Sheet

###### 2.2.18.2 *Definition of terms*

#### **Units of measurements and their symbols**

There are seven base units in the SI system:

- the kilogram (kg), for mass
- the second (s), for time
- the kelvin (K), for temperature
- the ampere (A), for electric current
- the mole (mol), for the amount of a substance
- the candela (cd), for luminous intensity
- the meter (m), for distance

Table 4: SI Units

| QUANTITIES  | UNIT                     | SYMBOL   |
|-------------|--------------------------|----------|
| Length      | • Millimeter             | mm       |
|             | • Meter                  | m        |
|             | • Kilometer              | km       |
| Mass        | • Gram                   | g        |
|             | • Kilogram               | kg       |
|             | • Tonne                  |          |
| Time        | 4 Second                 | s        |
| Temperature | Degree Celsius           | °C       |
| Area        | Square kilometer         | $km^2$   |
| Volume      | Cubic Meter              | $m^3$    |
| Speed       | 5 Meter per second       | m/s      |
|             | 6 Kilometer per hour     | km/hr    |
| Density     | Kilogram per cubic meter | $kg/m^3$ |
| Force       | Newton                   | N        |

## Conversion of units of measurement

Table 5: SI Prefix Symbols

| Prefix | Symbol | Ordinary Notation | Factor    |
|--------|--------|-------------------|-----------|
| Giga   | G      | 1000000000        | $10^9$    |
| Mega   | M      | 1000000           | $10^6$    |
| Kilo   | K      | 1000              | $10^3$    |
| Milli  | m      | 0.001             | $10^{-3}$ |
| Micro  | $\mu$  | 0.000001          | $10^{-6}$ |
| Nano   | N      | 0.000000001       | $10^{-9}$ |

Table 6: Conversions of SI Units

| QUANTITY | UNITY                 | VALUE IN SI UNITS      |
|----------|-----------------------|------------------------|
| Length   | 2.2.18.2.1 Millimeter | 2.2.18.2.4 1000mm = 1m |
|          | 2.2.18.2.2 Centimeter | 2.2.18.2.5 100cm = 1m  |
|          | 2.2.18.2.3 Kilometer  | 2.2.18.2.6 1km = 1000m |
| Time     | 2.2.18.2.7 Minute     | 1minute = 60s          |
|          | 2.2.18.2.8 Hour       | 1hour = 60minute=3600s |
|          | 2.2.18.2.9 Day        | 1day = 24hrs           |

## Calculation of length, width, height, perimeter, area and angles of figures

### Perimeter

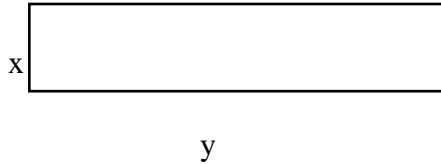
The perimeter is the length of the outline of a shape. To find the perimeter of a rectangle or square you have to add the lengths of all the four sides. X is in this case the length of the rectangle while y is the width of the rectangle.

The perimeter, P, is:

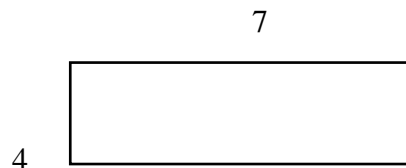
$$P = x + x + y + y$$

$$P = 2x + 2y$$

$$P = 2(x + y)$$



Find the perimeter of this rectangle



$$P = 7 + 7 + 4 + 4$$

$$P = 2 \cdot 7 + 2 \cdot 4$$

$$P = 2 \cdot (7 + 4)$$

$$P = 2 \cdot 11$$

$$P = 22\text{m}$$

### Area

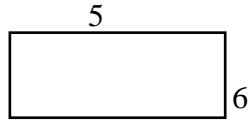
Area is the measurement of the surface of a shape. To find the area of a rectangle or a square you need to multiply the length and the width of a rectangle or a square.

Area, A, is x times y.

$$A = x \cdot y$$

Examples:

Find the area of this square.



$$A = x \cdot y$$

$$A = 5 \cdot 6$$

$$A = 30\text{m}^2$$

There are different units for perimeter and area. Perimeter has the same units as the length of the sides of rectangle or square whereas the area's unit is squared.

*Obtain volume and surface area of solids*

The surface area of a figure is defined as the sum of the areas of the exposed sides of an object.

The volume of an object is the amount of three-dimensional space an object takes up. It can be thought of as the number of cubes that are one unit by one unit by one unit that it takes to fill up an object.

Surface Area of a Rectangular Solid (Box)

$$SA = 2(lw + lh + wh)$$

**l = length of the base of the solid**

**w = width of the base of the solid**

**h = height of the solid**

Volume

Volume of a Solid with a Matching Base and Top

$$V = Ah$$

A = area of the base of the solid

h = height of the solid

Volume of a Rectangular Solid (specific type of solid with matching base and top)

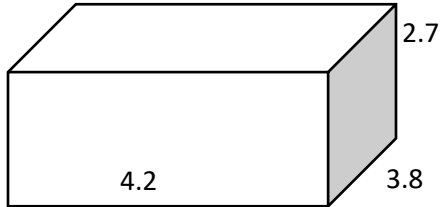
$$V = l \times w \times h$$

l = length of the base of the solid

w = width of the base of the solid

h = height of the solid

Example:



Based on the way our box is sitting, we can say that the length of the base is 4.2 m; the width of the base is 3.8 m; and the height of the solid is 2.7 m. Thus, we can quickly find the volume of the box to be:

$$V = lwh = 4.2 \times 3.8 \times 2.7 = 43.092m^3$$

A cylinder

A cylinder is an object with straight sides and circular ends of the same size. The volume of a cylinder can be found in the same way you find the volume of a solid with a matching base and top. The surface area of a cylinder can be easily found when you realize that you have to find the area of the circular base and top and add that to the area of the sides. If you slice the side of the cylinder in a straight line from top to bottom and open it up, you will see that it makes a rectangle. The base of the rectangle is the circumference of the circular base, and the height of the rectangle is the height of the cylinder.

Volume of a cylinder

$$V = Ah$$

A = the area of the base of the cylinder

h = the height of the cylinder

Surface Area of a Cylinder

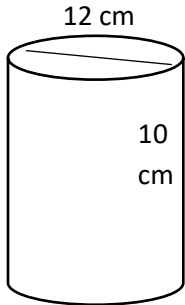
$$SA = 2(\pi r^2) + 2\pi rh$$

r = the radius of the circular base of the cylinder

$h$  = the height of the cylinder

$\pi$  = the number that is approximated by 3.141593

Find the area of the cylinder



$$SA = 2(\pi r^2) + 2\pi rh$$

$$SA = 2(\pi \cdot 6^2) + 2\pi(6)(10) = 603.18579$$

## Measuring tools and equipment

### Vernier Caliper

Vernier Caliper is a widely used linear measurement instrument with a least count of 0.02 mm. It is used to measure linear dimensions like length, diameter and depth.

### Micrometer

External Micrometer is also known as Outside Micrometer or External Micrometer.

It is used to check outside diameter of circle by the means of accuracy of 0.01 mm or up to 0.001 mm.

### Steel Scale

Steel scale is single piece linear measuring instrument. Steel scale indicates two units that are cm and inches, cm division on one side and inches, on another side.

### Measuring tape.

### Ruler and Rule

Performing measurements and estimations of quantities

#### 2.2.19 Learning Activities

1. In this particular activity, apples will be used to practice math skills of estimation and measurement of the circumference of an apple.



Materials you'll need:

- An apple
  - A ruler
  - Scissors
  - Thread
- e) You begin by placing the apple in front of your students. Let them hold the apple to ascertain its circumference. Encourage your students to cut the yarn to a length that they feel would properly wrap around the apple. This will require estimation on their part.
- f) Use multiple apples of varying sizes, and have students estimate the amount of string that they'll need for each measurement.
- g) Use the ruler to measure the string.
- h) After determining whether they're too long or too short, have your students cut a second string to try to get closer to the circumference of the apple.

#### 2.2.20 Self-Assessment

4. A rectangular tray is 820 mm long and 400 mm wide. Find its area in: (a)  $mm^2$  (b)  $m^2$  (c)  $cm^2$

2. Calculate the areas of the following sectors of circles having:

(a) Radius 6 cm with angle subtended at center  $50^\circ$

$$\text{Area of sector of a circle} = \frac{\theta^2}{360} (\pi r^2)$$

(b) Diameter 80 mm with angle subtended at center  $107^\circ 42'$

(c) Radius 8 cm with angle subtended at center 1.15 radians

3. A water tank is the shape of a rectangular prism having length 2 m, breadth 75 cm and height 50 cm.

Determine the capacity of the tank in (a)  $m^3$  (b)  $cm^3$  (c) litres

4. Find the volume and total surface area of a cylinder of length 15 cm and diameter 8 cm

#### 2.2.21 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books

- Dice
- Computers with internet connection
- Tape measure
- Thread
- Mathematical set

### 2.2.22 References

Hoyland, A., Rausand, and M. (1994), System Reliability Theory: Models and Statistical Methods, (New York).

Kaplan, W. (1984), Advanced Calculus, 3rd ed., Addison-Wesley (Cambridge, MA).

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### 2.2.23 Answers to Self-Assessment

4. A rectangular tray is 820 mm long and 400 mm wide. Find its area in: (a)  $mm^2$  (b)  $m^2$  (c)  $cm^2$

$$Area = length \times width = 820 \times 400 = 328000mm^2$$

$$1cm^2 = 100mm^2$$

$$Hence: 328000mm^2 = \frac{328000}{100} cm^2 = 3280cm^2$$

$$1m^2 = 10000cm^2$$

$$Hence: 3280cm^2 = \frac{3280}{10000} = 0.3280m^2$$

2. Calculate the areas of the following sectors of circles having:

(a) Radius 6 cm with angle subtended at center  $50^\circ$

$$Area \text{ of sector of a circle} = \frac{\theta}{360} (\pi r^2)$$

$$= \frac{50}{360} (\pi 6^2) = \frac{50 \times \pi \times 36}{360} = 5\pi = 15.71cm^2$$

(b) Diameter 80 mm with angle subtended at center  $107^\circ 42'$

If the diameter = 80mm, then the radius,  $r = 40mm$

$$= \frac{107 \frac{42}{60}}{360} (\pi 40^2) = 1504mm$$

(c) Radius 8 cm with angle subtended at center 1.15 radians

3. A water tank is the shape of a rectangular prism having length 2 m, breadth 75 cm and height 50 cm. Determine the capacity of the tank in (a)  $m^3$  (b)  $cm^3$  (c) litres

Volume of rectangular prism =  $l \times b \times h$

Volume of tank =  $2 \times 0.75 \times 0.5 = 0.75m^3$

$$1m^3 = 10^6cm^3$$

$$0.75m^3 = \frac{0.75}{10^6} = 750000cm^3$$

$$1 \text{ litre} = 1000cm^3$$

Hence:

$$750000cm^3 = \frac{750000}{1000} = 750 \text{ litres}$$

4. Find the volume and total surface area of a cylinder of length 15 cm and diameter 8 cm

Volume of cylinder =  $\pi r^2 h$

Since diameter = 8 cm, then radius = 4 cm

Hence:

$$\text{Volume} = \pi \times 4^2 \times 15 = 754cm^3$$

$$\text{Total surface area} = 2\pi r h + 2\pi r^2 = 477.5cm^2$$

### Learning Outcome 5: Apply Matrices in work

#### 2.2.24 Introduction to the learning outcome

This learning outcome covers: Matrix definition, types, matrix operations, compatibility and determination of inverse of a matrix, solving simultaneous equations with two and three and application of the matrices.

#### 2.2.25 Performance Standard

11. Meaning of matrix
12. Types of matrices
13. Matrix operations
14. Compatibility
15. Addition
16. Subtraction
17. Multiplication
18. Determination of inverse of a matrix
19. Solution of simultaneous equations with two and three unknowns

## 20. Applications of matrices

### 2.2.26 Information Sheet

**Matrix:** This is a set of real or complex numbers arranged in rows and columns to form a rectangular array and it is always denoted by capital letters.

**Order:** A matrix of order of ( $m \times n$ )

**Determinant:** It is a physical quantity/value assigned to any square matrix.

E.g. given  $\begin{bmatrix} a & b \\ c & d \end{bmatrix} = ad - cd$

**Inverse:** The inverse of a matrix  $Q^{-1}$  is the matrix than when multiplied by the original matrix  $Q$  gives the identity matrix. i.e.  $Q Q^{-1} = I$ .

### Matrices

The numbers within a matrix are called an array and the coefficients forming the array are called the elements of the matrix. The number of rows in a matrix is usually specified by  $m$  and the number of columns by  $n$  and a matrix referred to as an ‘ $m$  by  $n$ ’ matrix. Thus,  $\begin{pmatrix} 2 & 3 & 6 \\ 4 & 5 & 7 \end{pmatrix}$  is a ‘2 by 3’ matrix?

### Type of matrix

The numbers within a matrix are called an **array** and the coefficients forming the array are called the **elements** of the matrix. The number of rows in a matrix is usually specified by  $m$  and the number of columns by  $n$  and a matrix referred to as an ‘ $m$  by  $n$ ’ matrix.

### Matrix Operations

To be added or subtracted matrices must be of the same order.

In describing the matrix, the number of rows the number of rows is stated first and the number of columns second. i.e.

$\begin{pmatrix} 6 & 3 \\ 2 & 4 \\ 5 & 1 \end{pmatrix}$  is a matrix of order of  $3 \times 2$

## Compatibility

A row matrix consists of 1 row only

A column matrix consists of 1 column only.

## Addition

Corresponding elements in two matrices may be added to form a single matrix.

Problem 1. Add the matrices

$$\begin{pmatrix} 2 & -1 \\ -7 & 4 \end{pmatrix} + \begin{pmatrix} -3 & 0 \\ 7 & -4 \end{pmatrix}$$
$$\begin{pmatrix} 2 + -3 & -1 + 0 \\ -7 + 7 & 4 + -4 \end{pmatrix}$$
$$= \begin{pmatrix} -1 & -1 \\ 0 & 0 \end{pmatrix}$$

## Subtraction

If A is a matrix and B is another matrix, then (A-B) is a single matrix formed by subtracting the elements of B from the corresponding elements of A.

Problem 2. Subtract

$$\begin{pmatrix} -3 & 0 \\ 7 & -4 \end{pmatrix} - \begin{pmatrix} 2 & -1 \\ -7 & 4 \end{pmatrix}$$

To find matrix A minus matrix B, the elements of B are taken from the corresponding elements of A.

Thus:

$$\begin{pmatrix} -3 & 0 \\ 7 & -4 \end{pmatrix} - \begin{pmatrix} 2 & -1 \\ -7 & 4 \end{pmatrix}$$
$$\begin{pmatrix} -3 - 2 & 0 - -1 \\ 7 - -7 & -4 - 4 \end{pmatrix}$$

$$\begin{pmatrix} -5 & 1 \\ 14 & -8 \end{pmatrix}$$

## Multiplication

When a matrix is multiplied by a number, called scalar multiplication, a single matrix results in which each element of the original matrix has been multiplied by the number.

Problem 4.

$$\text{If } A = \begin{pmatrix} -3 & 0 \\ -7 & -4 \end{pmatrix}, B = \begin{pmatrix} -2 & -1 \\ -7 & 4 \end{pmatrix} \text{ and } C = \begin{pmatrix} -1 & 0 \\ -2 & -4 \end{pmatrix}$$

Find

$$2A - 3B + 4C$$

For scalar multiplication, each element is multiplied by the scalar quantity, hence

$$2A = 2 \begin{pmatrix} -3 & 0 \\ -7 & -4 \end{pmatrix} = \begin{pmatrix} -6 & 0 \\ -14 & -8 \end{pmatrix}$$

$$3B = 3 \begin{pmatrix} -2 & -1 \\ -7 & 4 \end{pmatrix} = \begin{pmatrix} -6 & -3 \\ -21 & 12 \end{pmatrix}$$

$$4C = 4 \begin{pmatrix} -1 & 0 \\ -2 & -4 \end{pmatrix} = \begin{pmatrix} -4 & 0 \\ -8 & -16 \end{pmatrix}$$

Hence  $2A - 3B + 4C$

$$\begin{pmatrix} -6 & 0 \\ -14 & -8 \end{pmatrix} - \begin{pmatrix} -6 & -3 \\ -21 & 12 \end{pmatrix} + \begin{pmatrix} -4 & 0 \\ -8 & -16 \end{pmatrix}$$

When a matrix A is multiplied by another matrix B, a single matrix results in which elements are obtained from the sum of the products of the corresponding rows of A and the corresponding columns of B. Two matrices A and B may be multiplied together, provided the number of elements in the rows of matrix A are equal to the number of elements in the columns of matrix B. In general terms, when multiplying a matrix of dimensions (m by n) by a matrix of dimensions (n by r), the resulting matrix has dimensions (m by r). Thus a 2 by 3 matrix multiplied by a 3 by 1 matrix gives a matrix of dimensions 2 by 1.

Problem 5. If  $A = \begin{pmatrix} -2 & 3 \\ 1 & -4 \end{pmatrix}$   $B = \begin{pmatrix} -5 & 7 \\ -3 & 4 \end{pmatrix}$

Find  $A \times B$ .

Let  $A \times B = C$  where  $C = \begin{pmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{pmatrix}$

$C_{11}$  is the sum of the products of the first row elements of A and the first column elements of B taken one at a time, i.e.  $C_{11} = (-2 \times (-5)) + (3 \times (-3)) = -19$

$C_{12}$  is the sum of the products of the first row elements of A and the second column elements of B, taken one at a time, i.e.  $C_{12} = (2 \times 7) + (3 \times 4) = 26$

$C_{21}$  is the sum of the products of the second row elements of A and the first column elements of B, taken one at a time, i.e.  $C_{21} = (1 \times -5) + (-4 \times -3) = 7$

Finally,  $C_{22}$  is the sum of the products of the second row elements of A and the second column elements of B, taken one at a time, i.e.  $C_{22} = (1 \times 7) + (-4 \times 4) = -9$

Thus,  $A \times B = \begin{pmatrix} -19 & 26 \\ 7 & -9 \end{pmatrix}$

### Determination of inverse of a matrix

The determinant of a 2 by 2 matrix

The determinant of a 2 by 2 matrix,  $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$  is defined as  $(ad - bc)$ .

The elements of the determinant of a matrix are written between vertical lines. Thus, the determinant of

$\begin{pmatrix} 3 & -4 \\ 1 & 6 \end{pmatrix}$  is written as  $\begin{vmatrix} 3 & -4 \\ 1 & 6 \end{vmatrix}$  and is equal to  $(3 \times 6) - (-4 \times 1) = 22$ . Hence the determinant of a

matrix can be expressed as a single numerical value, i.e.  $\begin{vmatrix} 3 & -4 \\ 1 & 6 \end{vmatrix} = 22$

The inverse or reciprocal of a 2 by 2 matrix

The inverse of matrix A is  $A^{-1}$  such that  $A \times A^{-1} = \mathbf{1}$ , the unit matrix.

Let matrix A be  $\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$  and let the inverse matrix,  $A^{-1}$  be  $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$

Then, since  $A \times A^{-1} = \mathbf{1}$

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} \times \begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Multiplying the matrices on the left hand side, gives

$$\begin{pmatrix} a + 2c & b + 2d \\ 3a + 4c & 3b + 4d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Equating corresponding elements gives:

$$b + 2d = 0$$

$$b = -2d \text{ And } 3a + 4c = 0$$

$$a = -\frac{4}{3}c$$

Substituting for a and b gives:

$$\begin{pmatrix} -\frac{4}{3}c + 2 & -2d + 2d \\ 3\left(-\frac{4}{3}c\right) + 4c & 3(-2d) + 4d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} -\frac{2}{3}c & 0 \\ 0 & -2d \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Showing that  $\frac{2}{3}c = 1$ ,  $c = \frac{3}{2}$  and  $-2d = 1$  i. e.  $d = -\frac{1}{2}$

Since  $b = -2d$ ,  $b = 1$  and since  $a = -\frac{4}{3}c$ ,  $a = -2$

Thus the inverse of matrix  $\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$  is  $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$  that is  $\begin{pmatrix} -2 & 1 \\ \frac{3}{2} & -\frac{1}{2} \end{pmatrix}$

### Solution of simultaneous equations with two and three unknowns

The procedure for solving linear simultaneous equations in two unknowns using matrices is:

- (i) Write the equations in the form  $a_1x + b_1y = c_1$ ,  $a_2x + b_2y = c_2$
- (ii) Write the matrix equation corresponding to these equations, i.e.  $\begin{pmatrix} a_1 & b_1 \\ a_2 & b_2 \end{pmatrix} \times \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix}$
- (iii) Determine the inverse matrix of  $\begin{pmatrix} a_1 & b_1 \\ a_2 & b_2 \end{pmatrix}$  i.e.  $\frac{1}{a_1b_2 - b_1a_2} \begin{pmatrix} b_2 & -b_1 \\ -a_2 & a_1 \end{pmatrix}$
- (iv) Multiply each side of (ii) by the inverse matrix
- (v) Solve for x and y by equating corresponding elements.

The procedure for solving linear simultaneous equations in three unknowns using matrices is:

- (ii) Write the equations in the form

$$a_1x + b_1y + c_1z = d_1$$

$$a_2x + b_2y + c_2z = d_2$$

$$a_3x + b_3y + c_3z = d_3$$

- (ii) Write the matrix equation corresponding to these equations, i.e.

$$\begin{pmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{pmatrix} \times \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} d_1 \\ d_2 \\ d_3 \end{pmatrix}$$

- (iii) Determine the inverse matrix of

$$\begin{pmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{pmatrix}$$

- (iv) Multiply each side of (ii) by the inverse matrix
- (v) Solve for x, y and z by equating the corresponding elements.

### Applications of Matrices

- Cryptography

This is the process of hiding information for security purposes.



- Fourier analysis
- Gauss theorem
- Finding forces in the bridge
- Finding electric currents using matrix equation

### 2.2.27 Learning Activities

#### 7. Adding and Subtracting Matrices

Use this kinesthetic activity to help students add and subtract matrices by creating human matrices.

#### Materials

- Masking/painter's tape
- Copy paper
- Markers

#### Teacher Directions

- Show students examples of matrices and demonstrate how to add and subtract them. If possible, use matrices that reflect real-life data, such as population numbers for a specific continent.
- Give each student a piece of paper and marker.
- Have students write a number of their choice on the paper.
- Divide the classroom in half using a piece of masking/painter's tape.
- Create a matrix on both sides of the tape using students as the numbers. Have students stand in rows and columns holding their number signs on either side of the tape.
- Have students not involved in creating the matrices add or subtract them.
- Review the correct answers with the class.
- Have students rotate between serving as the numbers in the matrices and figuring out the sums or differences.

#### Discussion Questions

- What steps do you follow to add and subtract matrices?
- In what real-world situations might you need to add and subtract matrices?

### 2.2.28 Self-Assessment

#### 1. Add the matrices

$$\begin{pmatrix} 4 & -2 \\ -1 & 3 \end{pmatrix} + \begin{pmatrix} -3 & 5 \\ 7 & 6 \end{pmatrix}$$

5. Subtract

$$\begin{pmatrix} 3 & 1 & -4 \\ 4 & 3 & 1 \\ 1 & 4 & -3 \end{pmatrix} - \begin{pmatrix} 2 & 7 & -5 \\ -2 & 1 & 0 \\ 6 & 3 & 4 \end{pmatrix}$$

6. Determine the value of:

$$\begin{vmatrix} 3 & -2 \\ 7 & 4 \end{vmatrix}$$

4. If  $A = \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix}$  and  $B = \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix}$ , show that  $A \times B \neq B \times A$

2.2.29 Tools, Equipment, Supplies and Materials

- Scientific calculator
- 15 cm ruler
- Pen, pencil
- Ruled and graph paper
- Mark Pens
- Cards

easyvet.com

2.2.30 References

Aitken, A.C (2017) Determinant and matrices Read Book Ltd.

Panju, M(2011) Iterative methods for computing eigen values and eigen vectors ar.xiv 11051185

Searle. S.R., & Khun, A.I. (2017) matrix algebra useful for statistics. John wiley & sons.

2.2.31 Answers to Self-Assessment

1. Add the matrices

$$\begin{pmatrix} 4 & -2 \\ -1 & 3 \end{pmatrix} + \begin{pmatrix} -3 & 5 \\ 7 & 6 \end{pmatrix} = \begin{matrix} 4 + (-3) & -2 + 5 \\ -1 + 7 & 3 + 6 \end{matrix} = \begin{pmatrix} 1 & -3 \\ 6 & 9 \end{pmatrix}$$

2. Subtract

$$\begin{pmatrix} 3 & 1 & -4 \\ 4 & 3 & 1 \\ 1 & 4 & -3 \end{pmatrix} - \begin{pmatrix} 2 & 7 & -5 \\ -2 & 1 & 0 \\ 6 & 3 & 4 \end{pmatrix} = \begin{pmatrix} 3-2 & 1-7 & -4-(-5) \\ 4-(-2) & 3-1 & 1-0 \\ 1-6 & 4-3 & -3-4 \end{pmatrix} = \begin{pmatrix} 1 & -6 & 1 \\ 6 & 2 & 1 \\ -5 & 1 & -7 \end{pmatrix}$$

3. Determine the value of:

$$\begin{vmatrix} 3 & -2 \\ 7 & 4 \end{vmatrix} = (3 \times 4) - (-2 \times 7) = 26$$

4. If  $A = \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix}$  and  $B = \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix}$ , show that  $A \times B \neq B \times A$

$$\begin{aligned} A \times B &= \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix} \times \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} [(2 \times 2) + (3 \times 0)] & [(2 \times 3) + (3 \times 1)] \\ [(1 \times 2) + (0 \times 0)] & [(1 \times 3) + (0 \times 1)] \end{pmatrix} \\ &= \begin{pmatrix} 4 & 9 \\ 2 & 3 \end{pmatrix} \end{aligned}$$

$$\begin{aligned} B \times A &= \begin{pmatrix} 2 & 3 \\ 0 & 1 \end{pmatrix} \times \begin{pmatrix} 2 & 3 \\ 1 & 0 \end{pmatrix} = \begin{pmatrix} [(2 \times 2) + (3 \times 1)] & [(2 \times 3) + (3 \times 0)] \\ [(0 \times 2) + (1 \times 1)] & [(0 \times 3) + (1 \times 0)] \end{pmatrix} \\ &= \begin{pmatrix} 7 & 6 \\ 1 & 0 \end{pmatrix} \end{aligned}$$

Therefore  $A \times B \neq B \times A$

### Learning Outcome 6: Apply Vectors in work

#### 2.2.32 Introduction to the learning outcome

This learning outcome covers; derivation of vectors in two and three dimensions and performing various operations on vectors which includes obtaining vector position and performing resolution of vectors.

#### 2.2.33 Performance Standard

8. Meaning of vector
9. Representations of vectors
10. Operations of vectors
11. Addition
12. Subtraction
13. Scalar and vector products
14. Determination of angles

#### 2.2.34 Information Sheet

##### 2.2.34.2 Definition of terms

**Scalar:** These are quantities with magnitude but no direction.

**Vector:** These are quantities with both magnitude and direction.

**Position vector:** This is a vector that originates from the origin to a given point e.g. velocity and acceleration.

### Meaning of vector

A vector is a quantity having both magnitude and direction such as force, velocity etc. A vector is also defined as a tensor of order one. A scalar has only magnitude and is completely characterized by one number.

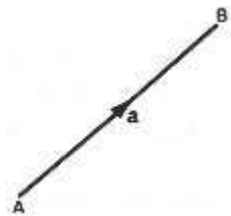
It is a tensor of order zero and temperature is an example of a scalar. A second order tensor, in a three-dimensional space, is represented by nine numbers (components).

### Representations of vectors

The vector quantity can be represented graphically by a line, drawn so that:

- iii. The length of the line denotes the magnitude of the quantity according to the stated vector scale
- iv. The direction of the line denotes the direction in which the vector quantity acts. The sense of the direction is indicated by an arrowhead.

The vector quantity AB is referred to as  $\overline{AB}$  or a.



The magnitude of the vector quantity is written  $|\overline{AB}|$  or  $|a|$  or simply AB or a.

### Operations of vectors

To add or to subtract vectors, we add or subtract the respective corresponding components.

I.e. let  $\vec{P} = (a, b)$  and  $\vec{Q} = (c, d)$

$$\text{Then } \vec{p} + \vec{q} = (a + c, b + d)$$

Let  $\vec{r} = (r_1, r_2)$  and  $\vec{S} = (s_1, s_2)$

$$=(r_1 - s_1, r_2 - s_2)$$

Example: Find

$$(\vec{P} + \vec{Q}) \quad \text{B) } (\vec{P} - \vec{Q}) \quad \text{Given } \vec{P} = (4, 5) \text{ And } \vec{Q} = (6, -1)$$

**Solution**

$$\begin{aligned} \vec{P} + \vec{Q} &= (p_1 + q_1, p_2 + q_2) \\ &= (4 + 6, 5 + -1) \\ &= (10, 4) \end{aligned}$$

$$\begin{aligned} \text{ii) } \vec{P} - \vec{Q} &= (p_1 - q_1, p_2 - q_2) \\ &= (4 - 6, 5 - (-1)) \\ &= (-2, 6) \end{aligned}$$

OR

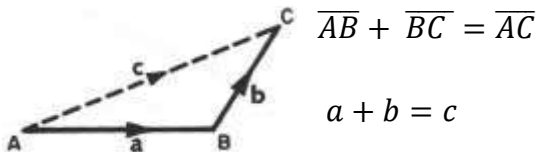
Rewrite the difference  $\vec{P} - \vec{Q}$  as the sum  $\vec{P} + (-\vec{Q})$ . To determine  $-\vec{Q}$ , we do a scalar multiplication of -1 times  $\vec{Q}$

$$\begin{aligned} -\vec{Q} &= -1 (6, -1) \\ &= (-6, 1) \end{aligned}$$

$$\text{Hence } \vec{P} + \vec{Q} = (4 - 6, 5 + 1) = (-2, 6)$$

**Addition**

The sum of two vectors,  $\vec{AB}$  and  $\vec{BC}$  is defined as the single equivalent or resultant vector  $\vec{AC}$ .



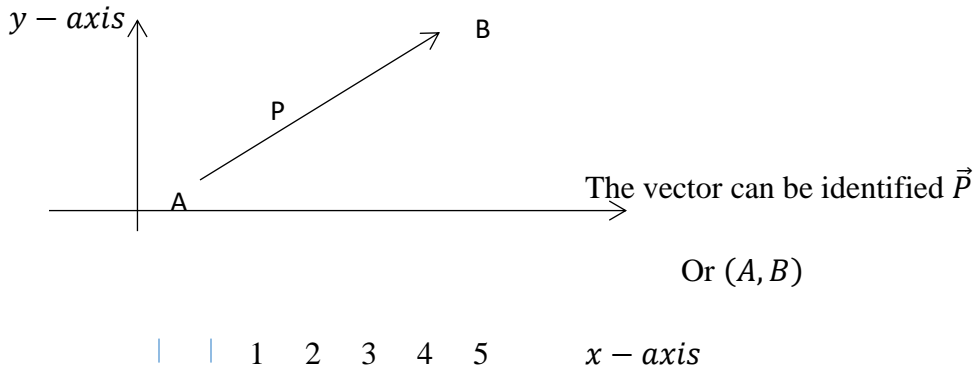
Example:

A force of 40N is acting in the direction due east represented by p and a force of 30N is acting in the direction due south represented as q, find the magnitude (r) of the vector of the two forces.

$$r^2 = p^2 + q^2 = \sqrt{(p^2 + q^2)} = \sqrt{(40^2 + 30^2)} = 50$$

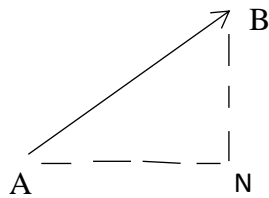
### Scalar and vector products

In the concept of two-dimensions, we can use the Cartesian planes to draw our vectors



Vector P is a 2-dimensional vector drawn with 3 units on the x-axis and 3 units on the y-axis.

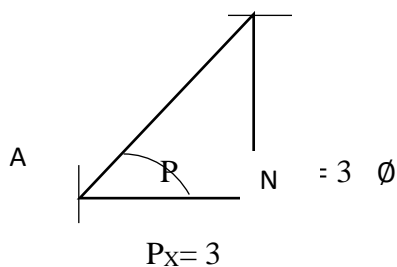
The magnitude of vector P is simply the length of vector P which we can calculate using the basic Pythagoras theorem i.e. we can denote the vector components as  $NB = 3$  and  $AN = 3$



Magnitude of P (denoted as  $|P|$ )

$$|P| = \sqrt{3^2 + 3^2} = 4.24 \text{ units}$$

Direction of a vector normally we use degrees or radians from the horizontal in an anticlockwise direction to describe direction of a vector



Where AB – Hypotenuse side

BN - Adjacent side

NB – Opposite side to angle  $\phi$

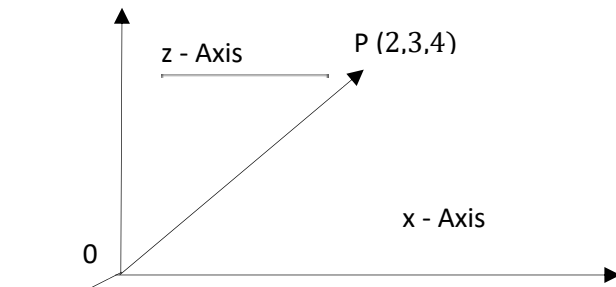
We first form a right-angled triangle by joining the ends of the vector then apply simple trigonometry.

So, we have:  $\tan\theta = \frac{3}{3} \left(\frac{\text{opposite}}{\text{adjacent}}\right) = 1$

$$\tan^{-1} 1 = 45^\circ = 0.785 \text{ radians}$$

Hence, we can describe our vector as having magnitude 4.24 units and direction  $45^\circ$  from the right horizontal axis. In three dimensional spaces, we construct three mutually perpendicular axes (commonly the x, y, z axis).

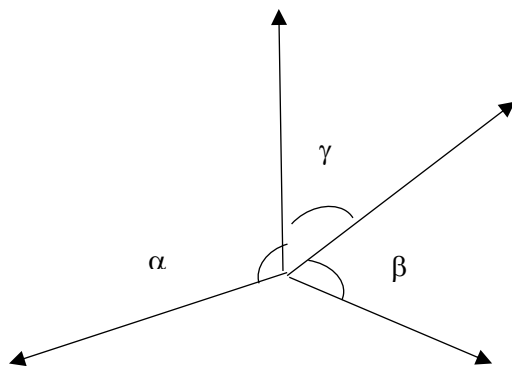
**Example:** Sketch point (2,3,4)



Just like y - Axis we can also denote three dimensional vectors using the standard unit vectors i, j, k,  $i=(1, 0, 0)$   $j=(0, 1, 0)$ ,  $k=(0, 0, 1)$  and then express the vector as sum of scalar multiples of these units vectors i.e.  $P=(P_1 P_2 P_3)= P_1i + P_2j + P_3k$

For vector  $OP_1$

$$|OP| = \sqrt{2^2 + 3^2 + 4^2} = 5.385 \text{ units}$$



$\delta$ -Angle between P and x-axis

Use scalar products to get the direction cosines.

I.e.  $p_1 = P \cdot I = 1 \times 1 \times \cos \delta$

$$p_2 = P \cdot j = 1 \times 1 \times \cos \beta$$

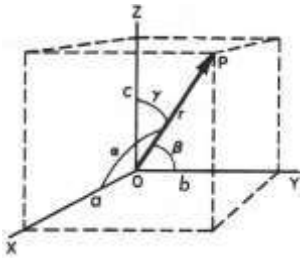
$$p_3 = P \cdot k = 1 \times 1 \times \cos \gamma$$

So, we can write a unit vector P as:

$$P = \cos \alpha i + \cos \beta j + \cos \gamma k$$

### Determination of angles

The direction of a vector in three directions is determined in angles which the vector makes with the three axes of reference.



$$\text{Let } \overline{OP} = r = ai + bj + ck$$

$$\text{Then; } \frac{a}{r} = \cos \alpha \therefore a = r \cos \alpha$$

$$\frac{b}{r} = \cos \beta \therefore b = r \cos \beta$$

$$\frac{c}{r} = \cos \gamma \therefore c = r \cos \gamma$$

Figure 33: Directional Cosines

$$\text{Also } a^2 + b^2 + c^2 = r^2$$

$$r^2 \cos^2 \alpha + r^2 \cos^2 \beta + r^2 \cos^2 \gamma = r^2$$

$$\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = 1$$

*Scalar (Dot) product of vectors*

Product of two non-zero vectors  $\vec{a}$  and  $\vec{b}$  denoted by  $\vec{a} \cdot \vec{b} = |\vec{a}| |\vec{b}| \cos \theta$

Where  $\theta$  is the angle between  $\vec{a}$  and  $\vec{b}$ .

When either  $\vec{a} = 0$  or  $\vec{b} = 0$  then  $\theta$  is not defined and in this case,  $\vec{a} \cdot \vec{b} = 0$

If both  $\vec{a}$  and  $\vec{b}$  are non-zero and yet  $\vec{a} \cdot \vec{b} = 0$ , then this implies that  $\vec{a}$  and  $\vec{b}$  are perpendicular to each other. The angle between two non-zero vectors is given by;

$$\cos \theta = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}| |\vec{B}|}$$



Or simply  $\theta = \cos^{-1} \frac{\vec{A} \cdot \vec{B}}{|\vec{A}| |\vec{B}|}$

If the  $\theta$  has not been given,

$$\vec{a} \cdot \vec{b} = (a_1 b_1 + a_2 b_2) = K \text{ (a constant).}$$

Example

Compute the product for each of the following.

$$\vec{p} = 4\mathbf{i} - 3\mathbf{j} \quad \vec{q} = 2\mathbf{i} + \mathbf{j}$$

*Solution*

$$\begin{aligned} \vec{p} \cdot \vec{q} &= (4 \times 2) + (-3 \times 1) \\ &= 8 - 3 = 5 \end{aligned}$$

$$\vec{p} = (8, 0, 3) \quad \vec{q} = (3, 2, 7)$$

*Solution*

$$\begin{aligned} \vec{p} \cdot \vec{q} &= (8 \times 3) + (0 \times 2) + (3 \times 7) \\ &= 6 + 0 + 21 \\ &= 27 \end{aligned}$$

Determine the angle between  $\vec{p} = (3, -4, -1)$  and  $(0, 5, 2)$

**Solution**

First, we need to calculate  $\vec{p} \cdot \vec{q}$  And then  $|\vec{p}|$  and  $|\vec{q}|$

$$\begin{aligned} \vec{p} \cdot \vec{q} &= (3 \times 0) + (-4 \times 5) + (-1 \times 2) \\ &= 0 + -20 - 2 \\ &= -22 \end{aligned}$$

$$|\vec{p}| = \sqrt{3^2 + (-4)^2 + (-1)^2} = \sqrt{26}$$

$$|\vec{q}| = \sqrt{0^2 + 5^2 + 2^2} = \sqrt{29}$$

$$\cos \theta = \frac{\vec{P} \cdot \vec{Q}}{|\vec{P}| |\vec{Q}|} = \frac{-22}{\sqrt{26} \sqrt{29}} = -0.8011927 =$$

$$\cos^{-1}(-0.8011927) = 143.24^\circ \text{ (2.5 radians)}$$

$$\text{Let } \vec{P} = (p_1, p_2, p_3) \text{ and } \vec{Q} = (q_1, q_2, q_3)$$

$$\text{Then } \vec{P} \times \vec{Q} = (p_2 q_3 - p_3 q_2) \mathbf{i} - (p_1 q_3 - p_3 q_1) \mathbf{j} - (p_1 q_2 - p_2 q_1) \mathbf{k}$$

### Position of vectors

Definition: A position vector is a vector that starts from the origin i.e. its origin is (0, 0, 0)

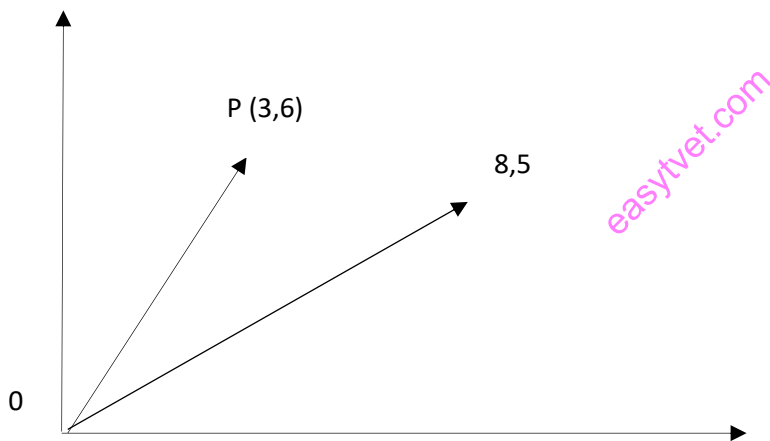


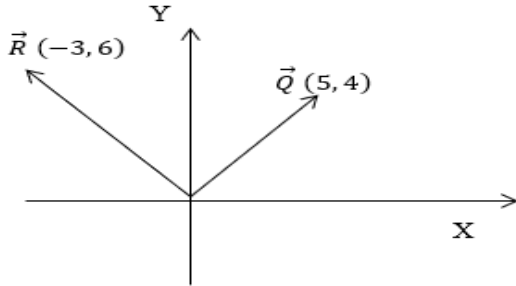
Figure 34: Position Vectors

The position vector of  $\vec{P}$  is  $\begin{pmatrix} 3 \\ 6 \end{pmatrix}$  and position vector of  $\vec{Q}$   $\begin{pmatrix} 8 \\ 5 \end{pmatrix}$

### Example 1

The position vector of  $\vec{Q}$  is  $\begin{pmatrix} 5 \\ 4 \end{pmatrix}$  and the position vector and the position vector of  $\vec{R}$   $\begin{pmatrix} -3 \\ 6 \end{pmatrix}$  is

Find the vector  $\vec{QR}$



*Solution*

$$\overrightarrow{QR} = \overrightarrow{QO} + \overrightarrow{OR}$$

NB:  $\overrightarrow{QO} = -\overrightarrow{OQ}$  (opposite direction)

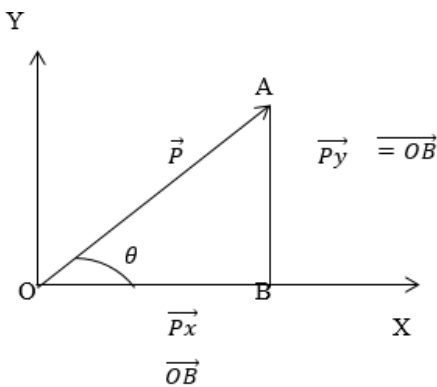
$$-\begin{pmatrix} 5 \\ 4 \end{pmatrix} + \begin{pmatrix} -3 \\ 6 \end{pmatrix} = \begin{pmatrix} -8 \\ 2 \end{pmatrix}$$

Generally,  $\overrightarrow{AB} = -a + b$  or simply  $b-a$  since from A to B, you must first move from A to the origin hence (-a) then from the origin to B.

*Performance of vector resolution*

Definition: A vector resolution is the breaking down of one vector into two or more smaller vectors. In this regard, we only discuss the rectangular components of a vector (X-component and Y component).

Thus,



The rectangular components of  $\vec{P}$  are  $\vec{P}_x$  and  $\vec{P}_y$

$$\cos\theta = \frac{OB}{OA}$$

$$OB = \vec{P} \cos\theta$$

$$\text{Recall Cosine} = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\text{But } OB = P_x$$

Hence  $P_x = \vec{P} \cos\theta$  -The magnitude of horizontal component

$$\sin\theta = \frac{AB}{OB} \left[ \sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}} \right]$$

$$AB = OA \sin\theta \text{ (but } AB = P_y)$$

Hence  $P_y = \vec{P} \sin\theta$  is the magnitude of vertical component.

### 2.2.35 Learning Activities

#### 1. Activity 1

##### Labeling Components

One of the first steps to understanding vectors is knowing what the different components are. Have your students work with partners for the first part of this activity. Each pair should create a graph that represents a vector. Their graphs should carefully represent the difference between a vector and a line, particularly because the graphs can have some similarities.

Then, have all students hang their graphs on a classroom wall, numbering each graph. Ask students to walk along the wall with their notebooks and notate the horizontal and vertical components of each of their classmates' vectors.

Once you have discussed their answers, ask each partnership to take their own graph and use colors and arrows to show how the horizontal and vertical components of their own vectors are determined.

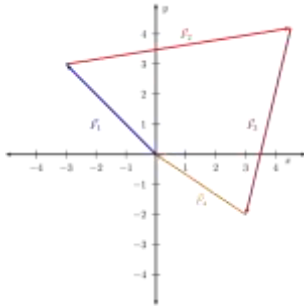
#### 2. Activity 2

To understand the principles of adding vectors by the graphical method and of adding vectors by component addition.

Two or more vectors can be added together to determine a vector sum or resultant. Two methods of adding vectors are the graphical or head-to-tail method and the trigonometric or component addition method. For each problem, vectors A, B and C are shown.

- vi. Sketch the head-to-tail addition of  $F_1, F_2, F_3$  and  $F_4$  on the empty grid; label each vector.

- vii. Draw and label the resultant (R).
- viii. Record the magnitude and direction of each component; use a + to indicate East or North; use a – to indicate a West or South.
- ix. Sum the components to determine the components of the resultant.
- x. Use the Pythagorean theorem and SOH CAH TOA to determine the magnitude and direction of R

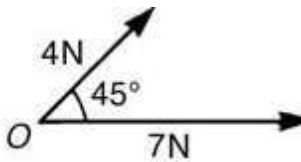


Magnitude of R =

Direction of R =

### 2.2.36 Self-Assessment

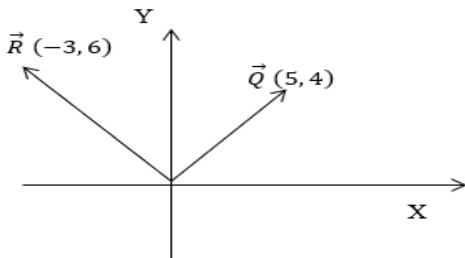
1. Calculate the resultant force of the two forces:



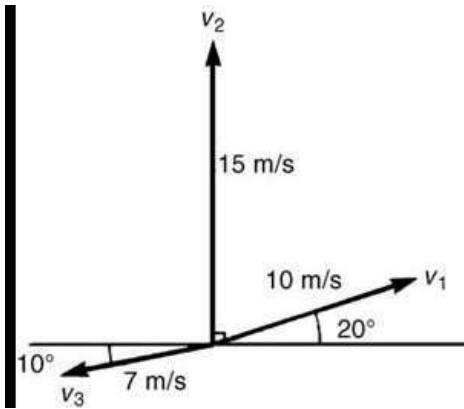
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- iii. The magnitude of the resultant of vector addition
  - iv. The direction of the resultant of vector addition
- 2 The position vector of  $\vec{Q}$  is  $\begin{pmatrix} 5 \\ 4 \end{pmatrix}$  and the position vector and the position vector of  $\vec{R}$  is  $\begin{pmatrix} -3 \\ 6 \end{pmatrix}$

Find the vector  $\vec{QR}$



3. Use a graphical method to determine the magnitude and direction of the resultant of the three velocities



### 2.2.37 Tools, Equipment, Supplies and Materials

- Calculator
- Ruler
- Black/white board
- Chalk/ board markers (Assorted)

### 2.2.38 References

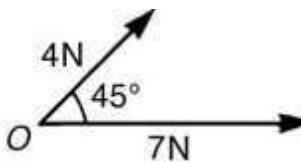
Pramod S. Joag. (2016). An introduction to vectors, vector operators and vector analysis. Delhi: Cambridge University Press.

Ray M. Bowen & C.C. Wang (2008). Introduction to vectors and tensors: Mineola: Dover Publications.

Richard E. Johnson (2010). Vector Algebra Meerut: Krishna Prakashan Media (P) Ltd.

### 2.2.39 Answers to Self-Assessment

1. Calculate the resultant force of the two forces:



Horizontal component of force,

$$H = 7\cos 0^\circ + 4\cos 45^\circ$$

$$= 7 + 2.828 = 9.828\text{N}$$

Vertical component of force,

$$V = 7\sin 0^\circ + 4\sin 45^\circ = 0 + 2.828 = 2.828$$

The magnitude of the resultant of vector addition

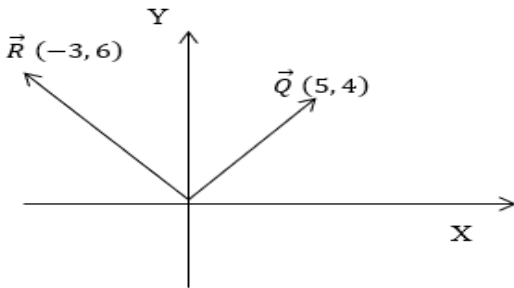
$$= \sqrt{H^2 + V^2} = \sqrt{9.828^2 + 2.828^2} = 10.23\text{N}$$

The direction of the resultant of vector addition

$$= \tan^{-1}\left(\frac{2.828}{9.828}\right) = 16.05^\circ$$

8. The position vector of  $\vec{Q}$  is  $\begin{pmatrix} 5 \\ 4 \end{pmatrix}$  and the position vector and the position vector of  $\vec{R}$   $\begin{pmatrix} -3 \\ 6 \end{pmatrix}$  is

Find the vector  $\vec{QR}$



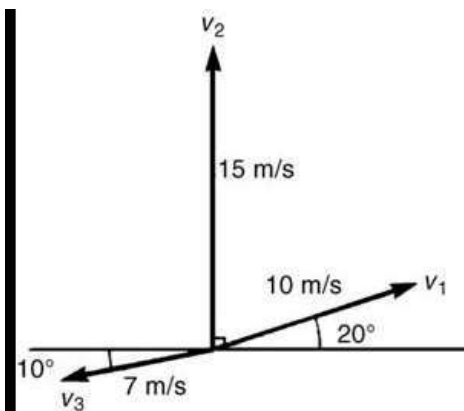
*Solution*

$$\vec{QR} = \vec{QO} + \vec{OR}$$

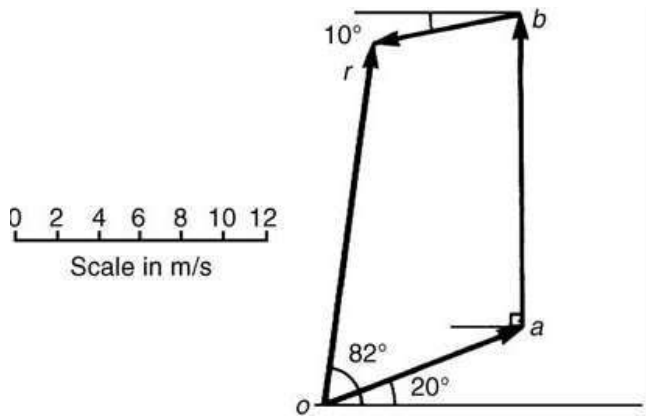
NB:  $\vec{QO} = -\vec{OQ}$  (opposite direction)

$$-\begin{pmatrix} 5 \\ 4 \end{pmatrix} + \begin{pmatrix} -3 \\ 6 \end{pmatrix} = \begin{pmatrix} -8 \\ 2 \end{pmatrix}$$

3. Use a graphical method to determine the magnitude and direction of the resultant of the three velocities



$$v_1 + v_2 + v_3 = 17.5 \text{ m/s at } 82^\circ \text{ to the horizontal}$$



### Learning Outcome 7: Collect, Organize and Interpret Statistical Data

#### 2.2.40 Introduction to the learning outcome

This learning outcome covers obtainment of mean, median, mode and standard deviation from given data, performance of calculations based on laws of probability, performance of calculation involving probability distributions, mathematical expectation sampling distributions and application of sampling distribution methods in data analysis.

#### 2.2.41 Performance Standard

7. Classification of data
  - c) Grouped data
  - d) Ungrouped data
8. Data collection
  - f) Tabulation of data
  - g) Class intervals
  - h) Class boundaries
  - i) Frequency tables
  - j) Cumulative frequency
9. Sampling



- d) Importance of sampling
  - e) Errors in sampling
  - f) Types of sampling and their limitations
10. Diagrammatic and graphical presentation of data e.g.
- f) Histograms
  - g) Frequency polygons
  - h) Bar charts
  - i) Pie charts
  - j) Cumulative frequency curves
11. Measures of central tendency
- c) Measures
  - d) Properties
12. Calculation and interpretation of mean, mode and median, variance and standard deviation

#### 2.2.42 Information Sheet

##### 2.2.42.2 *Definition of Terms*

**Mode:** This is the number which is the most repeated in a series.

**Standard deviation:** This is the amount of variation of a set of numbers. It is the square root variance.

**Variance:** This is the mean of the squared differences of the number from the mean.

#### **Classification of data**

A variable may be of two kinds:

Discrete – a variable that can be counted, or for which there is a fixed set of values.

Continuous – a variable that can be measured on a continuous scale, the result depending on the precision of the measuring instrument or the accuracy of the observer.

*Ungrouped data* can be presented diagrammatically in several ways and these include:

- (a) Pictograms, in which pictorial symbols are used to represent quantities
- (b) Horizontal bar charts, having data represented by equally spaced horizontal rectangles
- (c) Vertical bar charts, in which data are represented by equally spaced vertical rectangles

Trends in ungrouped data over equal periods of time can be presented diagrammatically by a percentage component bar chart.

*Grouped data*

When the number of members in a set is small, say ten or less, the data can be represented diagrammatically without further analysis, by means of pictograms, bar charts, percentage components bar charts or pie diagrams.

For sets having more than ten members, those members having similar values are grouped together in classes to form a frequency distribution. To assist in accurately counting members in the various classes, a tally diagram is used.

A frequency distribution is merely a table showing classes and their corresponding frequencies.

The new set of values obtained by forming a frequency distribution is called grouped data.

**Data collection**

We can use this example to define a number of terms, consider the class labelled 7.1 – 7.3

The class values stated in the table are the lower and upper limits of the class and their difference gives the class width.

The class boundaries are 0.05 below the lower class limit and 0.05 above the upper class limit.

The lower class boundary is  $7.1 - 0.05 = 7.05$

The upper class boundary is  $7.3 + 0.05 = 7.35$

The class interval is the difference between the upper and lower class boundaries.

$$\begin{aligned} \text{Class interval} &= \text{upper class boundary} - \text{lower class boundary} \\ &= 7.35 - 7.05 = 0.30 \end{aligned}$$

Where the classes are regular, the class interval can also be found by subtracting any lower class limit from the lower class limit of the following class.

The central value (mid value) of the class is the average of the upper and lower class boundaries.

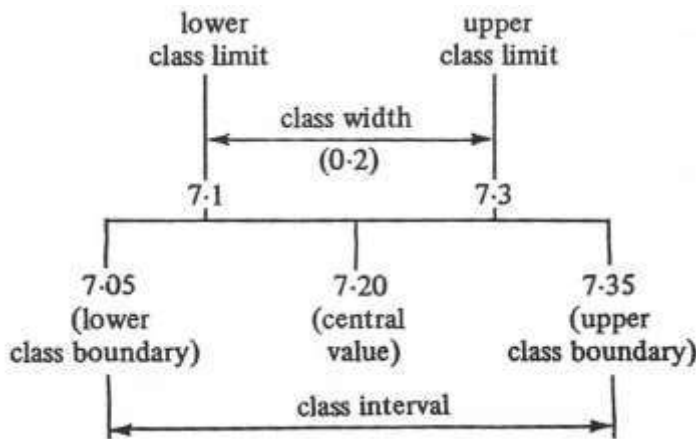


Figure 35: Class Boundaries

## Sampling

### *Performance of calculations involving use of standard normal table, sampling distribution, t-distribution and estimation*

Standard normal table (known Z table)

$$Z = \frac{x - \mu}{\alpha}$$

$X = \text{raw score}$

$\mu = \text{mean}$

$\alpha = \text{standard deviation}$

A Z found on the both tables should be used on the table provided to know the percentile and therefore compare. Note; if it is a negative then a table for negative values is used.

### *Sampling distribution*

It is also known as probability distribution and the standard deviation of this topic is known as standard error. Sampling distribution mean is equal to the mean of the population.

$$\mu_x = \mu$$

Therefore, standard error is:

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{n - 1}}$$

$$SE = \frac{\sigma}{\sqrt{n}}$$

SE Standard error

$\sigma$  = Standard deviation

$n$  = Size of population

n= size of sample

If  $fpc = 1$  from factor  $\sqrt{(N - n)/N - 1}$ , therefore standard error formula can be approximated by

$$\sqrt{(x - \alpha)/\sqrt{n}}$$

### **Distribution**

It is a type of distribution similar with the normal distribution curve but with a bit shorter and fatter tail. Therefore distribution is used because small size is small.

$$t = \frac{x - \mu}{\left(\frac{s}{\sqrt{n}}\right)}$$

Where,

$\bar{x}$  is the sample mean

$\mu$  is the population mean

s is the standard deviation

n is the size of the sample given

### **Estimation**

This is the process of identifying a value by approximating due to a certain purpose. It can be done by rounding off to the nearest whole number.

Application of sampling distribution methods in data analysis

There are three main types;

- Normal distribution; commonly used in investing, finance, science and engineering. It fully based on its mean and standard deviation.
- Binomial distribution: It is discrete, as opposed to continuous, since 1 or 0 / yes or no is a valid response.
- Chi-squared distribution

- Poisson distribution

## DIAGRAMMATIC AND GRAPHICAL PRESENTATION OF DATA

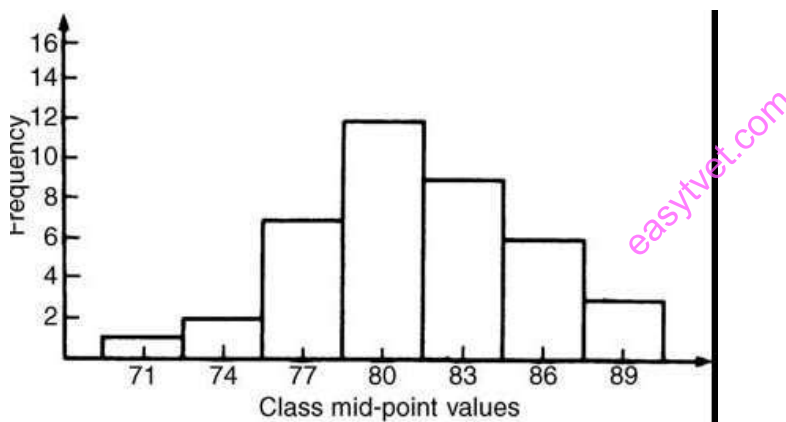
### *Histograms*

#### *Frequency histogram*

A histogram is a graphical representation of a frequency distribution, in which vertical rectangular blocks are drawn so that:

- iii. The centre of the base indicates the central value of the class
- iv. The area of the rectangle represents the class frequency

If the class intervals are regular, the frequency is then denoted by the height of the rectangle.



*Figure 36: Histogram*

#### *Frequency Polygon*

Another method of presenting grouped data diagrammatically is by using a **frequency polygon**, which is the graph produced by plotting frequency against class mid-point values and joining the coordinates with straight lines.

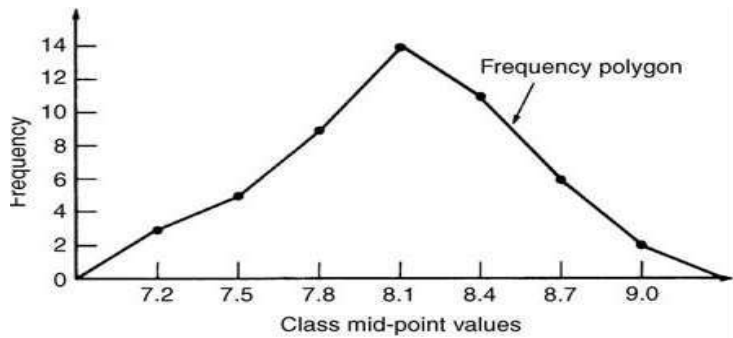


Figure 37: Frequency Polygon

A cumulative frequency distribution is a table showing the cumulative frequency for each value of upper class boundary. The cumulative frequency for a particular value of upper class boundary is obtained by adding the frequency of the class to the sum of the previous frequencies.

The curve obtained by joining the co-ordinates of cumulative frequency (vertically) against upper class boundary (horizontally) is called an **ogive** or a **cumulative frequency distribution curve**

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## MEASURES OF CENTRAL TENDENCY

A single value, which is representative of a set of values, may be used to give an indication of the general size of the members in a set, the word '**average**' often being used to indicate the single value.

The statistical term used for 'average' is the arithmetic mean or just the **mean**.

Other measures of central tendency may be used and these include the **median** and the **modal** values.

### Obtainment of mean, median, mode and standard deviation from given data

A **set** is a group of data and an individual value within the set is called a **member** of the set. Some members selected at random from a population are called a **sample**.

**Mean:** It is also known as average therefore it is addition of the number divided by the number of the numbers.

$$\text{Mean} = \frac{\sum \text{of numbers}}{\text{no of numbers}}$$

**Median:** This is the number in the middle after being arranged from the lowest to the highest number; if they are two, find the mean.

**Mode:** This is the number which is the most repeated in a series.

**Variance:** This is the mean of the squared differences of the number from the mean.

$$\text{Variance} = \sum(x_i - \mu)^2 / n$$

**Standard deviation:** This is the amount of variation of a set of numbers known as square root variance.

Example:

Determine the mean, median and mode for the set:

{2, 3, 7, 5, 5, 13, 1, 7, 4, 8, 3, 4, 3}

Thus, **mean value**,

$$\bar{x} = \frac{2+3+7+5+5+13+1+7+4+8+3+4+3}{13} = \frac{65}{13} = 5$$

Median

To obtain the median value the set is ranked, that is, placed in ascending order of magnitude, and since the set contains an odd number of members the value of the middle member is the median value.

Ranking the set gives: [1,2,3,3,3,4,4,5,5,7,7,8,13]

{1, 2, 3, 3, 3, 4, 4, 5, 5, 7, 7, 8, 13}

The middle term is the seventh member, i.e. 4, thus the **median value is 4**.

Mode

The **modal value** is the value of the most commonly occurring member and is **3**, which occurs three times, all other members on occurring once or twice.

#### 2.2.43 Learning Activities

1. As the teacher ask your students to collect 25 bottle tops and start making a histogram of their dates they forward the bottle tops. Each student has collected 25 bottle tops over the past few days. The students come to place the pennies in groups above a number line on the floor, according to the years in which the pennies were minted.

- iii. Construct a histogram of the dates of return within a week.
- iv. Ask the class to estimate the mean and standard deviation of the distribution

#### 2.2.44 Self-Assessment

1. The data given below refer to the gain of each of a batch of 40 transistors, expressed correct to the nearest whole number.

Form a frequency distribution for these data having seven classes.

81 83 87 74 76 89 82 84

86 76 77 71 86 85 87 88

84 81 80 81 73 89 82 79

81 79 78 80 85 77 84 78

83 79 80 83 82 79 80 77

- e) Calculate the range
- f) Calculate the range
- g) Construct the frequency distribution
- h) Construct the histogram

9. The frequency distribution for the value of resistance in ohms of 48 resistors is as shown.

Determine the mean value of resistance.

20.5–20.9: 3, 21.0–21.4: 10, 21.5–21.9: 11,

22.0–22.4: 13, 22.5–22.9: 9, 23.0–23.4: 2

10. Determine the standard deviation from the mean of the set of numbers: (5, 6, 8, 4, 10, 3) correct to 4 significant figures.

#### 2.2.45 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Computers with an internet connection

#### 2.2.46 References

K. A. Stroud, (2001). Engineering Mathematics, 5<sup>th</sup> Ed. Industrial Press Inc, New York.

John Bird, (2003). Engineering Mathematics, Fourth Edition. Elsevier Science, Oxford, UK

#### 2.2.47 Answers to Self-Assessment

1. The data given below refer to the gain of each of a batch of 40 transistors, expressed correct to the nearest whole number.



Form a frequency distribution for these data having seven classes.

81 83 87 74 76 89 82 84

86 76 77 71 86 85 87 88

84 81 80 81 73 89 82 79

81 79 78 80 85 77 84 78

83 79 80 83 82 79 80 77

e) Calculate the range

The value obtained by taking the value of the smallest member from that of the largest member.

Inspection of the set of data shows that,  $\text{range} = 89 - 71 = 18$

f) Construct a tally diagram

This is obtained by listing the classes in the left-hand column, and then inspecting each of the 40 members of the set in turn and allocating them to the appropriate classes by putting '1s' in the appropriate rows. Every fifth '1' allocated to the particular row is shown as an oblique line crossing the four previous '1s', to help with final counting.

| Class | Tally |
|-------|-------|
| 70-72 | 1     |
| 73-75 | 11    |
| 76-78 | 11    |
| 79-81 | 11    |
| 82-84 | 1111  |
| 85-87 | 1     |
| 88-90 | 111   |

Figure 38: Tally Diagram

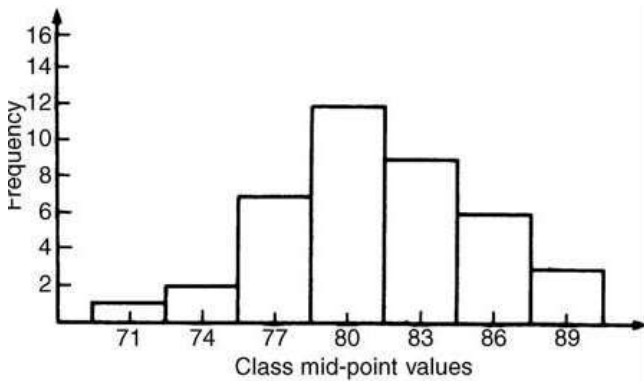
g) Construct the frequency distribution

| Class   | Class mid-point | Frequency |
|---------|-----------------|-----------|
| 70 - 72 | 71              | 1         |
| 73 - 75 | 74              | 2         |
| 76 - 78 | 77              | 7         |
| 79 - 81 | 80              | 12        |
| 82 - 84 | 83              | 9         |
| 85 - 87 | 86              | 6         |
| 88 - 90 | 89              | 3         |

Figure 39: Frequency Distribution

h) Construct the histogram

The width of the rectangles correspond to the upper class boundary values minus the lower class boundary values and the heights of the rectangles correspond to the class frequencies. The easiest way to draw a histogram is to mark the class mid-point values on the horizontal scale and draw the rectangles symmetrically about the appropriate class mid-point values and touching one another.



11. The frequency distribution for the value of resistance in ohms of 48 resistors is as shown.

Determine the mean value of resistance.

20.5–20.9: 3, 21.0–21.4: 10, 21.5–21.9: 11,

22.0–22.4: 13, 22.5–22.9: 9, 23.0–23.4: 2

The class mid-point/frequency values are:

20.7 - 3, 21.2 - 10, 21.7 - 11, 22.2 - 13, 22.7 - 9 and 23.2 - 2

For grouped data, the mean value is given by:

$$\bar{x} = \frac{\sum(fx)}{\sum f} = \frac{(20.7 \times 3) + (21.2 \times 10) + (21.7 \times 11) + (22.2 \times 13) + (22.7 \times 9) + (23.2 \times 2)}{48}$$

$$= 21.9$$

12. Determine the standard deviation from the mean of the set of numbers: (5, 6, 8, 4, 10, 3) correct to 4 significant figures.

$$\text{The arithmetic mean } \bar{x} = \frac{\sum x}{n} = \frac{5+6+8+4+10+3}{6} = 6$$

$$\text{Standard deviation } \sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

The  $(x - \bar{x})^2$  values are  $(5 - 6)^2, (6 - 6)^2, (8 - 6)^2, (4 - 6)^2, (10 - 6)^2, (3 - 6)^2$

The sum of the  $(x - \bar{x})^2$  values, i.e.

$$\begin{aligned}\sum (x - \bar{x})^2 &= 1 + 0 + 4 + 4 + 16 + 9 = 34 \\ &= \frac{\sum (x - \bar{x})^2}{n} = \frac{34}{6} = 5.6\end{aligned}$$

Since, there are 6 members in the set.

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}} = \sqrt{5.6} = 2.38$$

### **Learning Outcome 8: Apply Concepts of probability for Work**

#### 2.2.48 Introduction to the learning outcome

This learning outcome covers: Probability, Types of probability events, Laws of probability, Counting techniques, Permutation, Combination, Tree diagrams and Venn diagrams.

#### 2.2.49 Performance Standard

##### 9. Probability

##### 10. Types of probability events

- Dependent
- Independent
- Mutually exclusive

##### 11. Laws of probability

##### 12. Counting techniques

##### 13. Permutation

##### 14. Combination

##### 15. Tree diagrams

##### 16. Venn diagrams

## 2.2.50 Information Sheet

### 2.2.50.2 *Definition of terms*

#### **Probability**

Probability of something happening is the likelihood or chance of it happening. Values of probability lie between 0 and 1, where 0 represents an absolute impossibility and 1 represents an absolute certainty.

The probability of an event happening usually lies somewhere between these two extreme values and is expressed either as a proper or decimal fraction.

If  $p$  is the probability of an event happening and  $q$  is the probability of the same event not happening, then the total probability is  $p + q$  and is equal to unity, since it is an absolute certainty that the event either does or does not occur, i.e.  $p + q = 1$

The expectation,  $E$ , of an event happening is defined in general terms as the product of the probability  $p$  of an event happening and the number of attempts made,  $n$ , i.e.  $E = pn$ .

#### **TYPES OF PROBABILITY EVENTS**

##### ***Dependent event***

A dependent event is one in which the probability of an event happening affects the probability of another ever happening.

##### ***Independent event***

An independent event is one in which the probability of an event happening does not affect the probability of another event happening.

##### ***Conditional probability***

Conditional probability is concerned with the probability of say event B occurring, given that event A has already taken place. If A and B are independent events, then the fact that event A has already occurred will not affect the probability of event B. If A and B are dependent events, then event A having occurred will affect the probability of event B.

##### ***Mutually exclusive event***

Two events are known as mutually exclusive, when the occurrence of one of them excludes the occurrence of the other. I.e. in tossing of a coin the outcomes are either head or tail.

#### **Laws of probability**

### The addition law of probability

The addition law of probability is recognized by the word ‘**or**’ joining the probabilities. If  $P_A$  is the probability of event A happening and  $P_B$  is the probability of event B happening, the probability of **event A or event B** happening is given by  $P_A + P_B$  (provided events A and B are **mutually exclusive**, i.e. A and B are events which cannot occur together).

Similarly, the probability of events **A or B or C or . . . N** happening is given by

$$P_A + P_B + P_C \dots \dots \dots P_N$$

### The multiplication law of probability

The multiplication law of probability is recognized by the word ‘**and**’ joining the probabilities. If  $P_A$  is the probability of event A happening and  $P_B$  is the probability of event B happening, the probability of **event A and event B** happening is given by  $P_A \times P_B$ .

Similarly, the probability of events **A and B and C and . . . N** happening is given by:

$$P_A \times P_B \times P_C \dots \dots \dots P_N$$

### Not Mutually Exclusive Events

Consider the case where two events A and B are not mutually exclusive. The probability of that event that either A or B or both occur is given as

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

### Permutations

If n different objects are available, they can be arranged in different orders of selection. Each different ordered arrangement is called a **permutation**.

For example, permutations of the three letters X, Y and Z taken together are:

XYZ, XZY, YXZ, YZX, ZXY and ZYX

This can be expressed as  ${}^3P_3 = 6$ , the upper 3 denoting the number of items from which the arrangements are made, and the lower 3 indicating the number of items used in each arrangement.

In general,  ${}^n P_r = n(n - 1)(n - 2) \dots \dots \dots (n - r + 1)$  or  $= \frac{n!}{(n-r)!}$

### Combinations

Using three letters A, B, C we now make selections without regard to the order of the letters in each group i.e. AB is now the same as BA, etc. Each group is called a combination and  ${}^n C_r$ , where n is the total number of items and r is the number in each selection, gives the number of possible combinations. Note that AB and BA are different permutations, but are not different combinations.

## Tree Diagram

A **probability tree diagram** shows all the possible events. The first event is represented by a dot. From the dot, branches are drawn to represent all possible outcomes of the event. The probability of each outcome is written on its branch.

## Venn Diagram

A set is a collection of things. A Venn diagram uses overlapping circles or other shapes to illustrate the logical relationships between two or more sets of items. Often, they serve to graphically organize things, highlighting how the items are similar and different.

Each friend is an "element" (or "member") of the set. It is normal to use **lowercase letters** for them.

Now let's say that alex, casey, drew and hunter play **Soccer**:

$$\text{Soccer} = \{\text{alex, casey, drew, hunter}\}$$

*(It says the Set "Soccer" is made up of the elements alex, casey, drew and hunter.)*

And casey, drew and jade play **Tennis**:

$$\text{Tennis} = \{\text{casey, drew, jade}\}$$

We can put their names in two separate circles:

You can now list your friends that play **Soccer OR Tennis**.

This is called a "Union" of sets and has the special symbol **U**:

$$\text{Soccer } \mathbf{U} \text{ Tennis} = \{\text{alex, casey, drew, hunter, jade}\}$$

Not everyone is in that set ... only your friends that play Soccer or Tennis (or both).

In other words we combine the elements of the two sets.

"Intersection" is when you must be in BOTH sets.

In our case that means **they play both Soccer AND Tennis** ... which is Casey and Drew.

The special symbol for Intersection is an upside down "U" like this:  $\cap$

And this is how we write it:

$$\text{Soccer} \cap \text{Tennis} = \{\text{Casey, Drew}\}$$

### ***Difference***

You can also "subtract" one set from another.

For example, taking Soccer and subtracting Tennis means people that **play Soccer but NOT Tennis** ... which is Alex and Hunter.

And this is how we write it:

$$\text{Soccer} - \text{Tennis} = \{\text{Alex, Hunter}\}$$

### 2.2.51 Learning Activities

1. In groups of 2 have the students play the Rock, Paper and Scissors game. Play the first round:

- iii. What is the probability that your friend will throw a rock?
- iv. What is the probability that your friend will not throw a paper?

Now get a paper and pen and play 20 times and record your data.

- vii. How many times was rock thrown by the partner?
- viii. What was the probability of it being thrown?
- ix. How many times was paper thrown by the partner?
- x. What was the probability?
- xi. How many times was scissors thrown by the partner?
- xii. What was the probability?

### 2.2.52 Self-Assessment

4. Determine the probabilities of selecting at random (a) a man, and (b) a woman from a crowd containing 20 men and 33 women.
5. Find the expectation of obtaining a 4 upwards with 3 throws of a fair dice.
6. The probability of a component failing in one year due to excessive temperature is  $\frac{1}{20}$ , due to excessive vibration is  $\frac{1}{25}$  and due to excessive humidity is  $\frac{1}{50}$ . Determine the probabilities that during a one-year period component: (a) fails due to excessive temperature and excessive vibration, (b) fails due to excessive vibration or excessive humidity, and (c) will not fail because of both excessive temperature and excessive humidity.

### 2.2.53 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Computers with an internet connection

### 2.2.54 References

K. A. Stroud, (2001). Engineering Mathematics, 5<sup>th</sup> Ed. Industrial Press Inc, New York.

John Bird, (2003). Engineering Mathematics, Fourth Edition. Elsevier Science, Oxford, UK

### 2.2.55 Answers to Self-Assessment

1. Determine the probabilities of selecting at random (a) a man, and (b) a woman from a crowd containing 20 men and 33 women.

Solution

- a. The probability of selecting at random a man,  $p$ , is given by the ratio =  $\frac{\text{number of men}}{\text{number of crowd}}$

$$P = \frac{20}{20 + 33} = \frac{20}{53} = 0.3774$$

- b. The probability of selecting at random women,  $q$ , is given by the ratio =  $\frac{\text{number of women}}{\text{number of crowd}}$

$$Q = \frac{33}{20 + 33} = \frac{33}{53} = 0.6226$$

5. Find the expectation of obtaining 4 upwards with 3 throws of a fair dice.



6. The probability of a component failing in one year due to excessive temperature is  $\frac{1}{20}$ , due to excessive vibration is  $\frac{1}{25}$  and due to excessive humidity is  $\frac{1}{50}$ . Determine the probabilities that during a one-year period component: (a) fails due to excessive temperature and excessive vibration, (b) fails due to excessive vibration or excessive humidity, and (c) will not fail because of both excessive temperature and excessive humidity.

Solution

Let  $PA$  be the probability of failure due to excessive temperature, then

$$PA = \frac{1}{20} \text{ and } \overline{PA} = \frac{19}{20}$$

$\overline{PA}$  The probability of not failing.

Let  $PB$  be the probability of failure due to excessive vibration, then

$$PB = \frac{1}{25} \text{ and } \overline{PB} = \frac{24}{25}$$

Let  $PC$  be the probability of failure due to excessive humidity, then

$$PC = \frac{1}{50} \text{ and } \overline{PC} = \frac{49}{50}$$

- a. The probability of a component failing due to excessive temperature **and** excessive vibration is given by:

$$PA \times PB = \frac{1}{20} \times \frac{1}{25} = \frac{1}{500} = 0.002$$

- b. The probability of a component failing due to excessive vibration **or** excessive humidity is:

$$PB + PC = \frac{1}{25} + \frac{1}{50} = \frac{3}{50} = 0.06$$

- c. The probability that a component will not fail due to excessive temperature **and** will not fail due to excess humidity is:

$$\overline{PA} \times \overline{PC} = \frac{19}{20} \times \frac{49}{50} = \frac{931}{1000} = 0.931$$

## **Learning Outcome 9: Perform Commercial Calculation**

### 2.2.56 Introduction to the learning outcome

The learning outcome covers: Product pricing, Average sales determination, Stock turnover, Calculation of incomes, Profit and Loss calculations, Salaries,

### 2.2.57 Performance Standard

#### 9. Product pricing

#### 10. Average sales determination

#### 11. Stock turnover

#### 12. Calculation of incomes

#### 13. Profit and loss calculations

#### 14. Salaries

- Gross
- Net

#### 15. Wages

- Time rate
- Flat rate
- Overtime

- Piece rate
- Commission
- Percentage
- Bonus

#### 16. Exchange rates calculation

- Devaluation
- Revaluation

#### 2.2.58 Information Sheet

##### 2.2.58.2 *Definition of terms*

#### **Product pricing**

Price is the money that customers must pay for a product or service. In other words, price is an offer to sell for a certain amount of currency.

Pricing is the art of translating into quantitative terms the value of a product to customers at a point of time.

There are three components to the overall pricing strategy:

- Choice of a **Pricing Principle**: *Cost-Plus, Competitive, Value-Based*
- Choice of a **Price Positioning**: *Market Skimming, Neutral, Penetration*
- Choice of a **Pricing Structure**: *Unit Pricing, Tiered Pricing, Bundled Pricing, Subscriptions etc.*

#### **Average sales determination**

The selling price formula is:

$$\text{Selling Price} = \text{Cost Price} + \text{Profit Margin}$$

Cost price is the price a retailer paid for the product. And the profit margin is a percentage of the cost price.

- **Cost Price**: The price a retailer paid for the product
- **Profit Margin**: A percentage of the cost price.

#### How to Calculate Selling Price per Unit

6. Determine the total cost of all units purchased.
7. Divide the total cost by the number of units purchased to get the cost price.

8. Use the selling price formula to calculate the final price:  $\text{Selling Price} = \text{Cost Price} + \text{Profit Margin}$

### **Stock turnover**

Inventory turnover is a ratio showing how many times a company has sold and replaced inventory during a given period. A company can then divide the days in the period by the inventory turnover formula to calculate the days it takes to sell the inventory on hand.

$\text{Inventory Turnover} = \text{Sales} / \text{Average Inventory}$

### **Where:**

$\text{Average Inventory} = (\text{Beginning Inventory} + \text{Ending Inventory}) / 2$

Companies calculate inventory turnover by:

- Calculating the average inventory, which is done by dividing the sum of beginning inventory and ending inventory by two.
- Dividing sales by average inventory.

### **Profit and loss calculations**

Cost price (C.P.): This is the price at which an article is purchased.

Selling price (S.P.): This is the price at which an article is sold.

Profit or Gain: If the selling price is more than the cost price, the difference between them is the profit incurred.

**Formula:**  $\text{Profit or Gain} = \text{S.P.} - \text{C.P.}$

Loss: If the selling price is less than the cost price, the difference between them is the loss incurred.

**Formula:**  $\text{Loss} = \text{Cost price (C.P.)} - \text{Selling Price (S.P.)}$

Profit or Loss is always calculated on the cost price.

Marked price: This is the price marked as the selling price on an article, also known as the listed price.

Discount or Rebate: This is the reduction in price offered on the marked or listed price.

Below is the list of some basic formulas used in solving questions on profit and loss:

- $\text{Gain \%} = (\text{Gain} / \text{CP}) * 100$
- $\text{Loss \%} = (\text{Loss} / \text{CP}) * 100$
- $\text{SP} = [(100 + \text{Gain\%}) / 100] * \text{CP}$
- $\text{SP} = [(100 - \text{Loss \%}) / 100]*\text{CP}$

### **Salaries**

A salary is a form of payment from an employer to an employee, which may be specified in an employment contract. It is contrasted with piece wages, where each job, hour, or other unit is paid separately, rather than on a periodic basis.

#### *Gross Pay*

Gross income for an individual—also known as gross pay when it's on a paycheck—is the individual's total pay from his or her employer before taxes or other deductions. This includes income from all sources and is not limited to income received in cash; it also includes property or services received. Gross annual income is the amount of money a person earns in one year before taxes and includes income from all sources.

#### *Net Pay*

Net pay refers to the amount an employee takes home, not the amount it costs to employ them.

### **Wages**

- Time rate
- Flat rate
- Overtime
- Piece rate
- Commission
- Percentage
- Bonus

### **Exchange rates calculation**

The exchange rate is defined as the rate on the basis of which two countries involved in trade exchange marketable items or commodities. It is basically the cost of exchanging one currency for another currency.

Exchange rates fluctuate constantly throughout the week as currencies are actively traded. This pushes the price up and down, similar to other assets such as gold or stocks. Therefore, the exchange rate can be calculated as per the below-mentioned relationship: –

Exchange Rate = Money in Foreign Currency / Money in Domestic Currency

Additionally, it can also be determined as per the below-mentioned relationship: –

Exchange Rate = Money in After Exchange / Money before Exchange

### *Devaluation*

Devaluation is the deliberate downward adjustment of the value of a country's money relative to another currency, group of currencies, or currency standard. Countries that have a fixed exchange rate or semi-fixed exchange rate use this monetary policy tool. It is often confused with depreciation and is the opposite of revaluation, which refers to the readjustment of a currency's exchange rate.

Given two exchange rates in terms of a Base Currency and a Quote Currency we can calculate appreciation and depreciation between them using the percentage change calculation. Letting  $V_1$  be the starting rate and  $V_2$  the final rate.

The percentage change of the Quote Currency relative to the Base Currency is

$$\%change = \frac{(V_1 - V_2)}{V_2} \times 100$$

The percentage change of the Base Currency relative to the Quote Currency is

$$\%change = \frac{(V_2 - V_1)}{V_1} \times 100$$

A positive change is appreciation and a negative change is depreciation.

- Revaluation

A revaluation is a calculated upward adjustment to a country's official exchange rate relative to a chosen baseline. The baseline can include wage rates, the price of gold, or a foreign currency.

Revaluation is the opposite of devaluation, which is a downward adjustment of a country's official exchange rate.

## 2.2.59 Learning Activities

### Activity 1

The activity below is to enhance knowledge on taxes.

Materials:

- computer/internet
- W-2 form (pre-filled)
- 1040 tax form

Guiding Questions:

- What types of taxes do people in your community pay?
- What is the tax rate for each type of tax?
- How much of your income will go to taxes?

Procedures:

- Divide students into pairs or small groups.
- Have students determine their annual income if they work 40 hours a week 52 weeks a year at the current minimum wage rate.
- Have students fill out a 1040 tax form using a prepared W-2.
- Have students determine their income tax rate for federal and state taxes.
- Have students research what other taxes apply to their personal situation and figure out the amount.
- Have students create a slide presentation that explains the difference between their annual salary and the actual amount they are able to count as part of their budget after paying taxes.

## Activity 2

In groups of 4, have the students buy 20 biro pens at wholesale price of KShs. 10 per pen, they will spend a total cost of KShs. 2.50 per pen to advertise and on labor. If they made a total of profit of KShs. 120 from sale of the 20pens Using the template below let them fill the results.

Cost of the pen?

Profit per pen?

Selling price?

### 2.2.60 Self-Assessment

6. The market oriented pricing, there are three pricing ways, outline them?
7. Hot Pie's Bakery Supply needs to calculate the selling price for its product line of bread machines. The business purchased 20 bread machines for \$3,000.

a. Calculate the cost price

b. The cost price for each bread machine is \$150, and the business hopes to earn a 40% profit margin.

Calculate the selling price?

8. In a transaction, the profit percentage is 80% of the cost. If the cost further increases by 20% but the selling price remains the same, how much is the decrease in profit percentage?
9. A man bought two bicycles for Rs. 2500 each. If he sells one at a profit of 5%, then how much should he sell the other so that he makes a profit of 20% on the whole?

**10. A trader wants to make an investment in the exchange-traded funds traded in US markets. However, the trader lives in India and 1 INR corresponds to 0.014 USD. The trader has INR 10,000 to invest in the exchange-traded funds traded in the offshore market.**

**Help the trader determine the value of INR investment in terms of US currency.**

### 2.2.61 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books



- Computers with an internet connection

#### 2.2.62 References

K. A. Stroud, (2001). Engineering Mathematics, 5<sup>th</sup> Ed. Industrial Press Inc, New York.

John Bird, (2003). Engineering Mathematics, Fourth Edition. Elsevier Science, Oxford, UK

#### 2.2.63 Answers to Self-Assessment

4. In market oriented pricing, there are three pricing ways, outline them.

- **Price above market:** Consciously pricing your product above the competition to brand yourself as having a higher-quality or better-performing item
- **Copy market:** Selling your item at the same price as your competition to maximize profit while staying competitive
- **Price below market:** Using data as a benchmark and consciously pricing a product below competitors, to lure customers into your store over theirs

5. Hot Pie's Bakery Supply needs to calculate the selling price for its product line of bread machines. The business purchased 20 bread machines for \$3,000.

a. Calculate the cost price

**Total cost of units purchased:** \$3,000

**Number of units purchased:** 20

$$\text{Cost price:} = \frac{\$3,000}{20} = \$150$$

b. The cost price for each bread machine is \$150, and the business hopes to earn a 40% profit margin. Calculate the selling price?

$$\text{Selling Price} = \$150 + (40\% \times \$150)$$

$$\text{Selling Price} = \$150 + (0.4 \times \$150)$$

$$\text{Selling Price} = \$150 + \$60$$

$$\text{Selling Price} = \$210$$

6. In a transaction, the profit percentage is 80% of the cost. If the cost further increases by 20% but the selling price remains the same, how much is the decrease in profit percentage?

**Solution:**

Let us assume CP = Rs. 100.

Then Profit = Rs. 80 and selling price = Rs. 180.

The cost increases by 20%  $\rightarrow$  New CP = Rs. 120, SP = Rs. 180.

$$\text{Profit \%} = 60/120 * 100 = 50\%.$$

Therefore, Profit decreases by 30%.

9. A man bought two bicycles for Rs. 2500 each. If he sells one at a profit of 5%, then how much should he sell the other so that he makes a profit of 20% on the whole?

**Solution:**

Before we start, it's important to note here that it is not 15% to be added to 5% to make it a total of 20%.

Let the other profit percent be x.

Then, our equation looks like this.

$$105/100 * 2500 + [(100+x)/100] * 2500 = 120/100 * 5000 \rightarrow x = 35.$$

Hence, if he makes a profit of 35% on the second, it comes to a total of 20% profit on the whole.

- 10. A trader wants to make an investment in the exchange-traded funds traded in US markets. However, the trader lives in India and 1 INR corresponds to 0.014 USD. The trader has INR 10,000 to invest in the exchange-traded funds traded in the offshore market.**

**Help the trader determine the value of INR investment in terms of US currency.**

Determine the value of exchange in terms of US dollars.

$$\text{Money in after exchange} = \text{Exchange rate} \times \text{Money before exchange}$$

The value of exchange in terms of US dollars =  $0.014 \times 10000$

**Money in After Exchange = \$140**

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## CHAPTER 3 WORKSHOP TECHNOLOGY

Unit of learning code: ENG/CU/EI/CC/02/5

Related Unit of Competency in Occupational Standard: Perform workshop process (ENG/OS/EI/CC/02/5)

### Introduction to the unit of learning

Industrial safety: Health and safety act, safety at work (general), personal safety, workshops safety, fire safety and First aid. Bench work: tools and measuring instrument and their applications. Bench fitting and operation sequence. Sheet metal processes. Machine tool operations and processes: lathe work, milling, drilling and grinding. Joining processes: mechanical joining, riveting, shrink fitting, welding and adhesive joining. Woodwork: Nature and types of woods, methods of construction, woodworking hand tools. Wood working machines, working principles, applications, maintenance and safety aspects. Joinery and carpentry work.

### Summary of Learning Outcomes

- 1 Apply workshop safety
- 2 Use of workshop tools, Instruments and equipment's
- 3 Prepare workshop tools and instruments for an Electrical installation practical
- 4 Prepare the workshop for an Electrical practical
- 5 Store Electrical tools and materials after practical's
- 6 Troubleshoot and repair workshop tools and equipment

### 3.0 Learning Outcome 1: Apply workshop safety

#### 3.1.1 Introduction to the learning outcome

All workshops and stores must be under the direct control of a supervisor, who is responsible for ensuring they are maintained and used in a safe and healthy manner. Only those authorised to do so may enter or work in workshops or stores, and must comply with the requirements of the supervisor whilst in that area.

All persons using workshops and stores should apply good housekeeping practices, wear appropriate clothing and footwear, and use the workshop or store only for its intended purpose.

A tidy workplace makes it easier to spot and avoid hazards, and does not interfere with normal work operations. Good housekeeping is fundamental to workshop safety management, and the time allocated to a job must include cleaning up afterwards. This applies to both individual and shared areas.

Personal items, food, drink or cigarettes are not to be taken into workshops and stores, unless a clean work-free area has been set aside for this purpose. Where necessary, lockers should be provided and used.

The store or workshop must be suited to the proposed task. The supervisor shall make the decision as to what tasks are appropriate for each situation.

### 3.1.2 Performance Standard

#### 1.1 Meaning of PPE

- Standard operating procedure in PPE

#### 1.2 Workshop rules

#### 1.3 Electrical hazards e.g.

- Electric shock.

#### 1.4 Fire

- Classes of fire
- Causes of fire
- Various methods of fire extinguishing

### 3.1.3 Information Sheet

#### ➤ Meaning of PPE

It is protective clothing helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection. The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter. Protective equipment may be worn for job-related occupational safety and health purposes, as well as for sports and other recreational activities. "Protective clothing" is applied to traditional categories of clothing, and "protective gear" applies to items such as pads, guards, shields, or masks, and others. PPE suits can be similar in appearance to a cleanroom suit.

The purpose of personal protective equipment is to reduce employee exposure to hazards when engineering controls and administrative controls are not feasible or effective to reduce these risks to acceptable levels. PPE is needed when there are hazards present. PPE has the

serious limitation that it does not eliminate the hazard at the source and may result in employees being exposed to the hazard if the equipment fails.

Any item of PPE imposes a barrier between the wearer/user and the working environment. This can create additional strains on the wearer; impair their ability to carry out their work and create significant levels of discomfort. Any of these can discourage wearers from using PPE correctly, therefore placing them at risk of injury, ill-health or, under extreme circumstances, death. Good ergonomic design can help to minimize these barriers and can therefore help to ensure safe and healthy working conditions through the correct use of PPE.

- **Standard operating procedure in PPE**

This standard operating procedure incorporates the requirements for use of Personal Protective Equipment (PPE) for project staff, co-operators, volunteers, contractors, and those under the project's operational control.

PPE listed in this SOP shall be used to provide protection and safety necessary for those participating in a project activity with PPE requirements. Additional information on the purpose and type of PPE may be available through the SOP for that activity.

**Roles and responsibilities**

*Projects need to tailor the Roles/Responsibilities based on their staffing level*

Project Manager (PM) is responsible for the overall safety of the project staff and those participating in a project activity and must provide the appropriate PPE for those activities.

Project Safety Officer (PSO) is responsible for issuing project PPE, for training project staff on the proper use and care of the PPE, and to ensure compliance with this SOP.

Supervisor is responsible for ensuring project staff and others participating in a project activity are properly wearing their issued PPE. After temporarily issuing the appropriate PPE to non-project personnel, train them on how to use the PPE and retrieve the PPE upon completion of the activity.

Project Staff is responsible for properly wearing their issued PPE for that activity. They must also properly maintain their issued PPE and when needed request a new PPE to replace worn out or damaged PPE. They will assist the Supervisor when non-project people are participating in an activity requiring specific PPE.

Others participating in the activity must be trained in the proper use of the assigned PPE and wear it properly when directed by project staff.

### **Training**

The PSO or Supervisory staff will train project employees on the use and care of the PPE.

### **PPE selection**

PPE shall be provided, used, and maintained wherever hazards exist (e.g., processing, environmental, chemical, mechanical) or are encountered in a manner capable of causing injury or impairment in the function of any part of the body. Injury can occur through absorption, inhalation, or physical contact with these hazards. The designated PPE person shall set a good example by donning PPE and following Program policy. The following provides guidelines for hazard assessment and PPE selection.

**Eye and face protection.** Appropriate eye or face protection shall be worn if exposures to potentially injurious hazards exist (e.g., flying particles, liquid chemicals, corrosives, chemical gases, vapors, UV rays). All eyewear shall provide:

- eye and side protection (detachable or permanent)
- protective devices to be worn over prescription eyewear, if needed
- a proper and comfortable fit.

### **Foot hazards**

1 OSHA requires that staff wear protective footwear if the potential for foot injuries exist, including exposure to:

- compression, squeezing, smashing, falling, or rolling objects
- electrical hazards
- slipping
- chemicals
- temperature extremes
- repeated wetness which may result in fungal infections
- puncturing from objects which may pierce the sole of footwear

2. Engineering and work-practice solutions shall be utilized, including wearing footwear correctly (fully laced, etc.) to receive maximum protection. The Program shall prohibit the use of sandals or open shoes.

## **Hand and body protection**

1. Glove manufacturer specification charts provide guidance in selecting proper PPE. Appropriate hand and body PPE shall be worn when potential hazards exist, including exposure to:
  - cuts and punctures—severe cuts and lacerations, abrasions or punctures from tools, machines or from handling sharp objects
  - thermal exposure—caused by extreme cold or heat or hot work
  - blood borne pathogens—caused by first-aid or clean-up of blood, body fluids, or other infectious agents.
  - chemical exposure—skin contact from working with chemicals
  - repetitive motion disorders—caused by computer use or jobs requiring repetitive motion may cause carpal tunnel syndrome
  - entanglement—caused from wearing gloves, clothing, or jewelry near moving equipment
  
2. Potential engineering and work-practice solutions may include:
  - machine guards—protects against cuts, punctures, abrasion, and chafing
  - job rotation—protects against repetitive motion hazards
  - good housekeeping and clean-up—protects against chemical and blood borne hazards
  - workstation design—protects against repetitive motions and provides accident prevention
  - evaluating waste prior to handling—aids staff in determining appropriate PPE and process method
  - splash guards—protects against chemical contact with skin or eyes

**Head protection** Head protection (e.g., hard hat) shall be worn if potential for injury from falling objects exist. All head protection shall:



Be used according to manufacturer's instructions

Not be altered in any way include bump caps as an appropriate alternative (if exposure to scalp injuries exist)

**Hearing protection** Facility staff shall wear hearing protection when exposed to noise levels in excess of 85 dB (A) for an eight-hour time-weighted average.

**Respiratory protection** Site specific ventilation or exhaust systems are effective engineering control tools.

➤ **Workshop rules**

Before you can use equipment and machines or attempt practical work in a workshop you must understand basic safety rules. These rules will help keep you and others safe in the workshop.

1. Always listen carefully to the teacher and follow instructions.
2. Do not run in the workshop, you could 'bump' into another trainee and cause an accident.
3. Know where the emergency stop buttons are positioned in the workshop. If you see an accident at the other side of the workshop you can use the emergency stop button to turn off all electrical power to machines.
4. Always wear an apron as it will protect your clothes and hold loose clothing such as ties in place.
5. Wear good strong shoes. Training shoes are not suitable.
6. When attempting practical work all stools should be put away.
7. Bags should not be brought into a workshop as people can trip over them.
8. When learning how to use a machine, listen very carefully to all the instructions given by the teacher. Ask questions, especially if you do not fully understand.
9. Do not use a machine if you have not been shown how to operate it safely by the teacher.
10. Always be patient, never rush in the workshop.
11. Always use a guard when working on a machine.
12. Keep hands away from moving/rotating machinery.
13. Use hand tools carefully, keeping both hands behind the cutting edge.
14. Report any damage to machines/equipment as this could cause an accident.

➤ **Electrical hazards**

An electrical hazard is one of the most dangerous threats workers can face. It's estimated almost five percent of all workplace fatalities result from electrocution.

**Electrical shock**

An electric shock happens when an electric current passes through your body. This can burn both internal and external tissue and cause organ damage.

A range of things can cause an electric shock, including:

- power lines
- lightning
- electric machinery
- electric weapons, such as Tasers
- household appliances
- electrical outlets

While shocks from household appliances are usually less severe, they can quickly become more serious if a child chews on an electric cord or puts their mouth on an outlet.

Aside from the source of the shock, several other factors affect how serious an electric shock is, including:

- voltage
- length of time in contact with the source
- overall health
- electricity's path through your body
- type of current (an alternating current is often more harmful than a direct current because it causes muscle spasms that make it harder to drop the source of electricity)

If you or someone else has been shocked, you may not need emergency treatment, but you should still see a doctor as soon as possible. Internal damage from electric shocks is often hard to detect without a thorough medical exam.

## Effects of electric shock

The symptoms of an electric shock depend on how severe it is.

Potential symptoms of an electric shock include:

- loss of consciousness
- muscle spasms
- numbness or tingling
- breathing problems
- headache
- problems with vision or hearing
- burns
- seizures
- irregular heartbeat

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Electric shocks can also cause compartment syndrome. This happens when muscle damage causes your limbs to swell. In turn, this can compress arteries, leading to serious health problems. Compartment syndrome might not be noticeable immediately after the shock, so keep an eye on your arms and legs following a shock.

### ➤ **Electric Fire**

- Most electrical fires are caused by faulty electrical outlets and old, outdated appliances. Other fires are started by faults in appliance cords, receptacles and switches. Never use an appliance with a worn or frayed cord, which can send heat onto combustible surfaces like floors, curtains, and rugs that can start a fire.

- **Classes of fire**

There are 6 different classes of fire, and each should be attacked in a different way.

Class A (Solids)

Class A fires are fires involving solids. This type of fire could be paper and cardboard, common in offices and manufacturing. It could be furniture, or fixtures and fittings. It could even be the structure of the building.

This is one of the most common types of fire because solids are the most common type of fuel and one that is hard to eliminate. Good housekeeping should help to keep materials like packaging and waste reduced, minimizing risks. Water extinguisher is one of the most popular types of extinguishers used class A fire. It can handle most fires involving solids.

### **Class B (Liquids)**

Class B fires are fires involving liquids. Many of the fluids, liquids and chemicals used in workplaces can be flammable or explosive. Like cleaning fluids, solvents, fuels, inks, adhesives and paints.

According to statistics, in 2010/11 flammable liquids accounted for only 2% of fires, but a massive 21% of fatalities. These fires are rare but more deadly than other types of fire. So how can you protect yourself?

Make sure you know what flammable liquids are used in your workplace, and carry out a Control of Substances Hazardous to Health' (COSHH) assessment. Control of Substances Hazardous to Health assessments are a legal requirement, for any hazardous substances. This about safe storage and use of these substances, keep them in labeled containers and away from sources of ignition.

Should a class B fire ignite, foam or powder extinguishers are the best types of extinguishers to attack this type of fire.

Give examples of foam extinguishers

### **Class C (Gases)**

Class C fires are fires involving gases. This could be natural gas, Liquefied petroleum gas (LPG) or other types of gases forming a flammable or explosive atmosphere.

Work with gas is dangerous, and increases fire risk. Keep stored gases in sealed containers in a safe storage area, and ensure that gas work is carried out by competent persons.

While extinguishers can be used on class C gas fires, the only safe method to attack this type of fire is to shut off the gas supply. The best type of extinguisher to put out the fire when the supply of gas is off is a dry powder extinguisher

### **Class D (Metals)**

Metals are not often thought of as a combustible material, some types of metal can be, like sodium. Metals are also good conductors, helping a fire spread. All metals will soften and melt at high temperature, which can be a big problem when metal joists and columns are present in a fire as structural elements.

Water can actually act as an accelerate on metal fires, so how would you tackle a class D fire? There are dry powder extinguishers developed to tackle metal fires. The powder inside the extinguisher may vary depending on the type of metal risk it is designed for. Small metal fires can sometimes be smothered with dry earth or sand.

### **Electrical Fires**

This is not strictly a class (class E) of fire, because electricity is more or a source of ignition than a fuel. However, fires in live electrical equipment are an additional hazard. You don't want to be using water, or any other conductor as that could be fatal.

*Electrical fires are not given their own full class, as they can fall into any of the classifications. After all it is not the electricity burning but surrounding material that has been set alight by the electric current.*

### **To avoid electric fire;**

Making sure electrical equipment and installations are installed correctly, and inspected and maintained, will help to reduce the risk of this type of fire.

While you shouldn't use water to attack an electrical fire, you can use other types of fire extinguishers. Like carbon dioxide, and dry powder in low voltage situations. Always turn off the power supply if you can.

### **Class F (Cooking Fats & Oils)**

Deep fat frying and spillages of flammable oils near to heat sources in kitchens can result in a class F fire.

Never leave food or frying equipment unattended during use. The only type of fire extinguisher approved for use on cooking oils and fats is the wet chemical extinguisher. For small class F fires, you could also use a fire blanket.

### **➤ Causes of fire**

A house can easily catch fire from the misuse of appliances and heating equipment to smoking in bedrooms.

However you can take measures to avoid fire in home and ensure the safety of your family. Below are some of the most common causes of house fires, and some tips to take precautions.

### **1. Cooking equipment**

Pots and pans can overheat and cause a fire very easily if the person cooking gets distracted and leaves cooking unattended. Always stay in the room, or ask someone to watch your food, when cooking on hotplates.

### **2. Heating**

Keep portable heaters at least one metre away from anything that could easily catch fire such as furniture, curtains, laundry, clothes and even yourself. If you have a furnace, get it inspected once a year to make sure it is working to safety standards.

### **3. Smoking in bedrooms**

Bedrooms are best to be kept off limits for smoking. A cigarette that is not put out properly can cause a flame, as the butt may stay a lit for a few hours. It could burst into flames if it came into contact with flammable materials, such as furniture.

### **4. Electrical equipment**

An electrical appliance, such as a toaster can start a fire if it is faulty or has a frayed cord. A power point that is overloaded with double adapter plugs can cause a fire from an overuse of electricity. A power point extension cord can also be a fire hazard if not used appropriately. Double check the appliances and power points in your home.

### **5. Candles**

Candles look and smell pretty, but if left unattended they can cause a room to easily burst into flames. Keep candles away from any obviously flammable items such as books and tissue boxes. Always blow a candle out before leaving a room.

### **6. Curious children**

Kids can cause a fire out of curiosity, to see what would happen if they set fire to an object. Keep any matches or lighters out of reach of children, to avoid any curiosity turned disaster. Install a smoke alarm in your child's room and practice a home escape plan with your children and family in case there was a fire.

### **7. Faulty wiring**

Homes with inadequate wiring can cause fires from electrical hazards. Some signs to see if you've bad wiring are:

1. Lights dim if you use another appliance;
2. For an appliance to work, you have to disconnect another;
3. Fuses blow or trip the circuit frequently.
4. Have a licensed electrician come and inspect your house, or contact your landlord if you have any of the above occurrences.

## **8. Barbeques**

Barbeques are great for an outdoor meal, but should always be used away from the home, tablecloths or any plants and tree branches. Keep BBQs regularly maintained and cleaned with soapy water and clean any removable parts. Check the gas bottle for any leaks before you use it each time.

## **9. Flammable liquids**

If you have any flammable liquids in the home or garage such as petrol, kerosene or methylated spirits, keep them away from heat sources and check the label before storing. Be careful when pouring these liquids.

## **10. Lighting**

Lamp shades and light fittings can build up heat if they are very close to light globes. Check around the house to make sure. Lamp bases can become a hazard if they are able to be knocked over easily, and so should be removed if they are. Check that down lights is insulated from wood panelling or ceiling timbers.

The above tips are a good guide to avoiding a fire in your home. However it's a good idea to protect yourself with adequate home insurance cover to ensure you are covered in the unlikely event a fire were to happen

## **Various methods of fire extinguishing**

If the three parts of the 'fire triangle' are kept in mind, extinguishing a small blaze should be a matter of common sense. The principles of fire extinction state that a fire will be put out if one of the three elements are removed, and this can be done using three different approaches, as detailed below.

### **Cooling**

Removing the heat is one of the most effective methods of fire extinction available, which is why water is a popular extinguishing material. The fire will go out so long as the heat generated by the fire is less than that which is absorbed by the water.

Remember: water is not an appropriate extinguishing material to use on electrical fires, as well as those caused by cooking oils/fats or other flammable liquids.

### **Starving**

While cooling removes the heat/ignition element of the 'fire triangle', starving the blaze of its fuel source approaches extinction from a different angle. A raging fire will burn itself out if it runs out of

flammable materials, such as a bonfire out in the open that isn't in contact with any other wood or dry grass. Similarly, a gas fire will immediately extinguish if the gas supply is cut off – you only have to look at a gas stove or Bunsen burner to see that.

### **Smothering**

As the other key component present in the chemical reaction that causes combustion, removing oxygen from the equation is the final way of extinguishing a fire. For example, smothering a frying pan blaze with a fire blanket reduces the oxygen to below the 16% required to react, while covering a candle with a glass will snuff it out in a vacuum.

Smothering is a technique that is mostly applicable to solid fuel fires, although some materials may contain enough oxygen within their own chemical makeup to keep the blaze burning.

### ➤ **First Aid**

If the person has been injured by an electrical shock, Electrical shocks always need emergency medical attention even if the person seems to be fine afterward.

The following methods/procedures may be used to rescue the affected person

### **Separate the Person from Current's Source**

To turn off power:

- Unplug an appliance if plug is undamaged or shut off power via circuit breaker, fuse box, or outside switch.

If you can't turn off power:

- Stand on something dry and non-conductive, such as dry newspapers, telephone book, or wooden board.
- Try to separate the person from current using non-conductive object such as wooden or plastic broom handle, chair, or rubber doormat.

If high voltage lines are involved:

- The local power company must shut them off.
- Do not try to separate the person from current if you feel a tingling sensation in your legs and lower body. Hop on one foot to a safe place where you can wait for lines to be disconnected.
- If a power line falls on a car, instruct the passengers to stay inside unless explosion or fire threatens.

### **1. Is Cardiopulmonary resuscitation (CPR) if Necessary**

When you can safely touch the person, do CPR if the person is not breathing or does not have a pulse.

- For a child, start CPR for children
- For an adult, start adult CPR.



## 2. Check for Other Injuries

- If the person is bleeding, apply pressure and elevate the wound if it's in an arm or leg.
- There may be a fracture if the shock caused the person to fall.

### **For All Burns:**

#### **1. Stop Burning Immediately**

- Put out fire or stop the person's contact with hot liquid, steam, or other material.
- Help the person "stop, drop, and roll" to smother flames.
- Remove smoldering material from the person.
- Remove hot or burned clothing. If clothing sticks to skin, cut or tear around it.

#### **2. Remove Constrictive Clothing Immediately**

- Take off jewelry, belts, and tight clothing. Burns can swell quickly.

Then take the following steps:

### **For First-Degree Burns (Affecting Top Layer of Skin)**

#### Cool Burn

- Hold burned skin under cool (not cold) running water or immerse in cool water until the pain subsides.
- Use compresses if running water isn't available.

#### Protect Burn

- Cover with sterile, non-adhesive bandage or clean cloth.
- Do not apply butter, oil, lotions, or creams (especially if they contain fragrance). Apply a petroleum-based ointment two to three times per day.

#### Treat Pain

Give over-the-counter pain reliever such as acetaminophen (Panadol, Tylenol), ibuprofen (Advil, Motrin, Nuprin), or naproxen (Aleve, Naprosyn).

## When to See a Doctor

Seek medical help if:

- You see signs of infection, like increased pain, redness, swelling, fever, or oozing.
- The person needs tetanus or booster shot, depending on date of last injection. Tetanus booster should be given every 10 years.
- The burn blister is larger than two inches or oozes.
- Redness and pain last more than a few hours.
- The pain gets worse.
- The hands, feet, face, or genitals are burned.

## Follow Up

- The doctor will examine the burn and may prescribe antibiotics and pain medication.

### 4. Wait for 911 to Arrive

### 5. Follow Up

- A doctor will check the person for burns, fractures, dislocations, and other injuries.
- An ECG, blood tests, urine test, CT scan, or MRI may be necessary.
- The person may be admitted to the hospital or a burn center.

### 3.1.4 Learning Activities

**While working in busy production line in textile industry, fire erupts from one of the faulty electrical equipment. The fire gets contained but one of the workers gets minor burns on his left leg. Perform the following to relieve him from a lot of pain.**

1. Cool down the burn. After holding the burn under cool, running water, apply cool, wet compresses until the pain subsides.
2. Remove tight items, such as rings, from the burned area. Be gentle, but move quickly before swelling starts.
3. Avoid breaking blisters. Blisters with fluid protect the area from infection. If a blister breaks, clean the area and gently apply an antibiotic ointment.

4. Apply a moisturizing lotion, such as one with aloe vera. After the burned area has been cooled, apply a lotion to provide relief and to keep the area from drying out.
5. Loosely bandage the burn. Use sterile gauze. Avoid fluffy cotton that could shed and get stuck to the healing area. Also avoid putting too much pressure on the burned skin.
6. Take an over-the-counter pain reliever if necessary.  
Consider acetaminophen (Tylenol), ibuprofen (Advil), or naproxen (Aleve).

### **3.1.5 Self-Assessment**

1. How should PPE be stored?
2. Can PPE be shared, reused, or altered?
3. How do you clean lead-contaminated clothes?
4. **When Performing Cardio Pulmonary Resuscitation By You On An Adult, The Correct Ratio Of Compressions To Breaths Is?**
5. **How Do You Check For A Response To Determine Whether Someone Is Unconscious?**
6. **What Is The Very First Thing You Should Do When You Arrive At An Incident Scene?**
7. **How Do You Check For A Response To Determine Whether Someone Is Unconscious?**
8. **When Providing First Aid To An Unconscious Breathing Casualty, How Would You Position Them?**
9. **When Using A Defibrillator, How Do You Know Where To Place The Pads?**
10. **What Is The Best Way To Stop External Blood Loss?**

### **3.1.6 Tools, Equipment, Supplies and Materials**

- Pliers
- Hacksaws
- Hammer
- Spirit levels
- Phase Tester
- Side cutters

### **3.1.7 References**

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### 3.1.8 Answers to self-assessment

1. While some workplaces will have PPE that is required on a daily basis or worn at all times, other personal protective equipment should be safely stored. The storage of personal protective equipment is almost as important as having it on hand, and an obligation set forth by OSHA, specifically requiring that PPE must be “maintained in a sanitary and reliable condition.”
2. In many instances PPE is assigned to specific individual, and it is important to train workers on different types of personal protective equipment and what that means for sharing or reusing them. When employers purchase items specific to the employer (such as proper fitting boots), they should be assigned to that worker and not shared. On the other hand, items like safety glasses can be shared among a few employees if disinfected properly. Other pieces of equipment that can be shared among others after disinfection includes hard hats, safety vests, etc. For workplaces like hospitals, some gowns are meant to be washed, disinfected, and ready to use again.
3. Through the course of day to day work, clothes get dirty. For most people, this just means they have to toss them in the washing machine and they are ready to go. When clothes are contaminated with potentially dangerous materials, such as lead, however, it requires specialized action. As an employer, it is important to ensure that the clothes that are contaminated with lead are properly washed to help ensure not only employees are safe, but the environment as well.
4. 30 Compressions and 2 Breaths.
5. Checking for a response is part of the primary survey. You should check for a response by shouting at the victim to see if they are reusable. If this does not work, a gentle tap on the shoulders can be used.
6. The first thing you should do is identify and manage any hazards to yourself or bystanders. Your safety is the most important priority!

7. Checking for a response is part of the primary survey. You should check for a response by shouting at the victim to see if they are reusable. If this does not work, a gentle tap on the shoulders can be used.
8. You should place all unconscious but breathing casualties into the recovery position (on their side with their head tilted back).
9. Look at the pads! They will have a diagram indicating exactly where on the chest they should be placed.
10. The best way to stop external blood loss is by applying direct pressure over the wound. Elevation can also help slow bleeding from a limb.

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## Learning Outcome 2: Use of workshop tools, Instruments and equipments

### 3.2.1 Introduction to the learning outcome

The Occupational Safety and Health Administration states that most injuries on construction sites involve excavation cave-ins, **power tool accidents**, falls, electrical hazards, and exposure to potentially dangerous materials

Working with power tools, you can get an electric shock, lose a finger, lose an eye, or go deaf. It's especially dangerous to use a tool that's defective, that's been modified, or that's not designed for the job. Of course, you can also get injured if you use any tool carelessly.

### 3.2.1 Performance Standard

- Meaning of workshop tools, instruments and equipments
- Classification of workshop tools and equipments
- Uses of workshop tools, Instruments and equipments

Care and Maintenance of workshop tools and Instruments

### 3.2.3 Information Sheet

#### 3 Meaning of workshop tools, instruments and equipments

##### Drilling Machine

A drilling machine is a device used to cut holes into or through metal, wood, or other hard surface. This device is normally made of a tapered shank rotated by a motor or by hand (manually). Most drilling machines are made of hard elements like diamond or steel

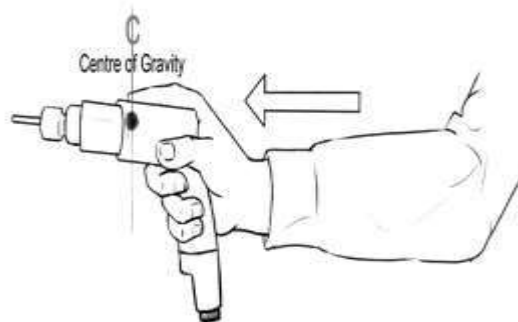
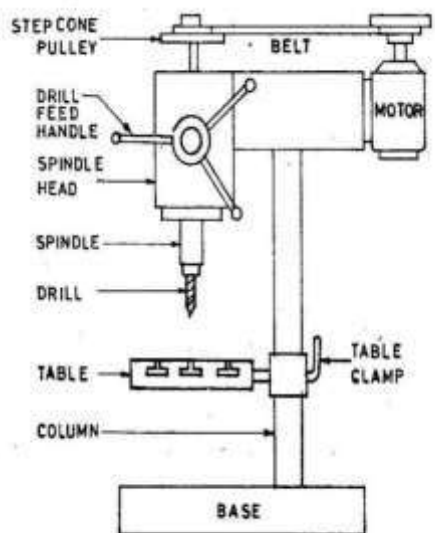


Fig.

*Figure 40 Drilling machine*

### **General Precautions for drilling machine**

- Lubrication is important to remove heat and friction.
- Machines should be cleaned after use
- Chips should be removed using brush.
- T-slots, grooves, spindles sleeves, belts, pulley should be cleaned.
- Machines should be lightly oiled to prevent from rusting

### **Safety Precautions**

- Do not support the work piece by hand – use work holding device.
- Use brush to clean the chip
- No adjustments while the machine is operating
- Ensure for the cutting tools running straight before starting the operation.
- Ease the feed if drill breaks inside the work piece.
- Do not wear loose or baggy clothing, ties, jewelry, or sandals. If you have long hair, tie it back or wear a cap — especially when drilling
- Wear eye protection when sawing and drilling. Safety glasses or goggles are inexpensive and available at any hardware store.
- Do not hold your finger on the switch button while carrying a plugged-in tool — it may start accidentally.
- Grip all tools firmly.
- Be sure to work at a safe distance from others.
- Do not use electric power tools in wet or damp locations.
- Never carry a power tool by its cord.

Never leave a running power tool unattended.

### **Grinding machine**

The grinding machine consists of a bed with a fixture to guide and hold the work piece, and a power-driven grinding wheel spinning at the required speed. The speed is determined by the wheel's diameter and manufacturer's rating. The user can control the grinding head to travel across a fixed work piece, or the work piece can be moved while the grind head stays in a fixed position.

### **Safety precautions:**

Grinding machines are used daily in a machine shop. To avoid injuries follow the safety precautions listed below.

- Wear goggles for all grinding machine operations.
- Check grinding wheels for cracks before mounting.
- Never operate grinding wheels at speeds in excess of the recommended speed.
- Never adjust the work piece or work mounting devices when the machine is operating.
- Do not exceed recommended depth of cut for the grinding wheel or machine.
- Remove work piece from grinding wheel before turning machine off.
- Use proper wheel guards on all grinding machines.
- On bench grinders, adjust tool rest 1/16 to 1/8 inch from the wheel.

### **Welding Machine:**

Welding is joining metal parts (usually) together by heating the surfaces to the point of melting with a blowpipe, electric arc, or other means, and uniting them by pressing, hammering, etc.

Two popular welding types:

Arc Welding and Gas Welding

### **General welding Precautions**

- Construction personnel that is welding should be properly trained and qualified
- Inspect work area for fire hazards before welding



- Make provisions for ventilation before welding
  - Compressed gas cylinders should always be secured in an upright position when not in use and handled with extreme care
  - Gas cylinders should be stored at least 20 feet away from flammable materials and heat sources
  - Oxygen cylinders should be stored at least 20 feet away from gas cylinders and combustible materials.
  - When not possible, use a 5 feet tall noncombustible barrier with a 30 min. fire-resistance rating or better.
- **Shearing machine :**

*A shearing machine is an industrial machine that cuts metal. An industrial shearing machine generally presses blades down into metal sheets to punch out shapes. These shapes may be the desired end product or they may be the waste product. While shearing metal sheets is most common, other metallic objects may be processed in one of these machines.*



Figure 41 power shearing machine

### **Safety Precautions**

- Bench shears must be securely fastened to a bench or purpose designed stand.
- Guards or safety devices must never be removed or adjusted, except by an authorized person for maintenance purposes.

- Shearing edges should be maintained in good condition, should be distortion free and correctly adjusted.
- Working parts should be well lubricated and the blades free of rust and dirt.
- Ensure no slip/trip hazards are present in work spaces and walkways.
- Sufficient space must exist around the machine to prevent accidental contact with passersby.
- Familiarize yourself with and check all machine operations and controls.
- Never use bench shears for cutting metal that is beyond the machine's capacity with respect to thickness, shape, or type.
- Material should be properly supported during cutting and industrial type gloves should be worn to protect the hands.
- Use supports for long material - signpost if a tripping hazard.
- Manual handling tasks should be assessed and appropriate procedures put in place.
- Hold material securely to prevent it tilting during the cut.
- Ensure fingers and limbs are clear before operating the bench shears.
- When not in use this machine must be locked by, for example, a stout pin through the hole in the blades and kept in place by a padlock.
- Leave the work area in a safe, clean and tidy state.
- Closing movements between shearing surfaces and other parts can result in trapping
- Sharp edges on cutters, work pieces can cause cuts
- Squash/crush and pinch points

### **Safety guidelines for tools used in engineering workshop:**

Hand tools are non-powered. They include hammers, hacksaw, spanners, chisels, vice, pliers...etc. The greatest hazards posed by hand tools result from misuse and improper maintenance.

#### **General precautions**

- Using a screwdriver as a chisel may cause the tip of the screwdriver to break and fly, hitting the user
- Using a tool with a wooden handle (e.g., hammer) if the handle is loose, splintered, or cracked, the head of the tool may fly off and strike the user or another worker;

- Using a spanner (wrench) if its jaws are sprung, because it might slip
- Using impact tools (e.g., chisels, wedges) if they have mushroomed heads, the heads might shatter on impact, sending sharp fragments flying.
- Hacksaw blades, knives or other tools be directed away from passage-way areas and others working in close proximity. Knives and scissors shall be sharp. Dull tools can be more hazardous than sharp ones;
- Floors shall be kept as clean and dry as possible to prevent accidental slips with or around dangerous hand tools; and
- Around flammable substances, sparks produced by iron and steel hand tools can be a dangerous ignition source. Where this hazard exists, spark-resistant tools made from brass, plastic, aluminum or wood shall be used.
- Disconnect tools when not in use, before servicing and when changing accessories such as blades, bits and cutters

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### ➤ **Classification of workshop tools and equipments**

A tool is a device that can be used to produce an item or accomplish a task, but that is not consumed in the process. It can be considered as extension of the human hand thus increasing speed, power, and accuracy and on the other hands equipment includes any machine powered by electricity.

1. Hand tools are tools manipulated by hands without using electrical energy such as: puller, hacksaw, pull-push rule, pliers, hammer, and others.
2. Machine/Power tools are tools manipulated by our hands and with the use of electrical energy such as: electric drill, grinding wheels, vacuum cleaner and others.
3. Pneumatic tools are tools or instruments activated by air pressure. Pneumatic tools are designed around three basic devices: the air cylinder, the vane motor, and the sprayer

### **Hand tools**

they include screwdrivers, hammers, pliers, wrenches and pullers. 1. Screwdrivers are used to drive, or turn screws. The common type has a single flat blade for driving screws with slotted heads. The other type has the cross slotted head.

1. Hammers are mostly used tools in the shop. They should be gripped at the end of the handle.
2. Pliers are specified types of adjustable wrenches. The two legs move on a pivot so that items of various sizes can be gripped.
3. Wrenches are used to turn screws, nuts and bolts with hexagonal heads. —Hexagonal means six-sided. A variety of wrenches are used in the shop.
4. Pullers are used to remove gears and hubs from shafts, bushings from blind holes, and cylinders' liners from the engine blocks.

### **Machine/Power Tools**

**Electric drill** has an electric motor that drives a chuck. The chuck has jaws that can be opened and then closed to grip a drill bit.

**Grinding tool** can be either bench-mounted or installed on a pedestal. They may either have a grinding wheel, v-wheel, or two grinding wheels.

Vacuum cleaner is used for cleaning the floor and car interiors after service.

### **Pneumatic tools**

These are tools powered by compressed air. Common types of these tools that are used in industry include; buffers, nailing and stapling guns, graders, drills, jacks chipping hammers, riveting guns, sanders and wrenches.

### ➤ **Uses of workshop tools, Instruments and equipments**

Basic electrical tools, equipment, and their uses include:

#### **Pliers**

*Pliers are available in different types, shape, and sizes. They are also available in both insulated and uninsulated handles. An insulated handle should be used when working on or near hot wires. It is also used for cutting big and small wires.*



Figure 42 pliers

### **Screw Drivers**

*A screwdriver comes in various sizes and with several tip shapes. Screwdrivers used by electricians should have insulated handles. Using a screwdriver for a particular job, the width of the screwdriver tip should match the width of the screw slot.*



Figure 43 screw drivers

### **Drilling Equipment**

Drilling equipment is needed to make holes in building structure passages of conduits and wires.



Figure 44 driller

### **Sawing and Cutting**

Tools Saws commonly used by electricians include the crosscut, keyhole, and hacksaw.



Figure 45 hand saw

### Soldering Equipment

*In doing electric wiring splices and taps (connections made to wire) should be soldered, unless you use solderless connectors. Typical equipments available for soldering are shown below.*



Figure 46 soldering equipment

### Hammers

Hammers are used with chisels and for nailing and fitting. Below are examples of carpenter's claw hammer, lineman's hammer, and machinist's ball-peen hammer



Figure 47 hammers

### Measuring Tools

To measure wire length and other items, the electrician finds considerable use for measuring tools such as the extension or zigzag rule, push-pull rule and a steel tape as shown below.



Figure 48 Measuring tools

### **Care and Maintenance of workshop tools and Instruments**

If you take care of your tools, they will return the favor. Proper care and routine maintenance of your hand tools and power tools makes any home improvement or repair project easier, safer and more successful. Proper tool care also saves you money because the better they're cared for, the longer they will last.

#### 1.4.1.1 Hand Tools

Hand tools such as screwdrivers, wrenches, hammers, pliers, levels, and wire cutters are examples of common household tools that are often left out in places such as basements, garages and tool sheds. Tools are tough, but they are not indestructible and exposure to the elements can take its toll.

Below are some tips on how to take care of your tools and store them properly so that you get optimum use out of them.

#### ➤ **Care and maintenance of tools**

Make it a habit to clean tools after each use before you return them to storage. Wipe them down with a rag or old towel and be sure they are free of dust, grease and debris before you put them into their proper places. This is also an opportunity to look for any damage or defects. Check your tools' handles for splinters, breaks and cracks. Also, make sure that metal parts show no signs of corrosion or rust. Repair or replace any tools that show signs of damage.

Cold chisels, log-splitting wedges and other striking tools can be very dangerous if they are not maintained properly. Because these types of tools are used for repeated striking, the surface of the metal head eventually mushrooms out and spreads to form a lip or ridge around the edge. With continued use, there is more spreading and the metal lip may continue to thin, split or curl until it finally breaks. If the metal head separates from the handle while in use, this could result in a dangerous projectile. To prevent this hazard, just grind off the metal edges with a powered grinder on a regular basis.

### **Store tools properly**

A proper storage system is a must for hand tools. A toolbox, storage container, shelving unit, or a combination of all of these can be used to keep your tools protected and in peak condition. Ideally, your storage units should be kept somewhere with minimal exposure to moisture and temperature changes. Remember to keep tools in their respective places or hung on designated hangers when a job has been completed.

#### **1.4.1.1.1 Helpful Tips**

Use a small tool bag for the tools you use most often such as tools for simple jobs around the house. The rest of your tool arsenal can remain in your main toolbox.

You should have a space where you can inspect your tools and perform necessary maintenance tasks, such as a worktable. Cover it with newspaper or plastic sheeting to protect the table and make it easier to clean up after you're done with the job.

Hang lawn and garden tools, such as shovels and rakes, on a wall to get them off of the ground and to protect them from moisture.

#### **1.4.1.2 Power tools**

Power tools such as electric drills, saws, sanders and nailers need routine maintenance just like your hand tools. Because of their mechanical and electrical parts, power tools are more susceptible to problems caused by poor maintenance, dust and debris accumulation and general malfunction. The following are some helpful tips on how to clean and properly store your tools.

### **Keep power tools clean**



Dust and grime can bring your power tools to a grinding halt if left unchecked over time. Wipe them clean with a rag after every job has been completed and then store them. Deep clean periodically by using a damp cloth. Get into exhausts and intakes and other hard-to-clean areas with lightly oiled cotton swabs or other slender tools.

### **Store power tools correctly**

Keep your power tools protected from dust, moisture and other adverse conditions by storing them properly after use. Keep them in their original cases if possible, or tuck them away in storage drawers or tool chests, preferably in a garage or basement with a moderately controlled climate. This not only protects them, it also keeps them organized so you can easily find the tool you need when you need it.

### **Inspect for wear or damage**

Periodically inspect power tools for any signs of wear or damage. Pay special attention to power cords. If you see frayed insulation or exposed wires, have the cord repaired or replaced immediately by a professional, unless you have the expertise to do it yourself. Damaged power cords can potentially lead to injury from electric shock or can cause a fire. Also, check the cord's prongs to see if they are bent or loose. If any are, repair or replace.

### **Lubricate moving parts**

Keep moving parts lubricated for premium performance. Not only does it keep the mechanics of a tool running smoothly, it also decreases the chance of rust developing. While common machine oil is a good choice, consult your owner's manual to see if the manufacturer recommends or requires a specific type of oil.

### **Keep batteries in shape**

Cordless, battery-powered tools are convenient and portable and have become very popular for contractors and homeowners alike. To keep them running efficiently and effectively, it is essential for their batteries to be maintained.

Batteries remain working at peak level by fully charging and then fully discharging their power once every couple of weeks. Don't let batteries sit unused for extended periods of time. Try to use batteries once every two weeks.

Care for batteries by cleaning contacts with cotton swabs and alcohol. Store batteries you won't be using for a while in a dry, clean place away from excessive heat.

### **3.2.4 Learning Activities**

You have been appointed as a group leader during a practical lesson. Prepare workshop tools and instruments for an Electrical installation practical to install a radial power circuit.

### **3.2.5 Self-Assessment**

- a) What should you do if you find a tool defective?
- b) When and how should you inspect powered hand tools
- c) What should you do while using powered hand tools?
- d) What are the general precautions for drilling machine that need to be observed?
- e) How does one avoid injuries while using machines?
- f) How do you maintain your equipment?
- g) What is the importance of maintaining tools and equipment?
- h) What is the importance of equipment?
- i) What are the different types of maintenance?
- j) What are the classification of tools and equipment?

### **3.2.6 Tools, Equipment, Supplies and Materials**

1. Pliers
2. Hacksaws
3. Hammer
4. Spirit levels
5. Phase Tester
6. Side cutters

### **3.2.7 References**

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### 3.2.8 Answers to self-assessment

1.

- If a tool is defective, remove it from service, and tag it clearly "Out of service for repair".
- Replace damaged equipment immediately – do not use defective tools "temporarily".
- Have tools repaired by a qualified person – do not attempt field repairs.

2.

- Inspect tools for any damage prior to each use.
- Check the handle and body casing of the tool for cracks or other damage.
- If the tool has auxiliary or double handles, check to see that they installed securely.
- Inspect cords for defects: check the power cord for cracking, fraying, and other signs of wear or faults in the cord insulation.
- Check for damaged switches and ones with faulty trigger locks.

3.

- Wear or use personal protective equipment (PPE) or clothing that is appropriate for the work you are doing; this may include items such as safety glasses or goggles, or a face shield (with safety glasses or goggles), hearing protection, dust mask, gloves, safety boots or shoes, or rubber boots.
- Switch off the tools before connecting them to a power supply.
- If a power cord feels more than comfortably warm or if a tool is sparking, have it checked by an electrician or other qualified person.
- Disconnect the power supply before making adjustments or changing accessories.
- Remove any wrenches and adjusting tools before turning on a tool.
- Inspect the cord for fraying or damage before each use. Tag defective tools clearly with an "Out of service" tag and replace immediately with a tool in good running order.
- During use, keep power cords clear of tools and the path that the tool will take.

- Use clamps, a vice or other devices to hold and support the piece being worked on, when practical to do so. This will allow you to use both hands for better control of the tool and will help prevent injuries if a tool jams or binds in a work piece.
- Use only approved extension cords that have the proper wire size (gauge) for the length of cord and power requirements of the electric tool that you are using. This will prevent the cord from overheating.
- For outdoor work, use outdoor extension cords marked "W-A" or "W".
- Suspend power cords over aisles or work areas to eliminate stumbling or tripping hazards.
- Eliminate octopus connections: if more than one receptacle plug is needed, use a power bar or power distribution strip that has an integral power cord and a built-in over current protection.
- Pull the plug, not the cord when unplugging a tool. Pulling the cord causes wear and may adversely affect the wiring to the plug and cause electrical shock to the operator.
- Follow good housekeeping procedures – keep the work area free of clutter and debris that could be tripping or slipping hazards.
- Keep power cords away from heat, water, oil, sharp edges and moving parts. They can damage the insulation and cause a shock.
- Ensure that cutting tools, drill bits, etc. are kept sharp, clean and well maintained.
- Store tools in a dry, secure location when they are not being used.
- Inspect the plug for cracks and for missing, loose or faulty prongs

4. The general precautions include:

- Lubrication is important to remove heat and friction.
- Machines should be cleaned after use
- Chips should be removed using brush.
- T-slots, grooves, spindles sleeves, belts, and pulley should be cleaned.
- Machines should be lightly oiled to prevent from rusting.

5. To avoid injuries follow the safety precautions listed below.

- Wear goggles for all grinding machine operations.
- Check grinding wheels for cracks before mounting.
- Never operate grinding wheels at speeds in excess of the recommended speed.
- Never adjust the work piece or work mounting devices when the machine is operating.
- Do not exceed recommended depth of cut for the grinding wheel or machine.
- Remove work piece from grinding wheel before turning machine off.
- Use proper wheel guards on all grinding machines.
- On bench grinders, adjust tool rest 1/16 to 1/8 inch from the wheel.

**6. Here are five top tips for large machinery maintenance:**

- Stay on top of large machinery operator training.
- Add and test lubricants frequently.
- Check for signs of wear. Keep large machinery clean, and maintain a clean environment.
- Have maintenance and repair schedule, and keep good records.

7. Good Quality tools can be a big investment, but if you take good care of them, they will last longer and return the favor. Making sure your tools are properly stored, cleaned, and well maintained will save you time and money as well as making your projects and jobs much easier.

8. Here are some of the long-term benefits of preventive equipment maintenance:

Extend equipment lifespan and reduce the need for having to purchase new equipment. Prevent unplanned downtime which can be costly and interrupt the manufacturing process. Avoid the need for expensive repairs due to negligence.

9. Types of maintenance?

- Preventive maintenance.
- Condition-based maintenance.
- Predictive maintenance.
- Corrective maintenance.
- Predetermined maintenance.
  - Gaining maintenance knowledge with interplay learning.

10. Classifications of tools and equipment according to their uses:

- Measuring tools.
- Holding tools.
- Cutting tools.
- Driving tools.
- Boring tools
- 6. Electrical equipment
- 7. Miscellaneous tools/instrument/equipment.
- 

### **3.3 Learning Outcome 3: Prepare workshop tools and instruments for an Electrical installation practical**

#### **3.3.1 Introduction to the learning outcome**

**Electrical engineering** is an engineering discipline concerned with the study, design and application of equipment, devices and systems which use electricity, electronics, and electromagnetism. It emerged as an identifiable occupation in the latter half of the 19th century after commercialization of the electric telegraph, the telephone, and electrical power generation, distribution and use.

#### **3.3.2 Performance Standard**

- Tools and instruments for an Electrical practical
  - Preparation of a list of tools and instruments for an Electrical practical.
  - Issuing and confirmation of tools and instruments before and after practical
- Testing of practical tools and Instruments

#### **3.3.3 Information Sheet**

##### **➤ Tools and instruments for an Electrical practical**

Electrical engineers work in a very wide range of industries and the skills required are likewise variable. These range from circuit theory to the management skills of a project manager. The tools and equipment that an individual engineer may need are similarly variable, ranging from a simple voltmeter to a top end analyzer to sophisticated design and manufacturing software.

- **Preparation of a list of tools and instruments for an Electrical practical**

#### **Essential Electrician Tools**

##### **Wire Strippers**

Professional electricians regularly strip the plastic coating on wires to expose the copper and make customized connections with other wiring or components. This essential electrical maintenance tool comes in a variety of models and types.

### **Fish Tape**

Fish tape is one of many popular electrician tools. It's used to run wiring between gang boxes (or other electrical components) through conduit piping. Fish tape is housed in a retractable coil and can be fed through installed conduit piping. Once the end of the fish tape appears on the opposite side, wiring can be hooked to the tape and the tape can be retracted—pulling the wire along the conduit.

### **Fishing Rods**

Fishing rods are essential electrician tools when installing wire through walls, below carpets, or above ceilings. Rods are typically fiberglass and include hooks on the end for easy manoeuvring.

### **Terminal Block**

These modular, insulated devices assist electricians when grouping multiple wires together. They're used to connect wiring to a ground or connect electrical switches and outlets to mains.

### **Voltage Tester**

To safely perform electrical work, electrical power must be cut off in key sections of the property (usually via the circuit breaker). A hand held voltage tester allows electricians to test outlets for power, so they know when they're safe to work on. Electricians also use this tool to confirm power has been restored.

### **Reaming Bit**

An installing new conduit (or replacing old ones) means connecting different segments of piping together to create a wiring route between electrical components. A reaming bit attaches to an electric drill and widens the opening on one end of the piping, allowing it to connect to another segment of piping and complete a secure conduit.

### **Conduit Bender**

When determining a wiring route, electricians often run wiring along the corner of the wall or in other mostly hidden areas. Conduit benders are electrician tools used to curve conduit piping to accommodate these routes and ensure the conduits remain non-intrusive and efficiently placed in the customer's home.

### **Splicing Connector**

These plastic clips help electricians make quick connections with multiple pieces of wire. They can be used with multiple cables, including device wires, telephone cables, and electrical cables.

### **Flashlights**

For an electrician, working in the dark is a potential hazard of the job. Keep essential electrician tools, like flashlights and other various work lights, handy and within reach

### **Issuing and confirmation of tools and instruments before and after practical**

You can specify tools on job plans and work orders to indicate which tools are needed to perform a task. In the Stocked Tools application, you can issue tools to those work orders to indicate that the tools are dispatched for use with the right job

### **Testing of practical tools and Instruments**

While planning for a practical, one needs to be sure that the tools are in the right order. Some of the things to consider while testing tools are:

1. making sure that they are working as expected
2. they can give accurate ,measurement
3. Screw drivers are not blunt
4. Stripping tools are.

#### **3.3.4 Learning Activities**

A textile manufacturing factory in Thika has organized a workshop and asked to train the electrical technicians on some new installation skills. As the lead technician, prepare workshop tools and instruments for the expected demonstration.

#### **3.3.5 Self- Assessment**

1. How can one improve my workplace safety?



2. Electrical tools need to last for a long time. What should be done to make them last for a long time?
3. There are different types of wire strippers. What are they?
4. Pliers are available in a variety of designs for different specialist tasks. Which are these types?
5. What are the best electrician's screwdrivers?
6. How do you manage tools and equipment?
7. How do you manage office equipment?
8. What are the basic maintenance of electrical tools and equipment?
9. Why is classifying tools and equipment important?
10. What equipment can be used to test electricity?

### 3.3.6 Tools, Equipment, Supplies and Materials

Pliers

Hacksaws

Hammer

Spirit levels

Phase Tester

Side cutters

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### 3.3.7 References

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### 3.3.8 Answers to self-assessment test

1. Workplace safety should be a continuous effort for any company. You will most likely never achieve perfect safety, so there will always be areas for improvement. Here are some ways you can start improving the safety or your facility:
  - **Organize:** Often times a messy or cluttered facility can lead to injury. A great first step in improving your safety strategy is to organize workbenches and cells. Arranging spaces in a

logical manner, organizing tools and materials, and cleaning will make it much easier for people to do their job without worrying about slipping or tripping.

- **Develop a committee:** Workplace safety is seen as a priority when workers are brought together to form a safety committee. The safety committee is a permanent committee dedicated to identifying potential safety risks and implementing a solution. Senior management should support changes or improvements recommended by the committee.
- **Perform a JSA:** In order to fully understand the state of your facility's safety it will be important to conduct a Job Safety Analysis. It is proven use to identify safety hazards in specific jobs and use accepted best practices to make improvements; the more specific the better!
- **Go visual:** Visual cues are one of the most effective ways to remind workers of safety practices and promote a culture of safety. The best visual communication strategies include a combination of equipment labels, wall signs, floor signs, floor markings, chemical labels, and more.
- **Take a Gemba walk:** Sometimes managers and supervisors don't spend much time on the production line or the facility floor and can often overlook safety hazards. Taking a Gemba walk in the workplace and speaking with the front line workers can show you if jobs are being performed safely, if there are any glaring issues, and how people feel about current safety procedures.

There are so many different avenues to choose from when looking to improve the safety of your facility; above are just a few! The most important thing to remember when addressing occupational safety is to do it with a continuous improvement mind-set and don't forget to include everyone.

2. It's all well and good to ensure you have all the tools of the trade, but if you don't look after them, it will just end up costing hundreds, if not thousands, to continually replace them.

On top of this, tools that are in better condition are safer and a safer working environment is essential. So, here are some tips and tricks.

- Ensure they are stored correctly. Store them in bags, boxes, hang them on the wall or create a dedicated tool shelf, but either way, never leave your tools just lying around. A peg board is a fantastic way to store your small tools.
- Make sure the storage place is dry. Humidity and moisture can do a world of damage to your tools so take the required measures to protect them. There's nothing worse than rusty tools.

- Whenever you're done for the day, clear your tools prior to storing them. A clean cloth to remove any excess oils, sawdust or grease.
- Repair your tools when required. Check your tools after every job and take immediate measures to fix anything that needs fixing. If the tool is completely ruined, replace it immediately.

3. Multiple models and designs are available, including:

**Adjustable strippers** - these combine stripping with crimping and wire-snipping abilities.

**Triple action wire strippers** – these strippers are made for thicker cabling with tough insulation and can use a unique spiral cutting motion.

**Wire stripper pliers** – these feature V-shaped stripping jaws for thicker, multicore cables.

**Sheath stripper** – these use a rotary action and produce a neat ring cut.

**Pistol wire stripper** – these strippers have a self-adjusting blade and use a compound stripping action with a firm grip.

**Automatic wire strippers** – these use a mechanism to remove insulation and cut wire rapidly, with a single application of pressure

**Manual wire strippers** – these are the standard, hand-operated model, but usually, include a spring-loaded handle and safety lock.

4. Pliers are available in a variety of designs for different specialist tasks. These include:

**Long nose pliers**- these have long tapered jaws making them ideal for gripping small objects.

**Combination pliers**– these feature a design that combines wire cutting, insulation stripping and gripping functions in a single tool.

**Water pump pliers**– also known as slip joint pliers, tongue-and-groove pliers and adjustable pliers (among other names), these tools feature a movable lower jaw, allowing the span of the grip to be adjusted. They are ideal for use with nuts, bolts and fasteners.

**Side-cutting pliers**– also known as wire cutters, these are typically used with wire. A variant called diagonal cutter applies different finishes to the cut wire.

**Mole grips/ locking pliers**– these are ideal when working with metal.

5. The best electrician's screwdrivers are fully insulated against electrical shocks: an obvious safety hazard.

Properly insulated tools are a safety basic.

#### 6. Tips for better equipment inventory management

- Know what you have.
- Track how it is used.
- Right asset, right place, right time.
- Don't spend more – spend smarter.
- Fix things before they break.
- Find underlying issues.
- Buy the best.
- Use the right **equipment** inventory system.

#### 7. Simple Ways to Maintain Your Office Equipment

- Keep your machines clean. Machines should be kept clean and free from dust at all times.
- Put some thought into where you place your machines. ...
- Regularly check for small repairs and defects. ...
- Follow instruction manuals for usage. ...
- Follow required inspection and maintenance. ...
- Need help managing your print equipment?

8. Basic maintenance of electrical tools and equipment • clean out the dust. to make sure that your electric tools are ready to go when you are, keep them clean and free of dust. spend some time to clean out the dust every once in a while on your tools while they are inactive in storage.
9. Each tool is precisely designed for a specific purpose, so choosing the correct tool will also decrease the amount of effort required to get a job done right without causing damage to either the equipment or the surface being worked on.
10. Multimeters are the most versatile of the electrical testers and, as the name implies, they are capable of many different testing functions. All professional electricians own one of these tools. Most multimeters can provide precise readings of resistance, AC and DC voltage, continuity, capacitance, and frequency.

### 3.3 Learning Outcome 4: Prepare the workshop for an Electrical practical

#### 3.4.1 Introduction to the learning outcome

A workshop is an informative or instructional class focused on teaching specialized skills or exploring a particular subject. Workshop presenters are usually educators, subject matter experts, managers or other leaders who possess knowledge of a particular subject or mastery of specific skills. Depending on the topic, workshops may be only one or two hours in length or extend across weeks of time. Workshop leaders can strengthen the effectiveness of their presentations through careful planning, organization, and presentation practice. Here are the steps for preparing a workshop.

<https://www.youtube.com/watch?v=piYv9cdMgP8>

#### 3.4.2 Performance Standard

- Practical stations
- Interpretation of a list of practical material

#### 3.4.3 Information Sheet

- **Practical stations**

Practical stations need good care and need to be kept clean all the time. The following steps may be followed when preparing the practical stations.

1. **Define the objective of the workshop.** Your objective may be to teach a concrete skill, such as how to create and save documents in a word processing application. Or your aim may be to deliver general information or guidance about a specific topic, such as painting or creative writing. Regardless of the focus, it's important to define the objective first.
2. **Determine the needs of workshop participants.** When teaching a particular skill, for example, understanding the participants' needs concerning skill level and learning pace will assist you in delivering appropriate content. The more you tailor the workshop to your audience, the more effective the workshop will be.
3. **Create an outline for your workshop presentation.**
  - Create an introduction. Decide how you will introduce yourself, the topic and the participant members.
  - List the skills and/or topics you will cover. Create a comprehensive bulleted list. Include subtopics, as needed.

- Decide on the order of the topics. Move the most important skills or information to the early part of the workshop. Depending on the subject of the workshop, it may also be useful to introduce and build on each topic, beginning with the simplest or most straight forward topic and concluding with the more difficult or complex topic.
  - Determine ground rules for the workshop. Rules or guidelines such as only one person speaks at a time or raising a hand to speak, as well as shutting off any cell phones or distracting devices are good to establish at the onset of the workshop.
  - Decide how you will wrap up the workshop. You might include a short review of learned skills, announce the next level in a series of workshops and/or implement a participant feedback form.
4. **Assign an estimated length of time to each item on the outline.** For particularly complicated topics or skills, allot a sufficient amount of time in case participants get stuck or have questions. It is also important to factor in scheduled breaks during the workshop to give the participants a chance to go to the bathroom or stretch their legs.
  5. **Once you complete your outline, practice giving your workshop presentation.** Rehearsal is an important part of the workshop preparation process. Present your information to colleagues, friends or relatives ahead of time, and ask them to give you feedback on the clarity and effectiveness of your presentation.

➤ **Interpretation of a list of practical material**

**Electrical Materials include;**

- **Electrical Conduit and Conduit Fitting.** Conduit fittings, also called electrical fittings, are used to connect runs of conduit together or to connect conduit to electrical devices. Select from conduit fittings such as adapters, bushings, couplings, elbows, straps, and connectors.
- **Electrical Wire and Cable.** Electrical cable and wires are considered as a same thing. In fact they are quite different. A wire is made of a single electrical conductor while a cable is a group or bundle of multiple wires inside a common sheathing. Both of them are used for carrying electrical current.
- **Circuit Breakers.** A *circuit breaker* is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current from an overload
- **Electrical Connectors.** An *electrical connector* is an electromechanical device used to join electrical conductors and create an electrical circuit.

*Electrical Box. Electrical boxes, also known as junction boxes, enclose wire connections. They help protect against short circuits, which can cause fires. ... Per their requirements, electrical boxes must be*

covered with matching electrical box covers. You can't cover them with drywall, paneling or other wall coverings.



### 3.4.4 Learning Activities

You are a team leader in a practical lesson. The trainer gives you the following circuit to install.

Interpret the circuit and prepare a list of materials to be used during the practical.

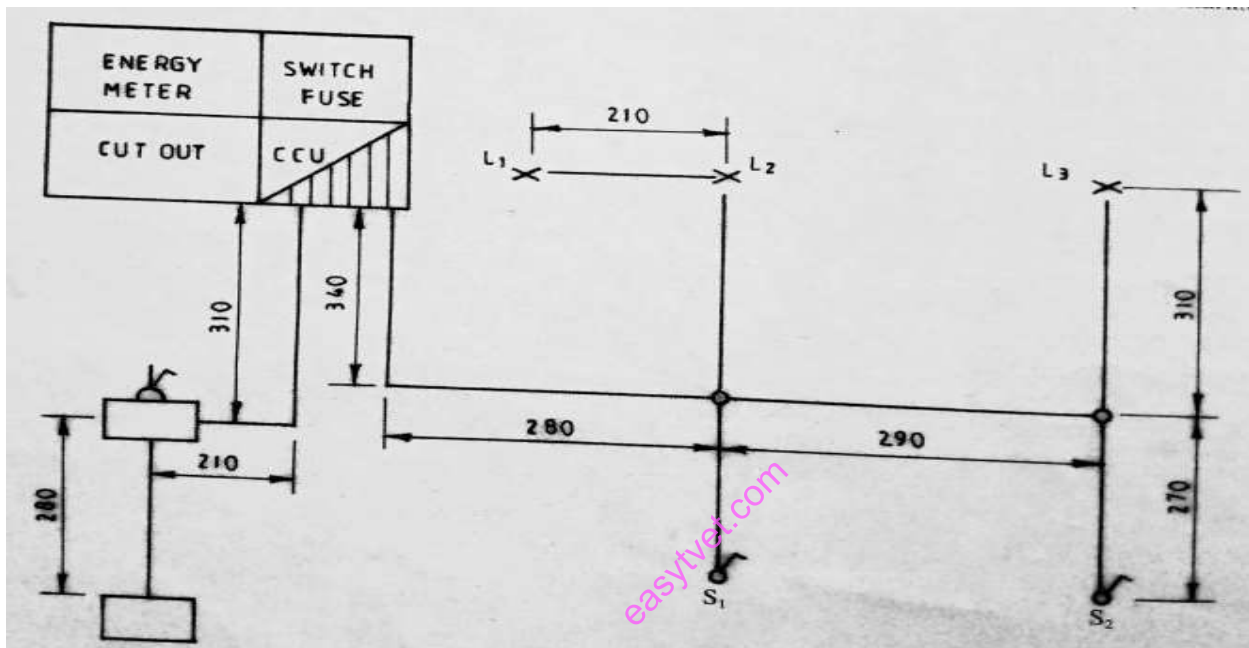


Figure 49 lighting and power circuits

### 3.4.5 Self-Assessment

1. What is an electrical workshop?
2. What are the other safety precautions that you apply when working?
3. What are the five safety measures while working in a workshop?
4. What is the most important rule of electrical safety?
5. How are electrical tools classified?
6. What are the basics of electrical?
7. What is an electrical workshop?
8. What are the 3 basic types of electrical circuits?
9. How do you estimate an electrical job?
10. How many amps do you need for a workshop?

### 3.4.6 Tools, Equipment, Supplies and Materials

- Pliers
- Hacksaws
- Hammer
- Spirit levels
- Phase Tester
- Side cutters

### 3.4.7 References

<https://www.wikihow.com/Prepare-a-Workshop>

<https://www.youtube.com/watch?v=piYv9cdMgP8>

### **3.4.8 Answers to Self-Assessment**

1. Industrial Electricity Workshop This workshop specializes in maintaining and repairing power circuits, alternators, power panels, electromechanical equipment, field generators and other related equipment.

2. Here are some tips to help make your workplace safe.

- Understand the risks. ...
- Reduce workplace stress. ...
- Take regular breaks. ...
- Avoid stooping or twisting. ...
- Use mechanical aids whenever possible. ...
- Protect your back. ...
- Wear protective equipment to suit the task. ...
- Stay sober.

3. The 5 safety rules at a glance

- Disconnect completely. Meaning that the electrical installation must be disconnected from live parts on all poles. ...
- Secure against re-connection. ...



- Verify that the installation is dead. ...
- Carry out earthing and short-circuiting. ...
- Provide protection against adjacent live parts.

4. What is the most important rule of electrical safety? Never work on an energized circuit except if the power cannot be disconnected. A piece of equipment can help us to think before acting. Do not depend on circuit breakers, fuses which may misguide wrongly.

5. A power tool is a tool that is actuated by an additional power source and mechanism other than the solely manual labor used with hand tools. The most common types of power tools use electric motors. Power tools are classified as either stationary or portable, where portable means hand-held.

#### 6. **Basic electricity:**

- Conductors: electrons flow easily. Low resistance.
- Semi-conductors: electron can be made to flow under certain circumstances. Variable resistance according to formulation and circuit conditions.
- Insulator: electrons flow with great difficulty. High resistance.

7. Industrial Electricity Workshop This workshop specializes in maintaining and repairing power circuits, alternators, power panels, electromechanical equipment, field generators and other related equipment.

8. Types of circuits include:

- Series Circuit. A series circuit there is only one path for the electrons to flow (see image of series circuit).
- Parallel Circuit. .
- Series/parallel circuits

#### 9. **Basic steps to estimate electrical job**

1. Choose the Right Work to Bid.
2. Review the Specifications.
3. Review the Drawings.
4. Perform a Quantity Takeoff.
5. Request Supplier Quotes.
6. Create your Estimate.
7. Add Overhead and Profit.

8. Build your Proposal.

10. Dedicate two 20-amp circuits for bench top and portable-tool outlets. Larger 120-volt machines (table saw, planer, dust-collector, etc.) require a 20- or 30-amp circuit. If you run two machines at once, such as your table saw and dust collector, then each needs a separate circuit.

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### 3.5 Learning Outcome 5: Store Electrical tools and materials after practicals

#### 3.5.1 Introduction to the learning outcome

The proper care and storage of tools and equipment are not only the concern of the management but of the workers who use the equipment.

#### 3.5.2 Performance Standard

- Classification of workshop tools and instruments.
- Storage of workshop Tools and equipment
- Tools are cleaned as per the workshop standard operating procedure
- Waste disposal

#### 3.5.3 Information Sheet

##### ➤ Classification of workshop tools and Instruments

##### Basic Electrical Tools.

- **Pliers.** Pliers—often referred to as cutting pliers or lineman pliers—are a staple on any electrical tools list.
- **Screwdrivers.** A *screwdriver* is a tool, manual or powered, used for screwing (installing) and unscrewing (removing) screws. A typical simple *screwdriver* has a handle and a shaft, ending in a tip the user puts into the screw head before turning the handle.
- **Electrical Contractor Software.** Originally created for electrical contractors, 360e is an all-in-one quoting, scheduling, tracking and billing software that is designed by contractors, for contractors. 360e bolsters efficiency and profit while eliminating the daily operational headaches that kill profits.
- **Tape Measure.** A *tape measure* or *measuring tape* is a flexible ruler used to *measure* size or distance. It consists of a ribbon of cloth, plastic, fibre glass, or metal strip with linear-*measurement* markings. It is a common *measuring* tool.
- **Electrical Tape.** *Electrical tape* (or *insulating tape*) is a type of pressure-sensitive tape used to insulate electrical wires and other materials that conduct electricity.
- **Cable Ties.** They're fasteners that bundle your cables and wires together to keep them organized and prevent damage. They come in different sizes, lengths, materials and even colors.
- **Electric Drill.** A *drill* or *drilling* machine is a tool primarily used for making round holes or driving fasteners.
- 

##### Electrical measuring equipments

Electrical instruments are classified according to the electrical quantity or the measured characteristics. It is also classified according to the type of test function, according to the current that can be measured by them.

### **Ammeter**

An ammeter is an instrument which is used to measure the electric current in amperes in a branch of an electric circuit. In order to measure the current it must flow through the ammeter, so the ammeter must be placed in series with the measured branch and it must have very low resistance so that the alteration of the current can be avoided which is measured. Instruments which is used to measure smaller currents are micro-ammeter. The ammeter is connected in series to the device which is to be measured because objects in series have the same current.

### **Types of ammeter**

#### **Moving iron ammeter**

In a moving iron, ammeter can measure the AC and DC; it has an iron piece instead of the spring and pointer system of the galvanometer. The iron will act by the magnetic field created in the coil.

#### **Zero centre ammeters**

Zero centre ammeters are used where the voltage needs to be monitored in two directions and they are used along with a battery. In this the charging of battery deflects the needle in one direction and discharging of the battery deflects the battery in the other.

### **Galvanometer**

*Galvanometer was the first type of ammeter, it is used to detect and measure electric current. It is an analogue electromechanical transducer which makes a rotary deflection in response to the electric current flowing through the coil. A galvanometer can read direct current flow, the magnetic field created as current flows through a coil acts on a spring, which will move the needle indicator.*

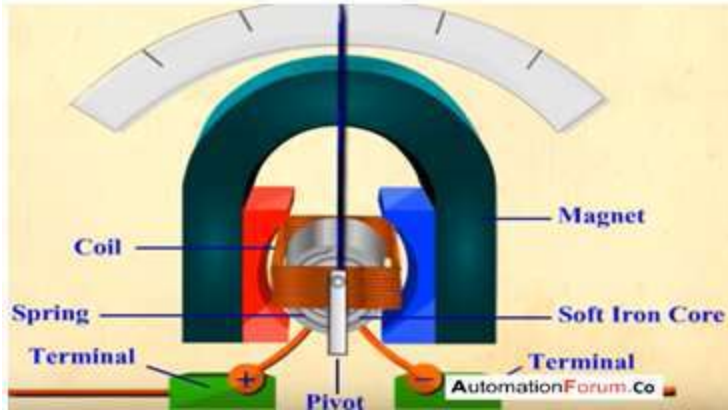


Figure 50 galvanometer

### ***Shunt***

A shunt can be used in ammeters to measure large currents, shunt acts as a resistor the known quantity of resistance is used to obtain an accurate reading. Digital ammeters use analog to digital converter to measure the current across the shunt.

### **Clamp meter**

Clamp meters are used to measure the current flowing through a conductor, AC clamp meters have a current transformer in it. With the help of the current transformer the reading will be taken. There are two types of clamp meters AC clamp meter which is used to measure the AC and the DC clamp meter which is used to measure the DC.

### **Voltmeter**

The voltmeter can be considered as a kind of galvanometer, which can be used to measure the voltage potential of an electrical circuit or the potential difference between two points. A voltmeter can also be considered as an ammeter they also measure the current, voltage is only measured when the current is transmitted in a circuit through resistance. Voltmeters are capable to measure the current, voltage and resistance. Voltmeters are also termed as high resistance ammeters they can also measure DC and AC. A voltmeter can measure the change in voltage by two points in an electrical circuit and they are connected in parallel with the portion of the circuit on which the measurement is made. Voltmeters must have high resistance so that it won't have any effect on the current or voltage associated with the circuit.

## **Types of voltmeter**

### **Digital voltmeter**

Digital voltmeters can measure the AC and DC voltages and it displays the result in converted digital form with decimal point and polarity. It can provide accurate details about the current draw and current continuity and this will help the users to troubleshoot erratic loads.

### **What are the advantages of digital voltmeter?**

- Outputs are accurate without any error
- Readings are taken quickly
- Versatile and accurate
- Less power consumption
- Portable instrument

### **Electrostatic voltmeter**

These voltmeters are instruments that can accurately measure the voltage without any charge transfer. Whereas conventional voltmeter needs charge transfer to the voltmeter and it will lead to loading and adjustment of the source voltage. The main advantage of an electrostatic voltmeter is that it can do the surface potential measurement on any type of material without any physical contact.

### **Ohmmeter**

An ohmmeter is an instrument that is used to measure the resistance and they can measure the value of resistance accurately. According to their measurement and construction, these instruments are classified into the series type and shunt type ohmmeter. It can be used to check the continuity of the electrical circuits and components. Series type ohmmeters are used to measure the high resistance values while the shunt type is used to measure low resistance values.

### **Potentiometer**

Potentiometer is instruments that can be used to measure the unknown voltage. The known voltage will be supplied from a standard cell or any other known voltage reference source. Potentiometer measurement has high accuracy because the measurement is done by the comparison method and the obtained result is not by the deflection of the pointer. Potentiometer can be used to compare the E.M.F of the two cells, it can be used to determine the E.M.F of a cell, it can be used to determine the internal resistance of a cell and to calibrate the voltmeter and ammeter.

## **Wattmeter**

Watt-meters are used to measure power; these instruments are similar in design and construction of an ammeter. It can be used to measure the average electric power in watts. Wattmeter has two coils they are current and pressure coil. Wattmeter can be used to measure the gain in amplifiers, bandwidth in filters.

## **Multi-meter**

Multi-meters can be used to make various electrical measurements; they can be used to measure AC and DC voltage, AC and DC current, and resistance. It is known as multi-meter because it can do the functions of various meters such as voltmeter, ammeter, and ohm-meter. Multi-meters can also be used to check the continuity. Multi-meters are of two types they are analog and digital multi-meter analog multi-meter has an analog scale and they are less accurate, while the digital multi-meter and the reading are in digital and they are more accurate.

### **➤ Storage of workshop Tools and Equipment**

The proper care and storage of tools and equipment are not only the concern of the management but of the workers who use the equipment.

### **Importance of proper storage of tools and equipment**

1. It is an important factor for safety and health as well as good business.
2. Improves appearance of general-shop and construction areas.
3. Reduces overall tool cost through maintenance.
4. This also ensures that tools are in good repair at hand.
5. Teaches workers principles of (tool) accountability.

Points to consider in storing tools and equipment:

1. Have a designated place for each kind of tools.
2. Label the storage cabinet or place correctly for immediate finding.
3. Store them near the point of use.
4. Wash and dry properly before storing.

5. Store knives properly when not in use with sharp edge down.
6. Put frequently used items in conveniently accessible locations.
7. Gather and secure electrical cords to prevent entanglement or snagging.
8. Cutting boards should be stored vertically to avoid moisture collection.
9. Metal equipment can be stacked on one another after drying such as storage dishes and bowls.
10. Make sure the areas where you are storing the equipment are clean, dry and not overcrowded.

Store short-handled tools in a plastic bin or box. Tie together long-handled tools in a garbage can while in storage. Otherwise hang these tools on a wall. If you are storing tools in self-storage, place small tools in plastic bins.

➤ **Tools are cleaned as per the workshop standard operating procedure**

To ensure tools have a longer utility and lifespan, they must be properly cared for. Cleaning your tools should be approached in the same manner that you clean any other equipment or surface in your facility.

**The cleaning principles are:**

1. **Dry clean.** Remove visible and gross soils and debris.
2. **Pre-rinse.** Rinse all areas and surfaces until they are visibly free of soil.
3. **Wash (soap and scrub).** Use the right detergent in the right concentration with the right level of mechanical action in the right water temperature for the right contact time.
4. **Post-rinse.** Rinse away all visible detergents and remaining soil.
5. **Inspect.** Look again at crevices and other contamination traps to ensure they're free of soils and detergents. Determine whether steps 1-4 should be performed again.
6. **Sanitize.** Foam, wipe or spray sanitizing chemicals onto surfaces as per the appropriate instructions.
7. **Dry.** Ensure adequate time is allotted for equipment to thoroughly dry.
8. **Verification.** Gather proof that the cleaning performed achieved the expected level by following facility verification protocols.



As part of the care strategy, cleaning tools should be hung to thoroughly dry. Brushes, brooms and squeegees should be stored in wall brackets and shouldn't touch the walls or other cleaning tools while drying or while being stored.

In addition to keeping tools clean, facilities should also move beyond the concept of just fixing or replacing a tool when it is broken. A tool that breaks while in use can trigger significant downtime and operational losses. Several companies have transitioned to the practice of diagnostic maintenance, where the maintenance crew sets a troubleshooting and monitoring schedule to ensure that tools and equipment are functioning as intended.

### ➤ **Waste Disposal**

**Waste** is any substance which is discarded after primary use, or is worthless, defective and of no use. A by-product by contrast is a joint product of relatively minor economic value.

**Waste management** (or **waste disposal**) includes the activities and actions required to manage waste from its inception to its final disposal. This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process.

Waste disposal methods

#### 1.4.1.3 Recycling

Recycling refers to both the direct **reuse** of used products (e.g. used clothing and functioning parts removed from used vehicles) and **material recycling**, that is the recovery of raw materials from waste (e.g. production of new glass from fragments, the melting of scrap iron and the production of recycled building materials from construction waste). **Down cycling** refers to the transformation of waste to materials of lower quality than the initially used material.

#### 1.4.1.4 Incineration

Combustible waste from households and waste wood that is not suitable for recycling undergo thermal treatment in waste incineration plants or waste wood furnaces. The heat released in the process **is used to generate electricity and heat buildings**. Waste with a high calorific value and low level of pollutant contamination can be used in industrial plants, e.g. cement plants, as an alternative to fossil fuels. Waste that is contaminated with organic pollutants undergoes separate thermal treatment (e.g. in hazardous waste incineration plants). Incinerators must have a flue gas treatment system. The requirements for flue gas treatment and the incineration system are based on the nature of the waste.

#### 1.4.1.5 Chemical-physical and biological treatment

The objective of both chemical-physical and biological treatment is to enable **the removal of pollutants from waste** or its **safe land filling**. Waste water and polluted excavated material are typical of the types of waste that are managed in this way. Following chemical-physical treatment, the pollutants can be disposed of in concentrated form in facilities suitable for this purpose.

#### 1.4.1.6 Landfills

Residues from waste incineration or waste that is not suitable for material recycling or thermal treatment are deposited in landfills that are compliant with the legal requirements. If the waste does not fulfil the requirements for land filling, it must be pre-treated

#### 1.4.1.7 Collection and logistics

The waste management sector involves many different specialised actors. Their tasks include the collection of waste at source (industry, commerce and households) in suitable transport containers, its intermediate storage and handover to waste disposal operations. The treatment of waste is often based on a cascade of specialised plants. In all cases, **smooth logistics** are a precondition for the efficient management of waste. In the case of hazardous waste, in accordance with the Ordinance on Movements of Waste, the handover must be **documented**.

### 3.5.4 Learning Activities

**You are provided with a number of electrical installation tools. Classify them into the following**

- Measuring **tools**.
- Holding **tools**.
- Cutting **tools**.
- Boring **tools**

### 3.5.5 Self- Assessment

1. What is the proper way to store tools and equipment?
2. What is the importance of storing tools and equipment?
3. What are the classification of tools and equipment?
4. What are workshop tools?
5. What does waste disposal mean?
6. Why waste disposal is a problem?
7. What are the main causes of waste?
8. What is storage equipment?
9. What are the methods of waste management?

10. What are the 5 R's of waste management?

### 3.5.6 Tools, Equipment, Supplies and Materials

- Pliers
- Hacksaws
- Hammer
- Spirit levels
- Phase Tester
- Side cutters

### 3.5.7 References

<https://www.storagefront.com/storagetips/auto-rv-boat/gardening-tools-storage/>

### 3.5.8 Answers to self-assessment

1. Pointers to follow in storing tools and equipment:

Have a designated place for each kind of tools.

Label the storage cabinet or place correctly for immediate finding.

Store them near the point of use.

Wash and dry properly before storing.

Store knives properly when not in use with sharp edge down.

2. Making sure your tools are properly stored, cleaned, and well maintained will save you time and money as well as making your projects and jobs much easier. When it comes to storing your tools you have to work with the space that you have.

3. **Classifications of tools and equipment according to their uses:**

- Measuring tools.
- Holding tools.
- Cutting tools.
- Driving tools.
- Boring tools

4. There are hundreds of tools used in a workshop. Saws are some of the most common. A circular saw is attached to a table and spins round in a circle. It is used to cut large sheets of wood. ... A drill is an electric tool that spins round and is used to make holes in material so that a screw can be put in.

5. **Waste disposal**, the collection, processing, and recycling or deposition of the waste materials of human society. The term waste is typically applied to solid waste, sewage (waste water), hazardous waste, and electronic waste.

6. **Disposing of waste** has huge environmental impacts and can cause serious problems. ...

Some waste will eventually rot, but not all, and in the process it may smell, or generate methane gas, which is explosive and contributes to the greenhouse effect. Leachate produced as waste decomposes may cause pollution.

7. **The mismanagement of landfill waste caused by garbage pollution**

- Litter on every corner or on the side of the road.
- Oil spills.
- Illegal dumping in natural habitats.
- Debris or damage caused from unsustainable logging practices.
- Pesticides and other farming chemicals.
- Nuclear accidents or radiation spills.

8. **Storage equipment** is any **equipment** used for holding or buffering materials over a period of time (and may include transport) typically they help preserve valuable work floor space.

9. **Waste disposal methods**

- Recycling. Incineration. ...
- Other thermal treatment plants. Chemical-physical and biological treatment. ...
- Chemical-physical and biological treatment. Landfills. ...
- Landfills. Collection and logistics.

10. As citizens of a society we have a responsibility to manage our waste sustainably. We can do this following the five R's of waste management: reduce, reuse, recycle, recover and residual management.

## 3.6 Learning Outcome 6: Troubleshoot and repair of workshop tools and equipment

### 3.6.1 Introduction to the learning outcome

The level of troubleshooting most often performed on tools and equipments hardware is exchanging *Field Replaceable Units (FRUs)*. The cost of using a technician to diagnose the problem further, and repair it, can quickly exceed the cost of the new replacement unit.

### 3.6.2 Performance Standard

- Meaning of troubleshooting
- Common faults in Electrical equipments
  - Fault diagnosis procedure
- Repair/Replace of components in Electrical equipments

### 3.6.3 Information Sheet

- **Meaning of troubleshooting**

**Troubleshooting** is a form of problem solving, often applied to repair failed products or processes on a machine or a system. It is a logical, systematic search for the source of a problem in order to solve it, and make the product or process operational again. Troubleshooting is needed to identify the symptoms. Determining the most likely cause is a process of elimination—eliminating potential causes of a problem. Finally, troubleshooting requires confirmation that the solution restores the product or process to its working state.

In general, troubleshooting is the identification or diagnosis of "trouble" in the management flow of a system caused by a failure of some kind. The problem is initially described as symptoms of malfunction, and troubleshooting is the process of determining and remedying the causes of these symptoms.

A system can be described in terms of its expected, desired or intended behavior (usually, for artificial systems, its purpose). Events or inputs to the system are expected to generate specific results or outputs. (For example, selecting the "print" option from various computer applications is intended to result in a hardcopy emerging from some specific device). Any unexpected or undesirable behavior is a symptom. Troubleshooting is the process of isolating the specific cause or causes of the symptom. Frequently the symptom is a failure of the product or process to produce any results. (Nothing was printed, for example). Corrective action can then be taken to prevent further failures of a similar kind.

### ➤ **Common faults in Electrical equipments**

Fault-finding for electronic/electrical equipment is a skill that is neither an art nor a science, but an engineering discipline in its own right. Effective fault-finding requires:

- A good general knowledge of electricity and electronics.
- Specialized knowledge of the faulty equipment.
- Suitable test equipment.
- Experience in using such test equipment.
- The ability to formulate a procedure for isolating a fault.
- The availability of service sheets and other guides.

### **Common Problems**

An electrical fault is the deviation of voltages and currents from nominal values or states. Under normal operating conditions, power system equipment or lines carry normal voltages and currents which results in safer operation of the system.

But when a fault occurs, it causes excessively high currents to flow which causes damage to equipment and devices. Fault detection and analysis are necessary to select or design suitable switchgear equipment, electromechanical relays, circuit breakers, and other protection devices.

There are mainly two types of faults in the electrical power system. Those are symmetrical and unsymmetrical faults.

### **Symmetrical faults**

These are very severe faults and occur infrequently in the power systems. These are also called balanced faults and are of two types namely line to line to ground (L-L-L-G) and line to line (L-L-L).

### **2. Unsymmetrical faults**

These are very common and less severe than symmetrical faults. There are mainly three types namely line to ground (L-G), line to line (L-L), and double line to ground (LL-G) faults.

### **Fault diagnosis procedure**

Here are six key points to consider

## **1. Collect the Evidence**

All the evidence collected must be relevant to the problem in hand. If one is in doubt as to whether anything is relevant, then include it. Reject it afterwards at the first opportunity if it clearly is not relevant. The quantity of information collected is unimportant, what matters are that all information collected is relevant. Observe the system running, if you consider it safe to do so. Use all your senses: smell (burning), hearing (vibration), touch (temperature), sight (for unusual conditions). Refer to any relevant documentation.

## **2. Analyze the Evidence**

Consider all the evidence collected and, if possible, reject any which after further careful consideration is not relevant. Study the hard core of relevant evidence and – through the process of careful, logical thinking – diagnose the likely fault or at least the area or region of the fault.

## **3. Locate the Fault**

In a sense this is a continuation of the process of ‘analyses. The areas or regions are systematically reduced in size until a specific part can be identified as being faulty. For example, if a door bell does not ring when it should; it is only by means of a systematic approach that one determines that the bell itself is faulty.

## **4. Determination and Removal of the Cause**

If the cause of a fault is not removed, the fault will recur even though the fault has been rectified. For instance, a flat bicycle tyre might be the result of a puncture (the fault) in the inner tube. If the puncture is repaired (i.e. the fault is removed) this will not be of much use if the cause of the puncture in the first place is not determined and appropriate action taken. The cause of the puncture may be a nail which has penetrated the outer cover. This must be removed

## **5. Rectification of the Fault**

This may be a simple task, as in the case referred to above, or it may be a much bigger one. Whatever is the case, it is a specific task based on earlier findings.

## 6. Check the System

It is important to ensure that the machine, equipment or system is functioning normally after the cause of the fault and the fault itself has been dealt with. In the case of the puncture, it is easy to confirm that the cause of the fault – and the fault itself – has indeed been dealt with satisfactorily, assuming that the tyre remains inflated. With more sophisticated equipment or systems it may necessary to ‘fine-tune’ the system in order to return it to optimum working conditions.

### ➤ **Repair/Replace of components in Electrical equipments**

Any electronic instrument or piece of equipment can be considered as a system. A system can be defined as “anything formed of component parts connected together to make a regular and complete whole”.

An instrument or piece of equipment can have subsystems made in blocks to perform specific functions. These subsystems are made up of electronic circuits, which are forms of electronic/electrical or electromechanical component parts. The failure of a component in equipment may lead to the failure of the system. Failure is said to be the inability of a system to perform its required function. The need for continuous performance of equipment requires that it is given regular maintenance. It is, therefore imperative that the meaning of maintenance is well understood.

## **Maintenance**

This is all the activities carried out on an equipment in terms of proper installation, good servicing, routine checks, repairs and replacement of faulty parts in order for such equipment to operate at it maximum output throughout its useful life. An equipment or instrument is considered to have failed when under any of these conditions:

- a) when it becomes completely inoperative
- b) when it is still in operation but unable to perform the required function any longer
- c) When it becomes unsafe for its continued use.



## **Maintenance of tools and equipment in electrical workshop**

### **Preventive Maintenance**

This is the practice or arrangement whereby a piece of equipment or instrument are regularly checked, oiled, greased or cleaned according to manufacturer's specification for effective performance. This maintenance method is normally carried out at a specified time of a year and in that case the entire working system is shut down. Fund is normally provided to ensure that spare parts and some other materials meant for such maintenance are provided. The essence of this form of maintenance is to ensure that the equipment does not break down and thus performs to specification.

### **Corrective Maintenance**

This method is applied to equipment that has failed and thus broken down due to either improper operations or a defective part. It is concerned with the detection, location and repairs of faults as they occur. This requires a good understanding of system fault location methods in addition to an understanding of overall system and circuit operation.

## **Types of Maintenance**

There are five different types of maintenance and these are as follows:

### **1. Fixed Time Maintenance**

This is servicing of equipment periodically at regular intervals. The particular maintenance requirements will probably vary with the level of service. For example the requirements for 12 monthly services will be different for those for 3 monthly.

### **2. Condition Based Maintenance**

This type of maintenance requires the use of human senses to know when it is needed. In the course of operating an equipment one may see signs of smoking, electrical sparks, feel for excessive heated, smells for signs of burning and some others. The condition at which the equipment is will necessitate that it should be opened up immediately for maintenance. This act will assist in preventing further damage. Some more complex systems have sensing devices built in to them, and alarm systems to detect variation from the norm.

### **3. Opportunity Based Maintenance**

This is carried out when an equipment is opened up for repairs and this opportunity is used to do any other maintenance tasks which are due in the near future, such as routine servicing and the replacement of any parts which are at the end of their useful life. Also, the opportunity can be used to replace a broken part which had occurred before opening the equipment but had no effect in its operation.

### **4. Design Out Maintenance**

This maintenance type is used on equipment which has a part that is failing regularly due to an apparent design weakness. It may be possible to upgrade the weak part and effectively change the design for the better. If a particular part is not available one may be able to change the design to allow a more common part to be used. In spectrophotometry, for example, it may be possible to modify a simple car headlamp bulb to enable it to function as a tungsten source.

### **5. Operate To Failure Maintenance**

These are cases whereby equipment is not given general routine care but it is allowed to fail before any other maintenance is attempted. This is widely used on electronic equipment which normally is not just taken to a mechanic for servicing while still functional. They are only opened up when they have broken down. This means that equipment is operated to failure before it is opened up for maintenance.

### 3.6.4 Learning Activities

You are an employee of Igembe tea factory in Meru County. The production manager notices that the circuit breaker connected to the tea leaves drying section keeps on tripping. As a qualified electrician, troubleshoot the root cause of the problem.

### 3.6.5 Self-Assessment

1. How do you troubleshoot electrical equipment?
2. What are the three main electrical test instruments used in troubleshooting?
3. What are the six steps in the troubleshooting process?
4. **Mention what are the challenges that maintenance and repair work usually face?**

**5. What is the potential risk that repair and maintenance work usually face?**

### 3.6.6 Tools, Equipment, Supplies and Materials

- Pliers
- Hacksaws
- Hammer
- Spirit levels
- Phase Tester
- Side cutters

easyvet.com

### 3.6.7 References

[https://www.industrial-electronics.com/elec-srvc-level-3\\_39.html](https://www.industrial-electronics.com/elec-srvc-level-3_39.html)

<https://www.mcptechnicaltraining.com/blog/six-step-approach-to-fault-finding>

<https://medium.com/@Adamu67981783/maintenance-and-repair-of-electronics-equipment-stp-221-4fe287c5208e>

### 3.6.8 Answers to self-assessment

1. Electrical Troubleshooting in Seven Steps

- Gather information.
- Understand the malfunction.
- Identify which parameters need to be evaluated.
- Identify the source of the problem.
- Correct/repair the component.

- Verify the repair.

- Perform root cause analysis.

2. Meters and test equipment, as well as print tools, such as operating logs and schematics, will all help you diagnose and solve electrical problems. The fundamental diagnostic tools and test equipment are the voltmeter, ammeter, and ohmmeter. The basic functions of these meters are combined in a multimeter.

3.

- Identify the problem.
- Establish a theory of probably cause.
- Test the theory to determine cause.
- Establish a plan of action to resolve the problem and implement the solution.
- Verify full system functionality and if applicable implement preventative measures.
- Document findings, actions, and outcomes

4. The challenges faced include:

- Unusual working condition like bad weather or low temperature
- May have to work in an unusual shift
- May have to work in a messy area
- May sometimes be physically distressing and exhausting
- May have to work in dangerous places like working at height or working with electrical appliances and wires

5. The potential risk that repair and maintenance worker faces are

- Faulty electrical: Risk of electrocuted always remains with repair and maintenance workers, if not equipped with electric-proof tools and attires. They are prone to burns, shocks, etc.
- Lifting equipment: Workers usually have to deal with heavy metal objects and lifting equipment is not inspected or maintained then they are at risk of a fatal accident
- Maintenance of working and walking surfaces: Slippery working surfaces, sharp tools and nails scattered on working surface, slip and trip, uneven and potholed are some potential hazard that may cause an accident
- Dust: It potential risk for the workers specially working in woodworking or iron industries

## CHAPTER FOUR: TECHNICAL DRAWING

**Unit of learning code:** ENG/LG/MC/CC/04/5/A

Related Unit of Competency in Occupational Standard; Prepare and interpret technical drawings

Introduction to the unit of learning

### Unit Description

This unit covers the competencies required to prepare and interpret technical drawings. It involves competencies to select, applying and maintaining drawing equipment and materials, producing plane geometry drawings, producing solid geometry drawings, producing orthographic and pictorial drawings and applying CAD packages

Summary of Learning Outcomes

1. Apply and maintain drawing equipment and materials
2. Produce plane geometry drawings
3. Produce solid geometry drawings
4. Produce orthographic and pictorial drawings
5. Apply CAD packages

### 4.1 Apply and Maintain Drawing Equipment and Materials

#### Introduction to the learning outcome

**This learning outcome is intended to equip the trainee to be competent in** identifying, and gathering drawing and drawing materials according to task requirements. It also covers content on maintenance of drawings and drawing materials.

#### Performance standard

- i. **Drawings** are identified and gathered according to task requirements
- ii. Drawing materials are identified and gathered according to task requirements
- iii. Drawings are used and maintained as per manufacturer's instructions
- iv. Drawing materials are used as per workplace procedures
- v. Waste materials are disposed in accordance with workplace procedures and **environmental**
- vi. **Personal Protective** is used according to occupational safety and health regulations

## Identification and care of drawing equipment and materials

### Basic Drawing Tools

A drafts person needs some basic tools to draw. These should include the following:

- i. A range of pencils
- ii. Ruler
- iii. Set squares
- iv. Rubber
- v. Compasses
- vi. Dividers
- vii. Drawing board
- viii. T-square
- ix. Clips or tape
- x. Emery board or fine sandpaper

**Pencils:** You will need a selection of pencils. A hard lead pencil (6H) can be used for light lines, a softer pencil (2H) for the outlines and an even softer pencil (HB) for printing. (More than one pencil of each grade will save you from frequent re-sharpening.)

**Ruler:** It is advisable to have a transparent ruler.

**Set squares:** You will need at least two set squares: a 60 ° and a 45 ° set square. It will be also useful to have an adjustable set square, which will enable you to set the angle on the set square to anywhere between 0 ° and 90 °. If you have an adjustable set square you can manage without the other two.

**Rubber:** Choose a good quality rubber, one that does not smudge.

**Compasses:** You will need at least two compasses: a small spring bow compass for small circles and one for larger circles.

**Dividers:** A pair of dividers is essential.

**Drawing board and T-square:** Drawing boards for size A2 paper can be bought with a fitted horizontal square which slides up and down on rollers. A less expensive board is one that is used with a separate T-square which slides up and down on the side of the drawing board and has to be held in place when used.

**Clips or tape:** The best tape to use to hold paper on the drawing board is masking tape but metal drawing board clips are easier to use.

**Emery board or fine sandpaper:** This is used to ensure that the lead in the pencils is kept sharp.

### Instruments for Drawing Straight Lines

- T- Square
- Set- squares

### **Instruments for Drawing Curved Lines**

- Compass
- French curve

### **Instruments for Measuring Distance**

- Divider
- Scales

### **Instruments for Measuring Angles**

- Protractors
- Set-squares
- Special Tool
- Mini drafter

There are other instruments that will help you to draw quickly and accurately.

These include the following:

- a) French curves (for drawing non-circular curves accurately).
- b) Large spring bow compasses.
- c) Trammel (for drawing circles with very large diameters).
- d) Scales (rulers with special markings for drawing items bigger or smaller than they are in real life)

### **Using the Equipment**

First fix the paper to your board, using clips or tape.

Then sharpen your pencils, either to a point using a pencil sharpener, or to a chisel shape using the emery board and use this shape for drawing lines, drawing from the ends of each line to meet in the middle.

Use the emery board to sharpen your compass leads to a chisel point too. Finally, draw a frame on your paper if required.

### **Precautions for Neatness in Drawing Work**

1. The hands should be kept clean at all times during work.
2. All the drawing instruments should be kept clean by wiping with a cloth/towel.
3. Special emphasis is to be given to sliding instruments on the drawing sheet, such as T- square and set squares. These instruments must be cleaned properly every time.
4. Pencil should always be kept sharp and used properly. It should be sharpened away from the drawing sheet and other instruments.
5. Dirt and graphite particles from the pencil will make the drawing dirty. Hence, every care should

- be taken to remove them from the drawing sheet.
6. Direct contact of hand with the drawing sheet should be avoided.
  7. Rubbing or erasing should be done properly with soft eraser.

## Identification and care of drawing materials

### Drawing materials

These are consumable items used for technical drawing. They are consumable because they cannot be reused after being used.

The following are the necessary drawing materials.

1. Drawing paper

These are white papers on which drawing is done. The mostly used sizes are A2 to A4

2. Erasers

Erasers are rubber materials used to clean errors made. A good eraser should be able to clean errors without tearing the paper.

3. Handkerchief

It is a small clothing material used for cleaning and dusting.

4. Emery clothes/glass paper

They are materials used to maintain the sharpness of pencils at all times

5. Adhesives

It is commonly called callotape. it is used to fix drawing paper on the drawing board.

6. Drawing pencils

The drawing pencil is used for preparing the drawing on the drawing paper.

### Pencils

Pencils are the main drawing instruments used to draw the lines, circles, arcs, polygons, etc. with respect to the scale provided. Some of the pencils are hard and some of the pencils are smooth.

The hard pencils are used to draw the construction lines and the smooth pencils are used to draw the main lines.

#### 4. H Grades:

H leads give cleaner lines and are also smudge resistant, making them perfect for outlining, technical drawings, painting with watercolors after the sketch and light sketches.

The only flip side is that as you move up the scale, the harder the leads will get and they tend to be scratchy. So make sure you practice and experiment before you begin on your actual art project.

#### 2. HB:



The HB grade lies in the middle of the spectrum. HB is dark enough to be read clearly with minimal smudging and is therefore used mostly for writing.

### 3. B Grade:

B grades smudge easily, are smooth to write and draw with. But they are easily erasable. As you go higher up the scale with these pencils, artists can take advantage of the brush- like expressions that can result while using this grade of pencils. Animators in particular love using 10B on the animator paper as it writes so smoothly – like butter, creating quick, heavy lines without friction.

### 4. F Grade:

The F grade also lies in the middle of the spectrum. The letter ‘F’ stands for ‘fine’. The lead with ‘F’ grade contains a limited amount of graphite and more amount of clay. It has a hard lead but gives a lighter shade when used.

Depending on the smooth and hard quality or the hardness, pencils are classified into 18 grades and they are as follows.

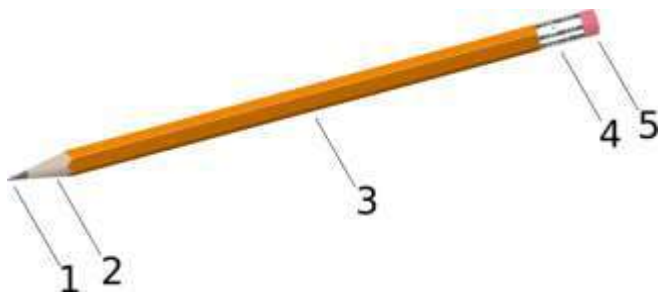
| Grade of Pencil | Hardness of Pencil        |
|-----------------|---------------------------|
| 9H              | Hardest                   |
| 6H, 5H, 4H      | Extremely Hard            |
| 3H              | Very hard                 |
| 2H              | Hard                      |
| H               | Moderately hard           |
| F               | Firm                      |
| HB              | Medium hard               |
| B               | Moderately soft and black |
| 2B              | Soft and black            |
| 3B              | Very soft and black       |
| 4B, 5B, 6B      | Very soft and very black  |
| 7B              | Softest                   |

Table 7: Grades of pencils

Out of the above 18 grades of pencils, the following grades are used in engineering drawings.

| Grade of Pencil | Used to Draw   |
|-----------------|--|
| 3H              | Construction lines   |
| 2H              | Dimension lines, center lines, sectional lines, hidden lines |
| H               | Object lines, lettering                                      |
| HB              | Dimensioning, boundary lines                                 |

Table 8: Continuation of grades of pencils



1. Solid pigment core (typically graphite, commonly called pencil lead).
2. Wood.
3. Painted body.
4. Ferrule.
5. Eraser.

### Care in handling and maintaining drawing instruments and materials

#### Drawing board

1. Do not use drawing board for any other purpose than for drawing
2. The surface of the drawing board must be in good condition. Do not using sharp object to cut on it.
3. Always clean the drawing board before use.
4. Cover drawing board surface with paper or cardboard after use

#### Tee square

1. Tee square should not be used as a walking stick.
2. The blade must be straight at angle  $90^{\circ}$  to the stock.

3. Always clean the tee square before using it.

### **Set of drawing instruments**

1. Do not place heavy load on them to prevent breakage.
2. Do not use sharp objects to cut on their edges.
3. Store them in a safe place

#### **Drawing pencil**

1. Drawing pencil should be kept in a pencil packet after use.
2. Pencil points must be pointed

#### **Other instruments**

All other instruments should be stored in a safe place to prevent damage

<http://schoolportalng.com/drawing-instruments-and-materials/>

### **Title Block**

The title block should lie within the drawing space at the bottom right hand corner of the sheet. The title block can have a maximum length of 170 mm providing the following information.

1. Title of the drawing
2. Drawing number
3. Scale
4. Symbol denoting the method of projection
5. Name of the firm
6. Initials of staff who have designed, checked and approved
7. Date when the drawing was finished
8. Name of the person who checked the drawing
9. Remarks

### **Lettering**

Lettering used in engineering drawing is referred to as a *Single Stroke, Commercial Gothic Hints on Lettering*

- To save time, use a guide lining device
- The recommended height of lettering is 3-mm
- During initial learning period, make a point of concentrating on hand control
- Endeavor to make your hand do what you want it to do and not otherwise. Remember your fingers are not used to such movements, so they have to be trained until hand control becomes effortless
- Do not guess at the construction of letters and numerals. Use the sample letter
- Make letters and numerals as wide as they are high with individual letters of a word almost touching

- Spacing between words is a matter of judgment and tends to improve with practice
- Lines of lettering should be spaced the same distance apart
- Do not attempt to erase guide lines after lettering has been completed

## Printing

Most notes on drawings are done in upper case (capital letters) although this is not always so. Two alphabets and numbers are shown below.

Most draftspersons develop great skills in printing by hand. If you need to print, try both standard and italic and develop a style that suits you.

## Standard print



A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

a b c d e f g h I j k l m n o p q r s t u v w x y z

1 2 3 4 5 6 7 8 9 0

## Lines

In Engineering Drawing, we make use of different lines and line styles to convey the desired message. These lines differ in (i) thickness and (ii) style

| Type of Line and Designation   | Applications   | Recommended line thickness [mm] |       |
|--|--|---------------------------------|-------|
|  |  | PAPER SIZE                      |       |
|  |  | A3/A2                           | A1/A0 |
| <br>continuous thick line | . Object line  | 0.5                             | 0.7   |
| <br>continuous thin line  | 1. Dimensioning line<br>2. Projection or extension lines<br><i>used to project points from one view to another)</i><br>3. Hatching<br>4. Outlines of adjacent parts<br>5. Outline of revolved views or revolved sections | 0.25                            | 0.35  |



|   |   |   |      |
|---|---|---|------|
|   | 6. Leaders for notes<br>7. Imaginary outlines                                       |   |      |
| <br>continuous wavy line | 1. Break line of part views and part sections when break lines are not center lines | 5 | 0.35 |
| <br>short thin dashes    | 4. Non-visible outline (hidden)<br>3 – 4-mm strokes, 1 – 2-mm spaces                | 5 | 0.35 |

Table 9: Types of lines in drawings

### Learning Activities

#### Learning activity 1: Apply and maintain drawing equipment and materials

Make a sketch of an A 1 size drawing sheet, showing in it, the border lines, margin lines, folding marks, zones and the title block. Give the untrimmed and trimmed sizes of this sheet.

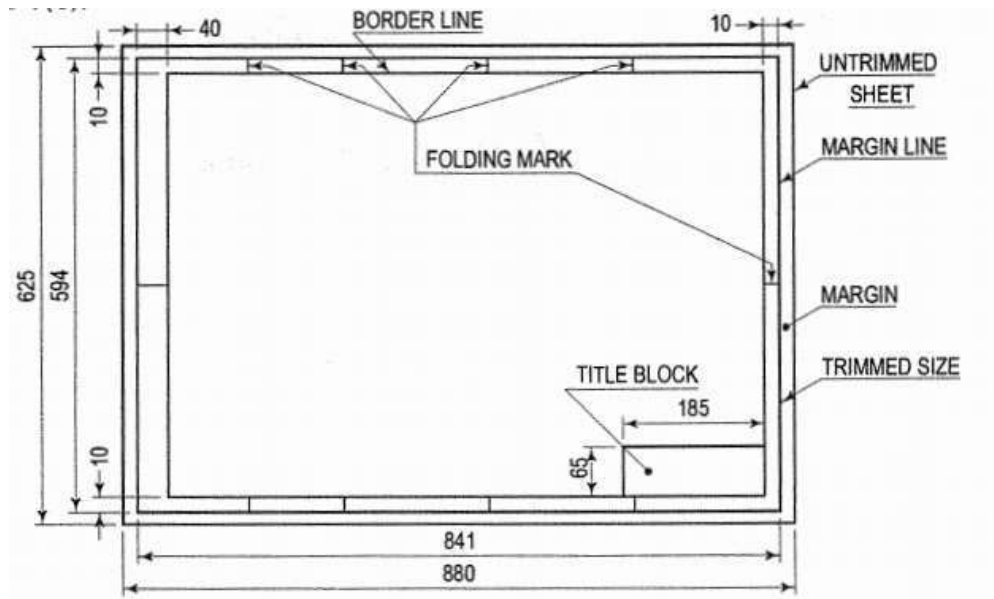


Figure 51: Drawing paper layout

## Learning activity 2: Apply and maintain drawing equipment and materials

In an A3 size sheet, Copy the drawings below as per layout shown. [All dimensions are in mm.]

- i. Draw the border lines as per the standards learnt.
- ii. Draw the title block as per the standards learnt.

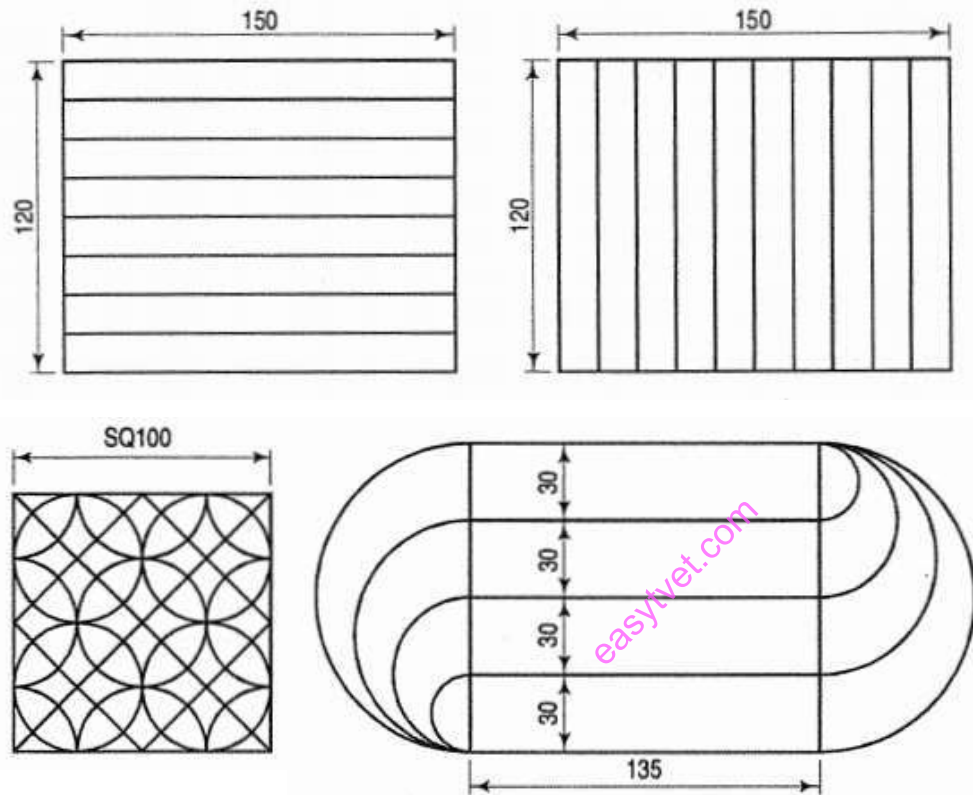


Figure 52: Patterns

## Learning activity 3: Apply and maintain drawing equipment and materials

Write freehand the following, using single stroke vertical (CAPITAL and lower-case) letters:

1. Alphabets (Upper-case & Lower-case) and Numerals 0 to 9 (h = 5 and 7 mm)
2. PRACTICE MAKES A PERSON PERFECT (h = 3.5 and 5)
3. BE A LEADER NOT A FOLLOWER (h = 5)
4. LETTERING SHOULD BE DONE FREEHAND WITH SPEED (h = 5)

### Self-assessment

1. What is a technical drawing?
  - A. A sketch
  - B. A detailed drawing with measurements
  - C. A brainstorming sketch

- D. A drawing with labels
2. Once a drawing is determined to be complete, the title block is used to document the change from:
    - A. A draft to a finished drawing
    - B. A finished to a working drawing
    - C. An assembly to a finished drawing
    - D. A working drawing to a draft
  3. Which of the following types of lines is used on construction line?
    - A. Thick line
    - B. Thin line
    - C. Dash line
    - D. Wavy line
  4. What is the size of an A3 drawing sheet?
    - A. 1189 x 841mm
    - B. 594 x 420mm
    - C. 420mm x 297mm
    - D. 297 x 210mm
  5. The primary unit of measurement for engineering drawings and design in the mechanical industries is the:
    - A. Millimeter
    - B. Centimeter
    - C. Meter
    - D. Kilometer
  6. With regard to lettering, the shapes of letters are not described as part of drawing standards.
    - A. True
    - B. False
  7. Scale is stated as a ratio of the number of drawing units to the number of actual units.
    - A. True
    - B. False
  8. Why the drawing is called the language of Engineers?
  9. What is the Necessity of Dimension a Drawing?

#### Tools, Equipment, Supplies and Materials

1. Drawing tools
2. Drawing set
3. Drawing papers
4. Erasers
5. Series of pencils
6. Drawing board

#### References

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2. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
3. Narayana, K. L., Kannaiah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
4. Reddy, K. V. 2010. Textbook of Engineering Drawing . B.S. Publ., Hyderabad.
5. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,

easytvvet.com



## 4.2. Produce Plane Geometry Drawings

### Introduction to the learning outcome

This learning outcome is intended to equip the trainee to acquire the competence of producing plane geometry drawings.

### Performance Standard

- i. Different types of lines used in drawing and their meanings are identified according to standard drawing conventions
- ii. Different types of *geometric forms* are constructed according to standard conventions
- iii. Different types of angles are constructed according to principles of trigonometry
- iv. Different types of angles are measured using appropriate measuring tools
- v. Angles are bisected according to standard conventions
- vi. Freehand sketching of different types of geometric forms, tools, , diagrams is conducted

Information sheet

### Construction of geometric forms and *geometrical constructions*

1. Dividing a straight line into equal parts

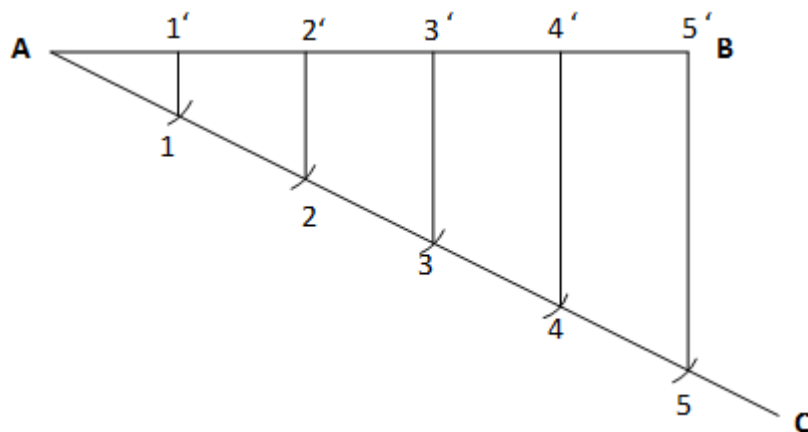


Figure 53: A line divided into equal parts

- i. Draw AC at any angle  $\theta$  to AB.
- ii. Construct the required number of equal parts of convenient length on AC like 1, 2, and 3.

- iii. Join the last point 5 to B
  - iv. Through 4, 3, 2, 1 draw lines parallel to 5B to intersect AB at 4', 3', 2' and 1'.
2. Dividing a line in ratios

Take the line to be divided in the ratio 1:3:4

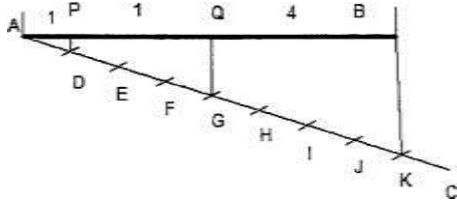


Figure 54: Line divided in ratio

- i. Add the ratios  $1+3+4 = 8$  and divide the line into 8 equal divisions.
- ii. Obtain P and Q to divide the line AB in the ratio 1:3:4.

### Construction of different types of triangles

#### Triangles

This is a plane figure bounded by three straight sides.

#### Types of triangles

- i. Scalene triangle is a triangle with three unequal sides and three unequal angles.
- ii. Isosceles triangle is a triangle with two sides, and hence two angles, equal.
- iii. Equilateral triangle is a triangle with all the sides, and hence all the angles, equal.
- iv. Right-angled triangle is a triangle containing one right angle. The side opposite the right angle is called the 'hypotenuse'.
- v. Obtuse-angled triangle

#### Acute-angled triangle

Construct the different triangles given:

- i. One of the sides
- ii. Perimeter and altitude
- iii. Base angles and perimeter
- iv. Base, altitude and vertical angle
- v. Perimeter and the ratio of the sides
- vi. Perimeter, altitude and vertical angle
- vii. Similar triangle with different perimeter

### Constructions of triangles

### 1. When all the three sides are given

To construct a  $\triangle ABC$  in which  $AB = 4$  cm;  $BC = 6$  cm and  $AC = 5$  cm.

- i. Draw  $AB = 4$  cm.
- ii. With A as centre and radius 5 cm, draw an arc.
- iii. With B as centre and radius 6 cm, draw an arc.
- iv. The two arcs cut each other at point C.
- v. Join AC and BC to complete the triangle ABC.

Example:

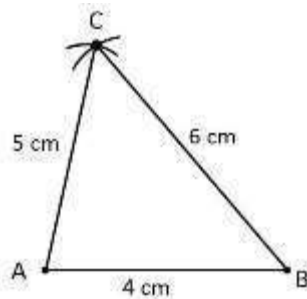


Figure 55: Triangle

### When Two Sides and an Angle are Given

To construct a  $\triangle ABC$  in which  $QP = 4$  cm;  $QR = 6.5$  cm and included angle  $Q = 60^\circ$

- Draw  $QR = 6.5$  cm
- Construct  $\angle XQR = 60^\circ$
- With Q as center and radius 4 cm, draw an arc to cut QX at P
- Join QP
- Thus,  $\triangle PQR$  is the required triangle

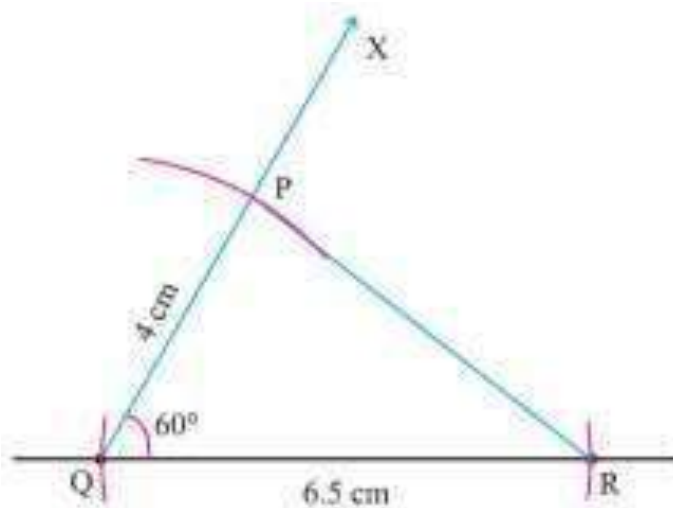


Figure 56: Construction Triangle

When two angles and their included side is given

To construct a  $\triangle ABC$  in which  $\angle B = 60^\circ$ ;  $\angle C = 45^\circ$  and their included side  $BC = 3\text{cm}$

- Draw  $BC = 3\text{cm}$
- Construct  $\angle BCQ = 45^\circ$
- Construct  $\angle PBC = 60^\circ$
- The lines  $BP$  and  $CQ$  at point  $A$
- Thus,  $\triangle ABC$  is the required triangle

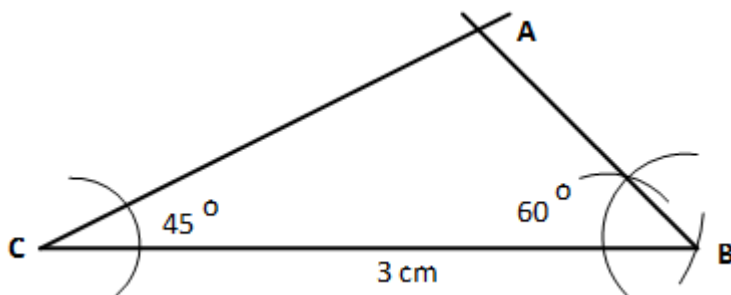


Figure 57: Construction of triangle

## Quadrilaterals

This is a plane figure bounded by four straight sides.

*Types of quadrilaterals*

- Square is a quadrilateral with all four sides of equal length and one of its angles (and hence the other three) a right angle.
- Rectangle is a quadrilateral with its opposite sides of equal length and one of its angles (and hence the other three) a right angle.
- Parallelogram is a quadrilateral with opposite sides equal and therefore parallel.
- Rhombus is a quadrilateral with all four sides equal.
- Trapezium is a quadrilateral with one pair of opposite sides parallel.
- Trapezoid is a quadrilateral with all four sides and angles unequal.

Steps to Construct a Rectangle:

**Step 1:** Draw a side of given length (say)  $QR = 4.8\text{ cm}$

**Step 2:** Draw side  $QP$  (say) of given length perpendicular to  $QR$  at  $Q$ .

**Step 3:** Draw side  $RS$  (say) of length equal to  $PQ$  and perpendicular to  $QR$  at  $R$ .

**Step 4:** Draw side  $PS$ .

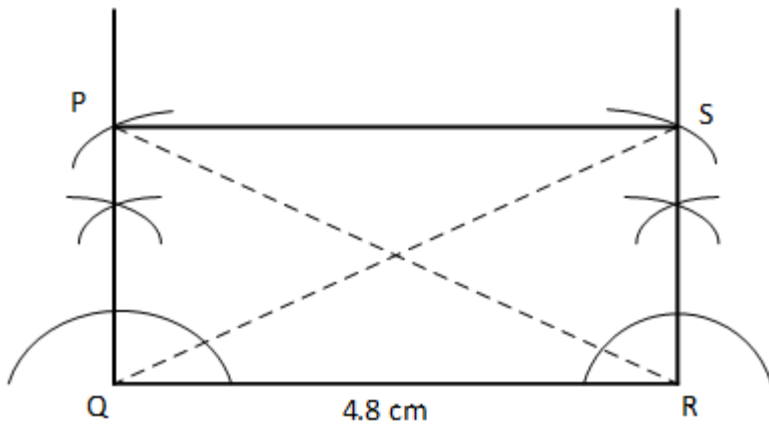


Figure 58: Construct a Rectangle

Steps to Construct a Kite:

**Step 1:** Draw diagonal (say) AY and its perpendicular bisector.

**Step 2:** Draw sides say AL and AZ of given length.

**Step 3:** Draw sides LY and YZ.

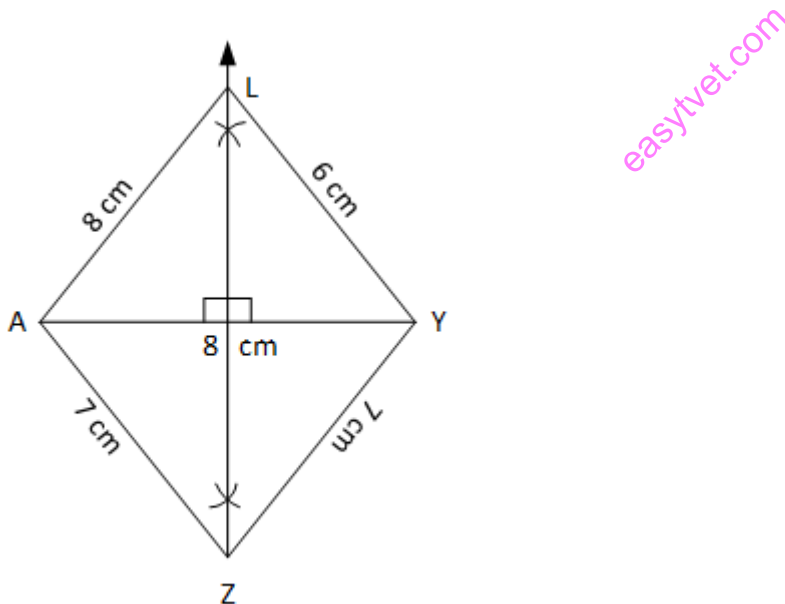


Figure 59: A Kite

### Construction of a Square

a) **Construct a square whose one side is given.**

Construct a square ABCD, given that  $AB = 3$  cm.

**Step 1:** Draw line segment  $AB = 3$  cm.

**Step 2:** Construct  $\angle ABX = 90^\circ$ .

**Step 3:** Draw an arc with B as the center and radius 5 cm, cutting ray BX at C.

**Step 4:** Draw an arc with C as the center and radius 5 cm.

**Step 5:** Draw another arc with A as the center and radius 5 cm, cutting the previous arc at D.

**Step 6:** Join points D, A and D, C. ABCD is the required square.

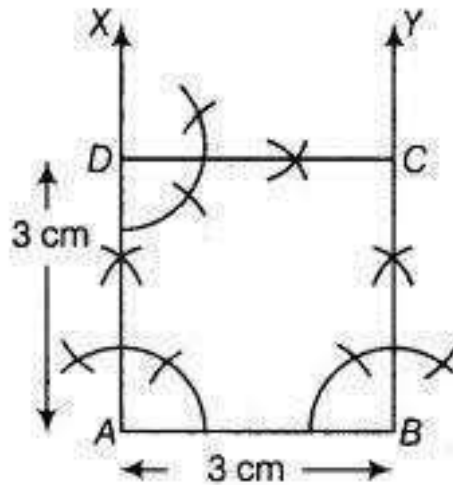


Figure 60: Square given one side

**b) Construct a square whose one diagonal is given.**

Construct a square ABCD, given that  $AC = 5$  cm.

**Step 1:** Draw diagonal  $AC = 5$  cm.

**Step 2:** Draw the perpendicular bisector of AC, meeting AC at O.

**Step 3:** Set the compass for a length equal to OA or OC.

**Step 4:** Draw arcs on the perpendicular bisector with O as the center, without changing the compass setting, cutting the perpendicular bisector at points B and D.

**Step 5:** Join points A, B; points A, D; points B, C and points C, D. ABCD is the required square.

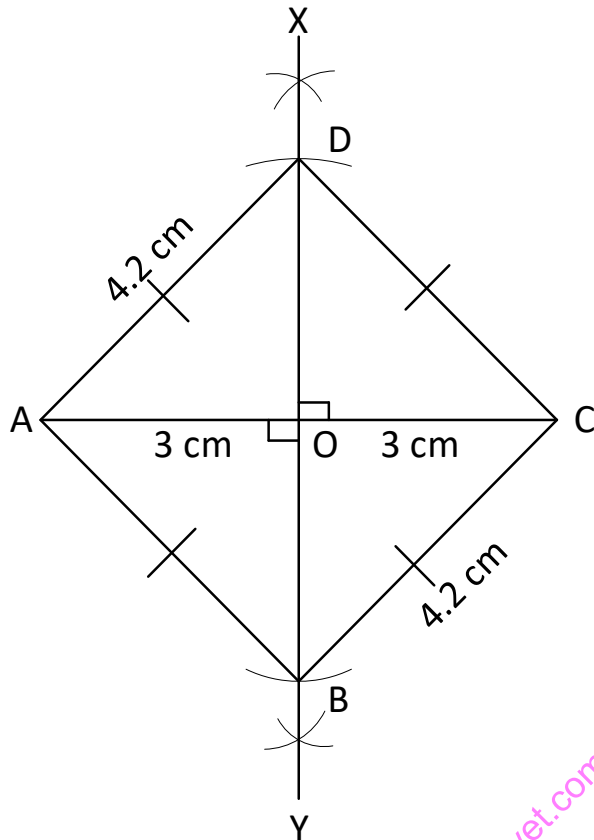


Figure 61: Construct a square whose one diagonal

### Construction of Parallelogram

**Construction of a parallelogram when both the diagonals and the angle between them are given.**

Construct a parallelogram ABCD in which diagonal AC = 8 cm, diagonal BC = 9.2 cm and the angle between them is  $50^\circ$ .

In a parallelogram, diagonals bisect each other:

$$AO = \frac{1}{2} AC = \frac{1}{2} \times 8 = 4 \text{ cm}$$

$$BO = \frac{1}{2} BD = \frac{1}{2} \times 9.2 = 4.6$$

cm

**Step 1:** Draw line segment AC = 8 cm

**Step 2:** Draw the perpendicular bisector of AC.

**Step 3:** Construct.  $\angle DAOX = 50^\circ$ . Extend XO to Y.

**Step 4:** With O as the centre and radius equal to 4.6 cm, draw an arc cutting OX at D, and OY at B.

**Step 5:** Join points A, B, points B, C, points C, D and points A, D. ABCD is the required parallelogram.

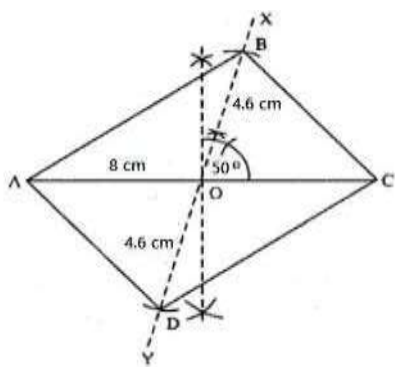


Figure 62: Parallelogram

**a) Construct a rhombus given one side and one angle**

Construct a rhombus ABCD in which AB = 6 cm and Angle A = 60° Steps of construction:

**Step 1:** Draw line segment AB = 6 cm.

**Step 2:** Construct Angle BAX = 60°.

**Step 3:** With A as the center and radius equal to 6 cm, draw an arc on ray AX.

**Step 4:** Mark the point of intersection as D.

**Step 5:** With D as the center and radius equal to 6 cm, draw an arc.

**Step 6:** With B as the center and the same radius, draw another arc such that it intersects the previous arc at C.

**Step 7:** Join points C, D and points C, B.

ABCD is the required rhombus.

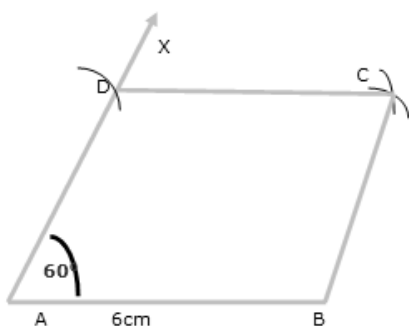


Figure 63: Rhombus

Construction a rhombus given one side and one diagonal:

Construct a rhombus ABCD in which AB = 5.4 cm and AC = 7.4 cm

**Step 1:** Draw line segment AB = 5.4 cm.

**Step 2:** With B as the center and radius equal to 5.4 cm, draw an arc.

**Step 3:** With A as the center and radius equal to 7.4 cm, draw another arc such that it intersects the



previous arc at C.

**Step 4:** Join points B, C and points A, C.

**Step 5:** With A as the center and radius equal to 5.4 cm, draw an arc.

**Step 6:** With C as the center and the same radius, draw another arc such that it intersects the previous arc at D.

**Step 7:** Join points D, A and points D, C.

ABCD is the required rhombus.

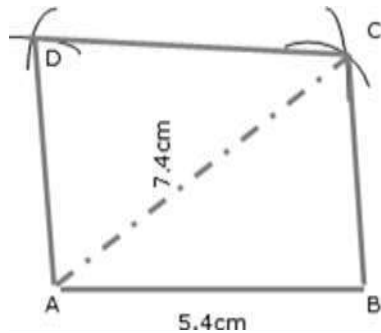


Figure 64: Rhombus

## CIRCLES

### Definition

A circle is a plane figure bounded by a curved line called the circumference, which is always equidistant from the center.

### PROPERTIES OF A CIRCLE

- i. A diameter is a straight line drawn through the center meeting the circumference at both ends.
- ii. A radius is a straight line drawn from the center to the circumference.
- iii. An arc is part of the circumference.
- iv. A chord is any straight line drawn across the circle meeting the circumference at both ends.
- v. A tangent is a straight line which touches the circumference. It is always at right angles to the radius.
- vi. A segment is part of a circle bounded by an arc and a chord.
- vii. A sector is a part of a circle bounded by two radii and an arc.
- viii. A quadrant is part of a circle bounded by two radii at right angles and an arc.
- ix. Concentric circles are circles of the same center but different radii

Eccentric circles are circles of different centers

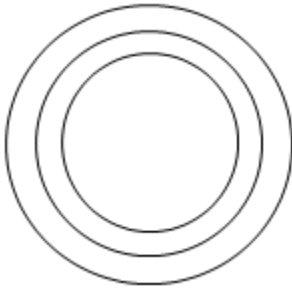


Figure 65: Concentric circles

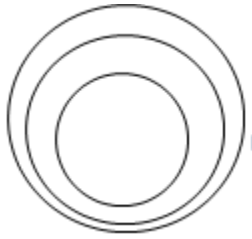


Figure 66: Eccentric circles

## POLYGONS

### Definitions

A polygon is a plane figure bounded by more than four straight sides. Polygons are frequently referred to have particular names. Some of these are listed below

### Polygons

1. A pentagon is a plane figure bounded by five sides
2. A hexagon is a plane figure bounded by six sides
3. A heptagon is a plane figure bounded by seven sides
4. An octagon is a plane figure bounded by eight sides
5. A nonagon is a plane figure bounded by nine sides
6. A decagon is a plane figure bounded by ten sides.
7. A regular polygon is one that has all its sides equal and therefore all its exterior angles equal and all its interior angles equal.

The diameter of that circle is called the diameter of the polygon.

The diagonal of a polygon is the distance from one corner to the corner furthest away from it.

### To construct a regular octagon given the diagonal, i.e. within a given circle Steps

1. Draw the circle and insert a diameter AE.
2. Construct another diagonal CG, perpendicular to the first diagonal.

3. Bisect the four quadrants thus produced to cut the circle in B, D, F, and H. ABCDEFGH is the required octagon.

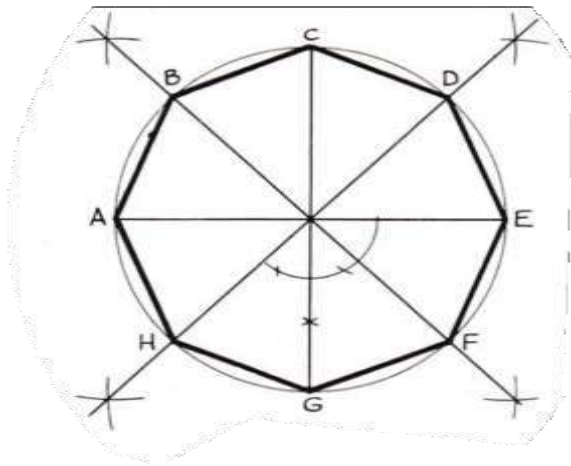


Figure 68: Regular octagon

To construct a rectangular octagon; given the diameter, i.e, within a given square.

1. Construct a square PQSR, length of side equal to the diameter.
2. Draw the diagonals SQ and PR to intersect in T.
3. With centres P, Q, R, and S draw four arcs, radius  $PT (=QT = RT = ST)$  to cut the square in A, B, C, D, E, F, G and H.

ABCDEFGH is the required octagon.

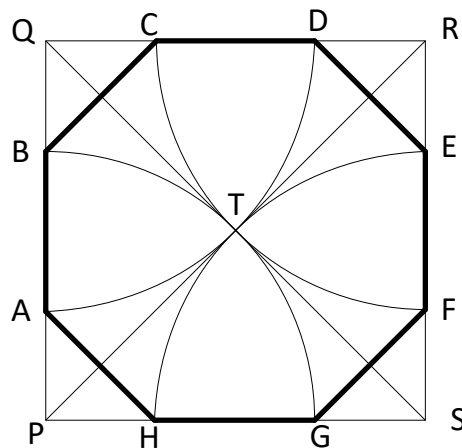


Figure 69: Rectangular octagon

### To construct any given polygon; given the length of a side.

There are three fairly simple way of constructing a regular polygon. Two methods require a simple calculation and the third requires very careful construction if it is to be exact. All three methods are shown. The constructions work for any polygon, and a heptagon (seven sides) has been chosen to illustrate them

#### Method 1

1. Draw a line AB equal in length to one of the sides and produce AB to P.
2. Calculate the exterior angle of the polygon by dividing  $360^{\circ}/7 = 51\ 3^{\circ}/7$ .
3. Draw the exterior angle PBC so that  $BC = AB$ .
4. Bisect AB and BC to intersect in O.
5. Draw a circle, centre O and Radius OA ( $=OB = OC$ ).
6. Step off the sides of the figure from C to D, D to E, etc.  
ABCDEFG is required heptagon.

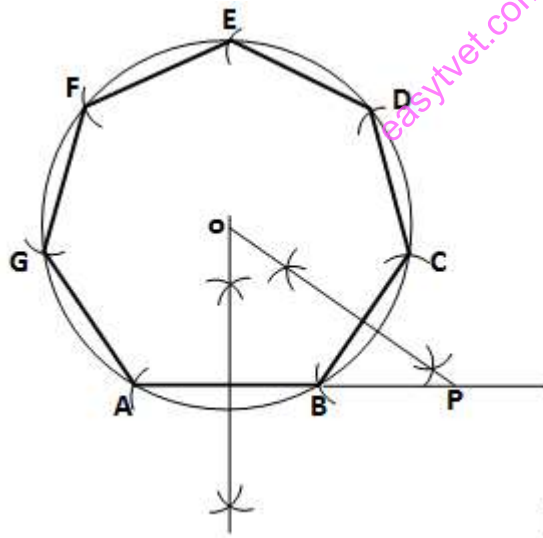


Figure 70: Construction of polygon given the length of a side

#### Method 2

1. Draw a line AB equal in length to one of the sides
2. From a, erect a semi-circle, radius AB to meet BA produced in P.
3. Divide the semi-circle into the same number of equal parts as the proposed polygon has sides. This may be done by trial and error or by calculation ( $180^{\circ}/7 = 25\ 5^{\circ}/7$  for each arc).

4. Draw a line from A to point 2 (For all polygons). This forms a second side to the polygon.
5. Bisect AB and A2 to intersect in O.
6. With center O draw a circle, radius OB (=OA = O2).
7. Step off the sides of the figure from B to C, C to D etc. ABCDEFG is the required heptagon.

### Method 3

1. Draw a line GA equal in length to one of the sides
2. Bisect GA
3. From A construct an angle of  $45^{\circ}$  to intersect the bisector at point 4.
4. From G construct an angle of  $60^{\circ}$  to intersect the bisector at point 6.
5. Bisect between points 4 and 6 to get point 5. Point 4 is the center of the circle containing a square. Point 5 is the center of a circle containing a pentagon. Point 6 is the center of a circle containing a hexagon. By marking off points at similar distance the centers of circles containing any regular polygon can be obtained.
6. Mark off point 7 so that 6 to 7 = 5 to 6 and =4 to 5.
7. With center at point 7 draw a circle, radius 7 to A (=7toG).
8. Step of the sides of the figure from A to B, B to C, etc. ABCDEFG is the required heptagon

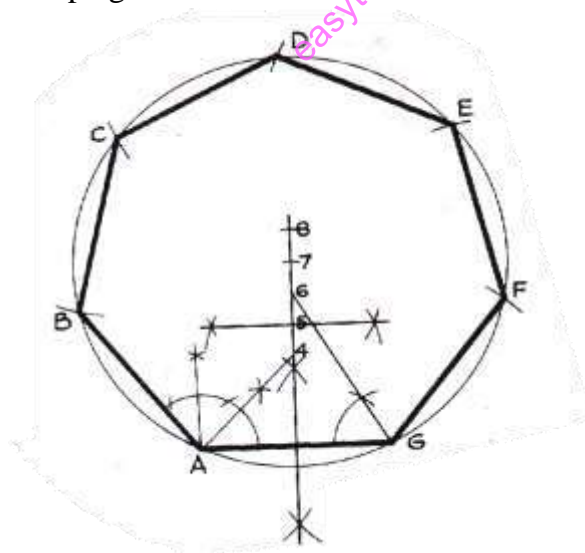


Figure 71: To construction Polygon by 45-60 degrees

To construct a regular polygon given a diagonal i.e. within a given circle

1. Draw the given circle and insert a diameter AM.
2. Divide the diameter into the same number of divisions as the polygon has sides.

3. With center M draw an arc, radius MA. With center A draw another arc of the same radius to intersect the first arc in N.
4. Draw N2 and produce to intersect the circle in B (for any polygon).
5. AB is the first side of the polygon. Step out the other sides BC, CD, etc.
6. ABCDE is the required polygon.
7. draw the given circumference AB
8. Bisect AB in C.
9. With center C, and radius CA, Draw a semi –circle.
10. With center B and radius BC, draw an arc to cut the semi-circle in D.
11. From D draw perpendicular to AB, to cut AB in E.
12. With center E and radius ED draw an arc to cut AB in F. AF is the required diameter. The rest of this chapter shows the construction for finding circles drawn to satisfy certain gain conditions.

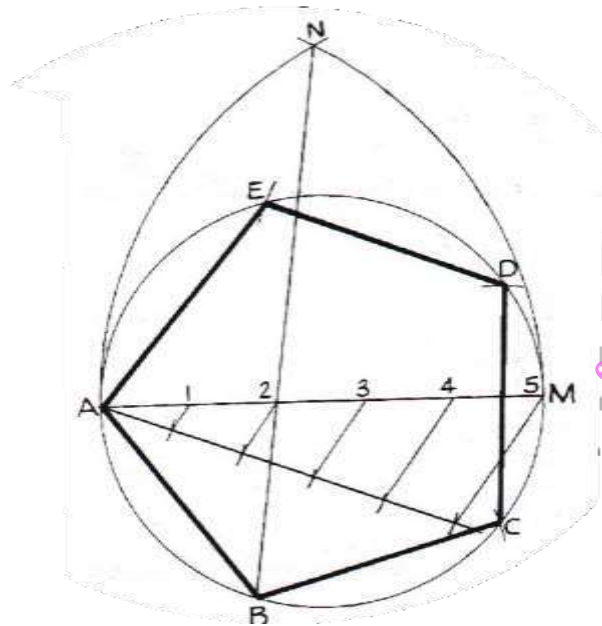


Figure 72: To construct a regular polygon given a diagonal

## Tangency

A tangent to a circle is a straight line that touches the circle at one point.

Construct the different conditions of tangency

1. Common tangent to two equal circles
2. Common interior tangent to two equal circles
3. Common tangent between two unequal circles
4. Common internal tangent between two unequal circles

Construct the following conditions Inscribed, Circumscribed and Escribed

### i. Inscribed Circle

Bisect any two of the interior angles to intersect in O. (If the third angle is bisected it should also pass through O.)

O is the center of the inscribed circle. This center is called the in center.

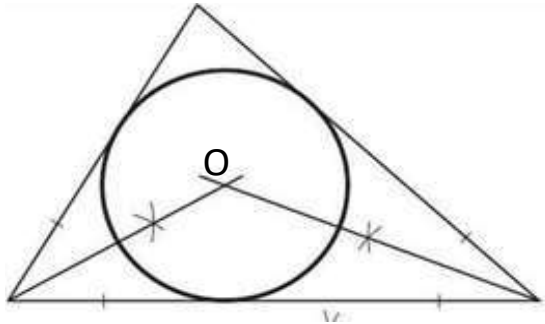


Figure 73: Inscribed Circle

### ii. Circumscribed Circle

Perpendicularly bisect any two sides to intersect in O. (If the third side is bisected it should also pass through O). O is the centre of the circumscribed circle. This centre is called the circumcenter.

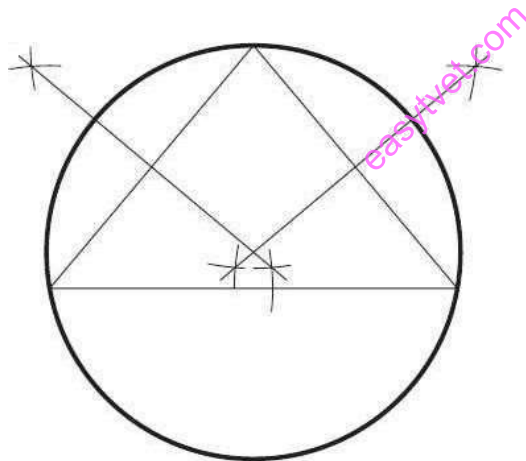


Figure 74: Circumscribed Circle

### iii. Escribed Circle

An escribed circle is a circle that touches a side and the two adjacent sides produced. Thus, the first step is to produce the adjacent sides.

Bisect the exterior angles thus formed to intersect in O. O is the centre of the escribed circle

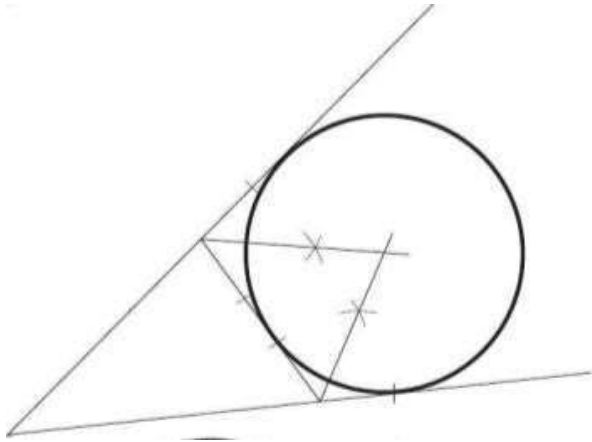


Figure 75: Escribed Circle

## Construction of different angles

### Construction of an angle using compass and ruler

#### To draw an angle equal to a given angle

In this section, we will learn how to construct angles of  $60^\circ$ ,  $30^\circ$ ,  $90^\circ$ ,  $45^\circ$  and  $120^\circ$  with the using a ruler and compasses only.

Construction of some standard angles

#### Construction of an angle of $60^\circ$

In order to construct an angle of  $60^\circ$  with the help of ruler and compasses only, we follow the following steps:

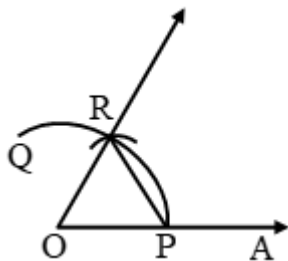


Figure 76: angle of  $60^\circ$

#### Steps of Construction

**Step 1:** Draw a ray OA.

**Step 2:** With centre O and any radius draw an arc PQ with the help of compasses, cutting the ray OA



at P.

**Step 3:** With centre P and the same radius draw an arc cutting the arc PQ at R.

**Step 4:** Join OR and produce it to obtain ray OB.

The angle  $\angle AOB$  so obtained is the angle of measure  $60^\circ$ .

**Justification:** In the above figure, join PR.  
 In  $\triangle OPR$ , we have  
 $OP = OR = PR$   
 $\Rightarrow \triangle OPR$  is an equilateral triangle.  
 $\Rightarrow \angle POR = 60^\circ$   
 $\Rightarrow \angle AOB = 60^\circ$  [ $\because \angle POR = \angle AOB$ ]

**(ii) Construction of an Angle of  $30^\circ$**

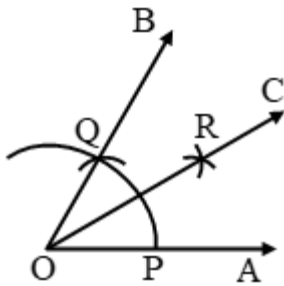


Figure 77: Angle of  $30^\circ$

easytvet.com

**Steps of Construction:**

**Step 1:** Draw  $\angle AOB = 60^\circ$  by using the steps mentioned above.

**Step 2:** With centre O and any convenient radius draw an arc cutting OA and OB at P and Q respectively.

**Step 3:** With centre P and radius more than  $\frac{1}{2}(PQ)$ , draw an arc in the interior of  $\angle AOB$ .

**Step 4:** With centre Q and the same radius, as in step III, draw another arc intersecting the arc in step III at R.

**Step 5:** Join OR and produce it to any point C.

**Step 6:** The angle  $\angle AOC$  is the angle of measure  $30^\circ$ .

(iii) Construction of An Angle of  $90^{\circ}$

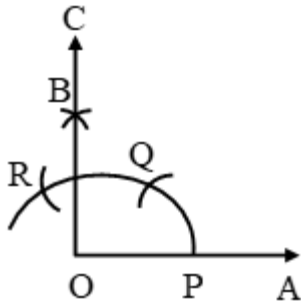


Figure 78: An Angle of  $90^{\circ}$

**Steps of Construction:**

**Step 1:** Draw a ray OA.

**Step 2:** With O as centre and any convenient radius, draw an arc, cutting OA at P.

**Step 3:** With P as centre and the same radius, an arc cutting the arc drawn in step 2 at Q.

**Step 4:** With Q as centre and the same radius as in steps 2 and 3, draw an arc, cutting the arc drawn in step 2 at R.

**Step 5:** With R as centre and the same radius, draw an arc.

**Step 6:** With Q as centre and the same radius, draw an arc, cutting the arc drawn in step 5 at B.

**Step 7:** Draw OB and produce it to C.  $\angle AOC$  is the angle of measure  $90^{\circ}$ .

(iv) Construction of An Angle of  $45^{\circ}$

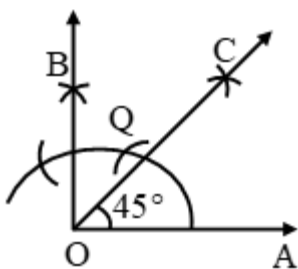


Figure 79: An Angle of  $45^{\circ}$

**Steps of Construction:**

**Step 1:** Draw  $\angle AOB = 90^{\circ}$  by following the steps given above.

**Step 2:** Draw OC, the bisector of  $\angle AOB$ .

The angle  $\angle AOC$  so obtained is the required angle of measure  $45^{\circ}$ .

(v) Construction of An Angle of  $120^{\circ}$

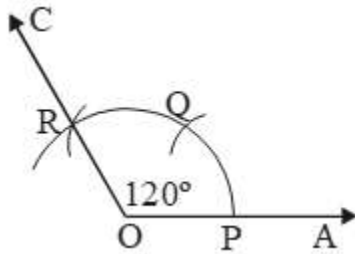


Figure 80: An Angle of  $120^{\circ}$

**Steps of Construction:**

- Step 1:** Draw a ray OA.
- Step 2:** With O as centre and any convenient radius, draw an arc cutting OA at P.
- Step 3:** With P as centre and the same radius draw an arc, cutting the first arc at Q.
- Step 4:** With Q as centre and the same radius, draw an arc, cutting the arc drawn in step II at R.
- Step 5:** Join OR and produce it to any point C.  $\angle AOC$  so obtained is the angle of measure  $120^{\circ}$

<https://www.aplustopper.com/construction-of-angles-using-compass-ruler/>

**Measurement of different angles**

**Different types of angles**

**Angle:**

Two rays with a common end point form an angle. OA, OB is rays & O is end point.

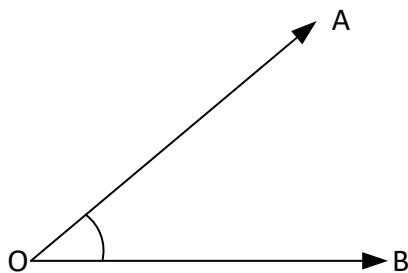


Figure 81: Rays & end point of an angle

**Types of Angles**

In geometry, angles can be classified according to the size (or magnitude) of the angle.

1. **Right angle:** An angle, whose measure is  $90^{\circ}$ , is called a right angle. Two lines that meet at a right angle are said to be perpendicular.

2. **Acute angle:** An angle, whose measure is less than  $90^\circ$ , is called an acute angle.
3. **Obtuse angle:** An angle, whose measure is greater than  $90^\circ$  and less than  $180^\circ$ , is called an obtuse angle.
4. **Straight angle:** An angle whose measure is  $180^\circ$  is called a straight angle.
5. **Reflex angle:** An angle, whose measure is more than  $180^\circ$  but less than  $360^\circ$ , is called a reflex angle.
6. **Complete angle:** An angle whose measure is  $360^\circ$  is called a complete angle.
7. **Zero angles:** An angle whose measure is  $0^\circ$  is called a zero angle.

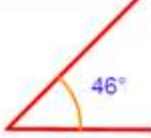
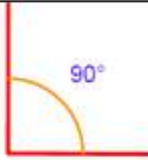
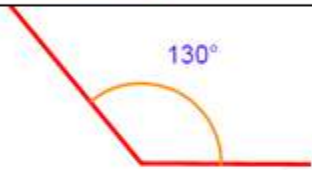
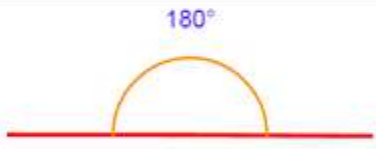

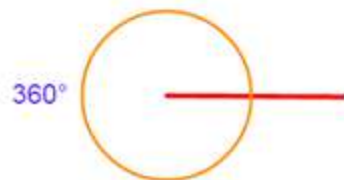
| Type of Angle  | Description   | Example   |
|----------------|---|---|
| Acute Angle    | An angle that is less than $90^\circ$                               |  A diagram showing an acute angle of $46^\circ$ formed by two rays meeting at a vertex. The angle is marked with a yellow arc and the value $46^\circ$ in blue text.  |
| Right Angle    | An angle that is exactly $90^\circ$                                 |  A diagram showing a right angle of $90^\circ$ formed by two perpendicular rays meeting at a vertex. The angle is marked with a yellow arc and the value $90^\circ$ in blue text.   |
| Obtuse Angle   | An angle that is greater than $90^\circ$ and less than $180^\circ$  |  A diagram showing an obtuse angle of $130^\circ$ formed by two rays meeting at a vertex. The angle is marked with a yellow arc and the value $130^\circ$ in blue text.  |
| Straight Angle | An angle that is exactly $180^\circ$                                |  A diagram showing a straight angle of $180^\circ$ formed by two rays meeting at a vertex and extending in opposite directions to form a straight line. The angle is marked with a yellow arc and the value $180^\circ$ in blue text. |
| Reflex Angle   | An angle that is greater than $180^\circ$ and less than $360^\circ$ |  A diagram showing a reflex angle of $308^\circ$ formed by two rays meeting at a vertex. The angle is marked with a yellow arc and the value $308^\circ$ in blue text.  |
| Full Angle     | An angle that is exactly $360^\circ$                                |  A diagram showing a full angle of $360^\circ$ formed by two rays meeting at a vertex and extending in opposite directions to form a complete circle. The angle is marked with a yellow arc and the value $360^\circ$ in blue text.   |

Table 10: types of angles

**Measure of an angle:**

The amount of turning from OA to OB is called the measure of  $\angle AOB$ , written as  $m \angle AOB$ . An angle is measured in degrees denoted by “°”.

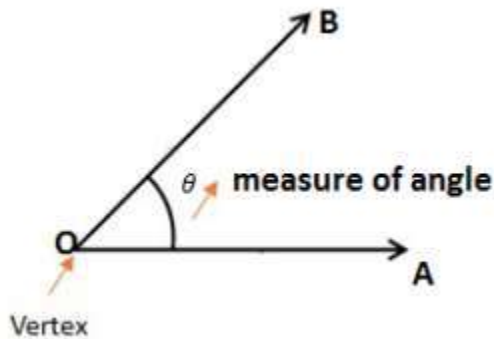


Figure 82: Measure of an angle

**An angle of 360°:**

If a ray OA starting from its original position OA, rotates about O, in the anticlockwise direction and after making a complete revolution it comes back to its original position, we say that it has rotated through 360 degrees, written as 360°.

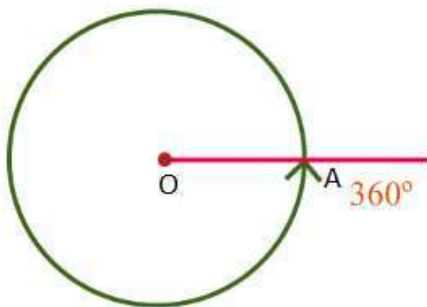


Figure 83: Angle of 360°

<https://www.aplustopper.com/different-types-of-angles/>

**A PROTRACTOR**

Protractor: The Protractor is a circular or semi-circular tool for measuring angles. The units of measurement used are degrees. Some protractors are simple half-discs. More advanced protractors

usually have one or two swinging arms, which can be used to help measuring angles.

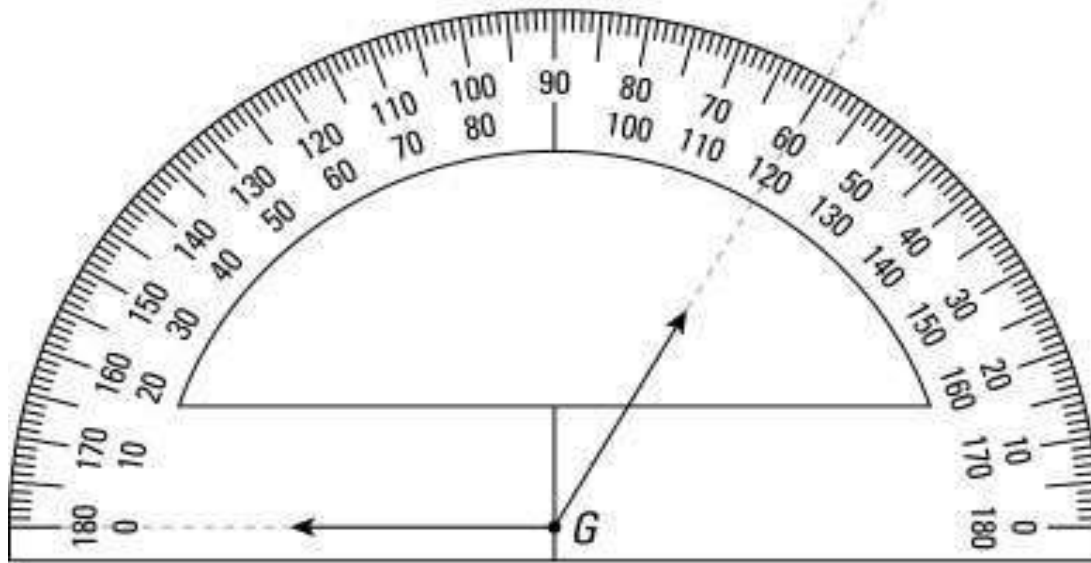


Figure 84: The handy-dandy protractor.

### How to use a protractor

1. Place the notch or center point of your protractor at the point where the sides of the angle meet (the vertex).
2. Place the protractor so that one of the lines of the angle you want to measure reads zero (that's actually  $0^\circ$ ).
3. Read the number off the protractor where the second side of the angle meets the protractor.

### Bisection of different angles and lines

1. Bisect a given angle

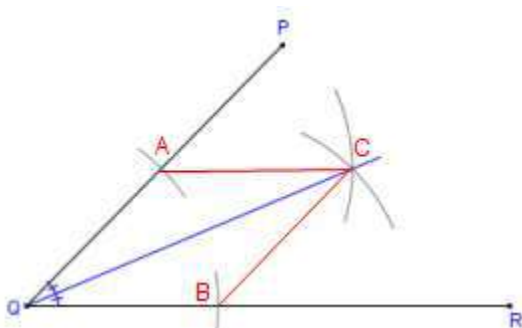


Figure 85: Bisection of an angle

- i. Draw line QP and QR making the given angle.

- ii. With centre Q and any convenient radius R draw an arc intersecting the sides at A and B.
- iii. With centres A and B and radius larger than half the chord length AC, draw arcs intersecting at C.
- iv. Join QC,  $\angle PQC = \angle RQC$

### Bisecting a Line

Draw a line segment AB of the desired length by using a graduated ruler.

1. With A as centre and radius more than half of AB, draw arcs, one on each side of AB.
2. With B as centre and the same radius as in step 2, draw arcs cutting the arcs drawn in step 2 at C and E respectively.
3. Draw the line segment with C and E as end-points. Suppose it meets AB at D. Then bisects the line segment AB.

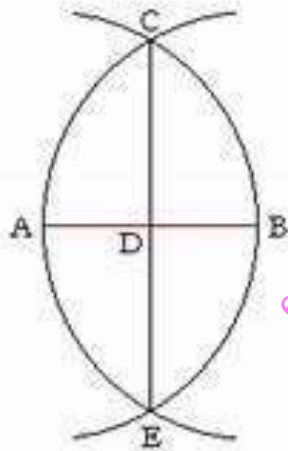


Figure 86: Bisection of line

### Standard drawing conventions

In the construction industry all drawings are carried out to a British Standard referred to as BS 1192.

## Dimensioning

Drawing of a component, in addition to providing complete shape description, must also furnish information regarding the size description. These are provided through the distances between the surfaces, location of holes, nature of surface finish, type of material, etc. The expression of these features on a drawing, using lines, symbols, figures and notes is called dimensioning.

## Principles of Dimensioning

Some of the basic principles of dimensioning are given below.

1. All dimensional information necessary to describe a component clearly and completely shall be written directly on a drawing.
2. Each feature shall be dimensioned once only on a drawing, i.e. dimension marked in one view need not be repeated in another view. Never repeat a dimension.
3. Dimension should be placed on the view where the shape is best seen
4. As far as possible, dimensions should be expressed in one unit only preferably in millimeters, without showing the unit symbol (mm).
5. As far as possible dimensions should be placed outside the view.
6. Dimensions should be taken from visible outlines rather than from hidden lines.
7. No gap should be left between the feature and the start of the extension line.
8. Crossing of center lines should be done by a long dash and not a short dash.
9. Circles are usually dimensioned using the measurement of their diameter.
10. There are dimension lines and projection lines. Projection lines are thin lines, which begin 1mm from the drawing and extend beyond the last dimension line by 2mm. They define the area being dimensioned and never touch the actual object. Dimension lines are also thin lines with arrows placed at each end that touch the projection line.
11. Each dimension line starts 10mm from the object and is then 10mm apart. The smaller dimensions are placed closer to the object. Longest dimension lines are furthest away from a view (for example, total height).
12. Each Dimension Line has an arrowhead that can be open or closed. Arrowheads touch (but do not cross) projection lines.
13. Dimension numbers can be written vertically or horizontally. The selection of vertical or horizontal writing must be consistent throughout the drawing.

*Dimensions should be shown as follows:*



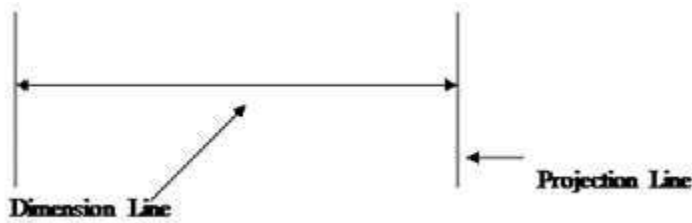


Figure 87: Dimension line and projection line

**The conventions relating to dimensions are as follows:**

- State dimensions once only.
- Place in the most appropriate view.
- Keep related dimensions on the same view.
- Select the functional dimensions.
- Avoid redundant dimensions.

Give metric dimensions to the least number of significant figures, for example;

|     |     |      |
|-----|-----|------|
| 2.5 | not | 2.50 |
| 3   | not | 3.0  |

Dimensions less than 1 are expressed with a zero preceding the decimal point; 0.5 not 5

Letters and Numbers

*All drawings require some form of lettering and numbers. The principles to remember are:*

They should be legible and clear – especially numbers, as they often have to be read on their own.

They should be of a suitable size and not less than 3mm tall. Title blocks and relative information are usually larger.

They should be correctly spaced and positioned. Notes and captions should be placed so that they can be read in the same direction as in the title block. In other words it should not be necessary to turn a drawing on its side to read the information.

Notes should be grouped together and not spread over the drawing.

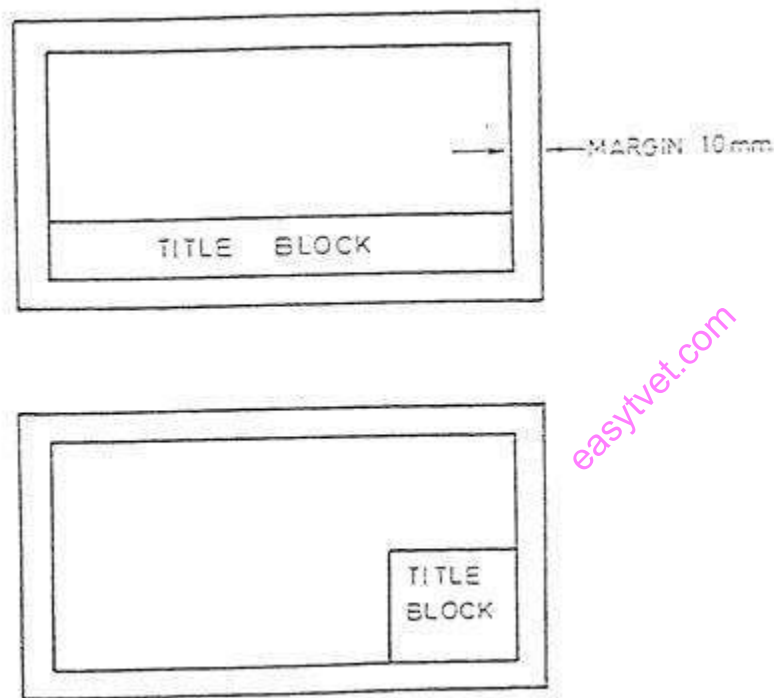
Underlining is not recommended.

Borders and Title Blocks

*One of the most important features of any drawing is the border and title block. The border (or margin) is a line which follows the outer edge of the drawing and is usually 10 or 20mm inside it. This margin is very important because everything inside it forms part of any contract. The 'Title Block' is locked within the boarder and contains information such as:*

- i. Project title
- ii. The subject
- iii. The date of the original drawing.
- iv. Dates of any revisions.
- v. Job Number.
- vi. Drawing Number.
- vii. Scale.
- viii. The name of the person who drew up the drawing.
- ix. Name of architects, consultant engineers or surveyors.

*Title Blocks are usually located along the bottom or sides of drawings as shown below:*



*Figure 88: Title block styles*

### **Scales**

A scale can be used to increase the detail of a small object or to accurately represent a large object on a smaller piece of paper. The majority of scaled work done in the construction industry is to reduce objects to a smaller more suitable size that will fit on a sheet of paper. The list below shows the scales used in BS 1192:

**Block Plans** 1:2500. These show the outlines of buildings and may also indicate roads, railway lines or rivers.

**Site Plans:** Between 1:500 and 1:2500 .Although often drawn at the same scale as the block plan site plans only give details relevant to the actual project. These details could relate to landscaping arrangements or show underground drainage pipe-work.

**General Location Drawings** 1:200 or 1:100. These drawings can show pipe runs within the building and the location of radiators and sanitary fixtures.

When details of boiler houses or plant rooms are given the scale may increase to 1:50. This enables greater detail to be shown. Where particular detail is necessary the scale could be as high as 1:20 or 1:10. This could be in the case of a bracket or support for a piece of equipment.

## LOCI

A locus (Plural loci) is the path traced out by a point which moves under given definite conditions or rules. You may not have been aware of it, but you have met loci many times before. One of the most common loci is that of a point which moves so that its distance from another fixed point remains constant: this produces a circle. Another locus that you know is that of a point which moves so that its distance from a line remains constant: this produces parallel lines.

The problems of loci can take several different forms. One important practical application in building is in the setting out of curves such as parabolic, hyperbolic and circular curves. Another important application of loci in engineering is finding the path traced out by points on mechanisms. This may be simply to see if there is sufficient clearance around a mechanism.

## ELLIPSE

### Definition

An ellipse is the locus of a point which moves so that distance from a fixed point (called the focus) bears a constant ratio, always less than 1, to its perpendicular distance from a straight line called the directrix). An ellipse has two foci and two and two directrices. Figure 3 shows how to draw an ellipse given the relative positions of and the directrix, and the eccentricity. In this case the focus and the directrix are 20mm apart and the eccentricity is  $\frac{4}{3}$

The first point to plot is the one that lies between the focus and the directrix. This is done by dividing DF in the same ratio as the eccentricity  $\frac{4}{3}$ . The other end of the ellipse, point is found by working out the simple algebraic sum shown on

The condition for the locus is that it is always  $\frac{3}{4}$  as far from the focus as it is from the directrix. It is therefore  $\frac{3}{4}$  as far from the directrix as it is from the focus. Thus. If the point is 30mm from F, it is  $40\frac{3}{4}$ mm from the directrix; if the point is 20mm from F, it is  $\frac{3}{4} \times 20$ mm from the directrix; if the

point is 30mm from F, it is  $\frac{3}{4} \times 30\text{mm}$  from the directrix. The intersections of radii drawn from F and line drawn parallel to the directrix, their distance from the directrix being proportional to the radii, give the outline of the ellipse. These points are joined together with a neat freehand curve.

### General method of construction of an ellipse

To construct an ellipse when the distance of the focus from the directrix is equal to 50 mm and eccentricity is  $\frac{2}{3}$

- i. Draw any vertical line AB as directrix.
  - ii. At any point C on it, draw the axis perpendicular to the AB (directrix).
  - iii. Mark a focus F on the axis such that  $CF = 50 \text{ mm}$ .
  - iv. Divide CF into 5 equal divisions (sum of numerator and denominator of the eccentricity
  - v. Mark the vertex V on the third division-point from C.  
Thus, eccentricity,  $e = VF/VC = \frac{2}{3}$
  - vi. A scale may now be constructed on the axis (as explained below), which will directly give the distances in the required ratio
  - vii. At V, draw a perpendicular VE equal to VF. Draw a line joining C and E.  
thus, in triangle CVE,  $VE/VC = VF/VC = \frac{2}{3}$
  - viii. Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at 1'.
  - ix. With centre F and radius equal to 1-1', draw arcs to intersect the perpendicular through 1 at points  $P_1$  and  $P'_1$ . These are the points on the ellipse, because the distance of  $P_1$  from AB is equal to C1,
  - x.  $P_1F = 1 - 1'$
- and

$$\frac{1 - 1'}{C1} = \frac{VF}{VC} = \frac{2}{3}$$

Similarly, mark points 2, 3 etc. on the axis and obtain points  $P_2$  and  $P'_2$ ,  $P_3$  and  $P'_3$  etc. (x)

### Exercise

Draw the ellipse through these points. It is a closed curve having two foci and two directrices.

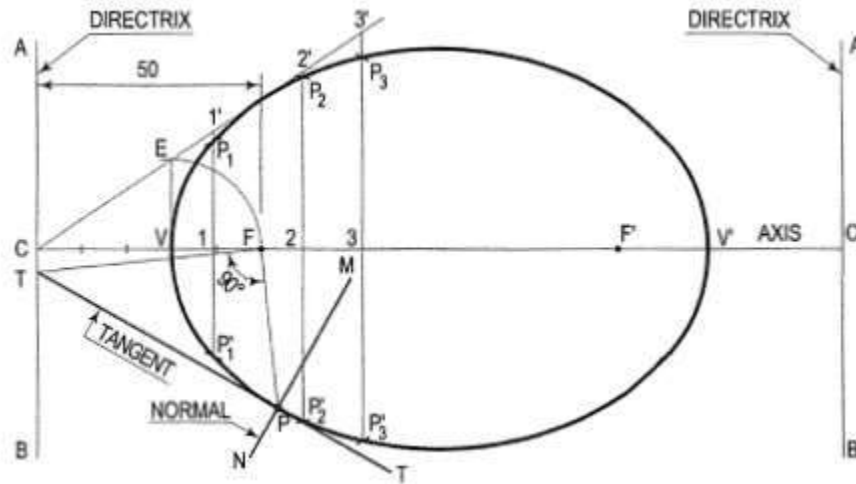


Figure 89: General method of construction of an ellipse

**To construct an ellipse, given the major and minor axes.**

The ellipse is drawn by, first determining a number of points through which it is known to pass and then, drawing a smooth curve through them, either freehand or with a french curve. Larger the number of points, more accurate the curve will be.

**Concentric circles method**

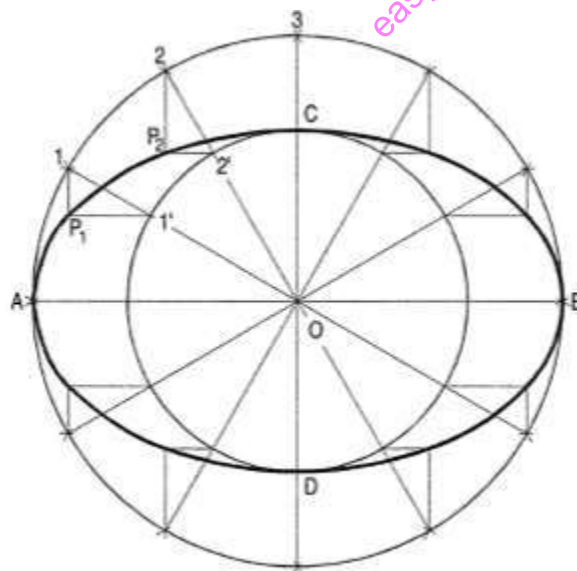


Figure 90: Concentric circle method

**Concentric circle method**

- i. Draw the major axis AB and the minor axis CD intersecting each other at O.

- ii. With centre O and diameters AB and CD respectively, draw two circles.
- iii. Divide the major-axis-circle into a number of equal divisions, say 12 and mark points 1, 2 etc. as shown.
- iv. Draw lines joining these points with the centre O and cutting the minor-axis-circle at points 1', 2' etc. (v) Through point 1 on the major-axis-circle, draw a line parallel to CD, the minor axis.
- v. Through point 1' on the minor-axis-circle, draw a line parallel to AB, the major axis. The point P<sub>1</sub>, where these two lines intersect is on the required ellipse.
- vi. Repeat the construction through all the points. Draw the ellipse through A, P<sub>1</sub>, P<sub>2</sub> ..... etc.

#### Oblong method

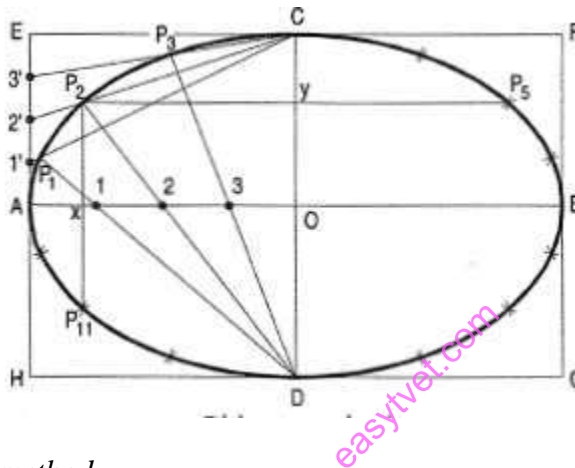


Figure 91: Oblong method

- (i) Draw the two axes AB and CD intersecting each other at O.
- (ii) Construct the oblong EFGH having its sides equal to the two axes.
- (iii) Divide the semi-major-axis AO into a number of equal parts, say 4, and AE into the same number of equal parts, numbering them from A as shown.
- (iv) Draw lines joining 1', 2' and 3' with C.
- (v) From D, draw lines through 1, 2 and 3 intersecting C<sub>1</sub>, C<sub>2</sub> and C<sub>3</sub> at points P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> respectively.
- (vi) Draw the curve through A, P<sub>1</sub> ..... C. It will be one quarter of the ellipse.
- (vii) Complete the curve by the same construction in each of the three remaining quadrants.

As the curve is symmetrical about the two axes, points in the remaining quadrants may be located by drawing perpendiculars and horizontals from P<sub>1</sub>, P<sub>2</sub> etc. and making each of them of equal length on both the sides of the two axes. For example, P<sub>2</sub>x = x P<sub>11</sub> and P<sub>2</sub>y = yP<sub>5</sub>.

## Trammel method

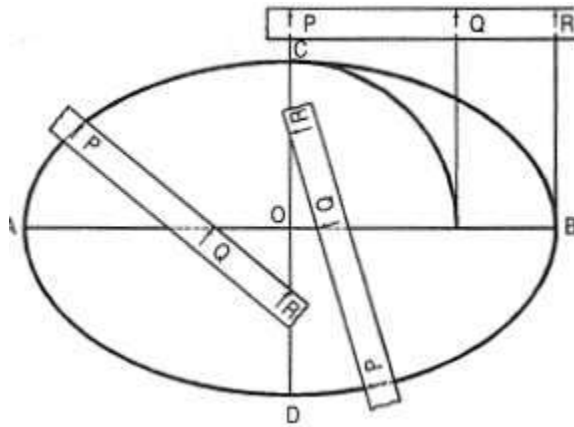
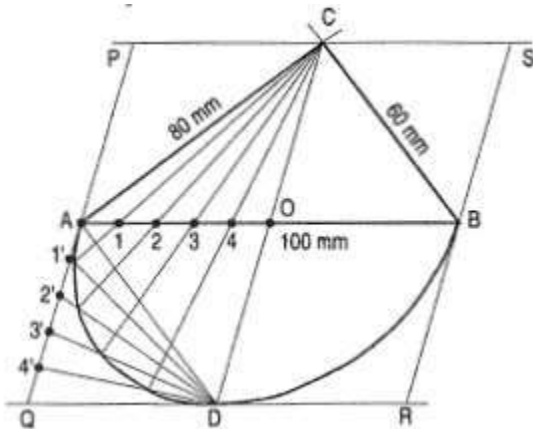


Figure 92: Trammel method

- i. Draw the two axes AB and CD intersecting each other at O. Along the edge of a strip of paper which may be used as a trammel, mark PQ equal to half the minor axis and PR equal to half the major axis.
- ii. Place the trammel so that R is on the minor axis CD and Q on the major axis AB. Then P will be on the required ellipse. By moving the trammel to new positions, always keeping R on CD and Q on AB, obtain other points. Draw the ellipse through these points.

## Learning activity

1. ABC is a triangle such that AB = 100 mm, AC = 80 mm and BC = 60 mm. Draw an ellipse passing through points A, B and C. (figure below)



- i. Draw horizontal line AB = 100 mm. Take A as centre draw an arc of 80 mm. Similarly B as centre and the radius equal to 60 mm, draw the arc such that it intersects previously drawn arc at the point C. Join ABC to complete triangle.
- ii. Mark the mid point of AB such that OA = OB = 50 mm. Join OC and extend CO such that CO = OD.

- iii. Draw parallel lines from C and D to the line AB. Similarly draw parallel lines from A and B to the line CD and complete the rhombus (PQRS).
- iv. Divide AO into convenient number of equal parts  $A1 = 12 = 23 = 34 = 40$  and AQ to same number of equal parts  $A1' = 1' 2' = 2' 3' = 3' 4' = 4' Q$ . Join A, 1', 2', 3', 4' with D. Join C1 and extend it to intersect line 01'. Similarly join C2, C3, C4 and extend it to intersect 02', 03', 04' respective. Draw smooth curve passing through all intersection.
- v. Complete the ellipse by above method for the remaining part.

## PARABOLA

Use of parabolic curves is made in arches, bridges, sound reflectors, light reflectors etc. Mathematically a parabola can be described by an equation  $y^2 = 4ax$  or  $x^2 = 4ay$ .

### General method of construction of a parabola

To construct a parabola when the distance of the Focus from the directrix is 50 mm.

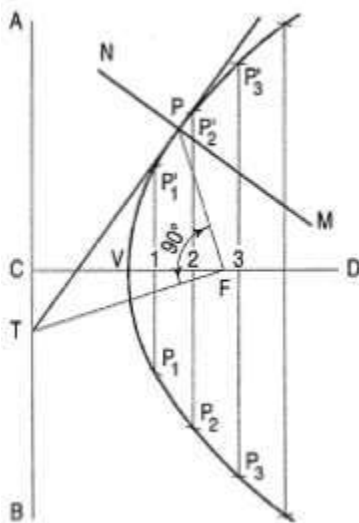


Figure 93: Parabola

Directrix and focus

- i. Draw the directrix AB and the axis CD.
- ii. Mark focus F on CD, 50 mm from C.
- iii. Bisect CF in V the vertex (because eccentricity = 1).
- iv. Mark a number of points 1, 2, 3 etc. on the axis and through them, draw perpendiculars to it.
- v. With centre F and radius equal to C1, draw arcs cutting the perpendicular through 1 at P<sub>1</sub> and P'<sub>1</sub>. Similarly, locate points P<sub>2</sub> and P'<sub>2</sub>, P<sub>3</sub> and P'<sub>3</sub> etc. on both the sides of the axis.

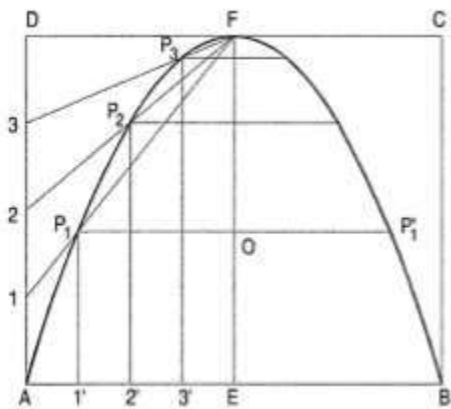


- vi. Draw a smooth curve through these points. This curve is the required parabola. It is an open curve.

#### Rectangle method

To construct a parabola given the base and the axis.

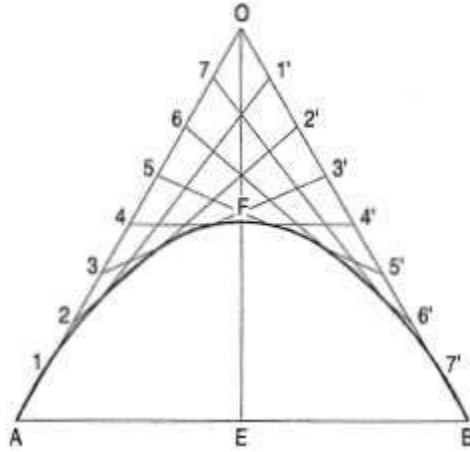
- (i) Draw the base AB.
- (ii) At its mid-point E, draw the axis ff at right angles to AB.
- (iii) Construct a rectangle ABCD, making side BC equal to ff.
- (iv) Divide AE and AD into the same number of equal parts and name them as shown (starting from A).
- (v) Draw lines joining F with points 1, 2 and 3. Through 1', 2' and 3', draw perpendiculars to AB intersecting F1, F2 and F3 at points P1, P2 and P3 respectively.
- (vi) Draw a curve through A, P1, P2 etc. It will be a half parabola. Repeat the same construction in the other half of the rectangle to complete the parabola. Or, locate the points by drawing lines through the points P1, P2 etc. parallel to the base and making each of them of equal length c on both the sides of ff, e.g. P1O = OP'1. AB and EF are called the base and the axis respectively of the parabola.



Rectangular method

#### Tangent method

- (i) Draw the base AB and the axis ff. (These are taken different from those in method I.)
- (ii) Produce ff to O so that EF = FO.
- (iii) Join O with A and B. Divide lines OA and OB into the same number of equal parts, say 8.
  - (iv) Mark the division-points as shown in the figure.
- (iv) Draw lines joining 1 with 1', 2 with 2' etc. Draw a curve starting from A and tangent to lines 1-1', 2-2' etc. This curve is the required parabola.



*Figure 94: Tangent method of constructing parabola*

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## HYPERBOLA

### Definition

A hyperbola is the locus of a point which moves so that its distance from a fixed point (called the focus) bears a constant ratio, always greater than 1, to its perpendicular distance from a straight line (called the directrix).

Figure 45 shows how to draw a hyperbola given the relative positions of the focus and the directrix and the eccentricity ( $3/2$ ). The first point to plot is the one that lies between the focus and the directrix.

This is done by dividing the distance between them in the same ratio as the eccentricity.  $3:2$ .

The condition for the locus is that it is always  $2/3$  as far from the directrix as it is from the focus. Thus, if the point is 15mm from the focus, it is  $2/3 \times 15\text{mm}$  from the directrix; if it is 20mm from the focus, it is  $2/3 \times 20\text{mm}$  from the directrix. This is continued for as many points as may be required.

Use of hyperbolic curves is made in cooling towers, water channels etc.

### Rectangular hyperbola

It is a curve traced out by a point moving in such a way that the product of its distances from two fixed lines at right angles to each other is a constant. The fixed lines are called asymptotes.

This curve graphically represents the Boyle's Law, viz.  $P \times V = a$ ,  $P$  = pressure,  $V$  = volume and  $a$  is a constant. It is also useful in design of water channels.

### General method of construction of a hyperbola

Mathematically, we can describe a hyperbola by  $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$

(figure 44): Construct a hyperbola, from the directrix is 65 mm and eccentricity is  $f$

- i. Draw the directrix AB and the axis CD.
- ii. Mark the focus F on CD and 65 mm from C.
- iii. Divide CF into 5 equal divisions and mark V the vertex, on the second division from C.

$$\text{Thus, eccentricity} = \frac{VF}{VC} = \frac{3}{2}$$

**To construct the scale for the ratio draw a line VE perpendicular to CD such that  $VE = VF$ .  
Join C with E.**

$$\text{Thus, in triangle CVE, } \frac{VE}{VC} = \frac{VF}{VC} = \frac{3}{2}$$

- i. Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at 1

- ii. With centre F and radius equal to 1-1', draw arcs intersecting the perpendicular through 1 at P<sub>1</sub> and P'<sub>1</sub>.
- iii. Similarly, mark a number of points 2, 3 etc. and obtain points P<sub>2</sub> and P'<sub>2</sub>, P<sub>3</sub> and P'<sub>3</sub> etc.
- iv. Draw the hyperbola through these points.

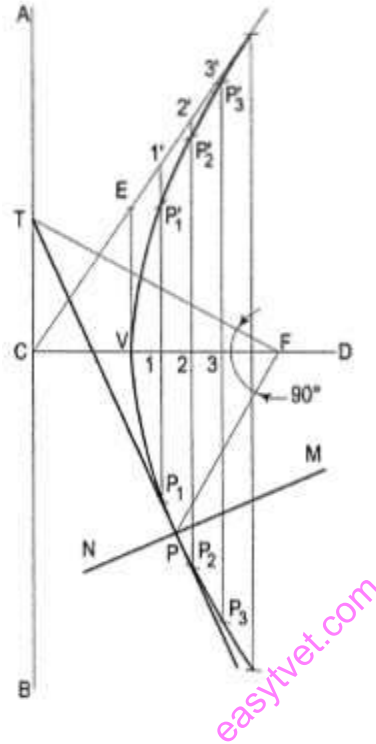
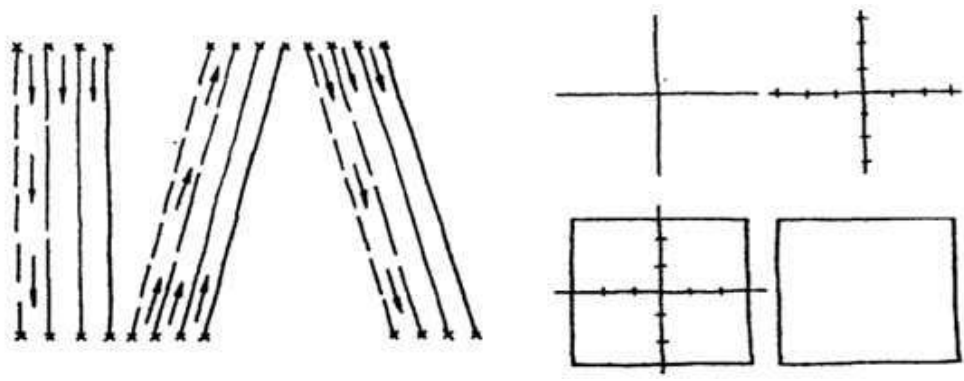


Figure 95

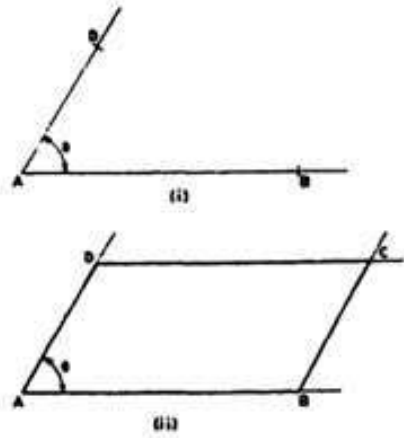
**Freehand Sketching**

Freehand sketching is one of the effective methods to communicate ideas irrespective of the branch of study. The basic principles of drawing used in freehand sketching are similar to those used in drawings made with instruments.

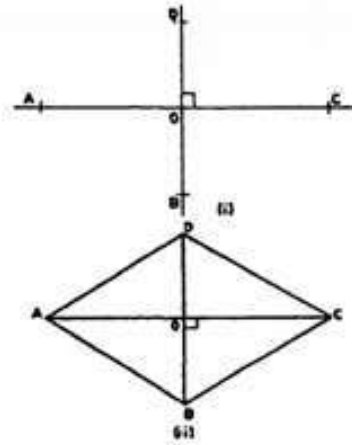


Sketching a Square

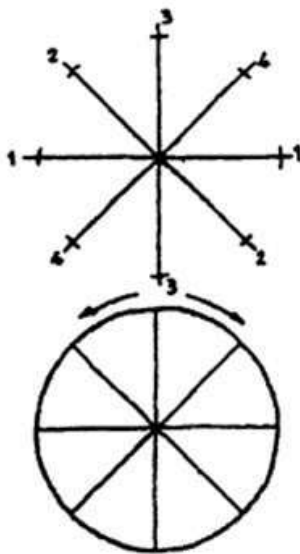
Sketching Straight Lines



Sketching a Rhombus

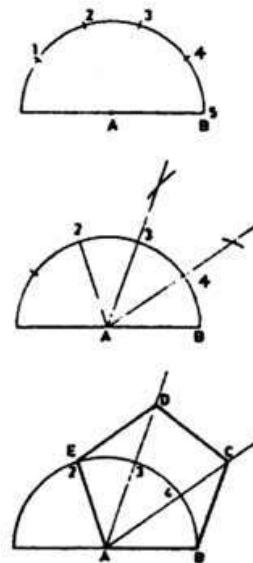


Sketching a Parallelogram

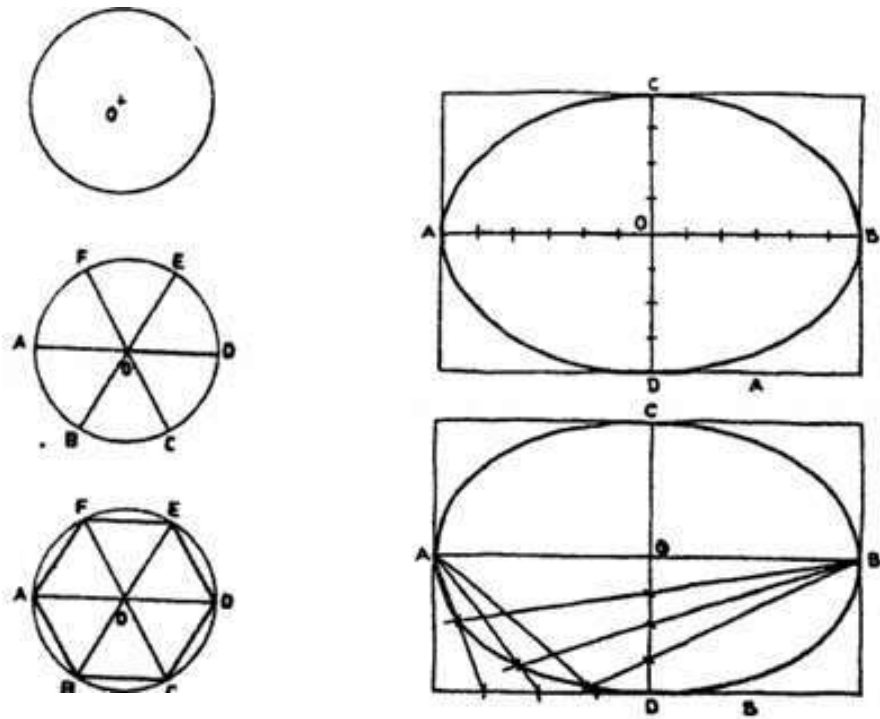


Sketching a Pentagon

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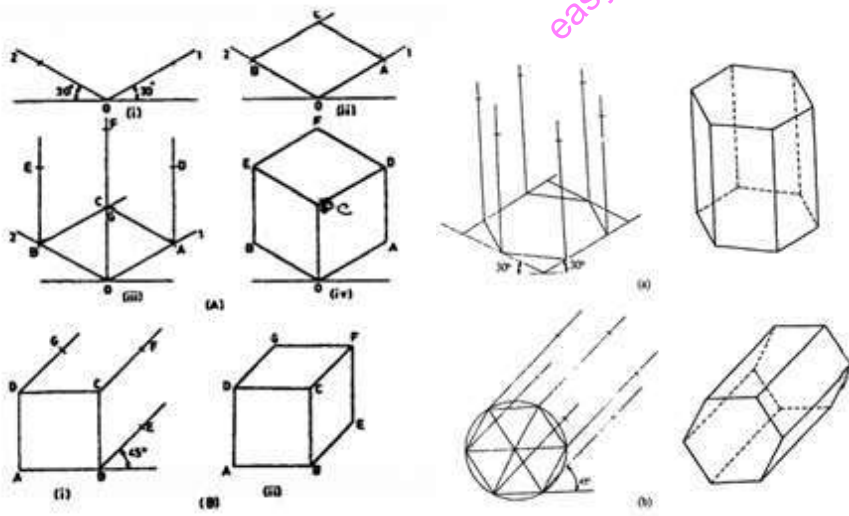


Sketching a Circle



Sketching an Ellipse

Sketching a Hexagon



Sketching a Hexagonal Prism

Sketching a Cube

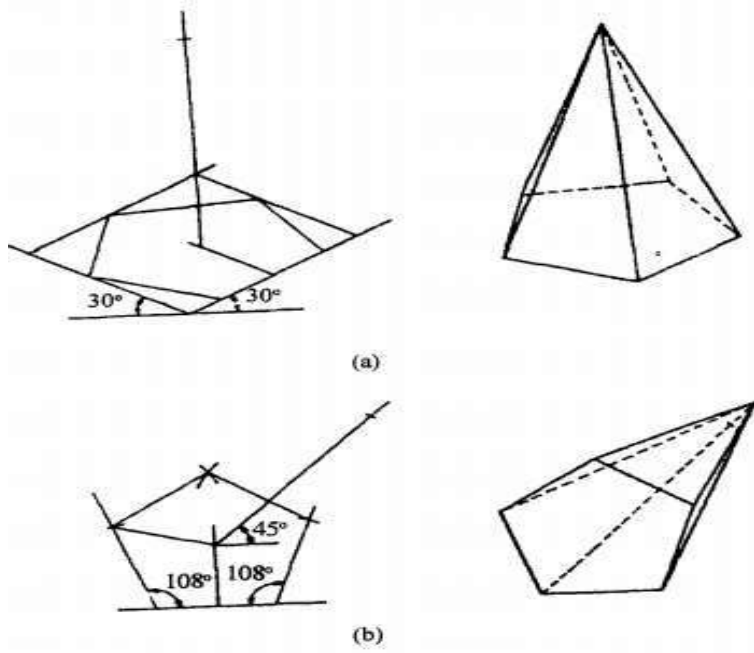
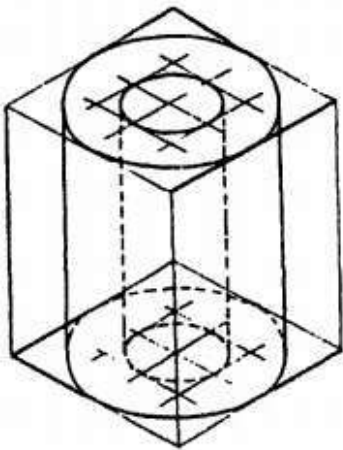
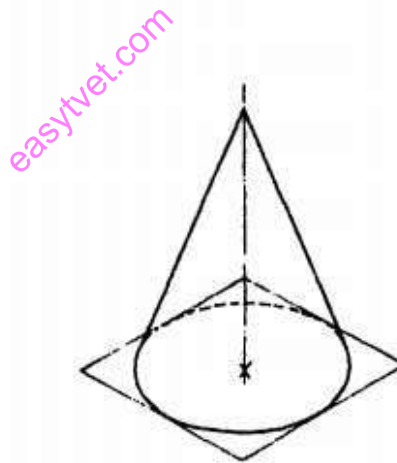


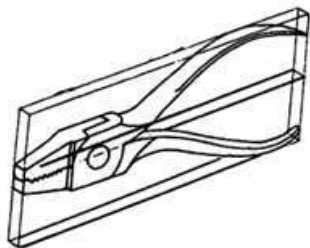
Figure 96: Sketching a Pentagonal Pyramid



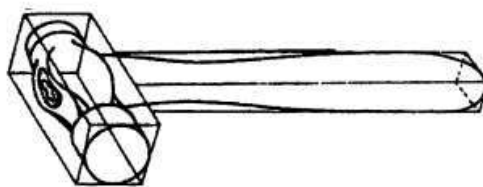
Sketching a Cone



Sketching a Hollow Cylinder



*Sketching a Ball Peen Hammer*



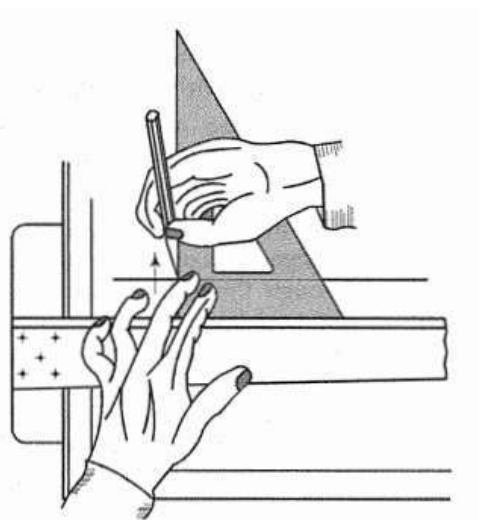
*Sketching a Cutting Plier*

Learning activities

### **Learning activity 1: Produce plane geometry**

To draw a fine perpendicular to a given horizontal line from a given point within it.

- i. Place the T-square a little below the given line
- ii. Arrange any one set-square with one of the edges containing the right angle touching the working edge of the T-square, and the other edge passing through the given point.
- iii. Hold the T-square and the set-square in this position firmly with the left hand.
- iv. With the right hand, draw the required line through the given point in the upward direction as shown by the arrow. The pencil point should always be in contact with the edge of the set-square. A perpendicular from any given point outside the line can also be drawn in the same manner. Vertical parallel lines may be drawn by sliding the set-square along the edge of the T-square to the required positions.





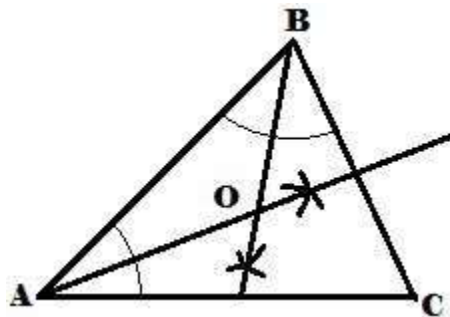
## Learning activity 2: Produce plane geometry

### To inscribe a regular polygon of any number of sides, say 5, in a given circle

- i. With centre O, draw the given circle.
- ii. Draw a diameter AB and divide it into five equal parts (same number of parts as the number of sides) and number them as shown.
- iii. With centres A and B and radius AB, draw arcs intersecting each other at P.
- iv. Draw a line P2 and produce it to meet the circle at C. Then AC is the length of the side of the pentagon.
- v. Starting from C, step-off on the circle, divisions CD, DE etc., equal to AC.
- vi. Draw lines CO, DE etc., thus completing the pentagon.

### Self-assessment

1. How many sides have a regular nonagon?
  - A. 12
  - B. 11
  - C. 10
  - D. 9
2. When the construction is completed, the figure drawn describes \_\_\_\_\_ circle.



- A. a circumscribed
  - B. a concentric
  - C. an eccentric
  - D. an escribed
  - E. an inscribed
3. Draw a parabola by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 1:1.
  4. Draw a hyperbola by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 2:3.
  5. Draw an ellipse by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 3:2.

6. A ground is in the shape of a rectangle 120 m X 60m. Inscribe an elliptical lawn in it to a suitable scale by concentric circle method.
7. Divide a line of 40 mm in ratio 1:3:4

#### Tools, Equipment, Supplies and Materials

1. Drawing tools
2. Drawing set
3. Drawing papers
4. Erasers
5. Series of pencils
6. Drawing board

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### 4.3 Produce Solid Geometry Drawings

#### Introduction to the Learning Outcome

This learning outcome is intended to equip the trainee with competence on how to produce solid geometry drawings. Knowledge on how to develop and interpret patterns is learnt and exercised in this learning outcome

#### Performance Standard

- i. Drawings of patterns are interpreted according to standard conventions
- ii. Patterns are developed in accordance with standard conventions
- iii. Interpretation of sketches and drawings of patterns e.g. cylinders, prisms and pyramids

#### Information sheet

## Concept of developing surfaces

A layout of the complete surface of a three-dimensional object on a plane is called the development of the surface or flat pattern of the object. The development of surfaces is very important in the fabrication of articles made of sheet metal.

### *Methods of development*

The method to be followed for making the development of a solid depends upon the nature of its lateral surfaces. Based on the classification of solids, the following are the methods of development.

#### **i. Parallel-line Development**

It is used for developing prisms and single curved surfaces like cylinders in which all the edges / generators of lateral surfaces are parallel to each other.

#### **ii. Radial-line Development**

It is employed for pyramids and single curved surfaces like cones in which the apex is taken as center and the slant edge or generator (which are the true lengths) as radius for its development.

### *Orthographic views*

## Development of surfaces of pyramids

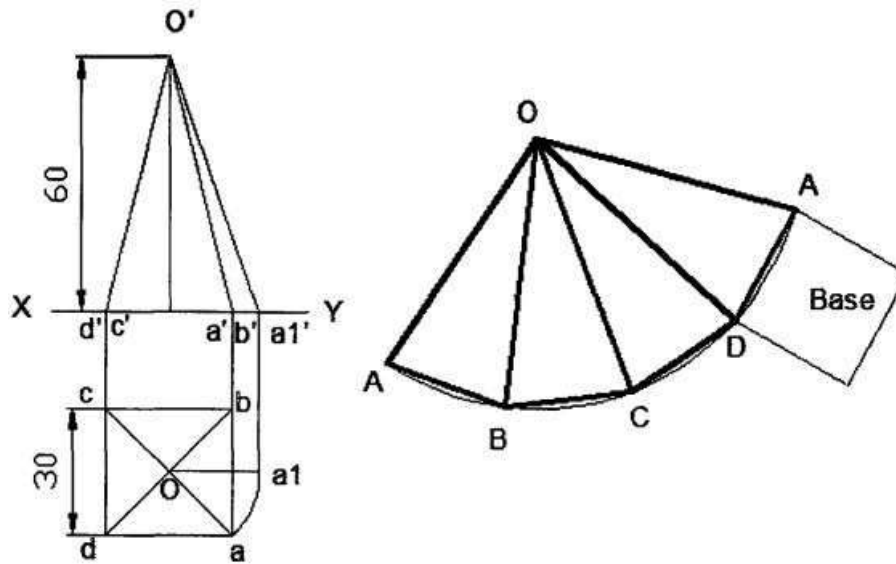


Figure 97: Development of surfaces of pyramids

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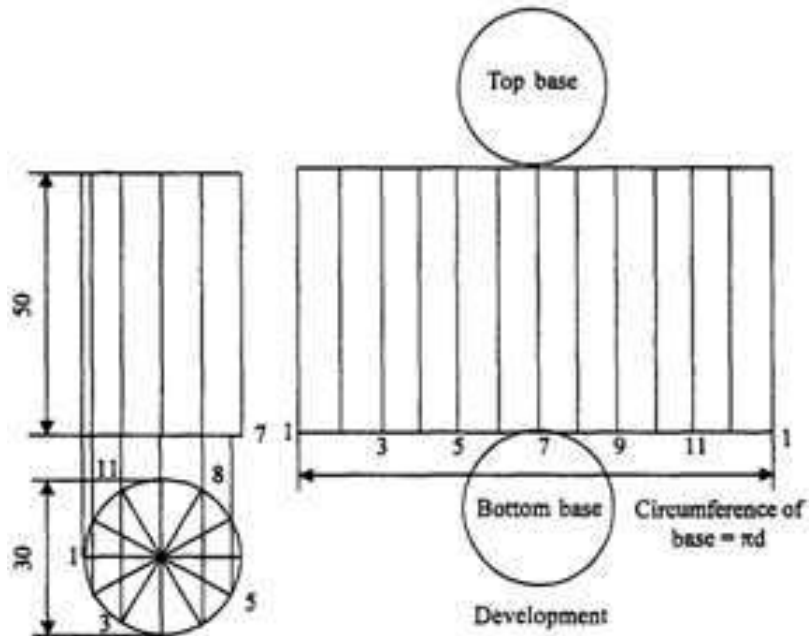


Figure 98: Development of cylinder surfaces

### Development of surfaces of cones

The development of the lateral surface of a cone is a sector of a circle. The radius and length of the arc are equal to the slant height and circumference of the base of the cone respectively. The included angle of the sector is given by  $(r / s) \times 360^\circ$ , where  $r$  is the radius of the base of the cone and  $s$  is the true length.

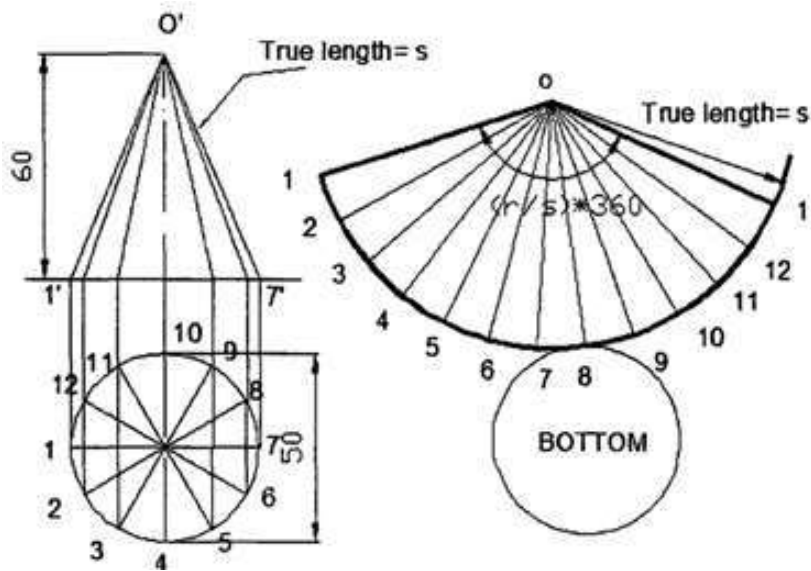


Figure 99: Development and interpenetrations of solids

## Development and interpenetrations of solids

### Intersection of regular solids

Ducts, pipe joints, smoke stacks, boilers, containers, machine castings etc., involve intersection of surfaces. Sheet metal work required for the fabrication of the above objects necessitates the preparation of the development of the joints objects. Orthographic drawings of lines and curves of intersection of surfaces must be prepared first for the accurate development of objects.

### Intersection of cylinder and cylinder

Case I: Cylinders of Same size

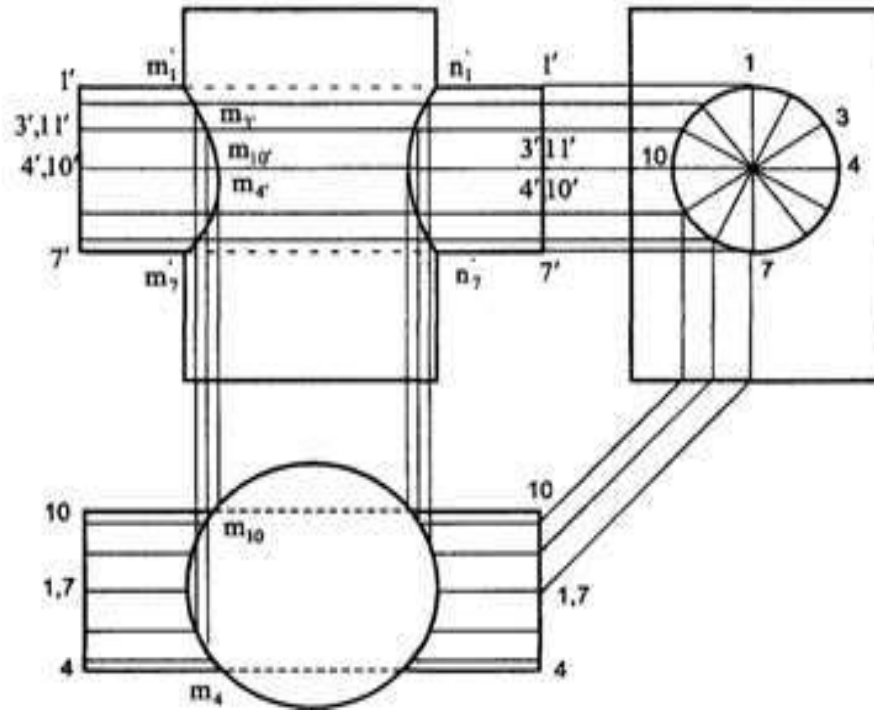
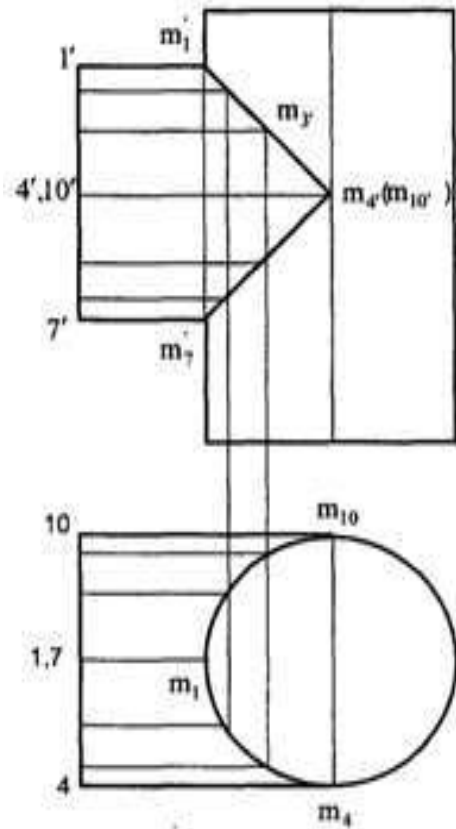


Figure 100: Cylinders of Same size

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Case II: Cylinders of Same size



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Figure 101: Cylinders of Same size



## **Intersection of prism and prism**

When a prism penetrates another prism, plane surface of one prism intersects the plane surfaces of another prism and hence the lines of intersection will be straight lines. In these cases, lines on the surface of one of the solids need not necessarily be drawn as it is done with cylinders. Instead, the points of intersections of the edges with the surface are located by mere inspection. These points are projected in the other view and the lines of intersection obtained.

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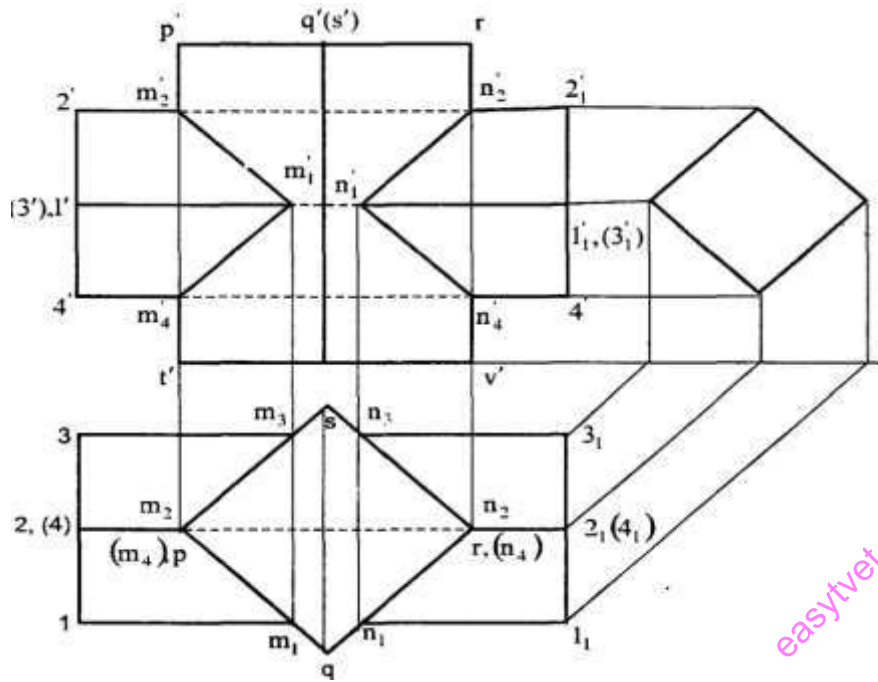


Figure 102: Intersection of prism and prism

Learning activities

**Learning activity 1:** Produce solid geometry drawings

**Develop the lateral surface of the truncated cylinder**

- i. Divide the circle in the top view into twelve equal parts. Project the division points to the front view and draw the generators. Mark points a', b' and b'<sub>1</sub>, c' and c'<sub>1</sub> etc. in which the generators are cut.

- ii. Draw the development of the lateral surface of the whole cylinder along with the generators. The length of the line 1-1 is equal to  $\pi \times D$  (circumference of the circle). This length can also be marked approximately by stepping off with a bow divider, twelve divisions, each equal to the chord-length  $ab$ . (The length thus obtained is about 1 % shorter than the exact length; but this is permitted in drawing work.)
- iii. Draw horizontal lines through points  $a'$ ,  $b'$  and  $b'1$  etc. to cut the corresponding generators in points  $A$ ,  $B$  and  $B1$  etc. Draw a smooth curve through the points thus obtained. The figure 1-A-A-1 is the required development.

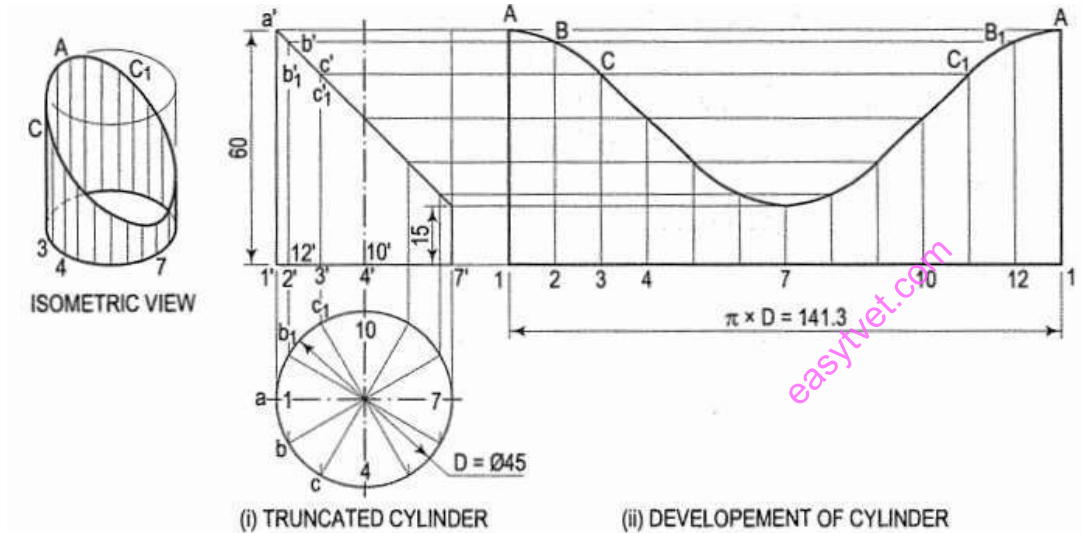


Figure 103: Lateral surface of the truncated cylinder

### Learning activity 2: Produce solid geometry drawings

#### Draw the development of the of the truncated cone

Assuming the cone to be whole, let us draw its development.

- i. Draw the base-circle in the top view and divide it into twelve equal parts.
- ii. With any point O as centre and radius equal to o'1' or o'7', draw an arc of the circle. The length of this arc should be equal to the circumference of the base circle. This can be determined in two ways.

- iii. Calculate the subtended angle  $\Theta$  by the formula,

$$\Theta = 3600 \times \frac{\text{radius of the base circle}}{\text{slant height}}$$

Cut-off the arc so that it subtends the angle  $\Theta$  at the centre and divide it into twelve equal parts.

- iv. Step-off with a bow-divider, twelve equal divisions on the arc, each equal to one of the divisions of the base-circle. (This will give an approximate length of the circumference. Note that the base-circle should not be divided into less than twelve equal parts.)
- v. Join the division-points with O, thus completing the development of the whole cone with twelve generators shown
- vi. The truncated portion of the cone may be deducted from this development by marking the positions of points at which generators are cut and then drawing a curve through them. For example, generators o'2' and o'12' in the front view are cut at points b' and b'1 which coincide with each other. The true length of o' b' may be obtained by drawing a line through b', parallel to the base and cutting o'7' at b". Then o'b" is the true length of o'b'.
- vii. Mark points B and B<sub>1</sub> on generators O2 and O-12 respectively, such that OB = OB<sub>1</sub> = o' b". Locate all points in the same way and draw a smooth curve through them. The figure enclosed this curve and the arc is the development of the truncated cone.

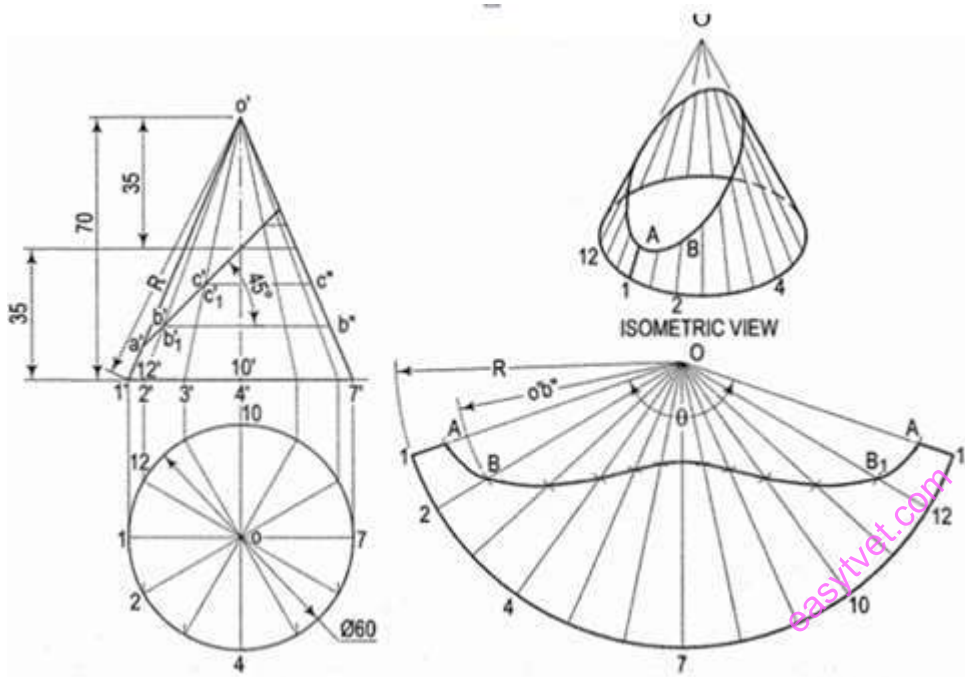
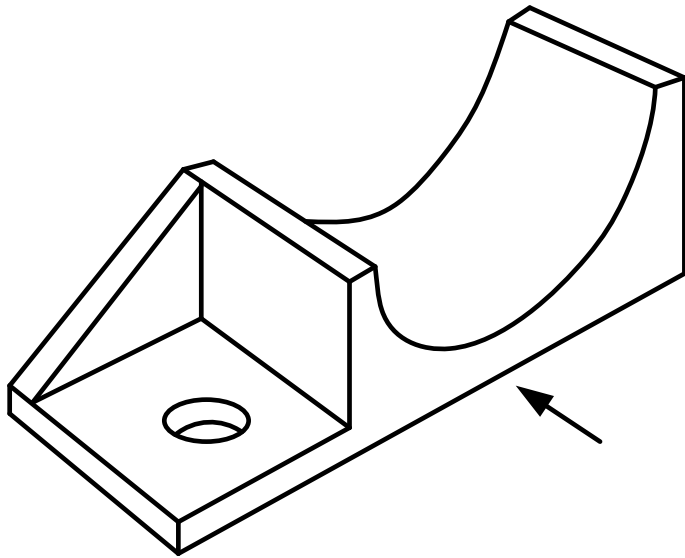


Figure 104: Truncated cone and surface development

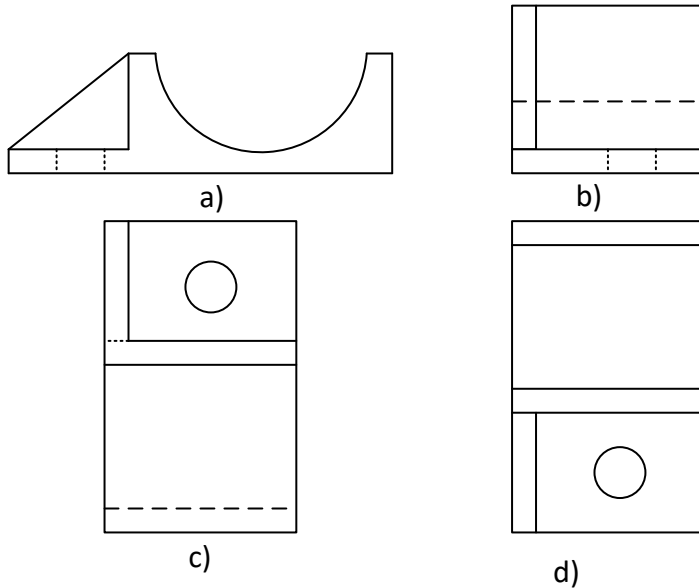
### Self-assessment

1. The bounding box method for setting up an isometric drawing helps the drafter \_\_\_\_\_.

- A. confines the isometric drawing to its maximum size
  - B. figure what lines are to be illustrated vertical and horizontal
  - C. position the isometric drawing in paper space
  - D. none of the above
2. This type of section is limited by a break line:
- A. Removed section
  - B. Revolved section
  - C. Broken-out section
  - D. Half section
3. In the section view, the areas that would have been in actual contact with the cutting plane are shown with:
- A. A cutting plane line
  - B. Section lining
  - C. Visible lines
  - D. Lines and arrows
4. What is the difference between regular and irregular polygons?
5. If an isometric drawing is made use of isometric scale then the drawings are called
- A. Isometric projection
  - B. Isometric view
  - C. Isometric perception
  - D. Orthographic view
6. Identify the front view of the pictorial drawing below.



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### Tools, Equipment, Supplies and Materials

- i. Drawing tools
- ii. Drawing set
- iii. Drawing papers
- iv. Erasers
- v. Series of pencils
- vi. Drawing board

### References

1. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing: Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.



2. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
3. Narayana, K. L., Kannaiah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
4. Reddy, K. V. 2010. Textbook of Engineering Drawing. B.S. Publ., Hyderabad.
5. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,

#### **4.4 Produce Orthographic and Pictorial Drawings**

##### **Introduction to the learning outcome**

This learning outcome is intended to equip the trainee with competence on how to produce orthographic and pictorial drawings.

##### **Performance Standard**

- i. Symbols and abbreviations are identified and their meaning interpreted according to standard drawing conventions
- ii. First and third angle orthographic drawings are interpreted and produced in accordance with the standard conventions
- iii. Orthographic elevations are dimensioned in accordance with standard conventions
- iv. Isometric drawings are interpreted and produced in accordance with standard conventions
- v. Assembly drawing is produced and interpreted in line with the operating standards

Information sheet

##### **Definitions**

##### **Projections**

The technique of representing an object in a drawn form is referred to as projection. Projection can be divided into pictorial (3- dimensional) projection and orthographic (2- dimensional) projection. Pictorial projection is further divided into isometric,

oblique and perspective projections; while the orthographic projection is divided into 1<sup>st</sup> angle and 3<sup>rd</sup> angle projection is referred to as projection. Projection can be divided into pictorial (3- dimensional) projection and orthographic (2- dimensional) projection. Pictorial projection is further divided into isometric, oblique and perspective projections; while the orthographic projection is divided into 1<sup>st</sup> angle and 3<sup>rd</sup> angle projection.

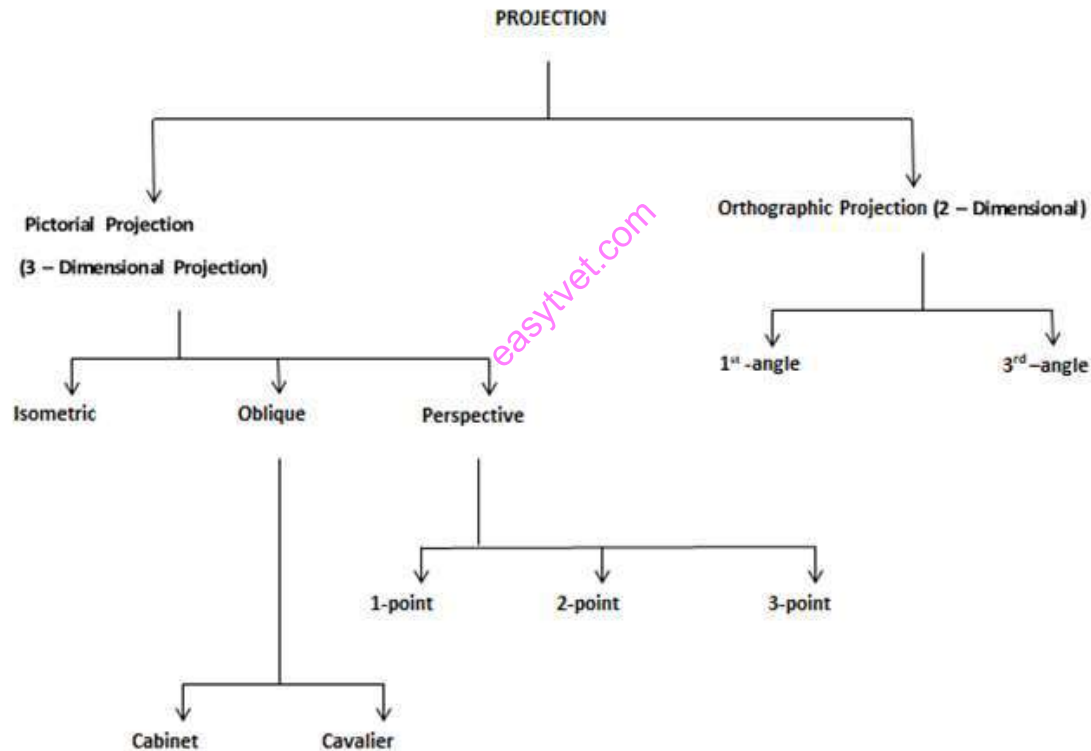


Figure 105: Types of projections

### Orthographic Drawing

'ORTHO' means right angle and orthographic means right angled drawing. When the projectors are perpendicular to the plane on which the projection is obtained, it is known as orthographic projection. It is in two dimensions (2D). It uses multiple views of the object, from points of view rotated about the object's center through increments of  $90^\circ$ . The views are positioned relative to each other according to either of two schemes: *first- Angle* or *third-Angle* projection. In each, the appearances of views may be thought of as being *projected* onto planes that form a transparent "box" around the object.

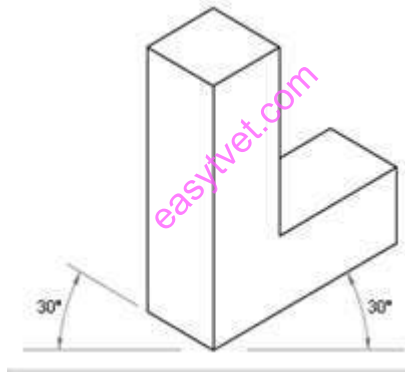


Figure 106: Isometric drawing

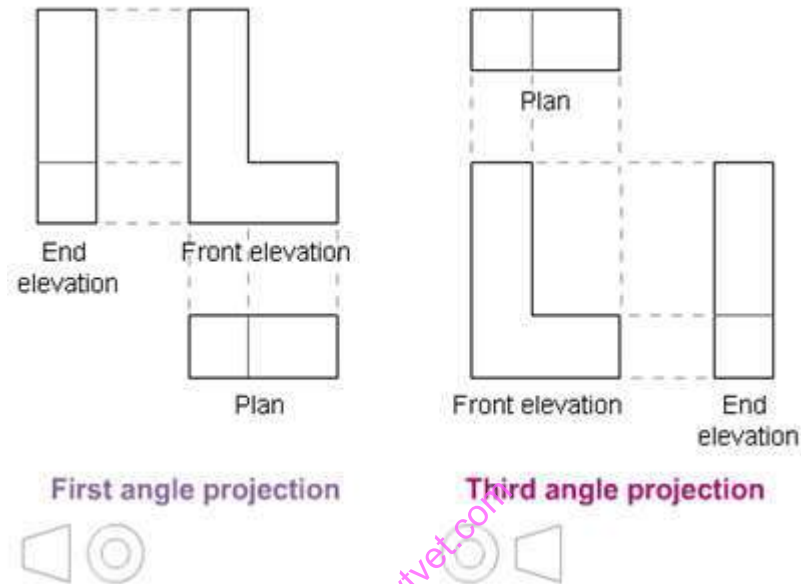
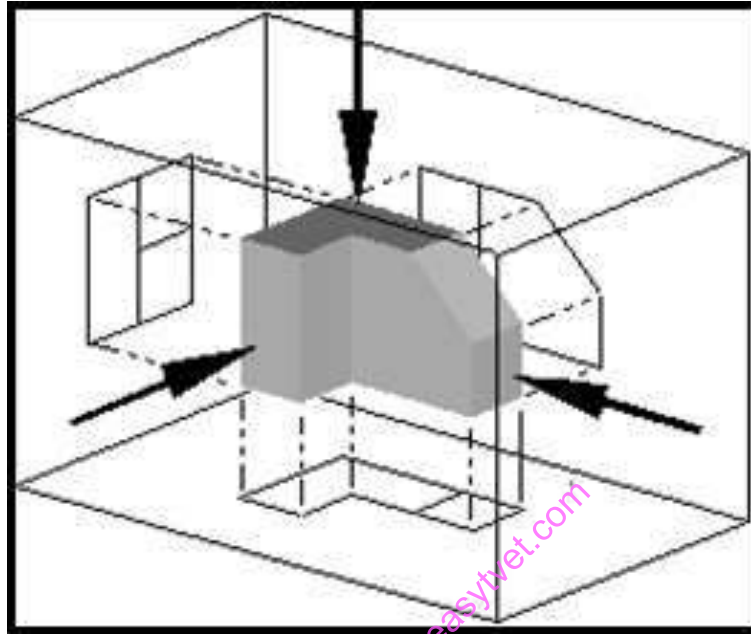


Figure 107: Illustrating the difference between 1st. and 3rd. angles projection

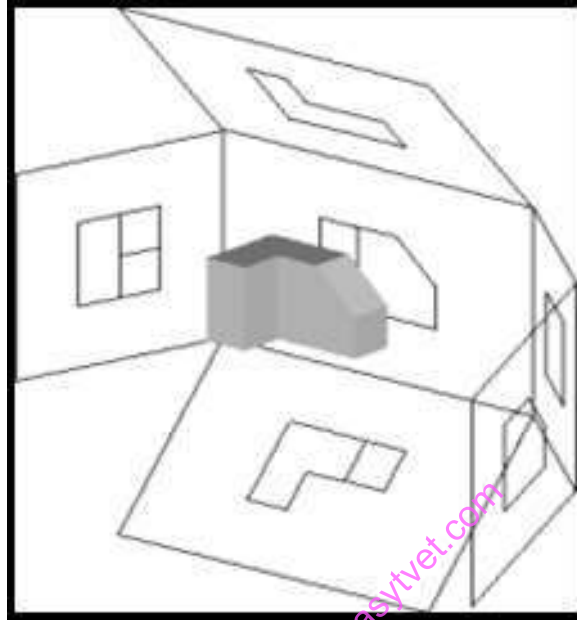
## The Differences between 1st & 3rd Angle Projection

### First-Angle Projection

In **first-angle projection**, each view of the object is projected in the direction (sense) of sight of the object, onto the interior walls of the box



A two-dimensional representation of the object is then created by "unfolding" the box, to view all of the *interior* walls



*Figure 108: unfolding*

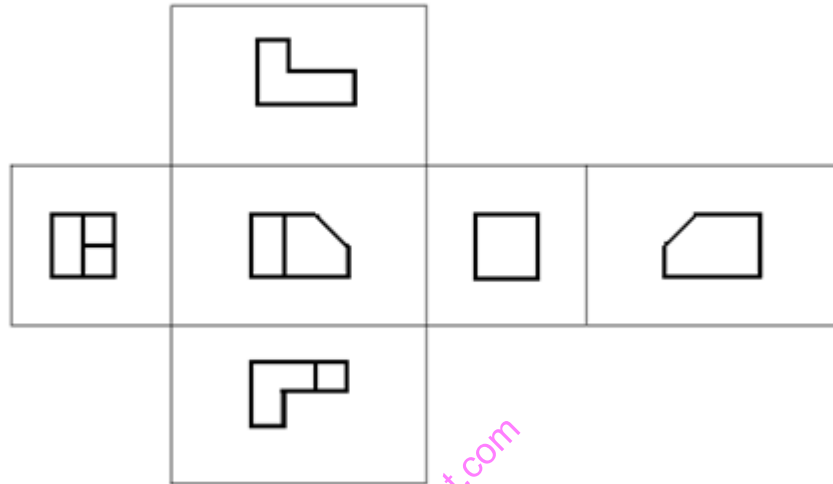
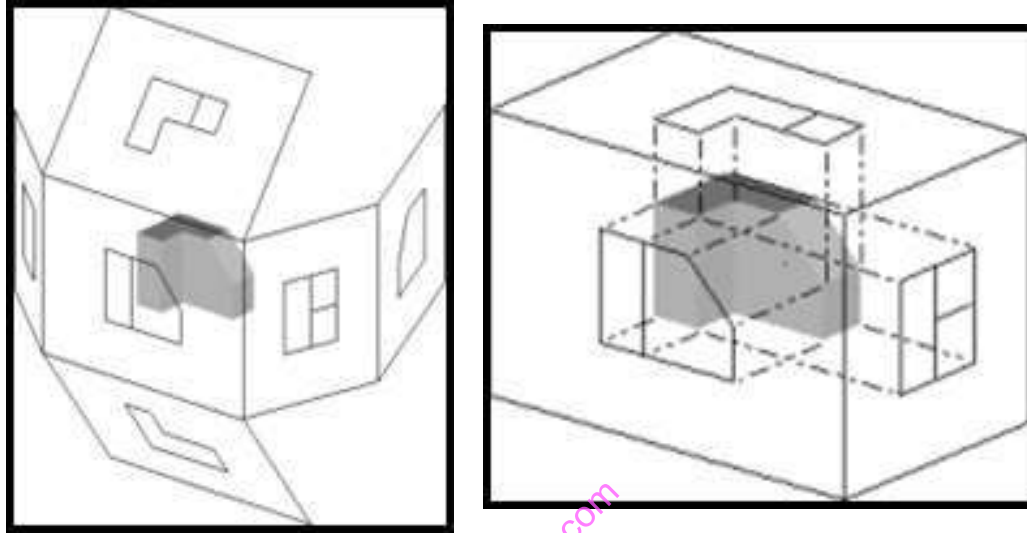


Figure 109: unfolded views

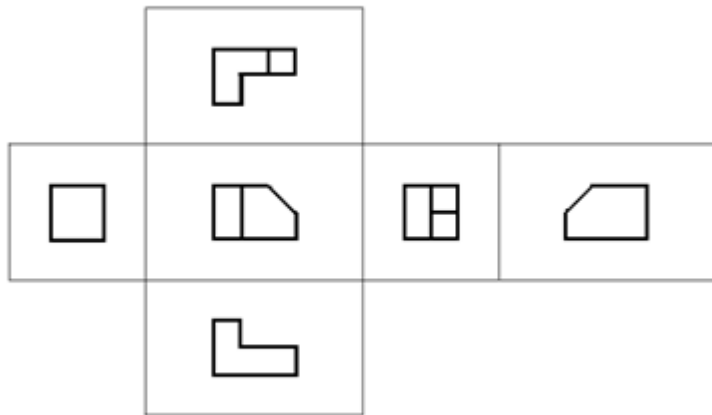
### Third-Angle Projection

In **third-angle projection**, each view of the object is projected opposite to the direction (sense) of sight, onto the (transparent) exterior walls of the box in the figure below.



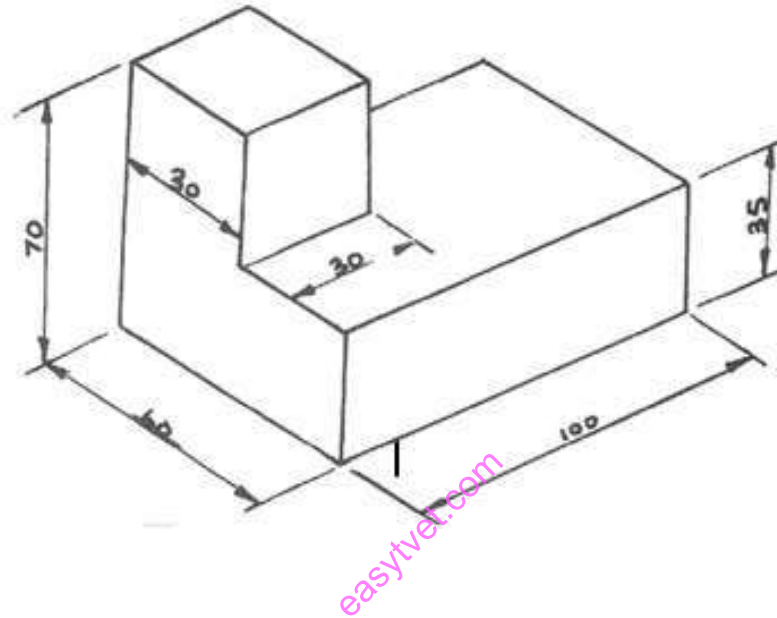
*Figure 110: unfolding*





*Figure 111: unfolding views*

A two-dimensional representation of the object is then created by unfolding the box, to view all of the *exterior* walls. Before starting drawing the views of the component shown in Figure below, it is necessary to decide the best Angle to project on the component; good decision will make the reading of the details of the views much easier afterwards.



## SECTIONING

To produce a sectional view, a cutting plane is imagined cutting through the part, as shown in fig. (a). Picture the two halves of the object pulled apart, exposing the interior construction, as shown in fig. (b). In this case, we will look toward the left half of the object in the section view. This sectional view replaces the right-side view.

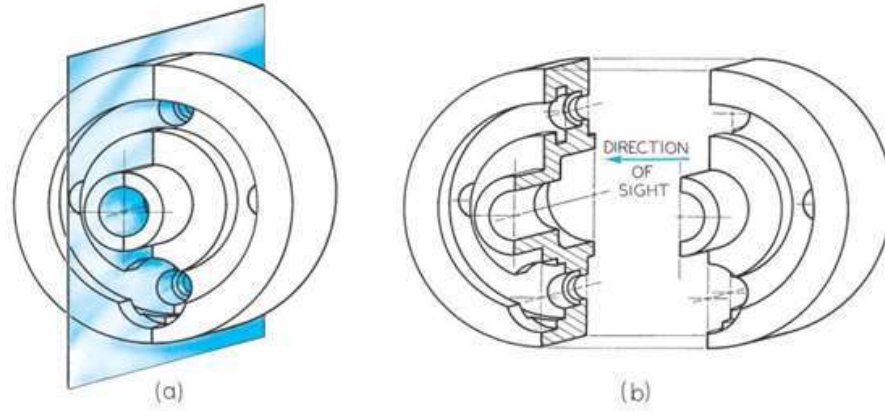
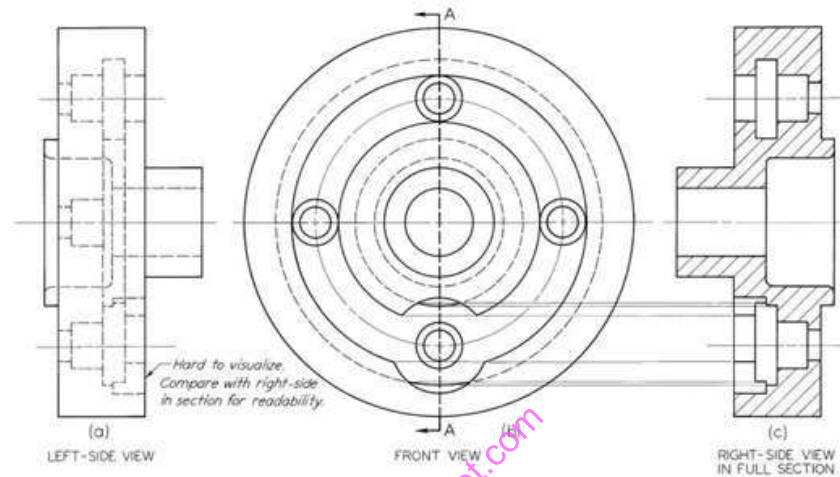


Figure 112: Cutting plane

### Full Sections

The section produced by cutting through the entire object is called a full Section, as shown in fig. (c) below.



*Figure 113: Full Sections*

## The Cutting Plane

The cutting-plane line is shown as a special pattern. The arrows at the ends of the cutting plane line indicate the direction of sight for the section view. We can think the cutting-plane line as showing the edge view of the cutting plane.

When a cutting-plane line coincides with a centerline, the cutting-plane line takes precedence.

## Cutting-Plane Line Patterns

Figures below show two line patterns used to show the cutting-plane line. Arrowheads indicate the direction in which the cut object is viewed.

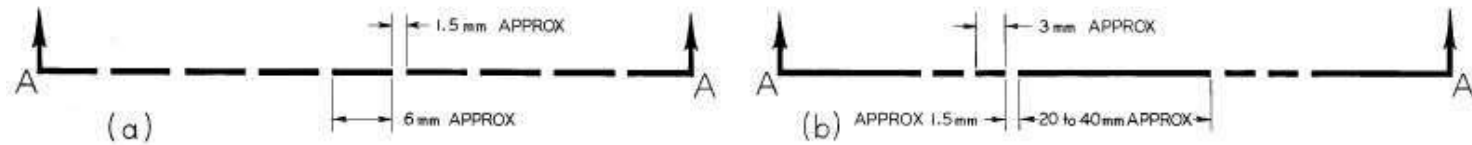


Figure 114: Cutting-Plane Line Patterns

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## Interpreting Cutting Planes and Sections

Sectional views often replace standard views. As figures shown, the cutting plane is a frontal plane and appears as a line in the top view. The arrows at the ends of cutting-plane line point in the direction of sight for front section. The result is called a front section, or front view in section, since it replaces the front view in the drawing.

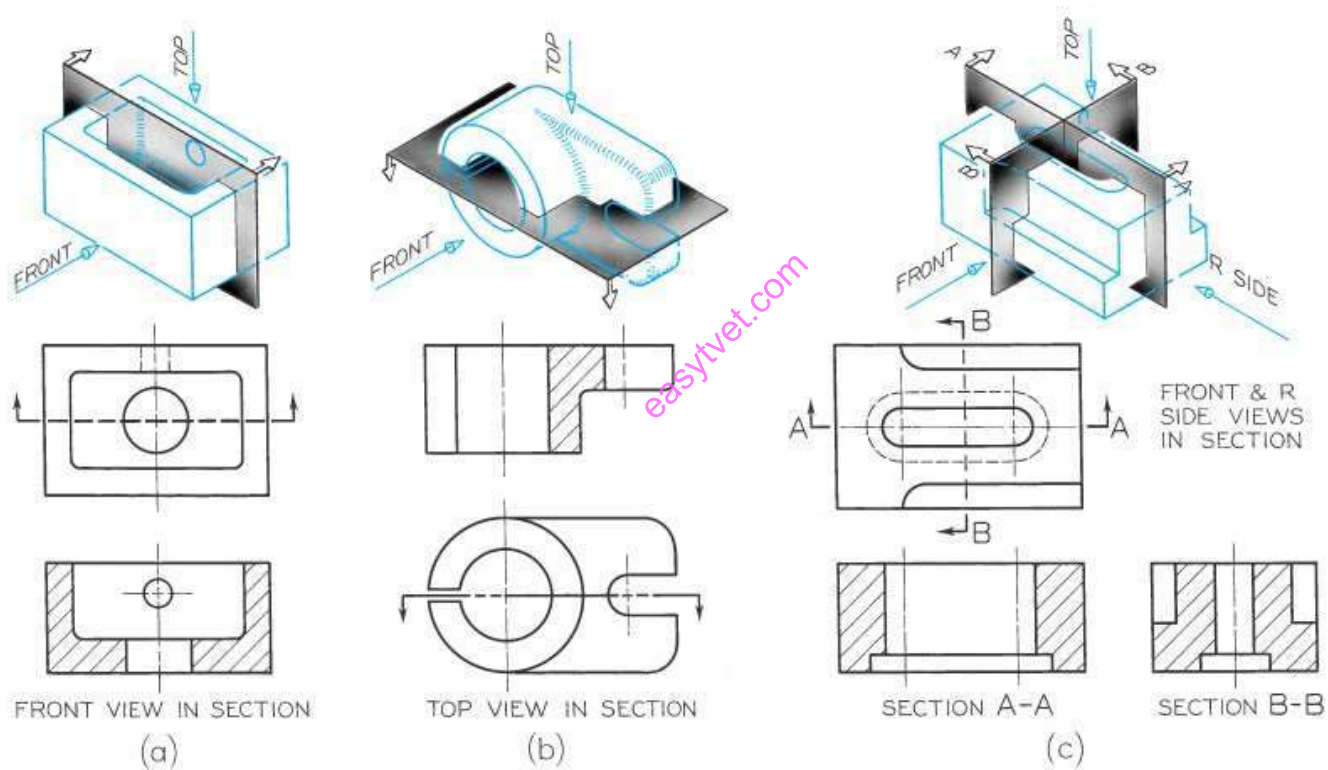
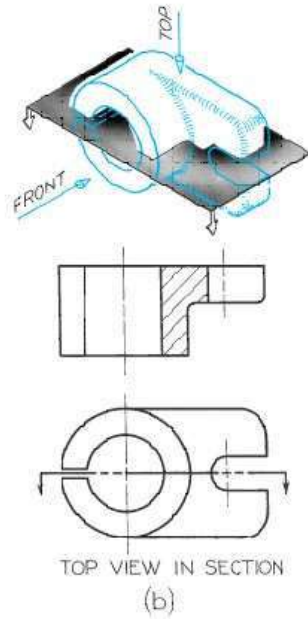


Figure 115: Cutting Planes and Sections

As shown in figures, the cutting plane is a horizontal plane, appearing as a line in the front view. The arrows point toward the lower half in the same direction of sight as for a top view. This result is top view in section.



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Figure 116: sectional views

Figures below show two cutting planes - one a frontal plane, the other a profile plane - and both appear on edge in the top view. Each section is completely independent of the other and drawn as if the other were not present.

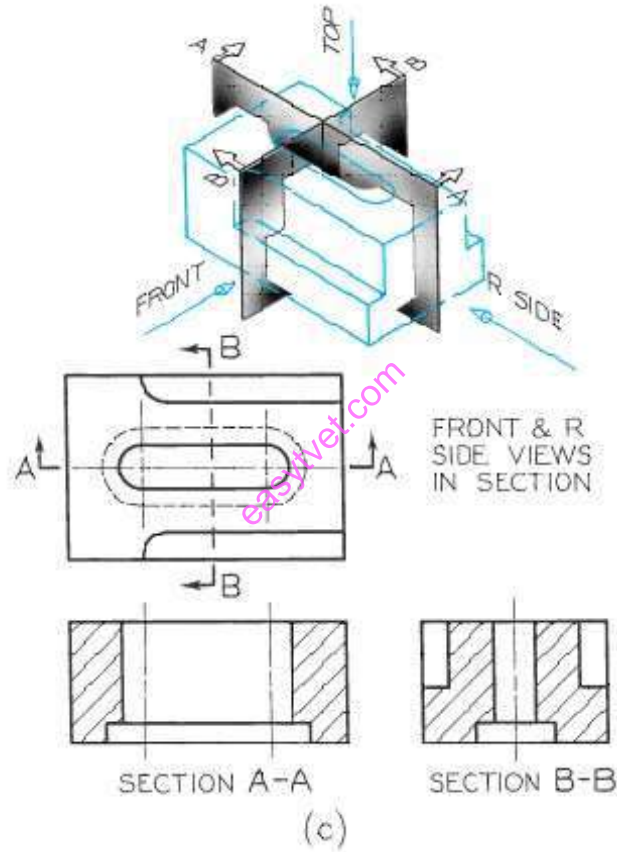
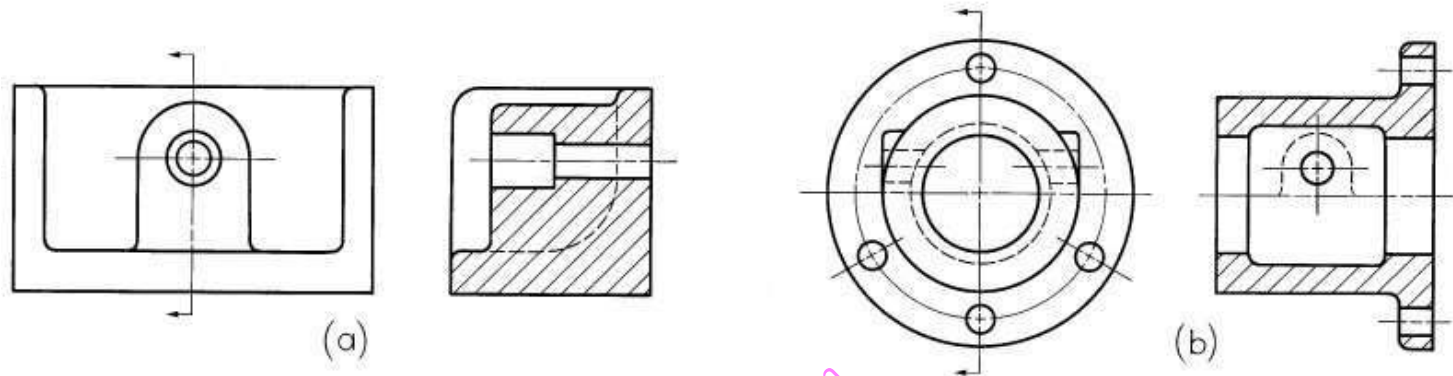


Figure 117:Sectional views

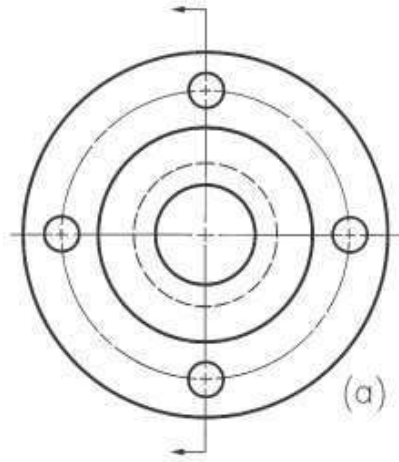


Keep the following things in mind when drawing sectional views. Visible edges and contours behind the cutting plane should be as shown in figure (a) below. Hidden lines should be omitted in section views unless they are necessary, as in figure (b).

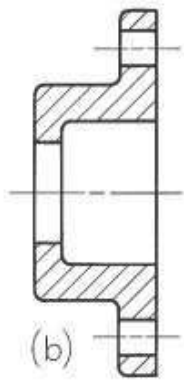


A section-lined area is always completely bounded by a visible outline never by a hidden line. The cross hatching in all hatched areas must be parallel in a sectional view of a single object, along or in assembly.

### Find the errors in section views

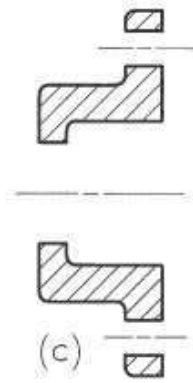


(a)



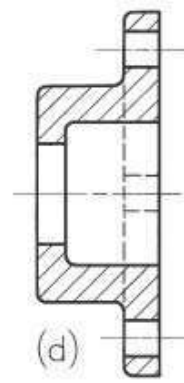
(b)

CORRECT



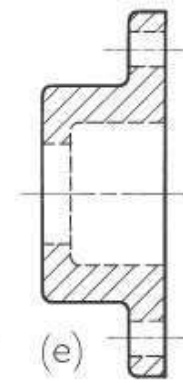
(c)

WRONG



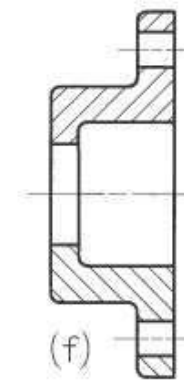
(d)

WRONG



(e)

WRONG



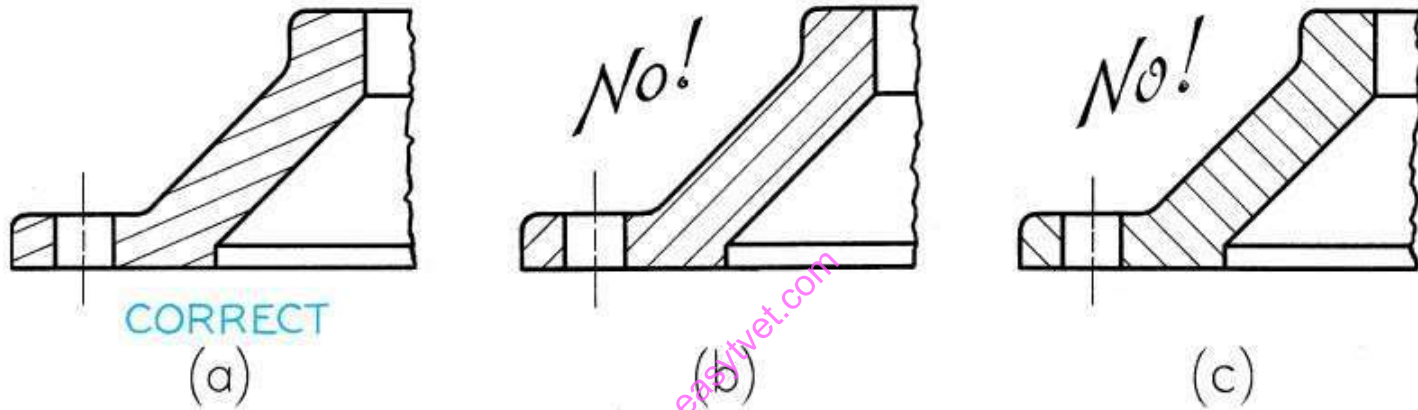
(f)

WRONG

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## Cross-Hatching

Cross-hatching patterns, shown in Fig. 7.6 are used to present general material types. Make hatching lines at 45 degrees with horizontal, unless they look better at a different angle.

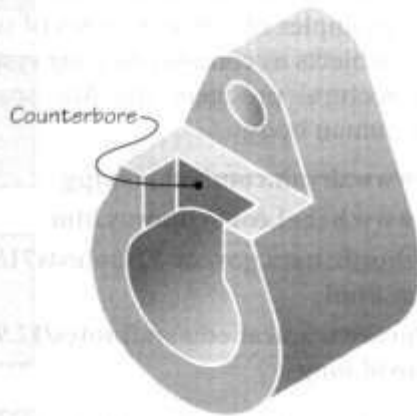


In figures above, cross-hatching at 45 degrees with horizontal would be nearly parallel or nearly perpendicular to a prominent feature. In this case, the hatching appears better drawn at 30 degrees, 60 degrees, or some other angle.

## Step by Step Visualizing of a full section

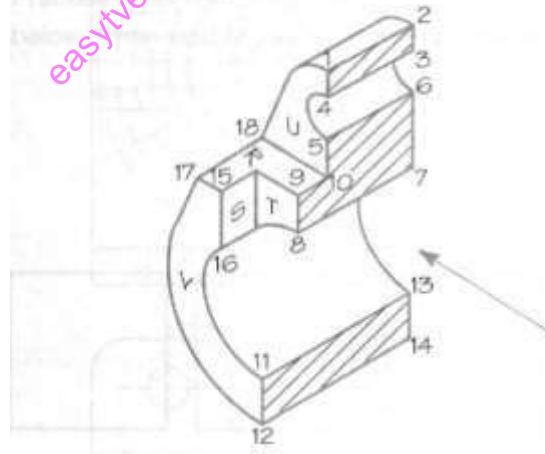
### STEP 1: CHOOSE A CUTTING PLANE

The illustration below shows two views of a collar to be sectioned. It has a drilled and counterbored hole. To produce a clear section showing both the counterbored hole and the smaller hole near the top of the object, choose the cutting plane to pass through the vertical center line in the front view and imagine the right half of the object removed.

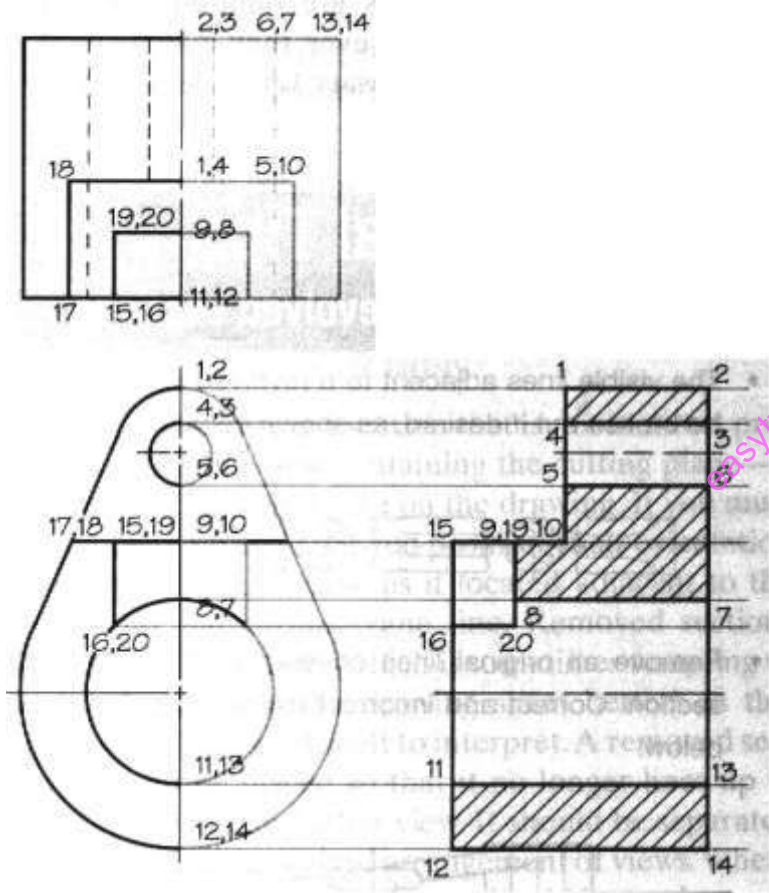


### STEP 2: IDENTIFY THE SURFACES

Below is a pictorial drawing of the remaining half. The first step in projecting the section view is making sure that you interpret the object correctly. Identifying the surfaces on the object can help. Surfaces R, S, T, U and V have been labeled on the given views and the pictorial view. Which surface is R in the front view? Which surface is U in the top view? Are they normal, inclined, or oblique surfaces. Can you identify the counterbore in each view?



### STEP 3: DRAWING THE SECTION VIEW



### STEP 4: PROJECTING THE VISIBLE LINES

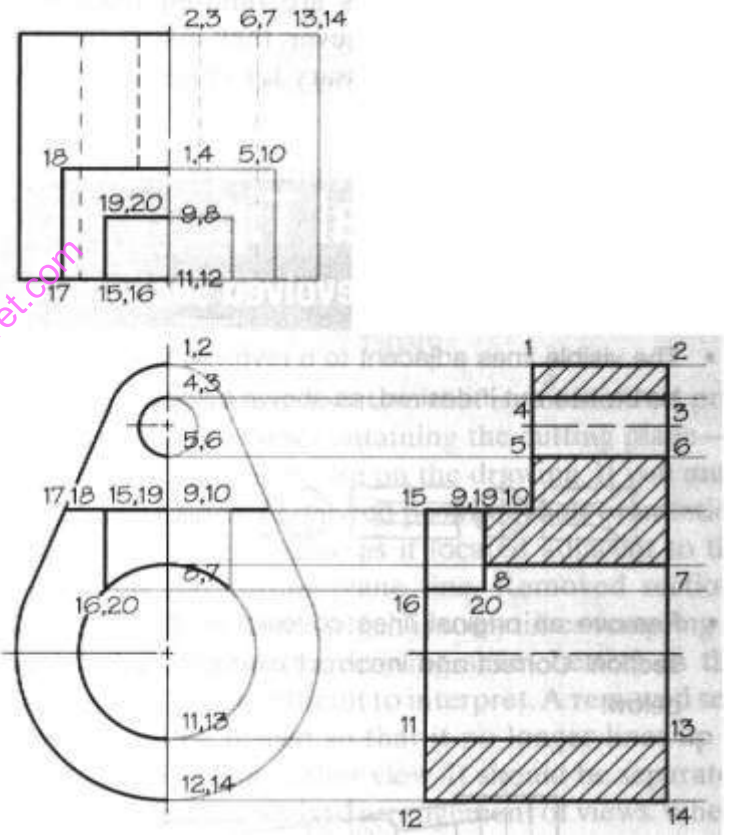


Figure 118: Drawing the sectional view

## Half Sections

Symmetrical objects can be sectioned using a cutting plane passing halfway through an object, resulting in a half section. A half section exposes the interior of one half of the object and still shows the exterior of the other half. Half sections are very useful in undimensioned assembly drawing since they show both internal and external construction on the same view.

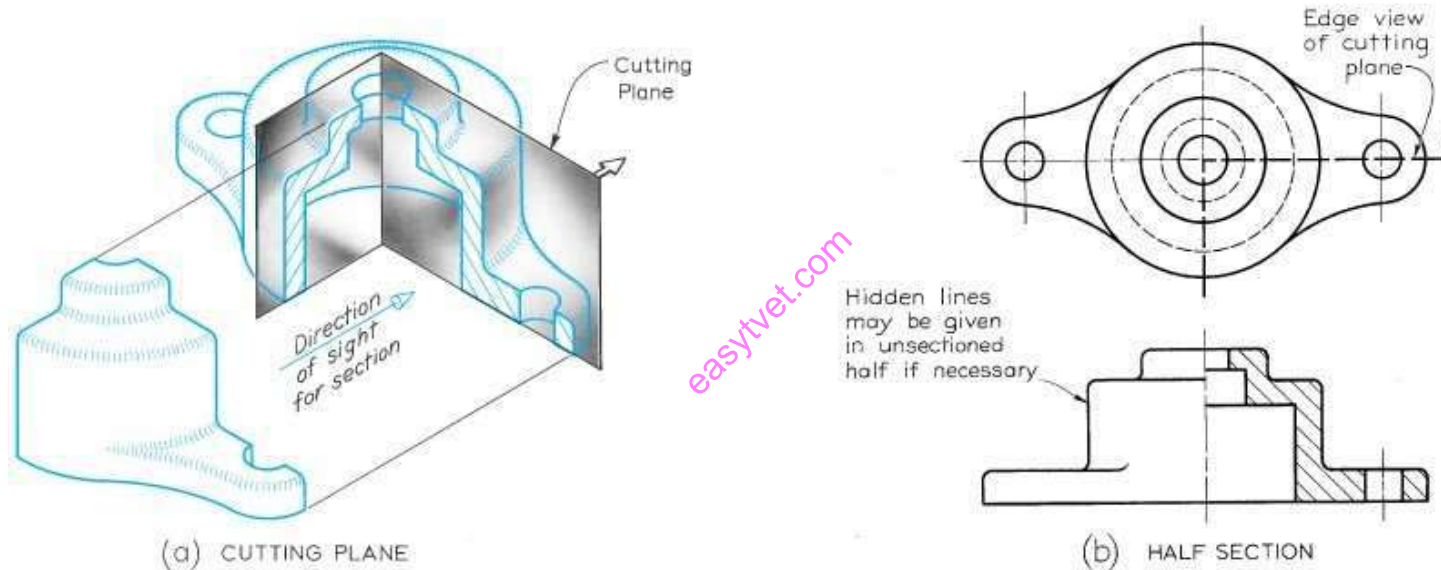


Figure 119: Half Sections

In general, hidden lines are omitted from both halves of a half section. However, they may be used in the unsectioned half if necessary for dimensioning.

## Broken-out Sections

Often, only a partial section of a view is needed to expose interior shapes. Such a section, limited by a break line, is called a broken-out section. In the first figure, a full or half section is not necessary. A broken-out section is sufficient to explain the construction.

In the second figure, a half section would have caused the removal of half the keyway. The keyway is preserved by breaking out around it. In this case, the section is limited partly by a break line and partly by a centerline (i.e., break-around keyway).

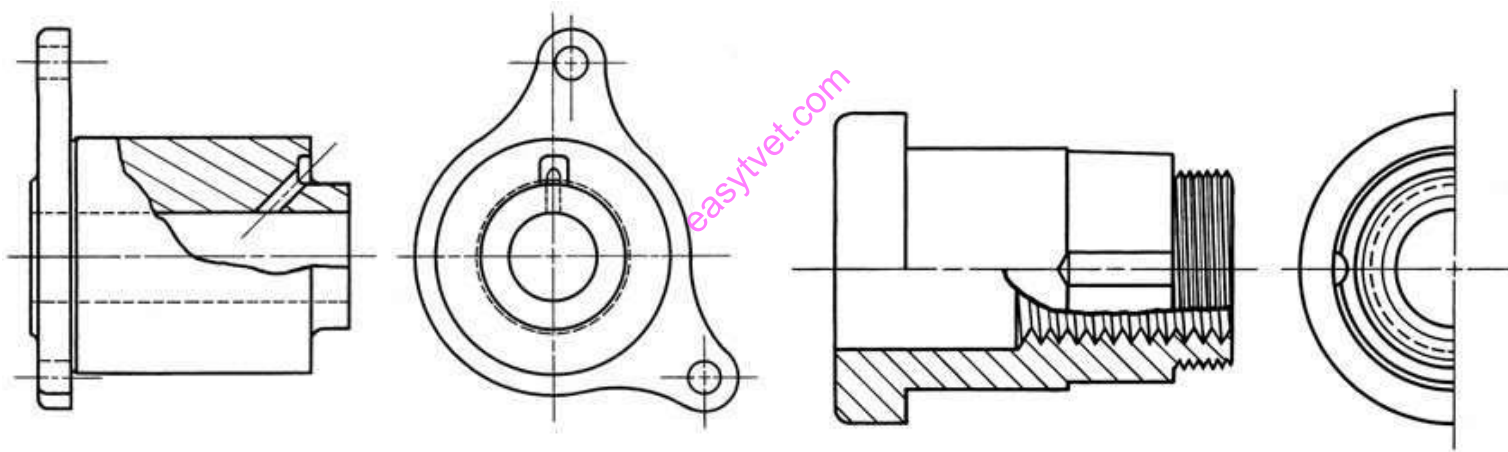


Figure 120: Broken-out Sections

## Revolved Sections

The shape of the cross-section of a bar, arm, spoke, or other elongated object may be shown by means of a revolved section.

Revolved sections are made by assuming a plane perpendicular to the centerline or axis of the bar or other object, and then revolving the plane through 90 degrees about a centerline at right angles to the axis.

The figure below depicts the process of creating a revolved section.

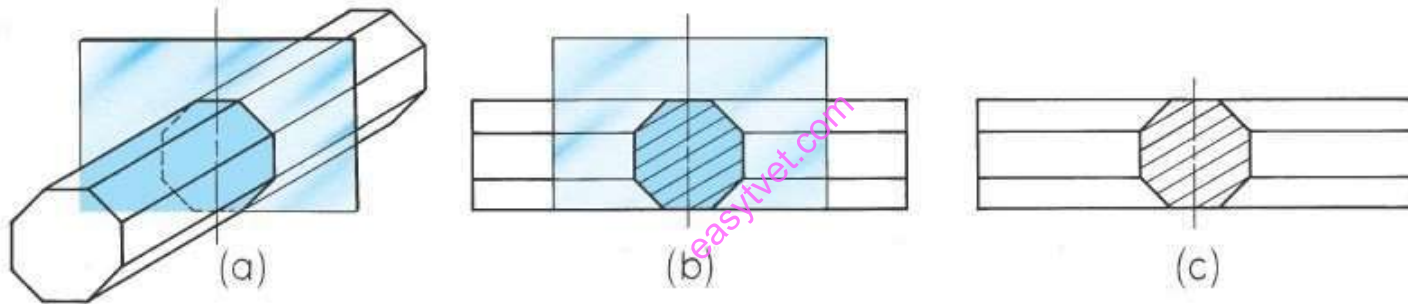
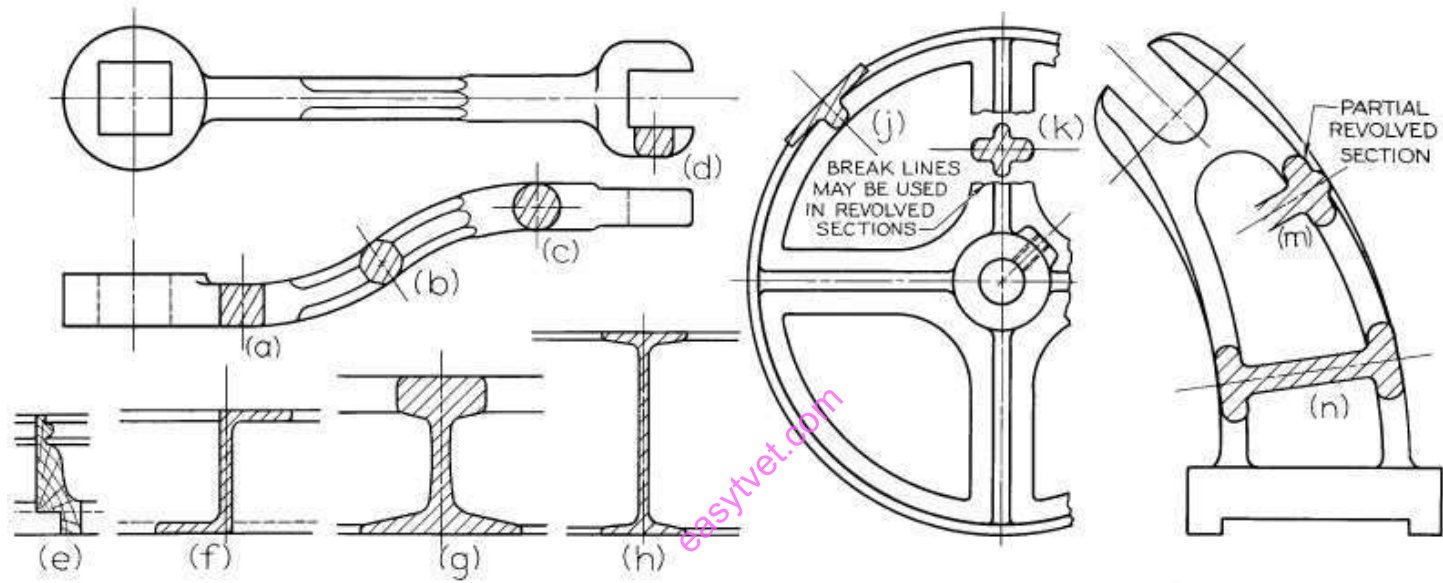


Figure 121: Revolved Sections

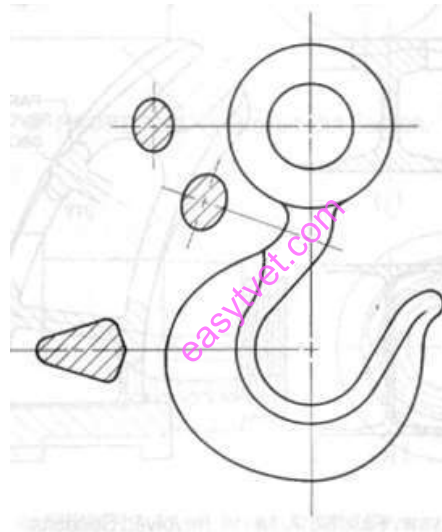
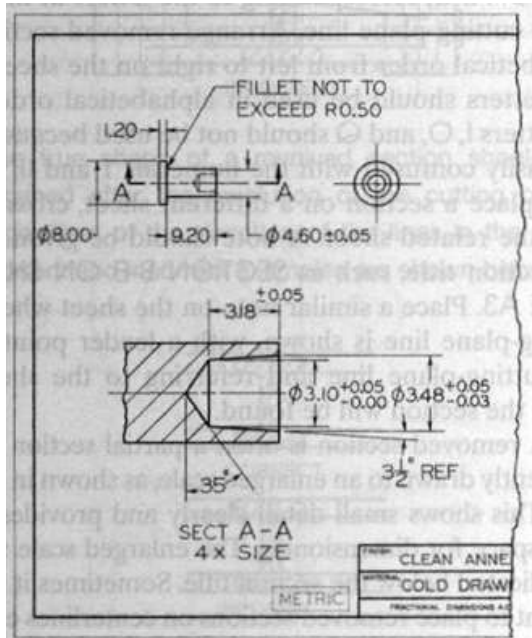


A number of examples of revolved sections are shown below.



## Removed Sections

A removed section is a section that is not direct projection from the view containing the cutting plane – it is located somewhere else in the drawing.



Removed sections

Figure 122: Removed Sections

## Offset Sections

In sectioning irregular objects, we may show features that do not lie in a straight line by offsetting, or bending the cutting plane. Such a section is called an offset section.

In figure (a) the cutting plane is offset in several places to include the hole at the left end, one of the parallel slots, the rectangular recess, and one of the holes at the right end.

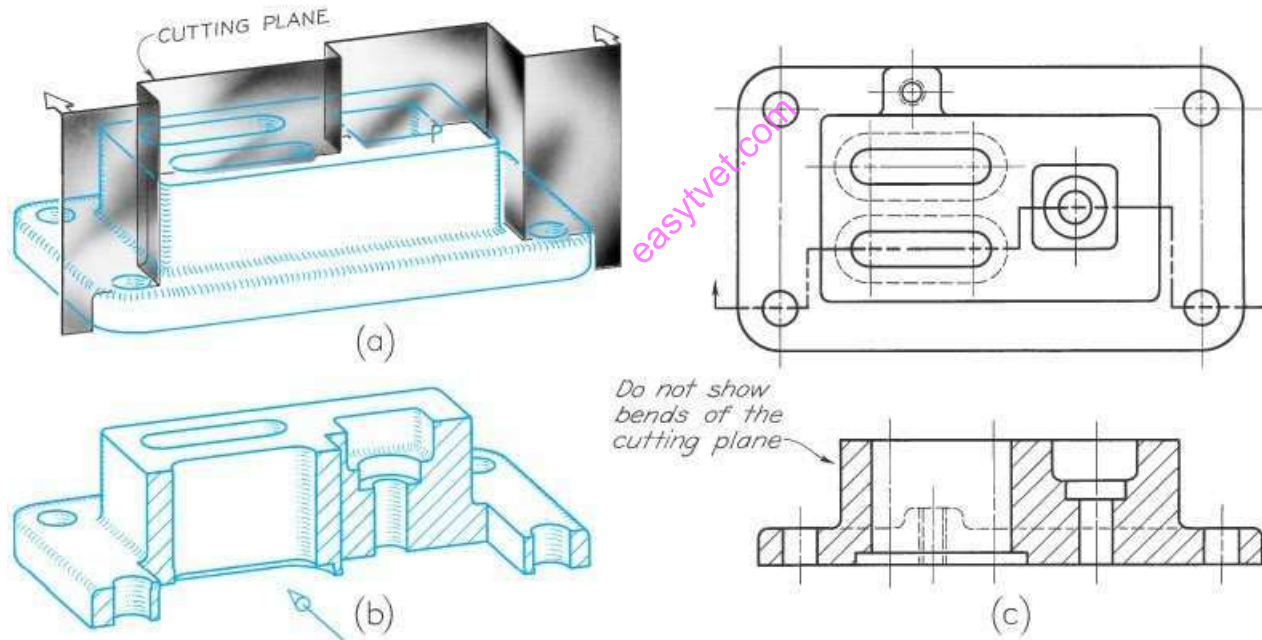


Figure 123: Offset Sections

The front portion of the object is then imagined to be removed, as shown in fig. (b). The path of the cutting plane is shown by the cutting-plane line in the top view of fig. (c), and the resulting offset section is shown in the front view. The offsets or bends in the cutting plane are all 90 degrees. Figure (c) also illustrates how hidden lines in a section eliminate the need for an additional view. If the hidden lines were not shown, an extra view would be needed to show the small boss on the back.

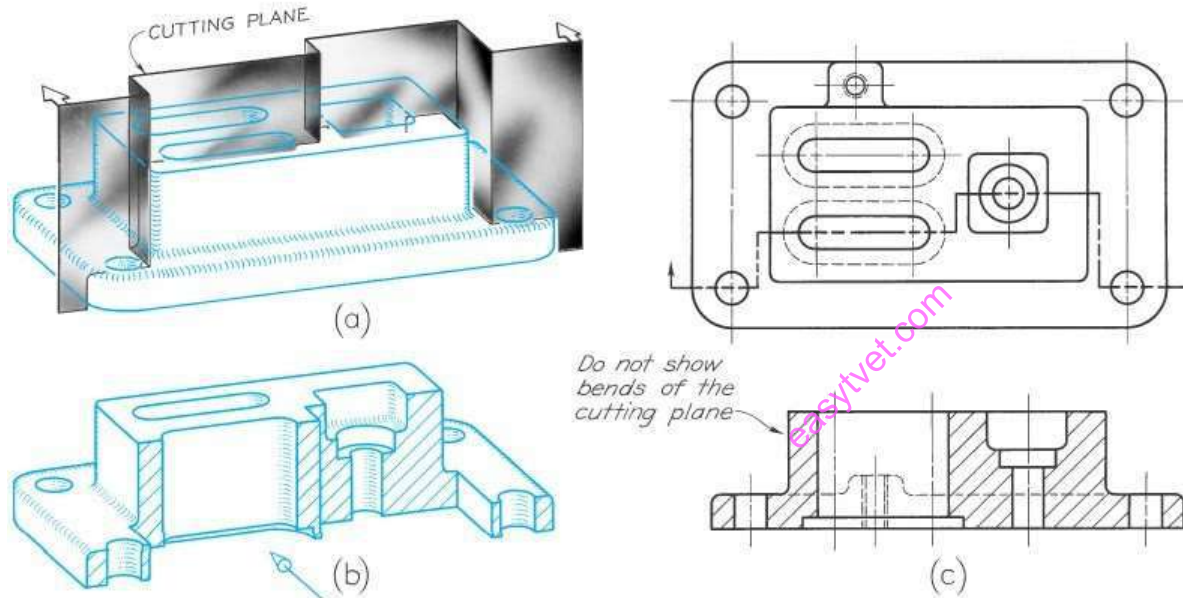
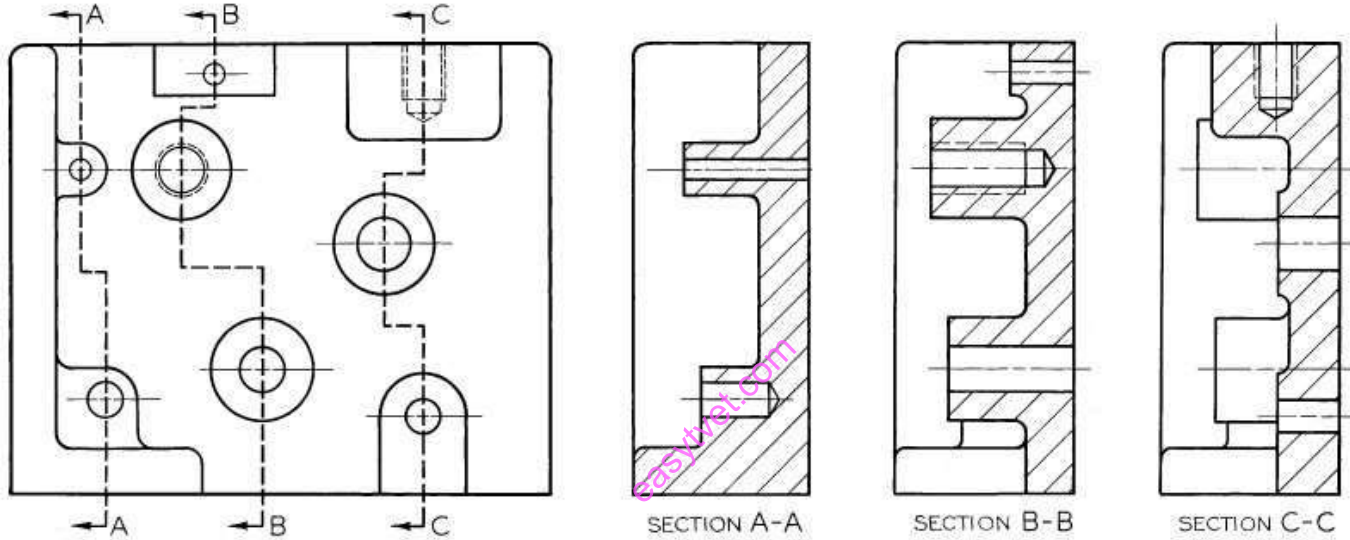


Figure below shows an example of multiple offset sections. Notice that the visible background shapes without hidden lines, appear in each sectional view.

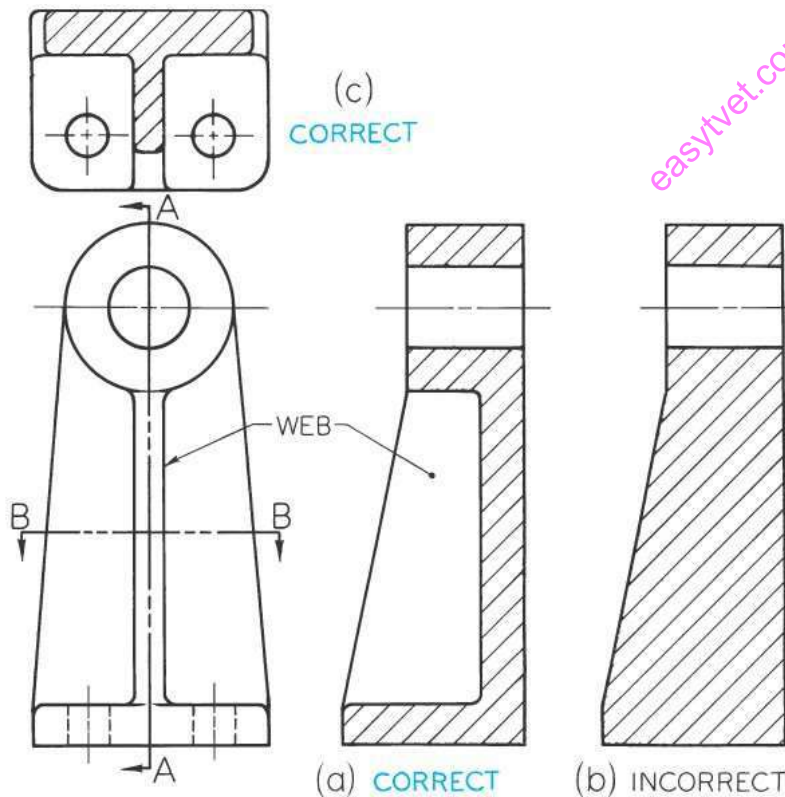


## Ribs in Sections

To avoid a false impression of thickness and solidity, ribs, webs, gear teeth, and other similar flat features are not sectioned, even though the cutting plane passes along the center plane of the feature.

For example, in figure at right the cutting plane A-A passes through the long dimension of the vertical web, or rib, but as figure a shows, the web is not section lined. Such thin features should not be section lined, even though the cutting plane passes through them.

Figure b shows an incorrect drawing.



## Aligned Sections

To include in a section certain angled features, the cutting plane may be bent to pass through those features. The plane and features are then imagined to revolve into the original plane.

For example, in figure below the cutting plane bends to pass through the angled arm and then is aligned to a vertical position, where it is projected to the sectional view.

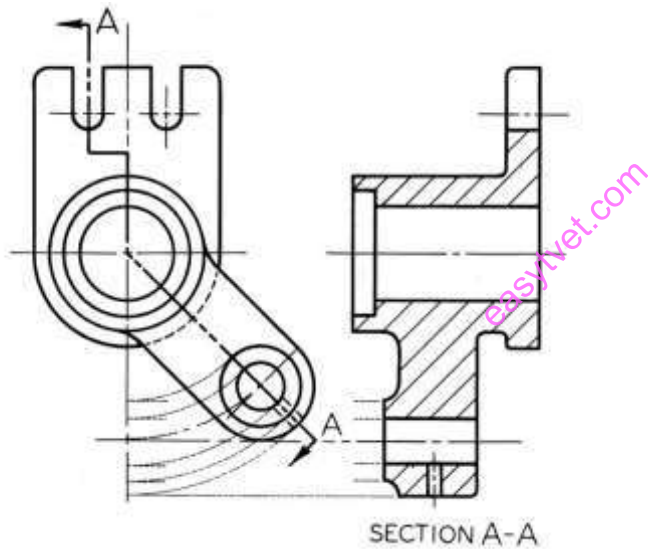
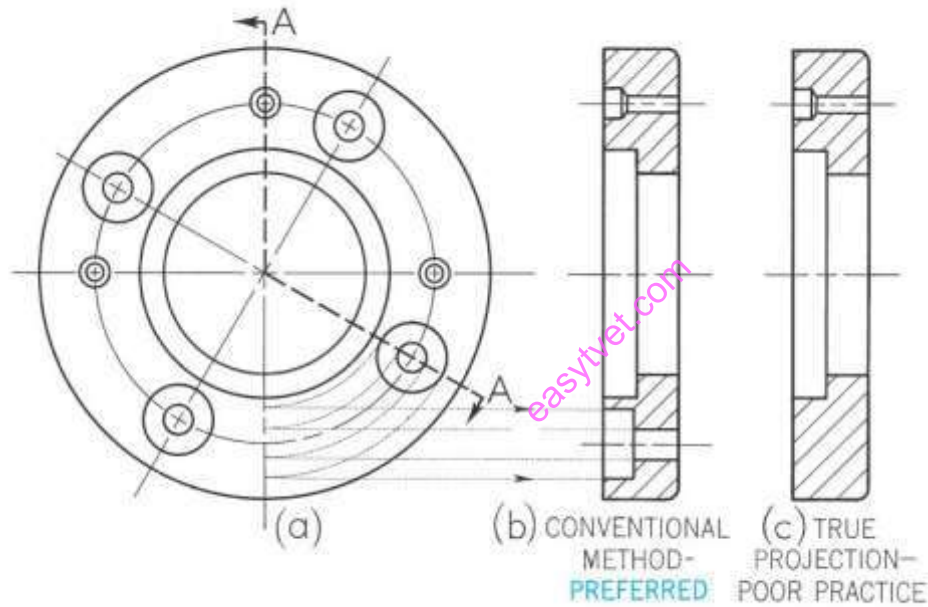


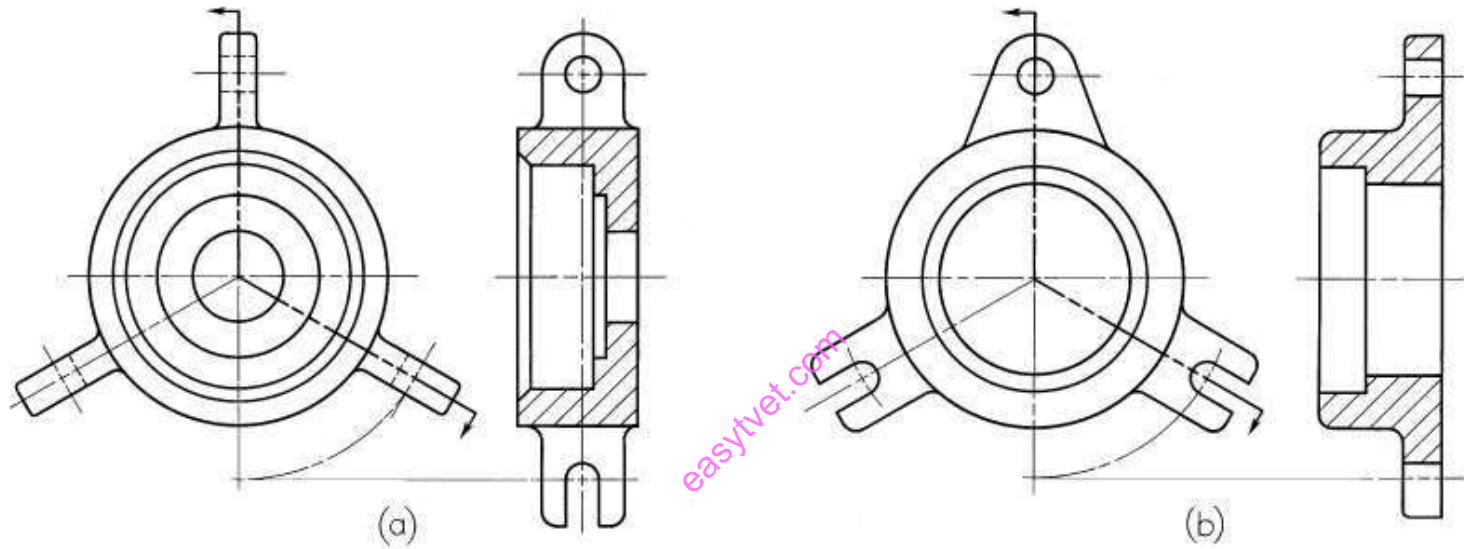
Figure 124: Aligned Sections

In the figure below, the cutting plane is bent so that both a drilled and a counterbored hole will be included in the sectional view. The correct sectional view, shown in fig. (b), is clearer and more complete than a full section, shown in fig. (c). The angle of revolution should always be less than 90 degree.

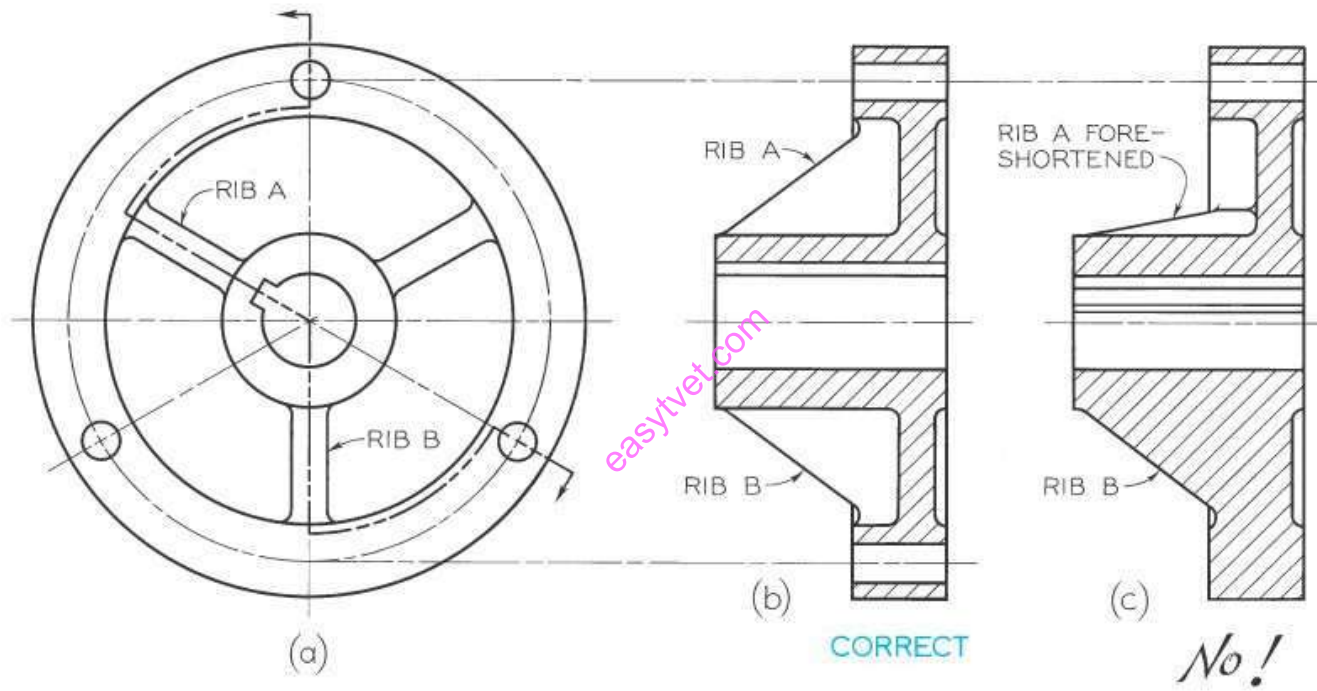




In figure (a) the projecting lugs are not sectioned for the same reason that ribs are not sectioned. In figure (b) the projecting lugs are located so that the cutting plane passes through them crosswise; therefore, they are sectioned.



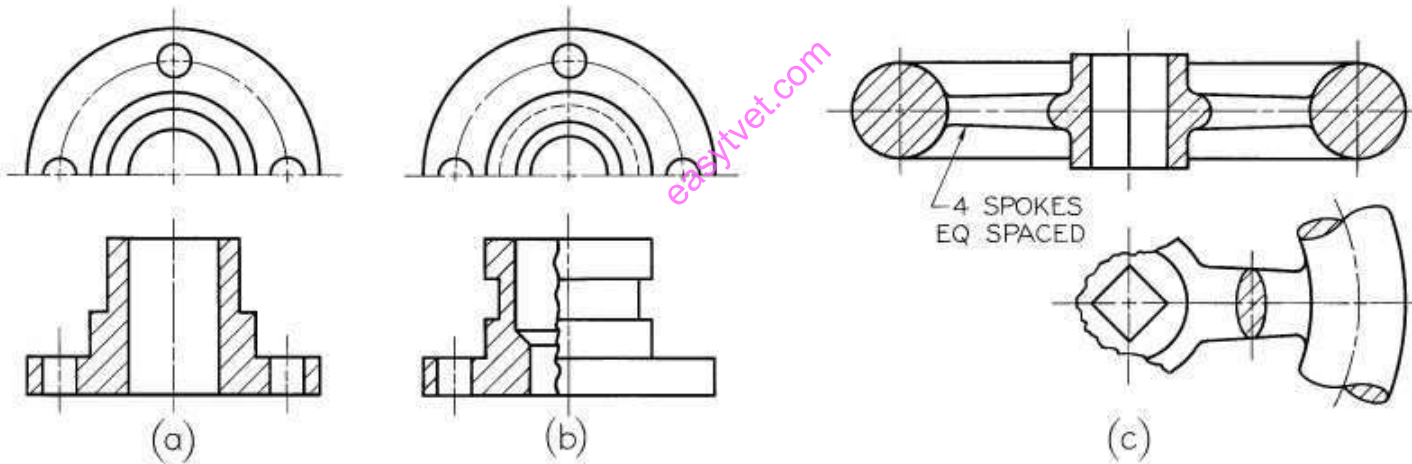
Another example involving rib sections and aligned sectioning is shown below.



## Partial Views

If space is limited on the paper or to save drafting time, partial views may be used in connection with sectioning. Figures (a) and (b) only show half views of the top view. In each case the back half of the object in the circular view is shown to expose the back portion of the object for viewing in section.

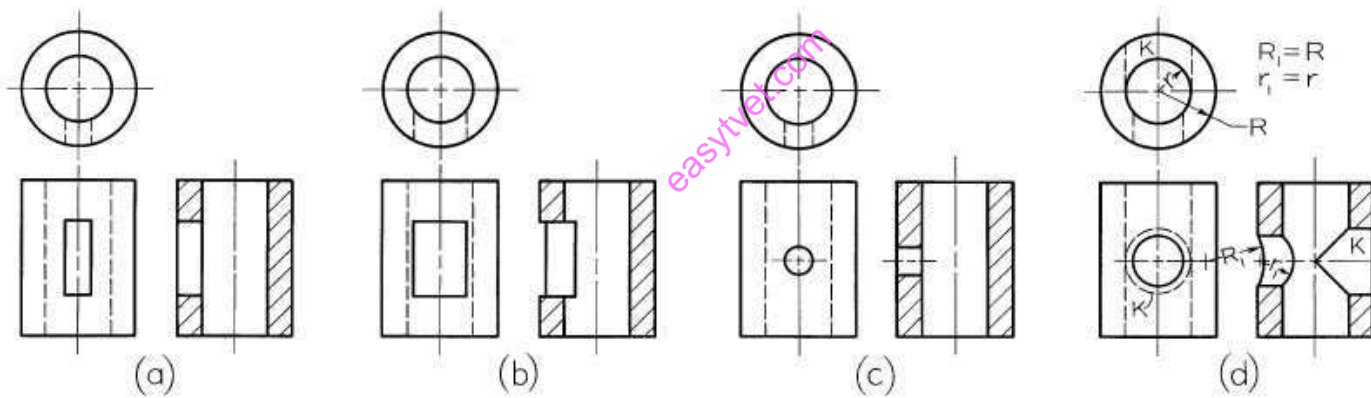
Another method of drawing a partial view is to break out much of the circular view, retaining only those features that are needed for minimum representation, as shown in figure (c).



## Intersections in Sectioning

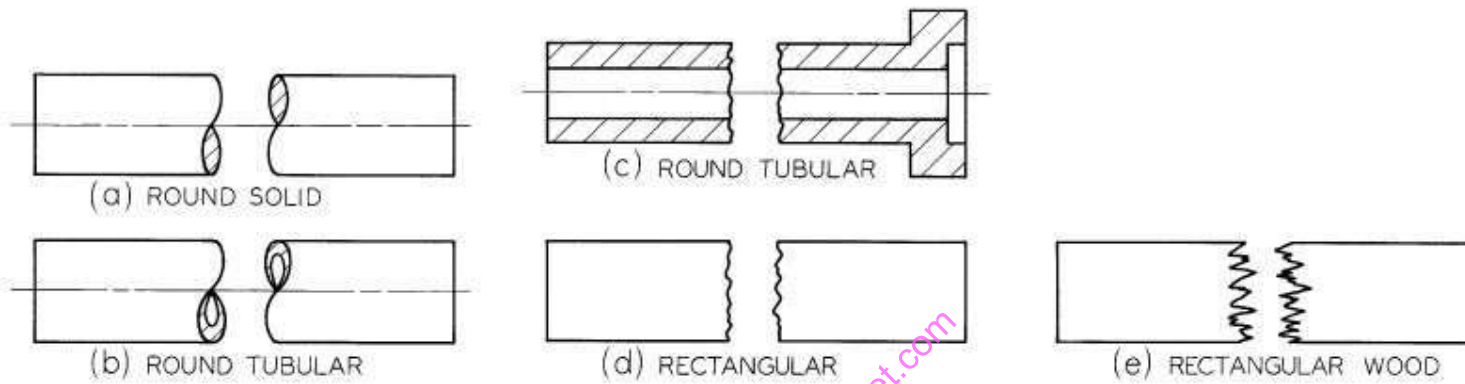
Where an intersection is small or unimportant in a section, it is standard practice to disregard the true projection of the figure of intersection, as shown in a and c. Larger figures of intersection may be projected, as shown in fig. (b), or approximated by circular arcs, as shown for the smaller hole in fig. (d).

Note that the larger hole K is the same diameter as the vertical hole. In such cases the curves of intersection, or ellipses, appear as straight lines, as shown.

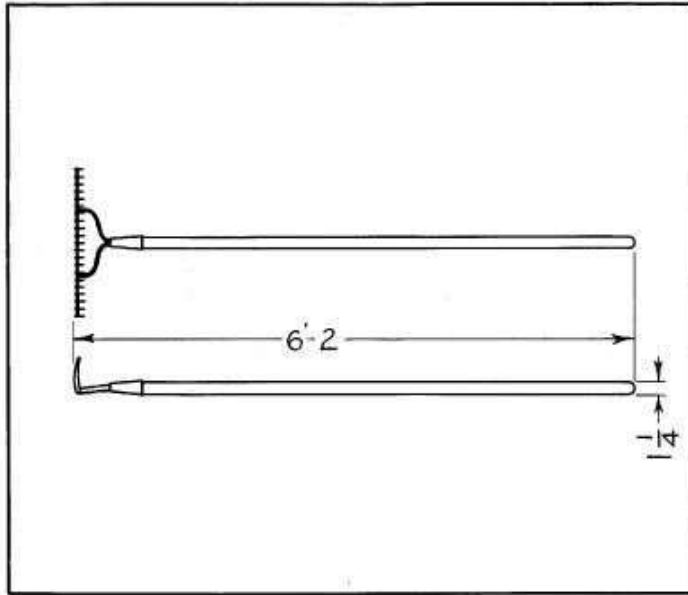


## Conventional Breaks

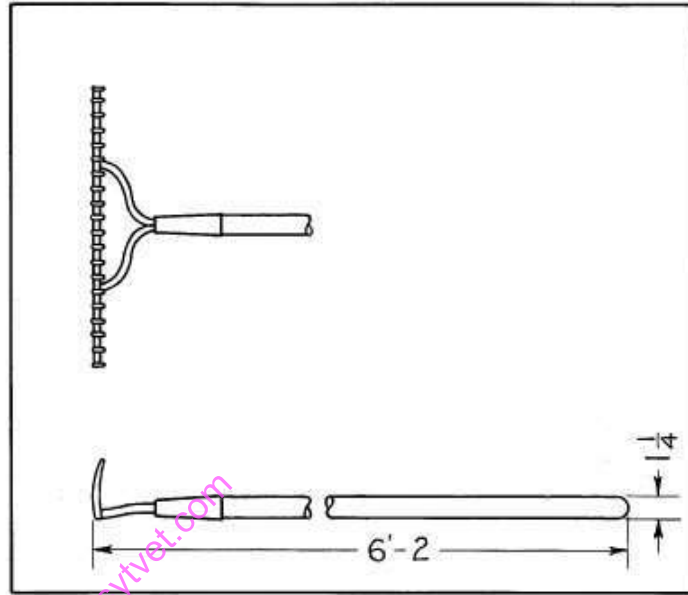
To shorten a view of an elongated object, whether in section or not, conventional breaks are recommended, as shown below.



Another example of conventional breaks is shown below.



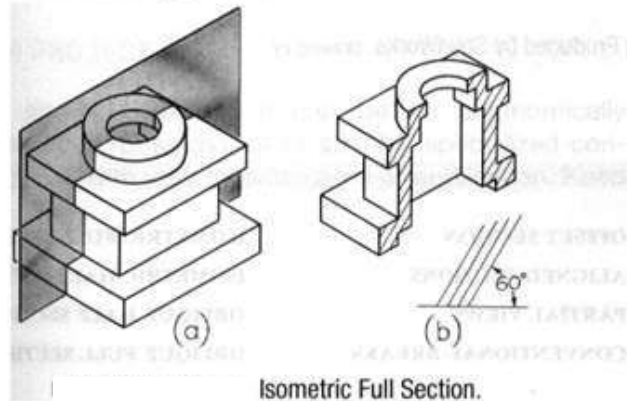
(a)



(b)

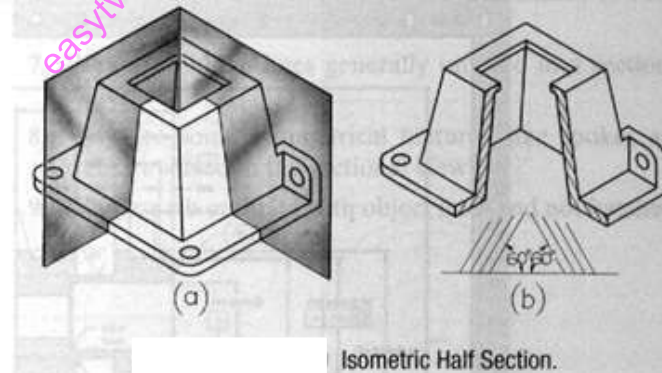
## Isometric Sectioning

You can create pictorial sectional views by showing the cut object in an isometric or oblique view and hatching the cut surfaces. An *isometric full section* is shown in Figure 7.32. It is usually best to draw the cut surface first and then to draw the portion of the object that lies behind the cutting plane.

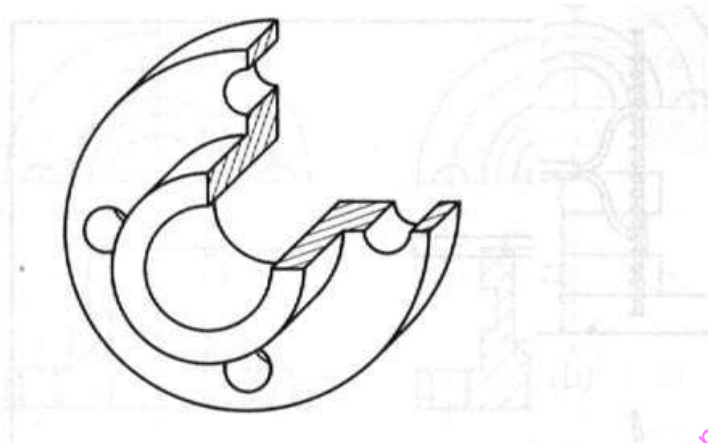


An *isometric half section* is shown in Figure 7.33. To sketch isometric half-sections, it is usually easiest to first sketch the entire object and then the cut surfaces. Since only a quarter of the object is removed in a half section, the resulting pictorial sketch is more useful than a full section to show both the exterior and interior shapes. Isometric broken-out sections are also sometimes used.

Hatching in an isometric sketch is similar to that in a multiview sketch. Showing it at an angle of 60 degrees with horizontal is recommended, but the direction should be changed if this would be parallel to major visible lines.



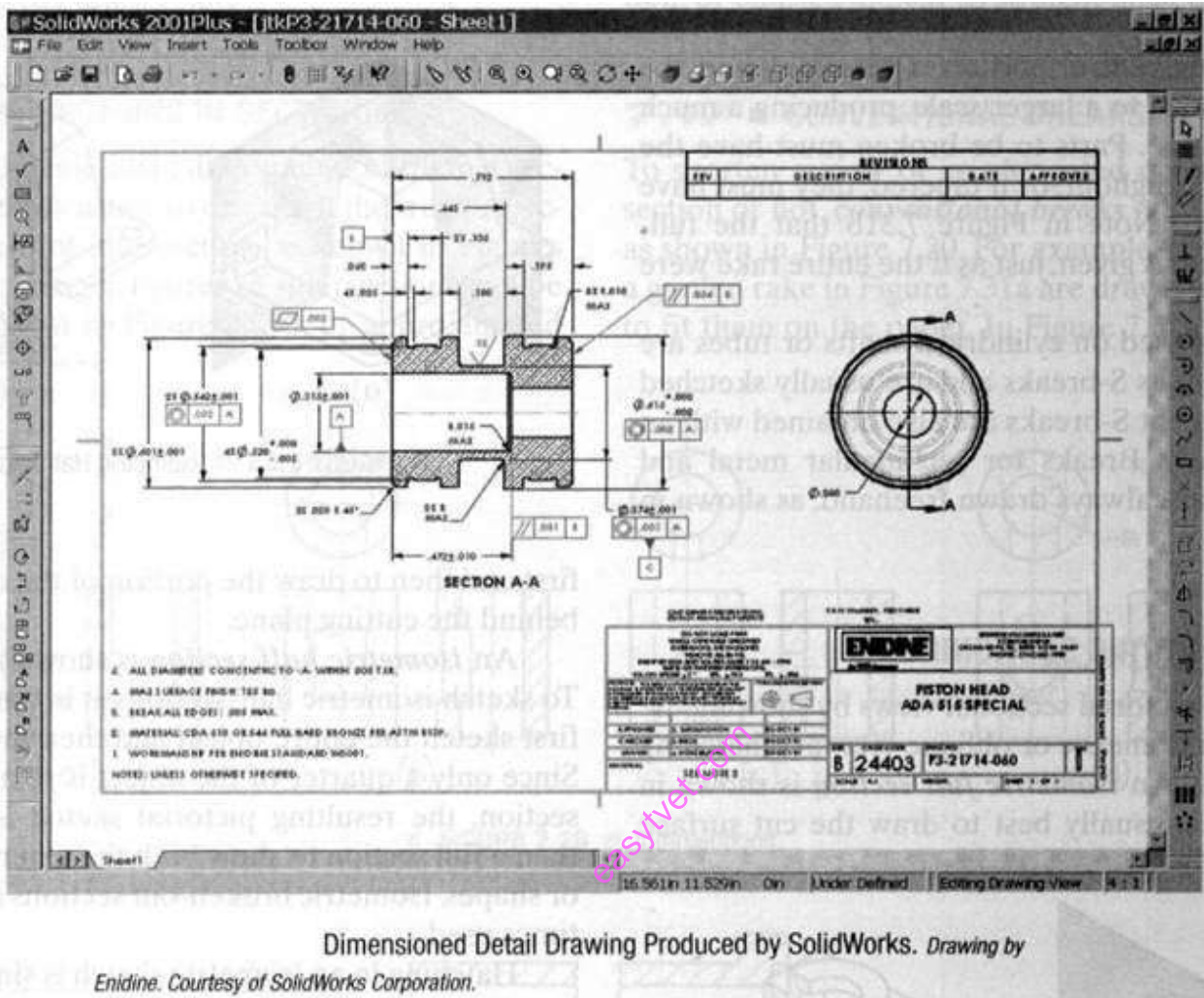
## Oblique Sections



Oblique Half Section.

You can also show pictorial sections in oblique view, especially to show interior shapes. An **oblique half section** is shown in Figure . . . . . **Oblique full sections** are seldom used because they do not show enough of the exterior shapes. In general, oblique sections are similar to isometric sections.





## Assembly drawings

### Introduction

A drawing which displays the parts of a machine or a machine unit assembled in their relative working positions is known as assembly drawing.

The assembly drawing would be such that it should satisfy:

- (i) Manufacturing requirements
- (ii) Operational requirements
- (iii) Maintenance requirements.

### **Designed assembly**

This assembly drawing is prepared at the design-stage on a larger scale.

### **Layout assembly**

This is an assembly drawing showing how the parts are assembled with their basic proportions (dimensions).

### **Installation assembly**

This is prepared for the installation or erection of a machine. This is also sometimes known as an outline assembly.

### **Working drawing assembly**

A complete set of working drawings of a machine comprises of detailed drawings, giving all necessary information for the production of individual parts and assembly drawing showing the location of each part. The assembly drawing should be ready before the detailed drawings are accepted as finished and the blue-prints are made.

### **General assembly**

It comprises of the detailed drawings of the individual parts, sub-assembly and the assembly drawings of the machine

Norms to be observed in preparing assembly drawings

- (i) Selection of views: The main or important view which is usually in section should show all the individual parts and their relative locations. Additional views are shown only when they add necessary information.
- (ii) Sectioning: The parts should be sectioned according to the requirements (i.e. half-section or partial section) to show important assembly details. Code of the BIS ( SP:46-1988) for general engineering drawings must be observed
- (iii) Dotted lines: The dotted lines should be omitted from the assembly drawing when a proper section is taken. If the view of a part is drawn by the half-section, then in un section portion of the view, the dotted lines may be drawn to clarify details of the part.
- (iv) Dimensions: The overall dimensions and centre-to centre distances showing the relationship of parts to the machine as a whole, are sometimes shown.
- (v) Detailed dimensions are given on working assembly drawings when the detailed drawings are not prepared.

### **Bill of Materials**

Bill of materials: Each part of the machine is identified on assembly drawing by the leader line and number, which are used in the detail drawing and in the bill of material. The height of the number may be

approximately 5 mm and encircled by 9 mm diameter. Leader lines are drawn radially touching the respective parts.

The bill of materials also shows the following:

- a) Number of parts
- b) Material of parts required for one unit
- c) Shop processes
- d) Name of the company
- e) Standard norm for standard components
- f) Designed by, drawn by and checked by
- g) Scale
- (i) Any special remark.

The table containing above information must be prepared as shown in the illustrative problems.

### **Suggested approach**

1. Preparing an assembly form exploded view is easy task as clue to the position and sequence is available
2. For preparing from orthographic view of the individual components some skill is needed

### **The suggested approach is**

1. Functional Matching or Mapping
2. Geometrical mapping
3. Dimensional mapping

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### **Sequences of preparing the assembly drawing**

- (i) Study functional requirements of each component and their inter relationship. • Learn the actual working of a machine.
- (ii) Study carefully the views of each component in the detail drawing and decide the relative location of each part for the proper functioning of the machine.
- (iii) Decide the mating dimensions between two components which are required to be assembled.
- (iv) Prepare free-hand sketch of the main view or an important view (generally front-elevation). Add additional views, if necessary.
- (v) Select a suitable scale for the entire assembly drawing.
- (vi) Lay out the views of the assembly drawing so that it become easier to understand.
- (vii) Prepare the bill of materials.
- (viii) Label each component by the leader-line and number it.
  
- (ix) Show overall dimensions.
- (x) Draw the section-lines according to the convention

(xi) Show required fits and tolerances between the two mating components.

### Classification of Drawings

#### Machine drawing

It is pertaining to machine parts or components. It is presented through a number of orthographic views, so that the size and shape of the component is fully understood. Part drawings and assembly drawings belong to this classification. An example of a machine drawing is given in the figure below.

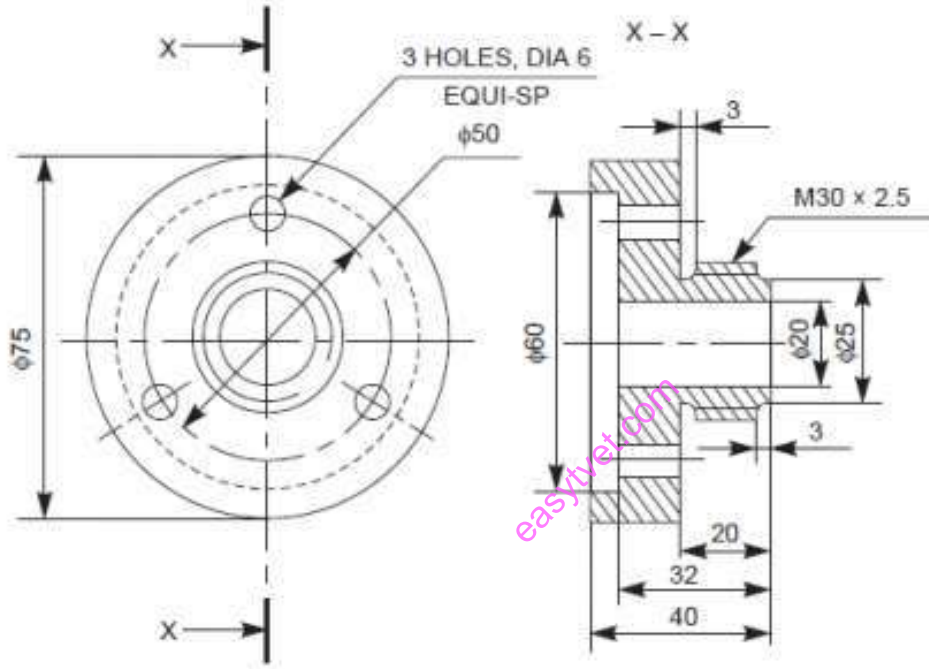


Figure 125: Machine drawing.

#### Production drawing

A production drawing, also referred to as working drawing, should furnish all the dimensions, limits and special finishing processes such as heat treatment, honing, lapping, surface finish, etc., to guide the craftsman on the shop floor in producing the component. The title should also mention the material used for the product, number of parts required for the assembled unit, etc. Since a craftsman will ordinarily make one component at a time, it is advisable to prepare the production drawing of each component on a separate sheet. However, in some cases the drawings of related components may be given on the same sheet. Figure below represents an example of a production drawing.

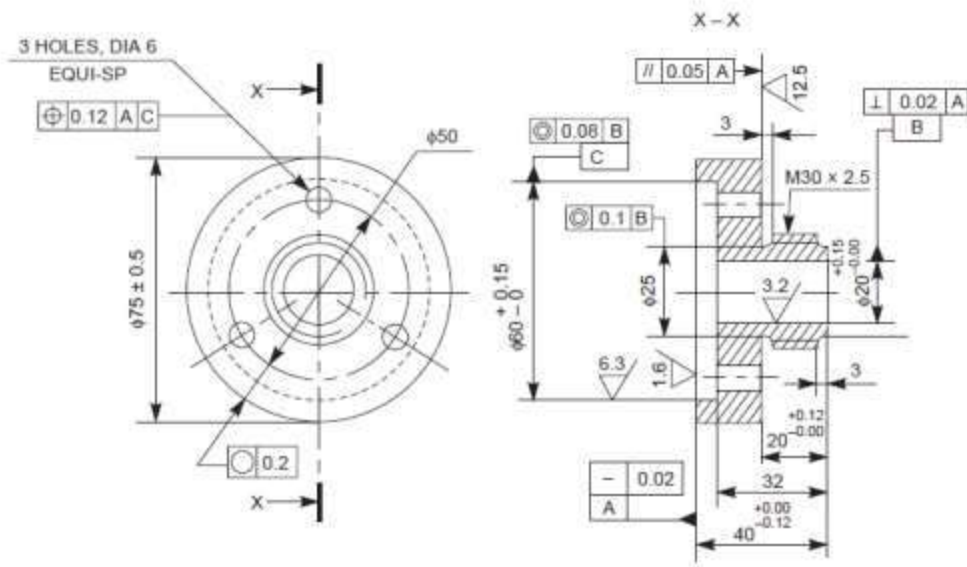


Figure 126: Production drawing.

### Assembly drawing

A drawing that shows the various parts of a machine in their correct working locations is an assembly drawing as shown in the figure below. There are several types of such drawings.

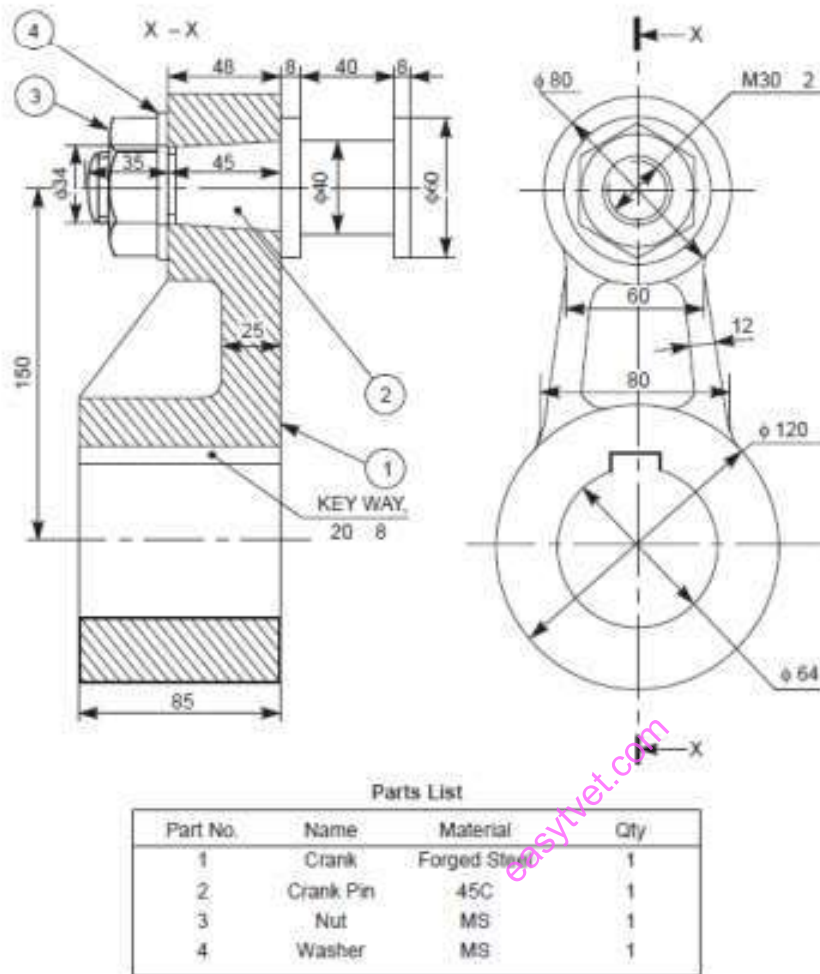


Figure 127: Assembly drawing.

Design Assembly Drawing When a machine is designed, an assembly drawing or a design layout is first drawn to clearly visualise the performance, shape and clearances of various parts comprising the machine.

### Detailed Assembly Drawing

It is usually made for simple machines, comprising of a relatively smaller number of simple parts. All the dimensions and information necessary for the construction of such parts and for the assembly of the parts are given directly on the assembly drawing. Separate views of specific parts in enlargements, showing the fitting of parts together, may also be drawn in addition to the regular assembly drawing.

### Sub- Assembly Drawing

Many assemblies such as an automobile, lathe, etc., are assembled with many pre-assembled components as well as individual parts. These pre-assembled units are known as sub-assemblies. A sub-assembly drawing is an

assembly drawing of a group of related parts, that form a part in a more complicated machine. Examples of such drawings are: lathe tail-stock, diesel engine fuel pump, carburettor, etc.

### **Installation Assembly Drawing**

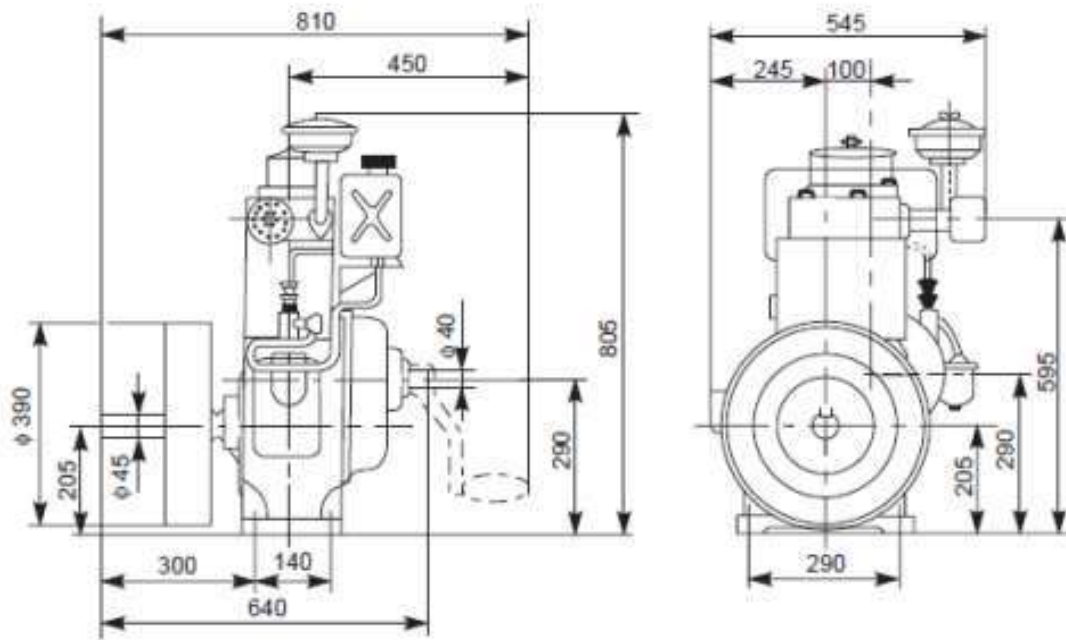
On this drawing, the location and dimensions of few important parts and overall dimensions of the assembled unit are indicated. This drawing provides useful information for assembling the machine, as this drawing reveals all parts of a machine in their correct working position.

### **Assembly Drawings for catalogues**

Special assembly drawings are prepared for company catalogues. These drawings show only the pertinent details and dimensions that would interest the potential buyer. Fig. 1.4 shows a typical catalogue drawing, showing the overall and principal dimensions. Assembly Drawings for instruction manuals These drawings in the form of assembly drawings, are to be used when a machine, shipped away in assembled condition, is knocked down in order to check all the parts before reassembly and installation elsewhere. These drawings have each component numbered on the job. Figure below shows a typical example of such a drawing.

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### **Assembly Drawings for instruction manuals**



These drawings in the form of assembly drawings, are to be used when a machine, shipped away in assembled condition, is knocked down in order to check all the parts before reassembly and installation elsewhere. These drawings have each component numbered on the job. Figure below shows a typical example of such a drawing.



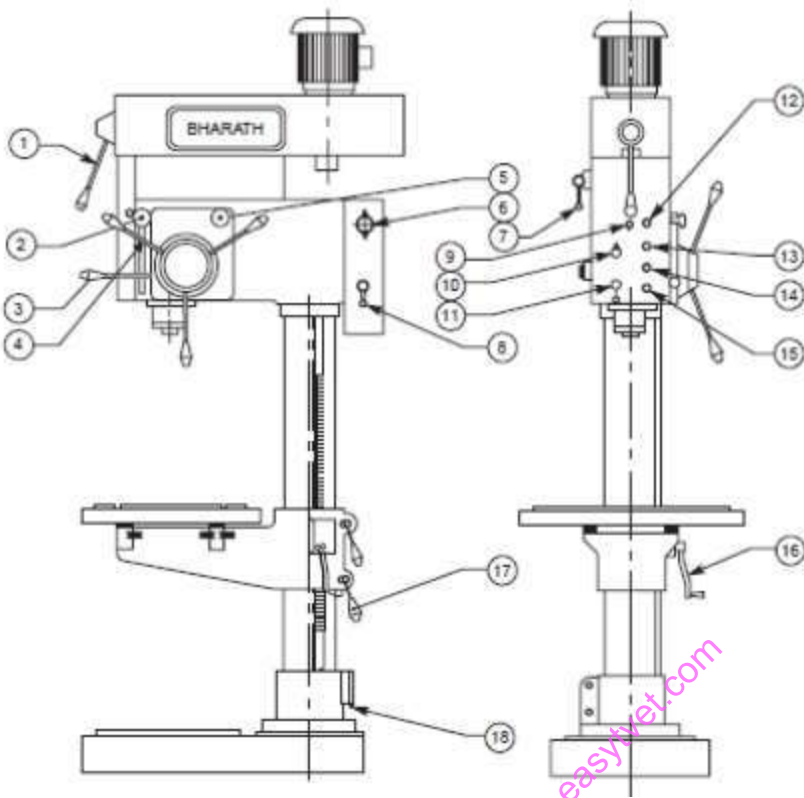


Figure 128: Assembly drawing for instruction manuals

Speed change lever (1)

Selector switch (10)

Depth adjusting knob (2)

Forward switch (11)

Mech. Feed engagement lever (3)

Pilot lamp (12)

Hand free lever (4)

Feed disengagement push button (13)

Feed change knob (5)

Start push button (14)

Switch for tapping(6)

Emergency stop (15)

Gear shifting lever (7)

Elevating handle (16)

Main switch(8)

Clamping handle(17)

Lamp switch(9)

Supply inlet (18)

### **Exploded Assembly Drawing**

In some cases, exploded pictorial views are supplied to meet instruction manual requirements. These drawings generally find a place in the parts list section of a company instruction manual. Figure shows drawings of this type which may be easily understood even by those with less experience in the reading of drawings; because in these exploded views, the parts are positioned in the sequence of assembly, but separated from each other.

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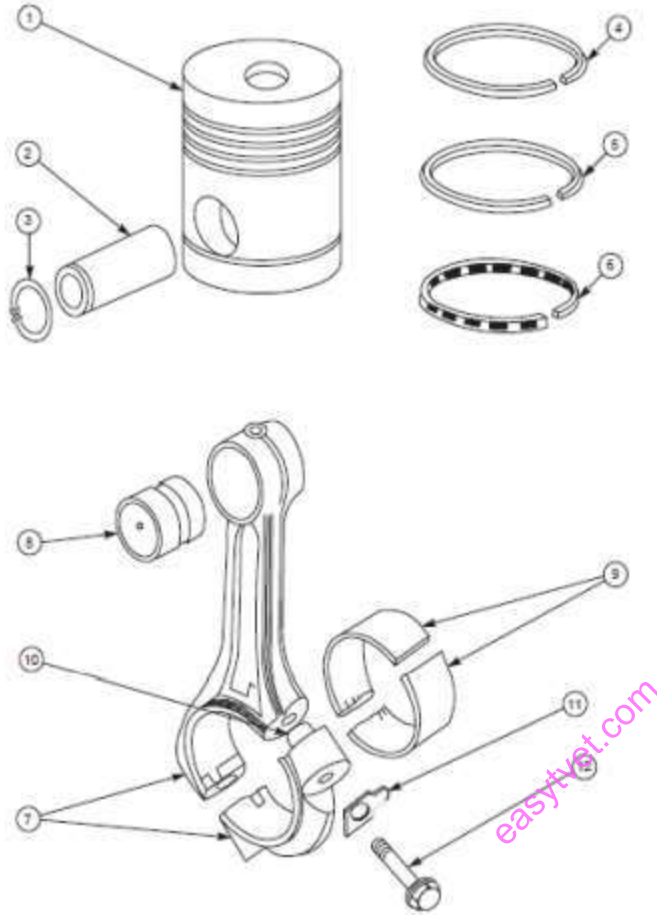


Figure 129: Exploded assembly drawing.

Schematic Assembly Drawing It is very difficult to understand the operating principles of complicated machinery, merely from the assembly drawings. Schematic representation of the unit facilitates easy understanding of its operating principle. It is a simplified illustration of the machine or of a system, replacing all the elements, by their respective conventional representations. The figure below shows the schematic representation of a gearing diagram.

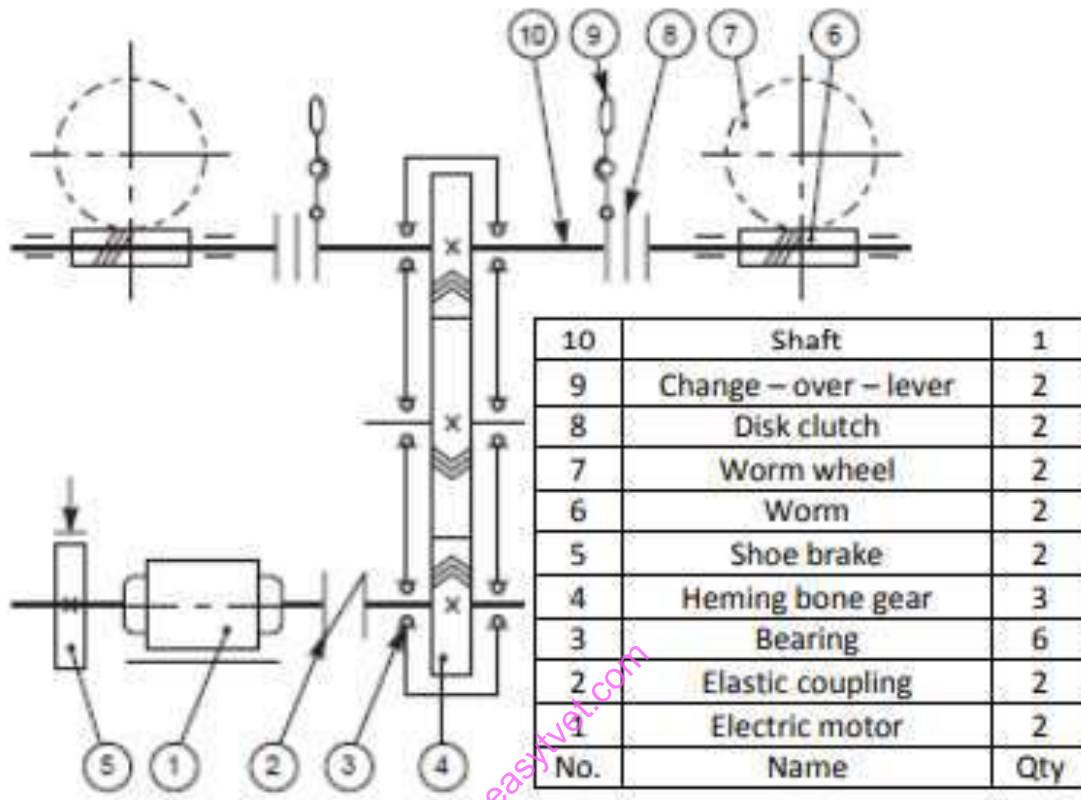


Figure 130: Schematic assembly drawing

### Machine Shop Drawing

Rough castings and forgings are sent to the machine shop for finishing operation. Since the machinist is not interested in the dimensions and information of the previous stages, a machine shop shown in figure below. Schematic assembly drawing.

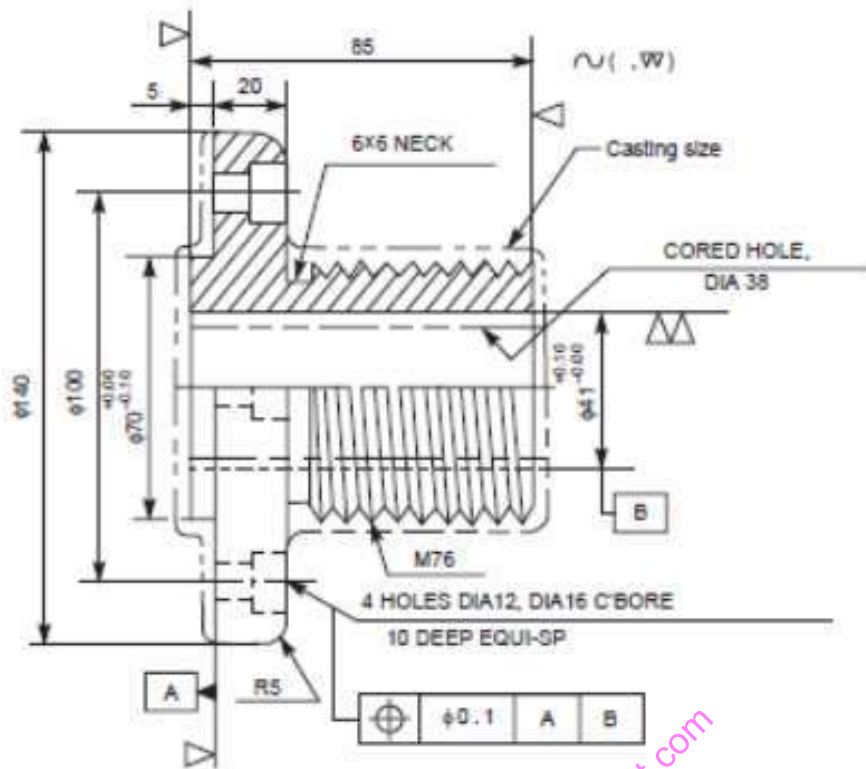


Figure 131: Machine Shop drawing.

Representation of external thread (Stud bolt)

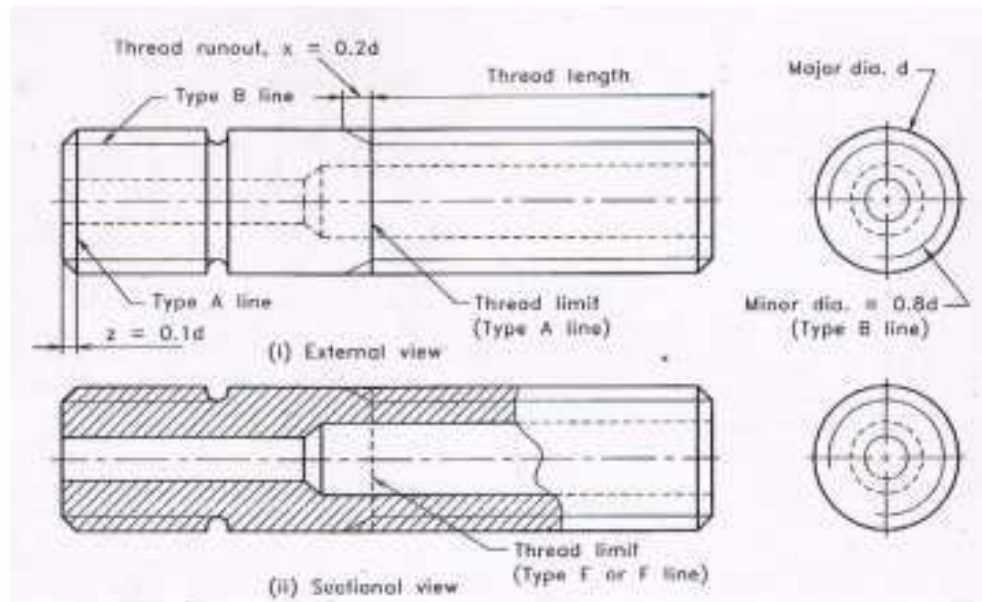


Figure 132: Representation of external thread.

### Representation of internal thread

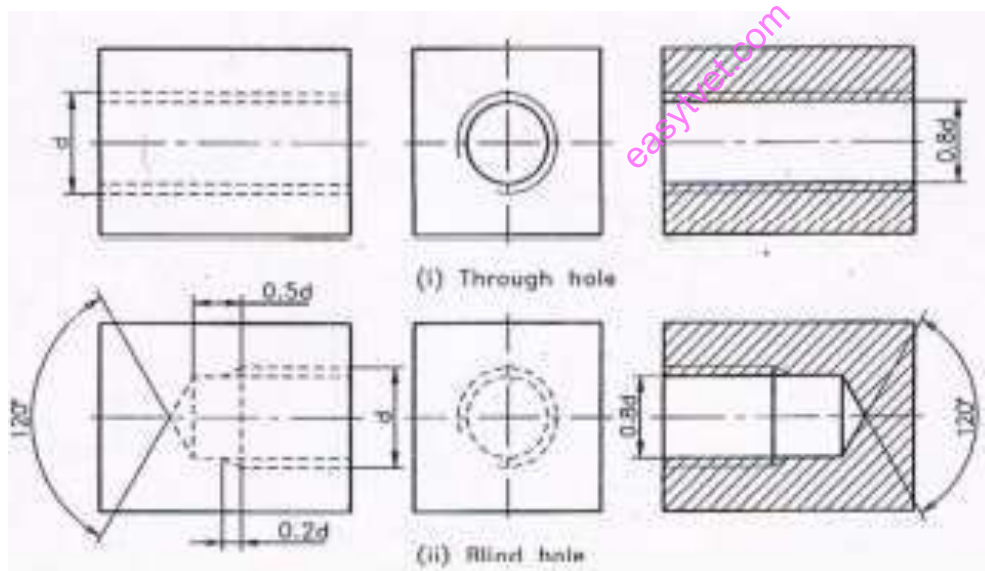


Figure 133:Representation of internal thread

### Terminology of bolt and nut

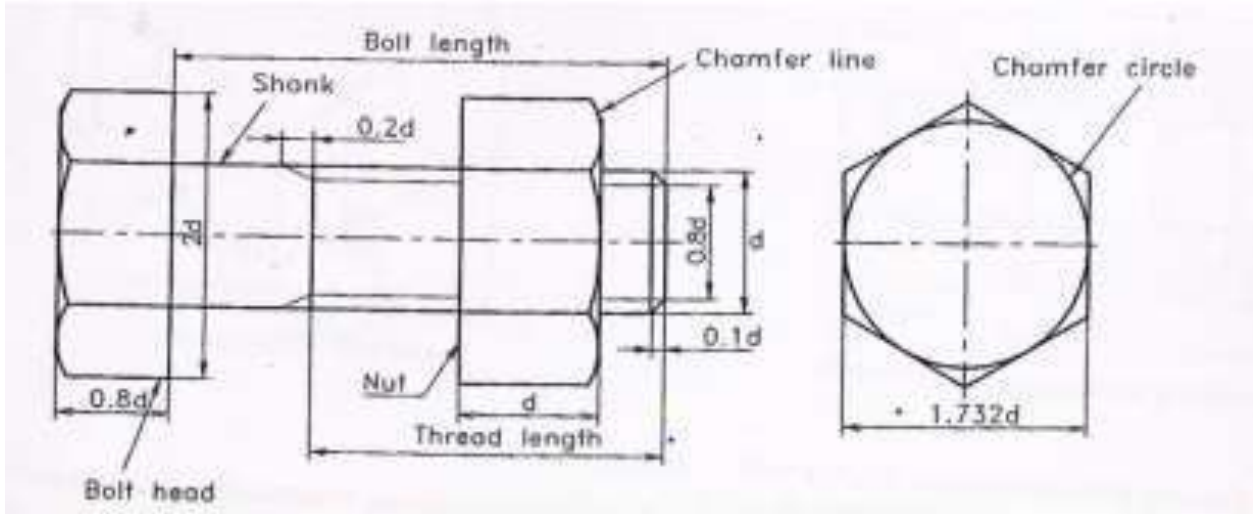


Figure 134: Terminology of bolt and nut

Figure: Terminology of bolt and nut.

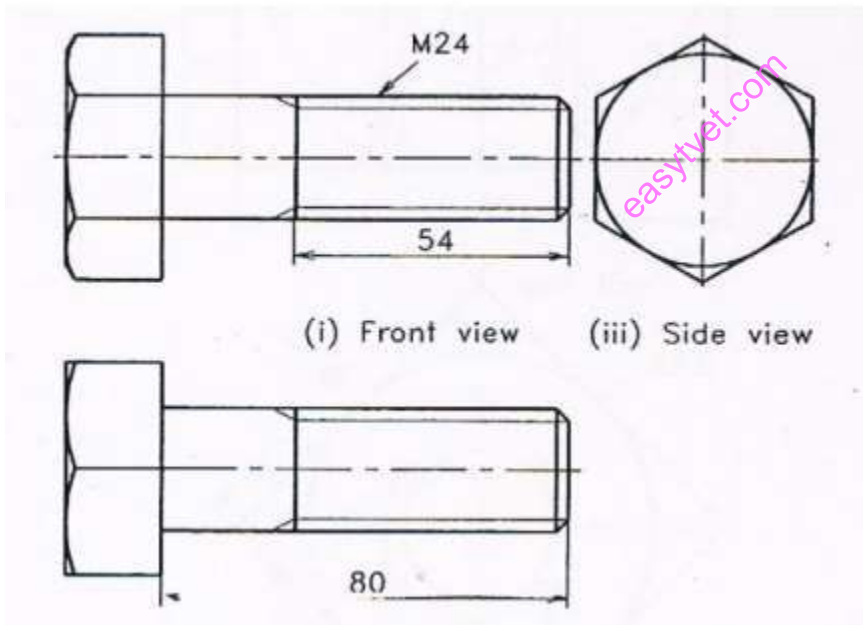


Figure 135: Hexagonal headed bolt

## Pictorial Drawing

Isometric Drawing

It is a pictorial orthographic projection of an object in which a transparent cube containing the object is tilted until one of the solid diagonals of the cube becomes perpendicular to the vertical plane and the three axes are equally inclined to this vertical plane.

#### *Types of isometric drawing*

- Cavalier
- Cabinet

#### *Lines in Isometric Projection*

The following are the relations between the lines in isometric projection

- The lines that are parallel on the object are parallel in the isometric projection.
- Vertical lines on the object appear vertical in the isometric projection.
- Horizontal lines on the object are drawn at an angle of  $30^\circ$  with the horizontal in the isometric projection.
- A line parallel to an isometric axis is called an isometric line and it is foreshortened to 82%.
- A line which is not parallel to any isometric axis is called non-isometric line and the extent of foreshortening of non-isometric lines are different if their inclinations with the vertical planes are different.

#### *Isometric drawing methods*

- Box construction
- Four center method

#### *Oblique Drawing*

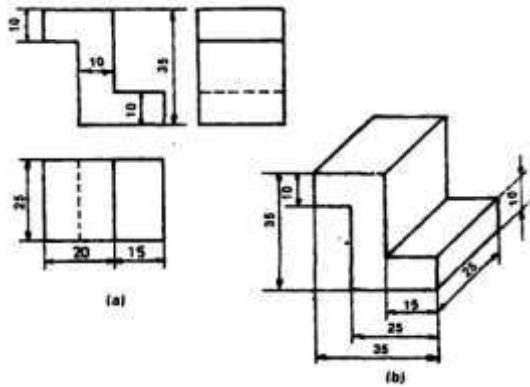
##### *Characteristics of an oblique drawing*

In oblique projection, the front face of the object appears in its true size and shape, as it is placed parallel to the picture plane. The receding lines representing the other two faces are usually drawn at  $30^\circ$ ,  $45^\circ$  or  $60^\circ$  to the horizontal,  $45^\circ$  being the most common practice.

Oblique projections are classified as cavalier, cabinet.

##### *Draw an oblique box*





## Isometric and Oblique Circles

### *Construction of Isometric circles using the method of points*

- i. Enclose the circle in a square 1-2-3-4 and draw diagonals. Also draw lines YA horizontally and XA vertically.
- ii. To draw the isometric view of the square 1-2-3-4
- iii. Mark the mid points of the sides of the square as B, D, F and H.
- iv. Locate the points X and Y on lines 1-4 and 1-2 respectively.
- v. Through the point X, draw AX parallel to line 1-2 to get point A on the diagonal 1-3. The point A can be obtained also by drawing YA through the point Y and parallel to the line 1-4.
- vi. Similarly obtain other points C, E and G
- vii. Draw a smooth curve passing through all the points to obtain the required isometric view of the horizontal circular plane.
- viii. Similarly obtain isometric view of the vertical circular plane

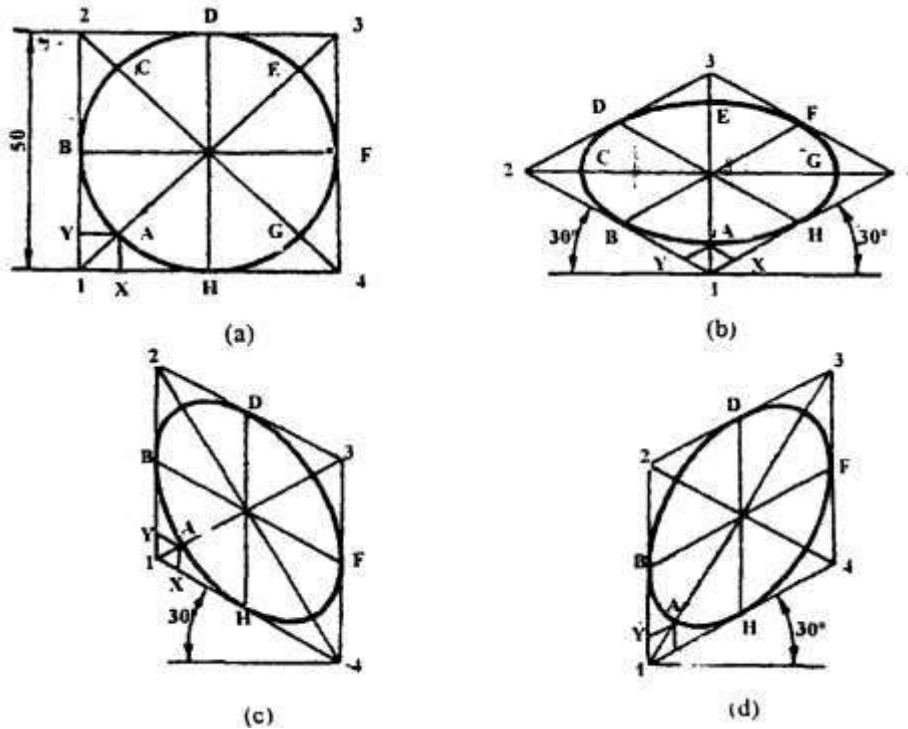


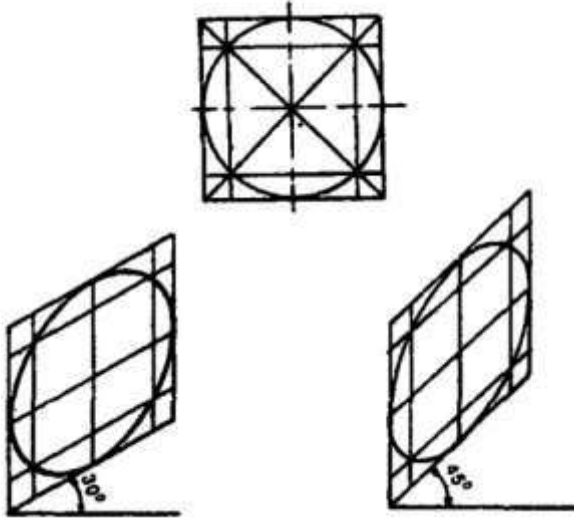
Figure 136: Angles, Circles and Curves in Oblique Projection

As already mentioned, angles, circles and irregular curves on the surfaces, parallel to the picture plane, appear in true size and shape. However, when they are located on receding faces, the construction methods, similar to isometric drawing may be followed.

For example, the method of representing a circle on an oblique face may be carried out by offset method and the four center method cannot be used. In case of cabinet oblique, the method and the result is the same as that of isometric drawing, since the angle of the receding axis can be the same as that of isometric axis.

Shows circles of same size in both isometric and oblique projections using  $45^\circ$  for the receding axis for oblique projections.

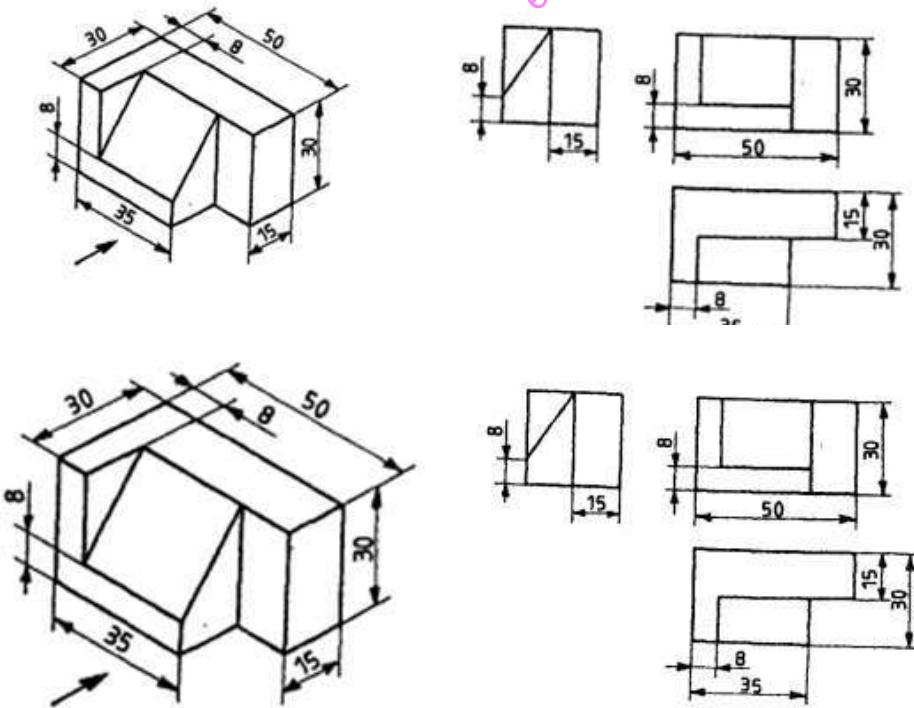
Curved features of all sorts on the receding faces or inclined surfaces may be plotted either by the off-set or co-ordinate methods as shown in the figure below.



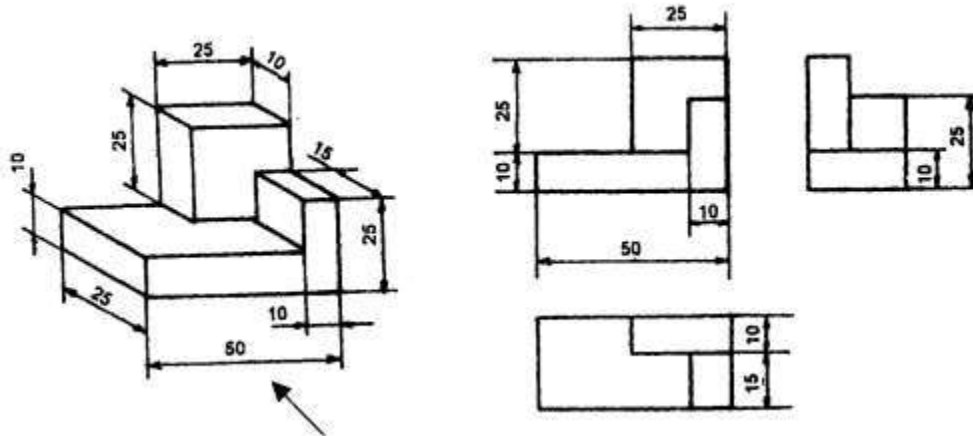
Learning activities

**LEARNING ACTIVITY 1: Produce orthographic and pictorial drawings**

i. The following figures are in isometric view. Draw the orthographic views in first angle.



ii. The following figures are in oblique view. Draw the orthographic views in first angle.



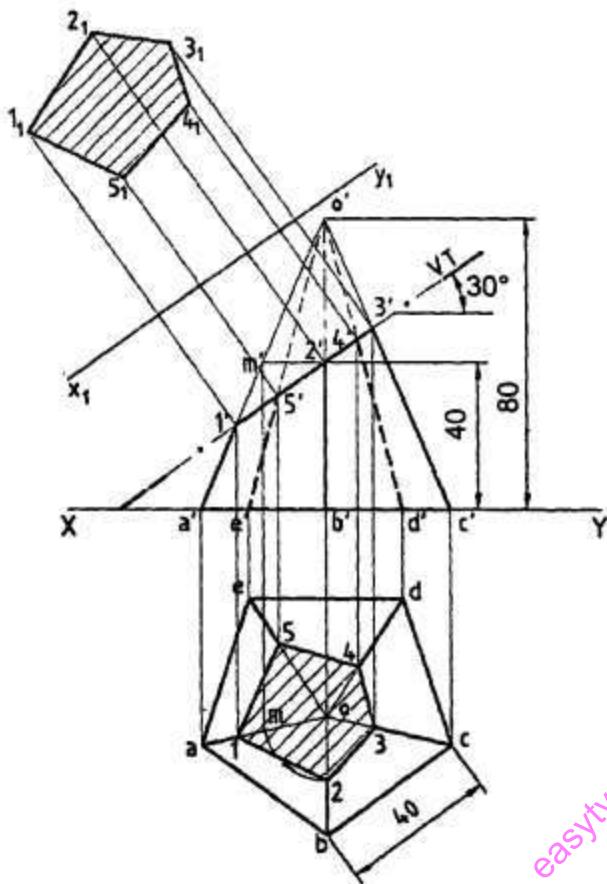
### Learning activity 2: Produce orthographic and pictorial drawings

A pentagonal pyramid of base side 40 mm and axis length 80mm is resting on HP on its base with one of its base side parallel to VP. It is cut by a plane inclined at  $30^\circ$  to HP and perpendicular to VP and is bisecting the axis. Draw its front view, sectional top view, and the true shape of section.

Draw the projection of the pyramid in the given position. The top view is drawn and the front view is projected.

To draw the cutting plane, front view and sectional top view

1. Draw the VT of the cutting plane inclined at  $30^\circ$  to XY line and passing through the midpoint of J the axis.
2. As a result of cutting, new comers 1', 2', 3', 4' and 5' are obtained on slant edges a '0', b '0', c '0', d'o' and e '0' respectively.
3. Show the remaining portion in front view by drawing dark lines.
4. Project the new points to get 1,2,3,4 and 5 in the top view on the respective slant edges.
5. Note that 2' is extended horizontally to meet the extreme slant edge a '0 ' at m', it is projected to meet ao in top view at m. Considering 0 as centre, om as radius, draw an arc to get 2 on bo



6. Join these points and show the sectional top view by drawing hatching lines.

To draw true shape of section.

I. Draw the new reference. Line  $x_1 y_1$  parallel to VT of the cutting plane.

1.2.3.2 Projectors from  $1', 2'$  etc. are drawn perpendicular to  $x_1 y_1$  line.

1.2.3.3 The distance of point 1 in top view from XY line is measured and marked from  $x_1 y_1$  in the projector passing through  $1'$  to get  $1'_1$ . This is repeated to get  $2'_1, 3'_1$  etc.

I. Join these points and draw hatching lines to show the true shape of section.

### Learning activity 3

Assemble the following parts and Draw full sectional view of the assembly for the following:

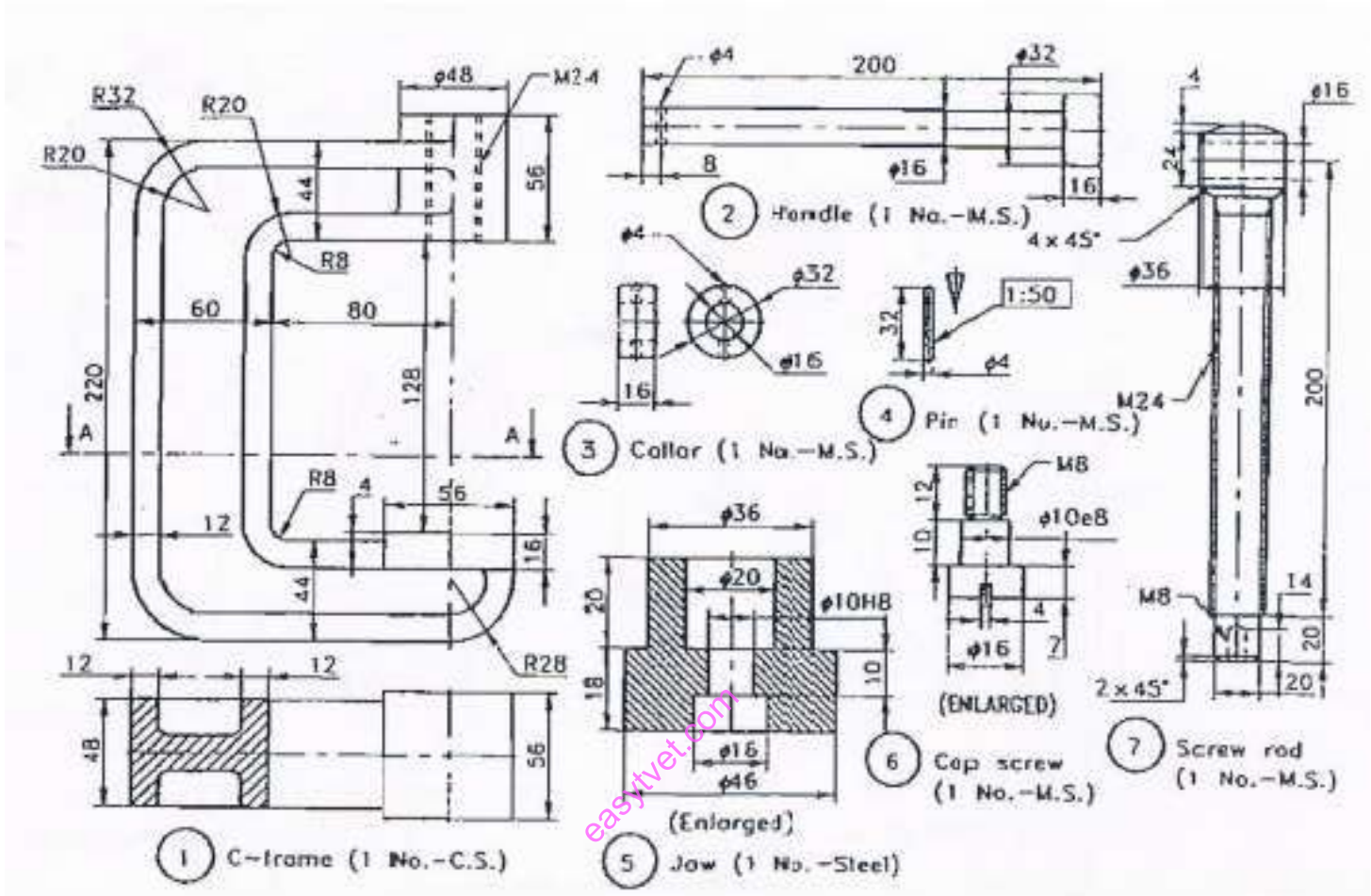


Figure: C-clamp parts.

**The assembled clamp**

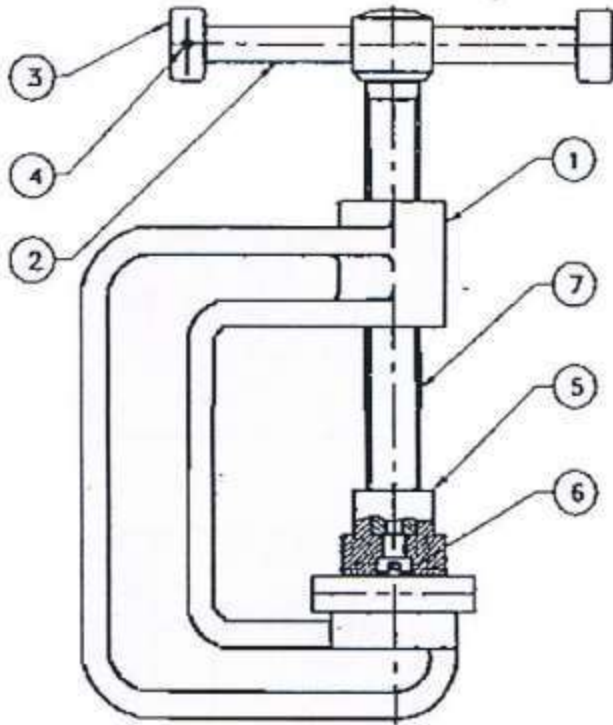


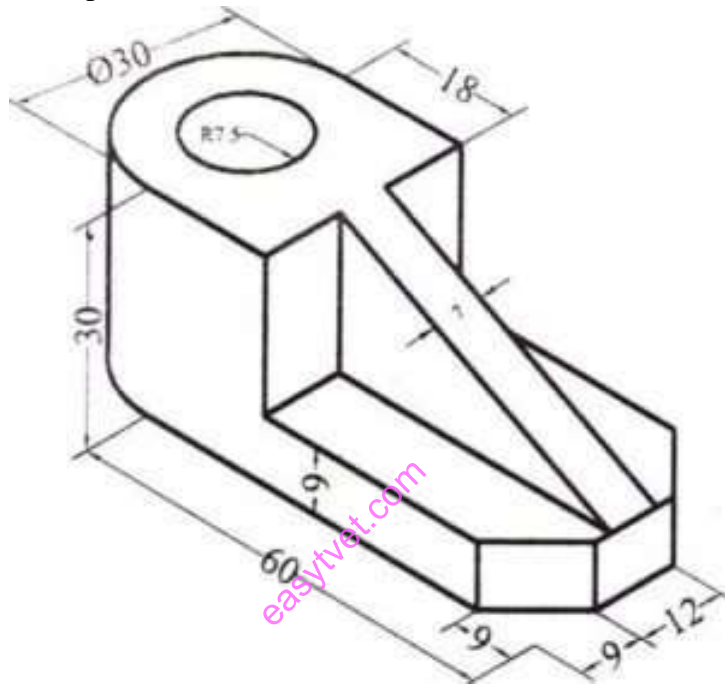
Figure: C-clamp assembly.

|     |              |          |       |   |
|-----|--------------|----------|-------|---|
| 7   | Screw rode   | M.S.     |       | 1 |
| 6   | Cap screw    | M.S.     |       | 1 |
| 5   | Jaw          | Steel    |       | 1 |
| 4   | Pin          | M.S.     |       | 1 |
| 3   | Collar       | M.S.     |       | 1 |
| 2   | Handle       | M.S.     |       | 1 |
| 1   | C-frame      | C.S.     |       | 1 |
| No. | Name of part | Material | Notes | Q |

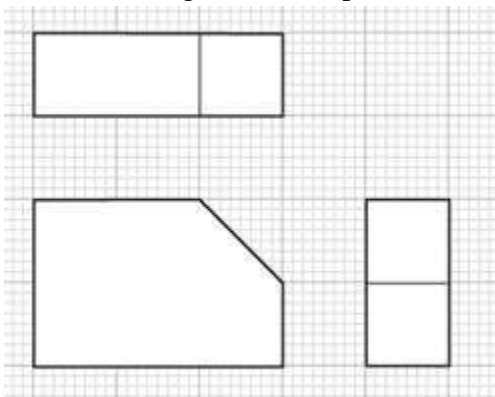
#### Self-assessment

1. What are the types of orthographic projections?
2. Isometric drawings are often used by \_\_\_\_\_ to help illustrate complex designs.
  - A. mechanical engineers
  - B. piping drafters
  - C. aerospace engineers
  - D. all of the above

3. When the receding lines are true length, and the projectors are at 45 degrees to the plane of projection, the oblique drawing is called this:
- A. Cabinet projection
  - B. Cavalier projection
  - C. Axonometric projection
  - D. Isometric projection
4. This drawing is an example of:



- A. An orthographic drawing
  - B. An isometric drawing
  - C. A perspective drawing
  - D. An oblique drawing
5. This drawing is an example of:



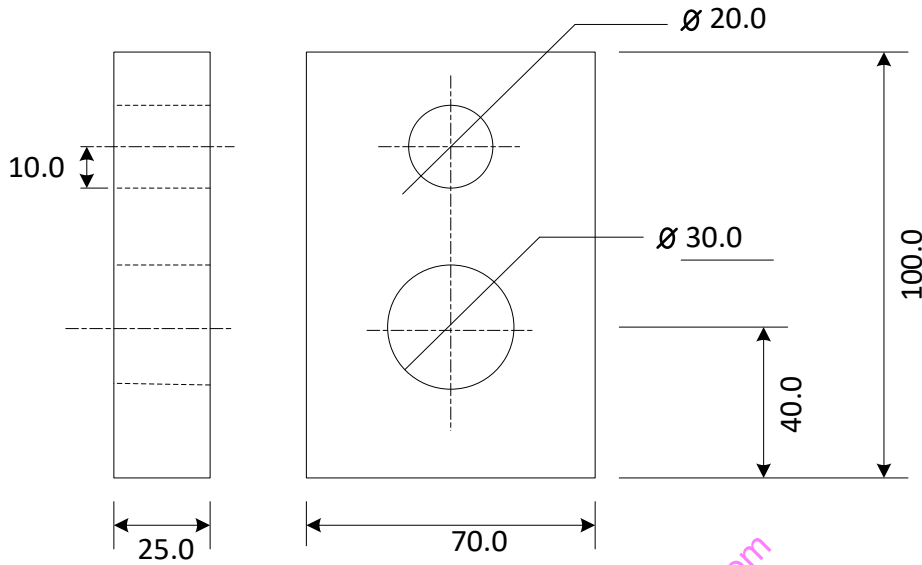
- A. An orthographic drawing
- B. An isometric drawing



- C. A perspective drawing
  - D. An oblique drawing
6. This type of projection is when projectors are parallel to each other, but is at an angle other than 90 degrees to the plane of projection:
    - A. Oblique projection
    - B. Perpendicular projection
    - C. Aesthetic projection
    - D. Angular projection
  7. Name the views in an Orthographic Drawings
  8. The top, front, and bottom views align in this manner:
    - A. Horizontally
    - B. Vertically
    - C. According to the planar views
    - D. Parallel to the frontal plane
  9. If a plane is parallel to the plane of projection, it appears:
    - A. True size
    - B. As a line or edge
    - C. Foreshortened
    - D. As an oblique surface
  10. Three systems are used to arrange orthographic views: first, second, and third angle projection.
    - A. True
    - B. False
  11. This line pattern is composed of three dashes, one long dash on each end with a short dash in the middle:
    - A. Object
    - B. Hidden
    - C. Center
    - D. Phantom
  12. This is the plane upon which the top view is projected:
    - A. Horizontal
    - B. Frontal
    - C. Profile
    - D. Base
  13. An advantage of this type of view is that each view shows the object all the way through as if it were transparent:
    - A. Planar
    - B. Horizontal
    - C. Auxiliary
    - D. Orthographic
  14. This type of surface is tipped to all principal planes of projection and does not appear true size in any standard view:

- A. Foreshortened
- B. Parallel
- C. Orthographic
- D. Oblique

15. From the following figure, which is the repetitive dimension?



- A. 30
- B. 70
- C. 10
- D. 20

#### Tools, Equipment, Supplies and Materials

1. Drawing tools
2. Drawing set
3. Drawing papers
4. Erasers
5. Series of pencils
6. Drawing board

#### References

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## 4.6 Apply Cad Packages

### Introduction to the learning outcome

This learning outcome is intended to equip the trainee with competence on how to apply CAD packages.

In this learning outcome AutoCAD has been selected to be the dominant CAD software to be learnt.

### Performance Standard

- i. CAD packages are selected according to task requirements
- ii. CAD packages are applied in production of electrical drawings

Information sheet

### Identification of CAD packages

#### Computer-Aided Design (CAD) Software

Computer-Aided Design (CAD) is the use of an application to help create or optimize a design. Therefore, CAD software allows engineers, architects, designers, and others to create precision drawings or technical illustrations in 2D or 3D. This category of software can increase productivity, improve quality, and maximize organization by creating a documentation database for manufacturing.

CAD software has a host of applications, including the design of manufacturing parts, electronic circuit boards, prototypes for 3D printers, and buildings. Typically, this software uses either traditional vector-based graphics or raster graphics which show how finished objects would actually look.

CAD software can also facilitate the flow from the design process to the manufacturing process. This software can simulate the movement of a part through the manufacturing process in three dimensions. As this software becomes ever better at simulating the manufacturing process, specialized software for designing the manufacturing process and controlling machine tools called Computer-Aided Manufacturing (CAM) has become integrated with CAD as a single platform.

Computer-Aided Design (CAD) Features & Capabilities

#### AutoCAD

## DEFINITION OF TERMS

### Basics

This section reviews the basic AutoCAD controls.

## **Viewing**

Pan and zoom in a drawing, and control the order of overlapping objects.

## **Geometry**

Create basic geometric objects such as lines, circles, and hatched areas.

## **Precision**

Ensure the precision required for your models.

## **Layers**

Organize your drawing by assigning objects to layers.

## **Properties**

You can assign properties such as color and linetype to individual objects, or as default properties assigned to layers.

## **Modifying**

Perform editing operations such as erase, move, and trim on the objects in a drawing.

## **Blocks**

Insert symbols and details into your drawings from commercial online sources or from your own designs.

## **Layouts**

Display one or more scaled views of your design on a standard-size drawing sheet called a layout.

## **Notes and Labels**

Create notes, labels, bubbles, and callouts. Save and restore style settings by name

## **Dimensions**

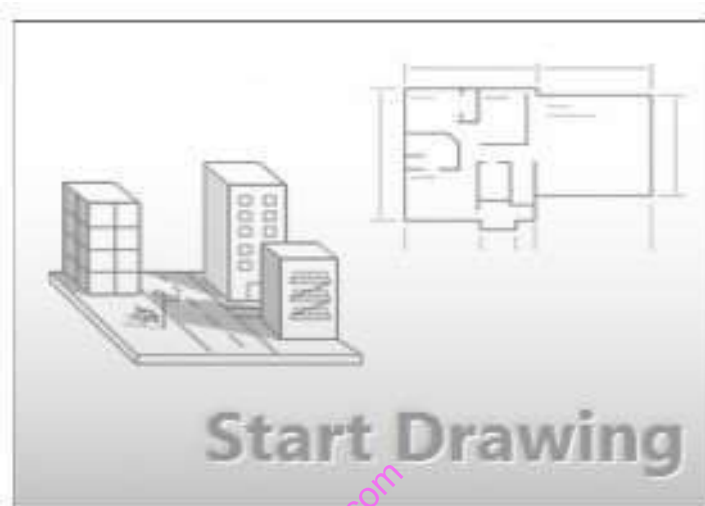
Create several types of dimensions and save dimension settings by name.

## **Printing**

Output a drawing layout to a printer, a plotter, or a file. Save and restore the printer settings for each layout.

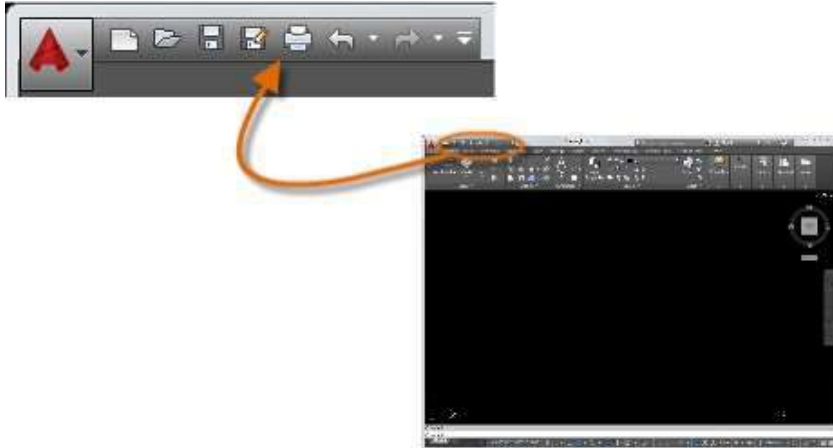
## Basics

Review the basic AutoCAD controls. After you launch AutoCAD, click the Start Drawing button to begin a new drawing.



AutoCAD includes a standard tabbed ribbon across the top of the drawing area. You can access nearly all the commands presented in this guide from the **Home** tab. In addition, the Quick Access toolbar shown below includes familiar commands

such as New, Open, Save, Print, Undo, and so on.



### The Command Window

At the heart of AutoCAD is the Command window, which is normally docked at the bottom of the application window. The Command window displays prompts, options, and messages.



You can enter commands directly in the Command window instead of using the ribbon, toolbars, and menus.

Many long- time AutoCAD users prefer this method.

Notice that as you start to type a command, an autocomplete menu appears.

When several options are available, such as in the example below, make your choice by clicking the correct option or using the arrow keys and then pressing Enter or the Spacebar to confirm your selection.



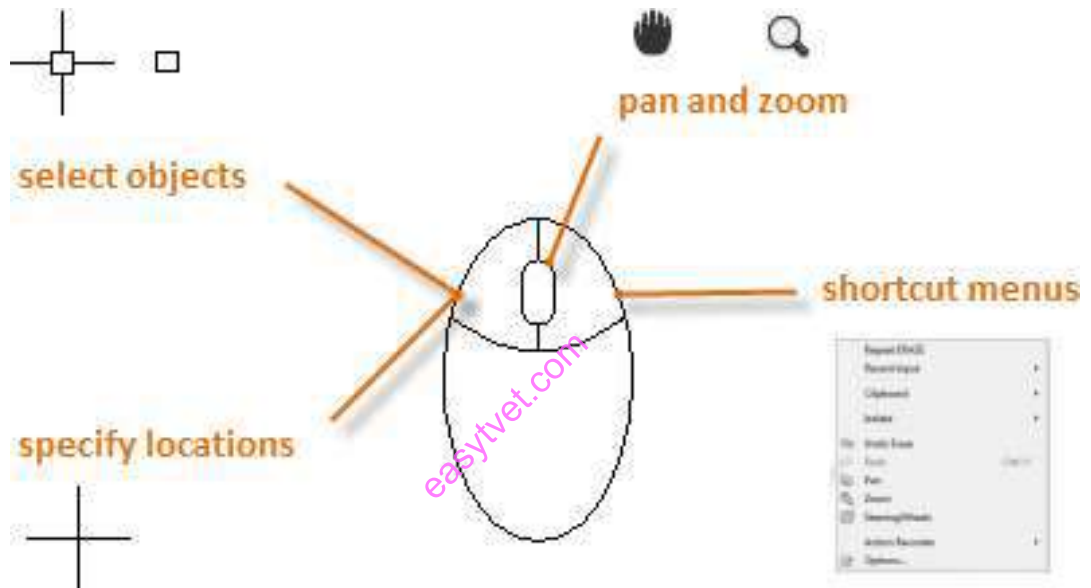
## The Mouse

Most people use a mouse as their pointing device, but other devices have equivalent controls.

Here's a Tip:

When looking for a command or option, try right-clicking.

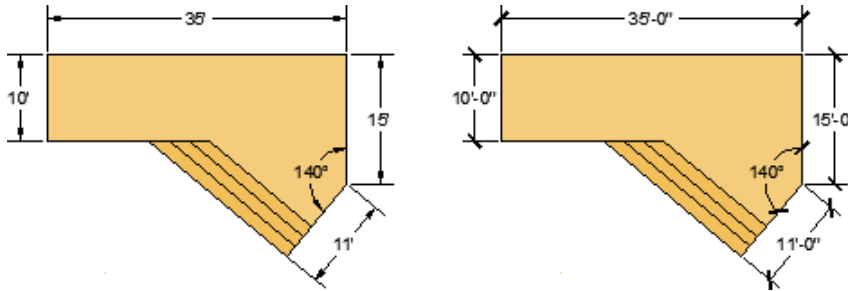
Depending on where your cursor is located, different menus will display relevant commands and options.





## New Drawings

You can easily conform to industry or company standards by specifying settings for text, dimensions, linetypes, and several other features. For example, this backyard deck design displays two different dimension styles.



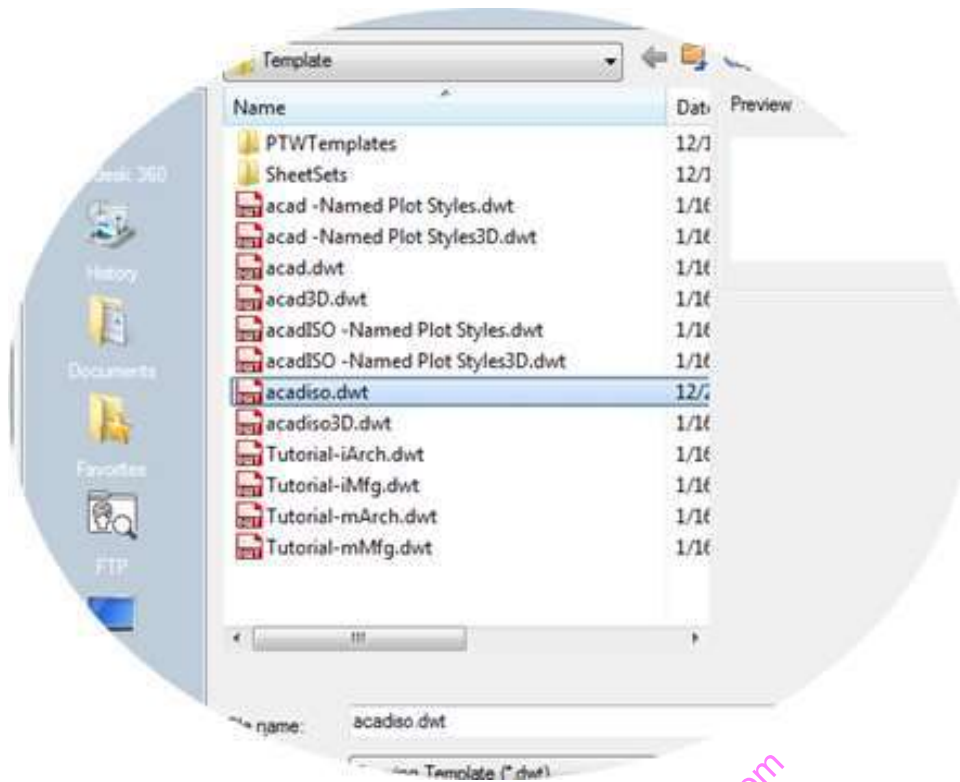
All these settings can be saved in a *drawing template* file. Click New to choose from several drawing



### Template files:

For imperial drawings that assume your units are inches, use *acad.dwt* or *acadlt.dwt*.

For metric units that assume your units are millimeters, use *acadiso.dwt* or *acadltiso.dwt*.



The “Tutorial” template files in the list are examples of the architectural or mechanical design templates using both imperial (i) and metric (m) measurements.

You might want to experiment with them.

Most companies use drawing template files that conform to company standards, and they will often use different drawing template files depending on the project or client.

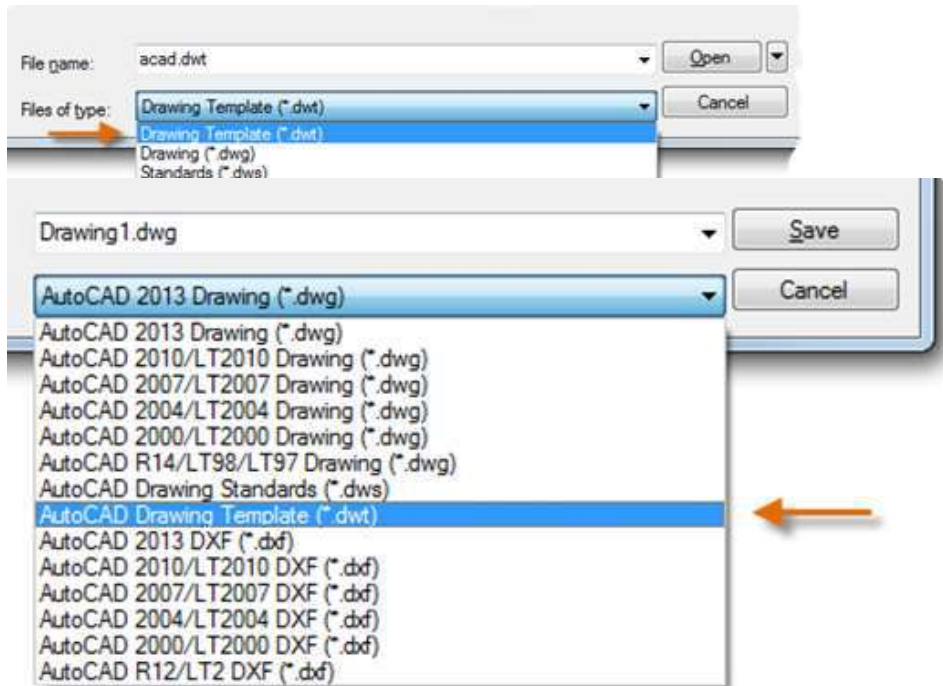
### Create Your Own Drawing Template File

You can save any drawing (.*dwg*) file as a drawing template (.*dwt*) file. You can also open any existing drawing template

If you work independently, you can develop your drawing template files to suit your working preferences, adding settings for additional features as you become familiar with them.

To modify an existing drawing template file, click Open, specify Drawing Template (\*.*dwt*) in the Select File dialog box, and choose the template file. Important:

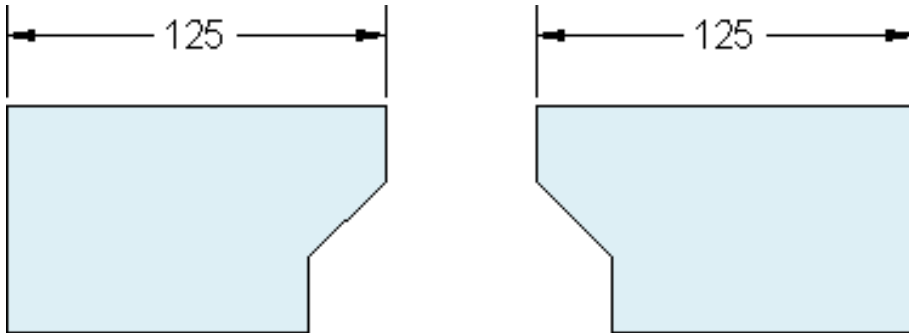
If your company has already established a set of drawing template files, check with your CAD manager before modifying any of them.



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## Units

When you first start a drawing, you need to decide what the length of one unit represents an inch, a foot, a centimeter, a kilometer, or some other unit of length. For example, the objects below could represent two buildings that are each 125 feet long, or they could represent a section from a mechanical part that is measured in millimeters.



## Unit Display Settings

After you decide what unit of length that you want to use, the **UNITS** command lets you control several unit display settings including the following:

**Format (or Type):** For example, a decimal length of 6.5 can be set to display as a fractional length of 6-1/2 instead.

**Precision:** For example, a decimal length of 6.5 can be set to display as 6.50, 6.500, or 6.5000.

If you plan to work in feet and inches, use the **UNITS** command to set the unit type to Architectural, and then when you create objects, specify their lengths in inches. If you plan to use metric units, leave the unit type set to Decimal. Changing the unit format and precision does not affect the internal precision of your drawing, it affects only how lengths, angles, and coordinates are displayed in the user interface

Here's a Tip:

If you need to change the **UNITS** settings, make sure that you save the drawing as a drawing template file (.dwt). Otherwise, you will need to change the **UNITS**

## Model Scale

Always create your models at full size (1:1 scale). The term *model* refers to the geometry of your design. A *drawing* includes the model geometry along with the views, notes, dimensions, callouts, tables, and the title block displayed in the *layout*.

You can specify the scaling that is necessary to print a drawing on a standard-sized sheet later, when you create the layout.

### Recommendations

To open **Help** for information about the command in progress, press F1.

To **repeat** the previous command, press Enter or the Spacebar.

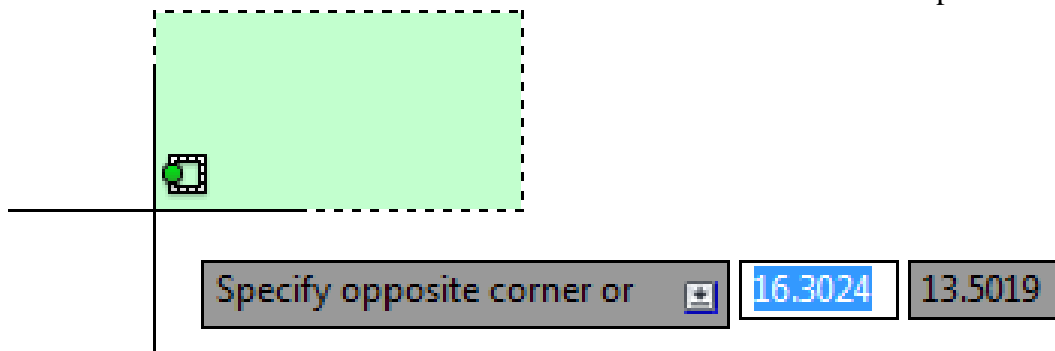
To see various **options**, select an object and right-click or right-click a user interface element.

To **cancel** a command in progress or if you ever feel stuck, press Esc.

For example GUIDE TO AUTOCAD BASICS: PRINTING e, if you click in the drawing area before entering a command, you will see something like the following:

Here's a Tip:

Press Esc to cancel this preselection operation.



## Viewing

Zoom in on a drawing to better control the order of overlapping objects. The easiest way to change your view is by using the mouse wheel.

Zoom in or out by rolling the wheel.

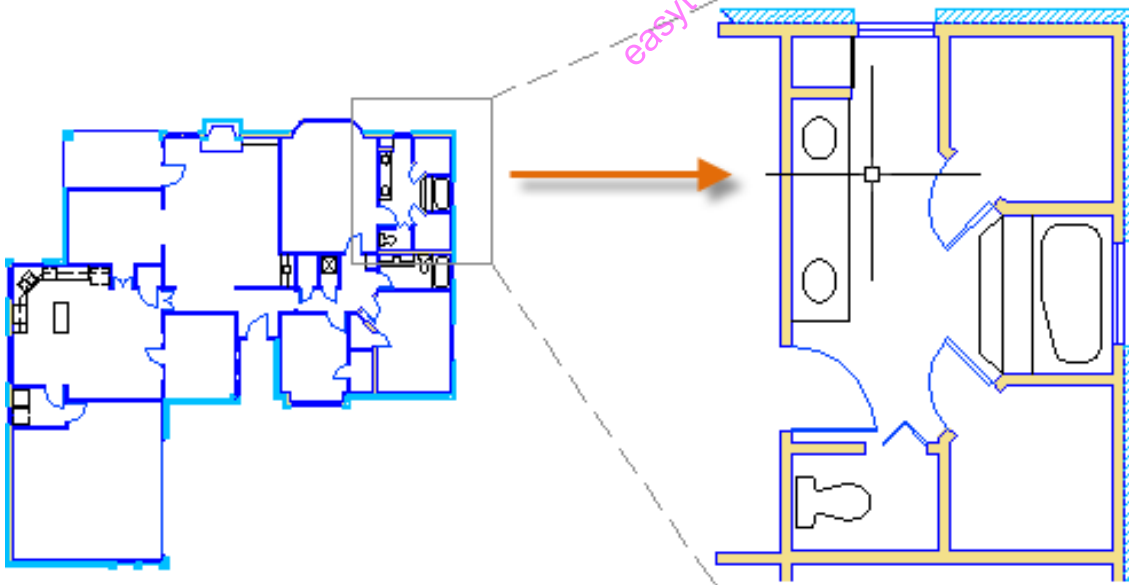
Pan a view in any direction by holding the wheel down while moving your mouse.

Zoom in on a specific area for greater detail holding your mouse over the area and clicking the wheel twice.

Here's a Tip:

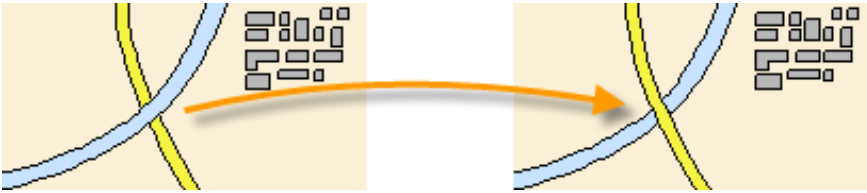
When you zoom in or out, the location of the cursor is important. Think of your cursor as a magnifying glass. For example, if you position the cursor in the upper-right area of the floor plan as shown below, zooming in magnifies the dressing room without shifting the view.

**NOTE:** If you cannot zoom or pan any more, type **REGEN** in the Command window and press Enter. This command regenerates the drawing display and resets the extents available for panning and z



## Overlapping Objects

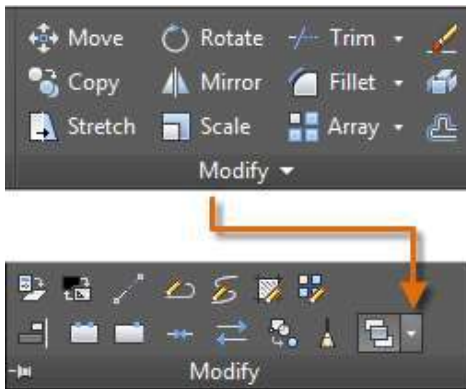
If you create objects that overlap, you might need to change which objects are displayed on top or in front of the others. For example, if you want the yellow highway to cross the blue river rather than the other way around,



use the **DRAWORDER** command to reorder the objects.

You can access several draw order options from the Modify panel on the ribbon. Click to expand the Modify panel, and then click the down-arrow as shown below.

The draw order options that are listed include sending all hatches to the back, all text to the front, and so on.



## Geometry

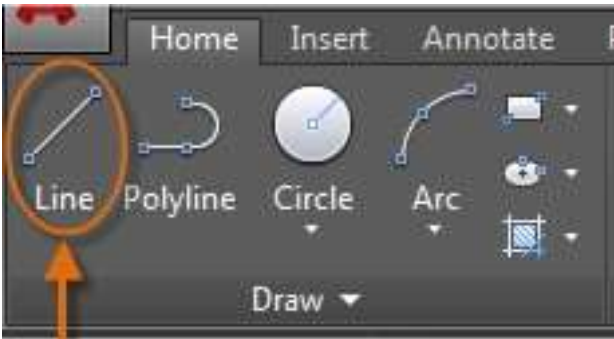
Create basic geometric objects such as lines, circles, and hatched areas.

You can create many different types of geometric objects in AutoCAD, but you only need to know a few of them for most 2D drawings.

**NOTE:** If you want to simplify the display while creating geometric objects, press *F12* to turn off dynamic input.

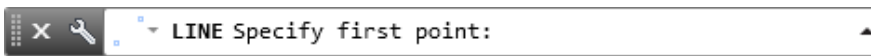
## Lines

The line is the most basic and common object in AutoCAD drawings. To draw a line, click the Line tool.



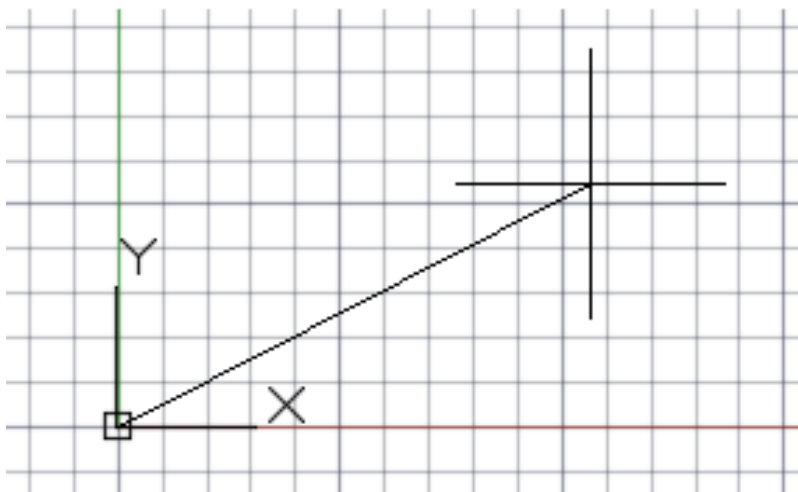
Alternatively, you can type **LINE** or just **L** in the Command window, and then press Enter or the Spacebar.

Notice the prompt in the Command window for a point location.



To specify the starting point for this line, you would type in the coordinates 0,0. It is a good idea to locate one corner of your model at 0,0, which is called the origin point. To locate additional points, you could specify additional X,Y coordinate

locations in the drawing area, however more efficient methods for specifying points are available, and will be presented in the Precision topic.



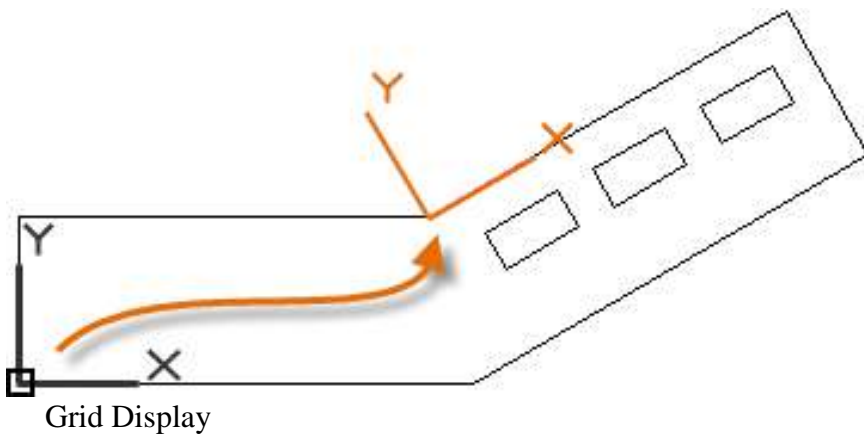


**After you specify the next point, the LINE command automatically repeats itself, and it keeps prompting you for additional points.**

**Press Enter or the Spacebar to end the sequence.**

### The User Coordinate System

The user coordinate system (UCS) icon indicates the direction of the positive X and Y axis for any coordinates that you enter, and it also defines the horizontal and vertical directions in a drawing. In some 2D drawings, it can be convenient to click, drag, and rotate the UCS to change the origin point, and the horizontal and vertical directions.



Some people like working with grid lines as a reference, while others prefer working in a blank area. To turn off the grid display, press F7. Even with the grid turned off, you can force your cursor to snap to grid increments by pressing F9.

### Lines as Construction Aids

Lines can serve as reference and construction geometry such as:

### Property line setbacks

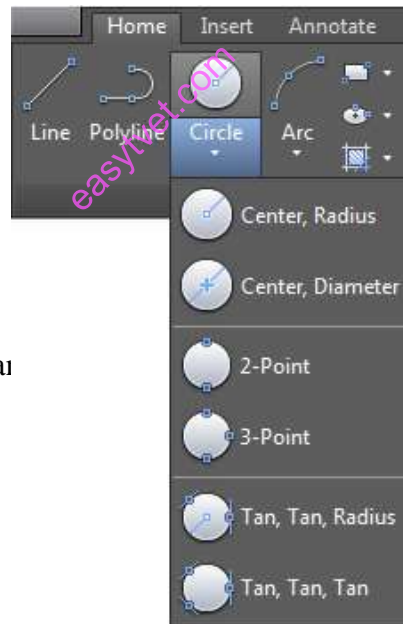
The mirror line of a symmetrical mechanical part

Clearance lines to avoid interferences

Traversal path lines

Circles

The default option of the **CIRCLE** command

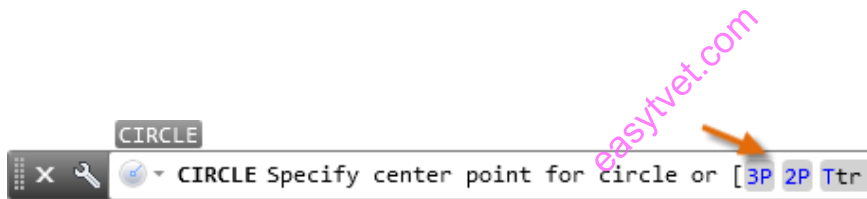


ter point and a radius.

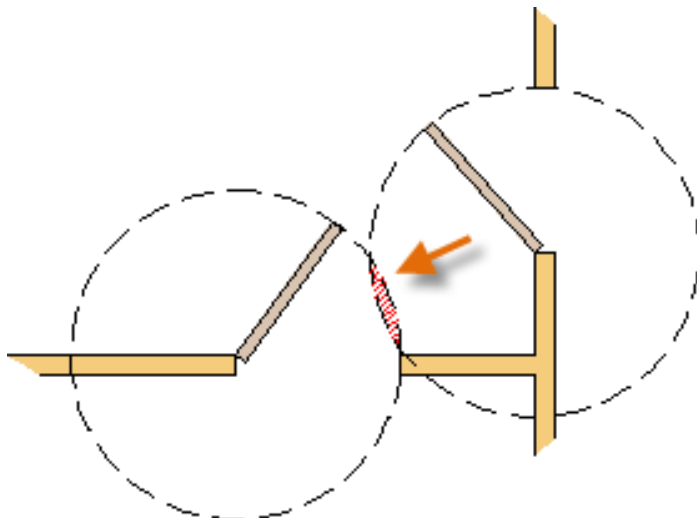


The other circle options are available from the drop-down:

Alternatively, you can also enter **CIRCLE** or just **C** in the Command window and click to choose an option. If you do, you can specify a center point, or you can click one of the highlighted command options as shown below.



Circles can be useful as reference geometry. For example, you can see that the two doors in the illustration can interfere with each other.



## Polylines and Rectangles

A polyline is a connected sequence of line or arc segments that is created as a single object.



Use the **PLINE** command to create open or closed polylines for:

Geometry that requires fixed-width segments

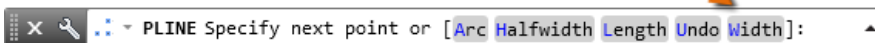
Continuous paths for which you need to know the total length

Contour lines for topographic maps and isobaric data

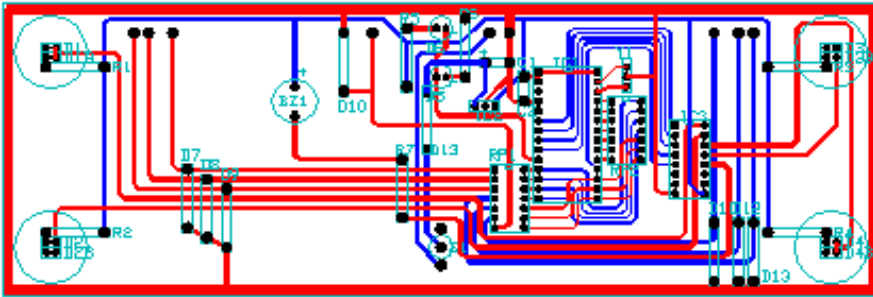
Wiring diagrams and traces on printed circuit boards

Process and piping diagrams

Polylines can have a constant width or they can have different starting and ending widths. After you specify the first point of the polyline, you can use the Width option to specify the width of all subsequently created segments. You can change the width value at any time, even as you create new segments.



Here is an example of a printed



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## Polylines and Rectangles

Polylines can have different starting and ending widths for each segment as shown here:



A fast way to create closed rectangular polylines is to use the **RECTANG** command (enter **REC** in the Command window).

Simply click two diagonal points for the rectangle as illustrated. If you use this method, turn on grid snap (F9) for precision.



## Hatches and Fills

In AutoCAD, a hatch is a single, compound object that covers a specified area with a pattern of lines, dots, shapes, a solid fill color, or a gradient fill.



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When you start the **HATCH** command, the ribbon temporarily displays the Hatch Creation tab. On this



tab, you can choose from over 70 industry-standard imperial and ISO hatch patterns along with many specialized options.

The simplest procedure is to choose a hatch pattern and scale from the ribbon, and click within any area that is completely enclosed by objects. You must specify the scale factor for the hatch in order to control its size and spacing.

After you create a hatch, you can move the bounding objects to adjust the hatch area, or you can delete one or more of the bounding objects to create partially bounded hatches:

Here's a Tip:

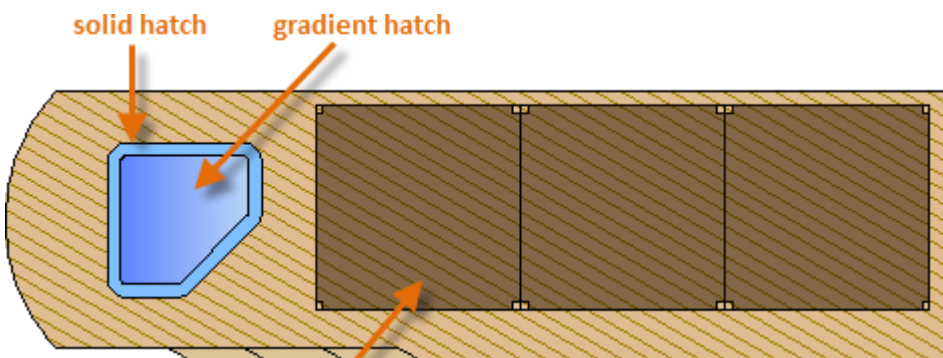
If you set a solid or gradient fill hatch pattern, also consider setting a transparency level on the Hatch Creation tab for interesting overlap effects.

### Hatches and Fills (continued)

Here are some examples of how you can use solid-fill hatches:

Here's a Tip:

If you need to align the pattern in a hatch, which might be the case with the decking boards above, use the Set Origin option to specify an alignment point.





## Precision

Ensure the precision required for your models.

There are several precision features available, including:

**Polar tracking:** Snap to the closest preset angle and specify a distance along that angle.

**Locking angles:** Lock to a single, specified angle and specify a distance along that angle.

**Object snaps:** Snap to precise locations on existing objects, such as an endpoint of a polyline, the midpoint of a line, or the center point of a circle.

**Grid snaps:** Snap to increments on a rectangular grid

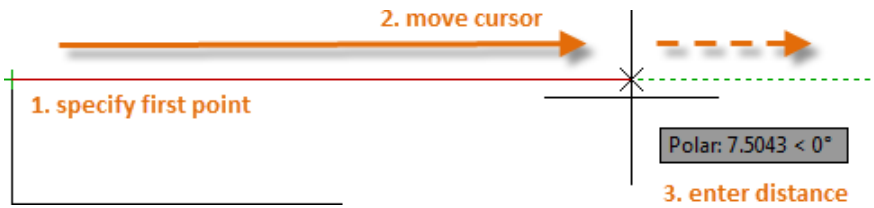
**Coordinate entry:** Specify a location by its Cartesian or polar coordinates, either absolute or relative.

The three most commonly used features are polar tracking, locking angles, and object snaps.

### Polar Tracking

When you need to specify a point, such as when you create a line, you can use polar tracking to guide the movement of your cursor in certain directions.

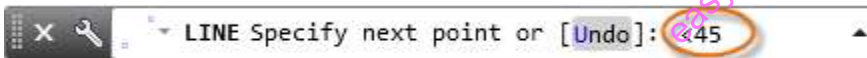
For example, after you specify the first point of the line below, move your cursor to the right, and then enter a distance in the Command window to specify a precise horizontal length for the line.



By default, polar tracking is turned on and guides your cursor in a horizontal or vertical direction (0 or 90 degrees).

### Locking Angles

If you need to draw a line at a specified angle, you can lock the angle for the next point. For example, if the second point of a line needs to be created at a 45 degree angle, you would enter '<45' in the Command window.

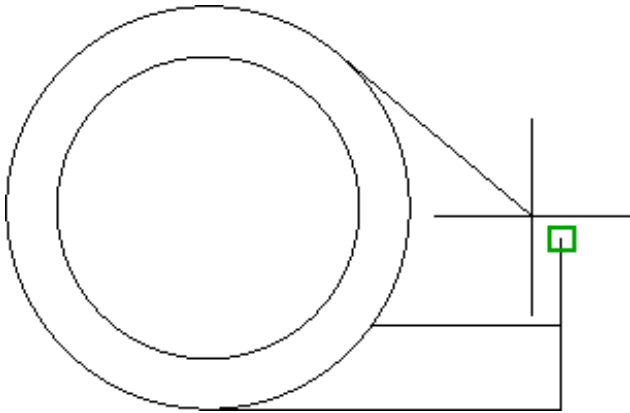


After you move your cursor in the desired direction along the 45-degree angle, you can enter the length of the line.

### Object Snaps

By far, the most important way for you to specify precise locations on objects is to use object snaps. In the following illustration, several different kinds of object snaps are represented by markers.

Object snaps become available during a command whenever AutoCAD prompts you to specify a point. For example, if you start a new line and move your cursor near the endpoint of an existing line, the cursor will automatically snap to it.



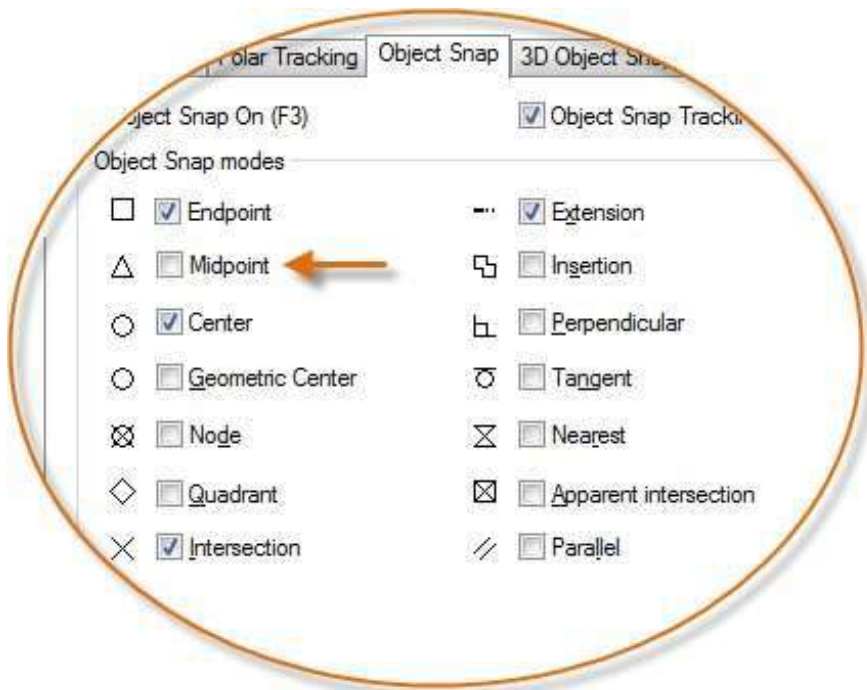
## Set Default Object Snaps

Enter the **OSNAP** command to set the default object snaps, which are also called “running” object snaps. For example, you might find it useful to turn on the Midpoint object snap by default.

## Recommendations

At any prompt for a point, you can specify a single object snap that overrides all other object snap settings. Hold down Shift, right-click in the drawing area, and choose an object snap from the Object Snap menu. Then move the cursor to select a location on an object.

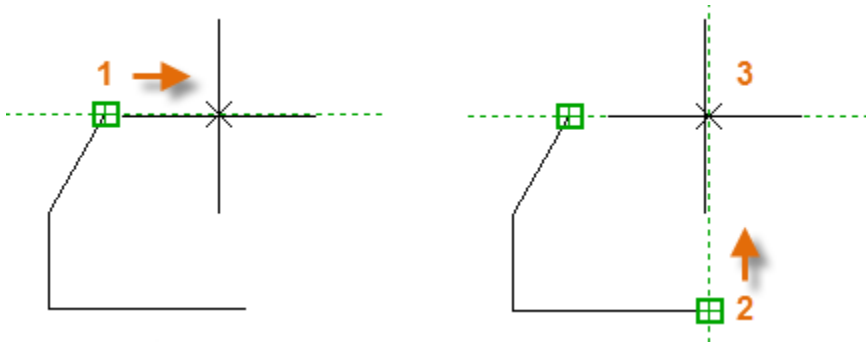
Make sure that you zoom in close enough to avoid mistakes. In a densely populated model, snapping to the wrong object will result in an error that can propagate throughout your model.



## Object Snap Tracking

During a command, you can align points both horizontally and vertically from object snap locations. In the following illustration, you first hover over endpoint 1 and then hover over endpoint

2. When you move your cursor near location 3, the cursor locks into the horizontal and vertical location shown.



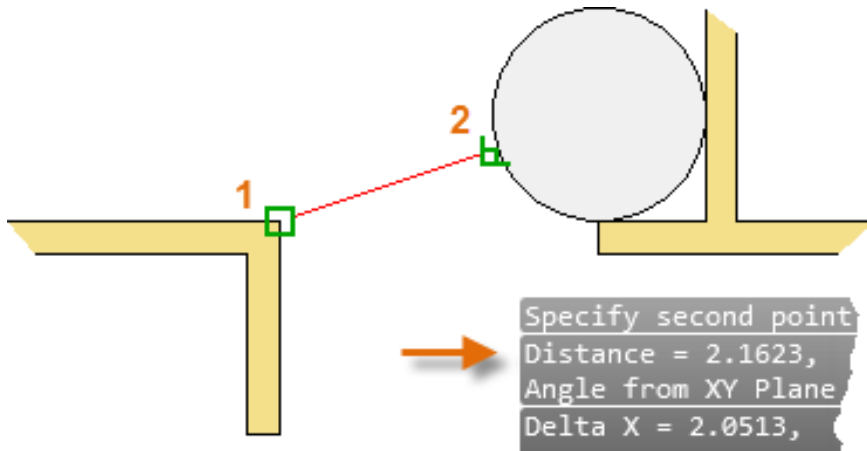
You can now finish creating the line, circle, or other object that you were creating from that location.

## Verify Your Work

Recheck your geometry to catch mistakes early. Enter the **DIST** command (or just **DI**) to measure the distance between any two points in your model.

For example, you might need to find the clearance between two points shown, which might represent the corner of a wall and a small table, or perhaps a 2D section of a plastic part and a wire.

After you enter **DIST**, click the endpoint on the corner (1). Next, hold down Shift as you right-click, and then choose Perpendicular from the object snap menu. Finally, click the circle (2).



## Handy Function Key Reference

All keyboard function keys have assignments in AutoCAD. The ones that are most commonly turned on and off are indicated with a key.

| Key | Feature              | Description  |
|-----|----------------------|--|
|     | Help                 | Displays Help for the active tooltip, command palette, or dialog box.    |
| F2  | Expanded History     | Displays expanded command history in the Command Window.                 |
| F3  | Object Snap          | Turns object snap on and off.  |
| F4  | 3D Object Snap       | Turns on additional object snaps for 3D elements.                        |
| F5  | Isoplane             | Cycles through 2-1/2D isoplane settings.                                 |
| F6  | Dynamic UCS          | Turns on UCS alignment with planar surfaces.                             |
| F7  | Grid Display         | Turns the grid display on and off.                                       |
|     | Ortho                | Locks cursor movement to horizontal or vertical.                         |
| F9  | Grid Snap            | Restricts cursor movement to specified grid intervals.                   |
|     | Polar Tracking       | Aids cursor movement to specified angles.                                |
| F11 | Object Snap Tracking | Tracks the cursor horizontally or vertically from object snap locations. |

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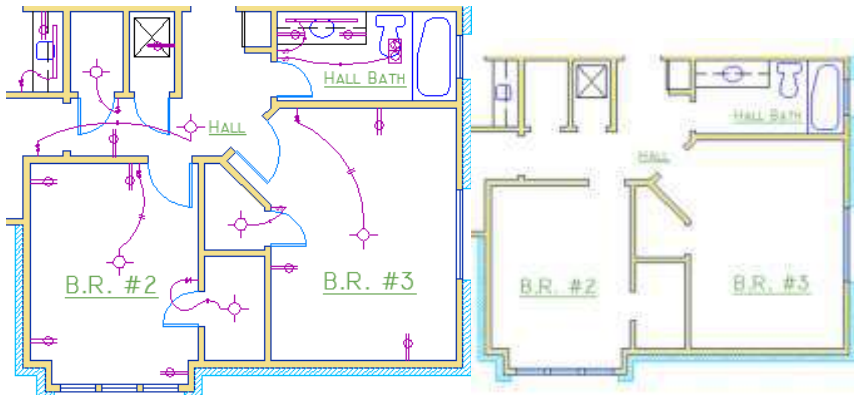
[easytvvet.com](http://easytvvet.com)

## Layers

Organize your drawing by assigning objects to layers.

When a drawing becomes visually complex, you can hide objects that you currently do not need to see.

In the drawing below, the doors and electrical wiring were temporarily hidden by hiding their layers.



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## Layers

You gain this level of control by organizing the objects in your drawing on layers that are associated with a specific function or purpose. It might be helpful to think of layers as clear plastic sheets:

With layers, you can:

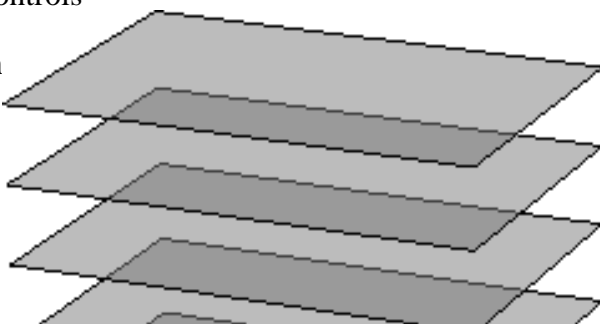
Associate objects by their function or location

Display or hide all objects related to a single operation

Enforce linetype, color, and other property standards for each layer

## Layer Controls

To see h  
You can



**Cabinets** the Layer Properties Manager.  
click the Layer Properties tool

**Fixtures**

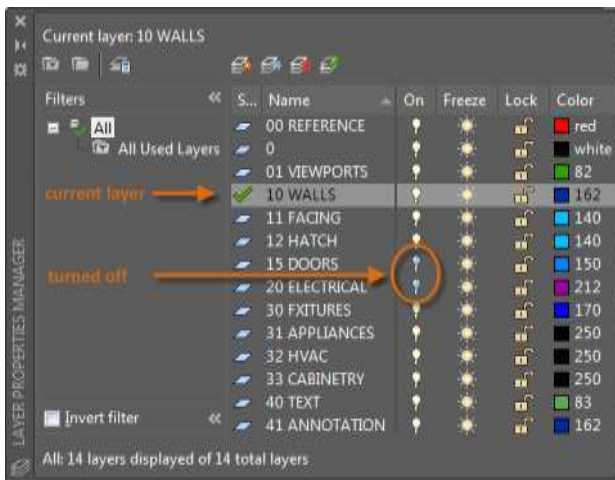
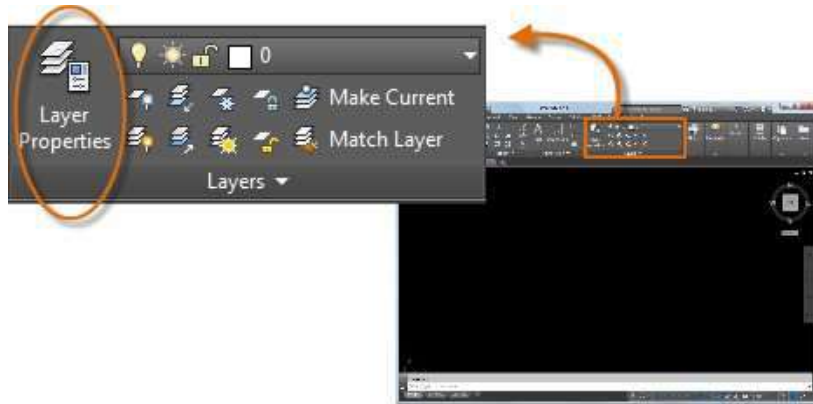
**Electrical**

**Doors**



on the ribbon.

Here's what the Layer Properties Manager displays for this drawing.



As indicated, layer 10 WALLS is the *current layer*. All new objects are automatically placed on that layer. In the list of layers, the green check next to layer 10 WALLS indicates that it is the current layer.

In the column labeled On, notice that the light bulb icons for two layers are dark. This indicates that these layers were turned off to hide the doors and electrical wiring in the floor plan.

Notice that each layer name starts with a two-digit number. This convention makes it easy to control the order of the layers because their order does not depend on the alphabet.

Here's a Tip:

For complex drawings, you might want to consider a more elaborate layer naming standard. For example, layer names could begin with 3 digits followed by a naming code that accommodates multiple floors in a

building, project numbers, sets of survey and property data, and so on.

### Practical Recommendations

Layer 0 is the default layer that exists in all drawings and has some esoteric properties. Instead of using this layer, it's best to create your own layers with meaningful names.

Any drawing that contains at least one dimension object automatically includes a reserved layer named Defpoints.

Create a layer for behind-the-scenes construction geometry, reference geometry, and notes that you usually do not need to see or print.

Create a layer for layout viewports. Information about layout viewports is covered in the Layouts topic.

Create a layer for all hatches and fills. This lets you to turn them all on or off in one action.

### Layer Settings

The following are the most commonly used layer settings in the Layer Properties Manager. Click the icon to turn the setting on and off.

**Turn off Layers: This will help reduce the visual complexity of your drawing while you work**

**Freeze Layers:** Freeze layers that you do not need to access for a while. Freezing layers is similar to turning them off, but improves performance in very large drawings.

**Lock Layers:** Locking layers prevents accidental changes to the objects on those layers.

## Controls in the Layer Properties Manager

To create a new layer, click the button shown and enter the name of the new layer. To make a different layer the current one, click the layer and then click the indicated button.



## Quick Access to Layer Settings

The Layer Properties Manager takes up a lot of space, and you may not always need to access all the options. For quick access to the most common layer controls, use the controls on the ribbon. When no objects are selected, the Layers panel on the Home tab displays the name of the current layer as shown here.

Occasionally, check to make sure that the objects you create will be on the correct layer. It's easy to forget to do this, but it's also easy to set. Click the drop-down arrow to display a list of layers, and then click a layer on the list to make it the current layer. You can also click on any layer setting icon in the list to



change its setting.

## Maintain Your Standards

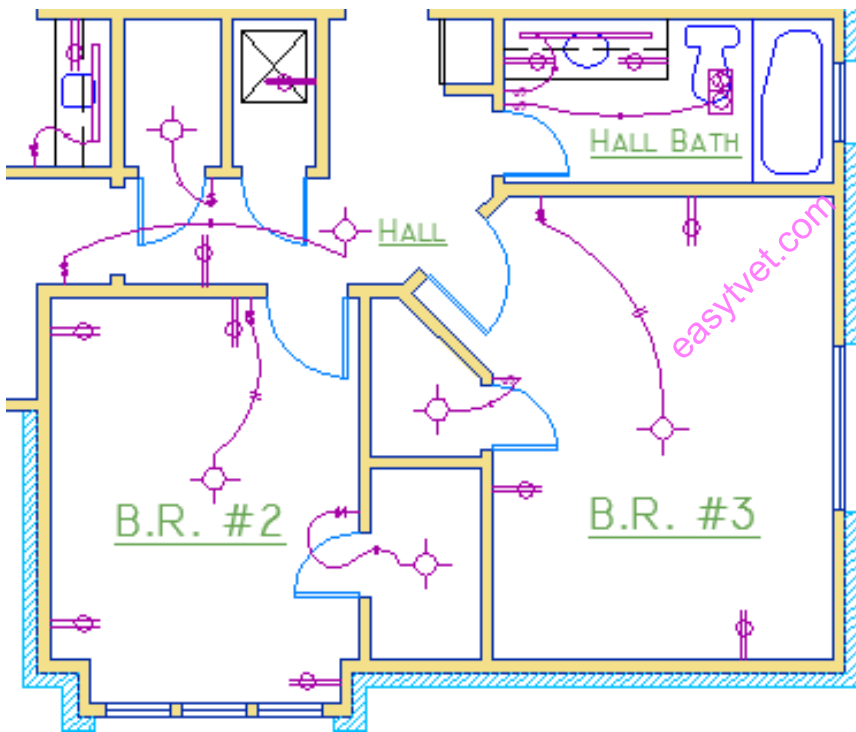
It's important to either establish or conform to a company-wide layer standard. With a layer standard, drawing organization will be more logical, consistent, compatible, and maintainable over time and across departments. Layer standards are essential for team projects.

If you create a standard set of layers and save them in a drawing template file, those layers will be available when you start a new drawing, and you can start working immediately. Additional information about drawing template files is presented in the Basics topic.

### Properties

You can assign properties such as color and linetype to individual objects, or as default properties assigned to layers.

In the following drawing, the walls, exterior stone facing, doors, fixtures, cabinetry, HVAC, electrical, and text were created using different colors to help differentiate them.



### The Properties Palette

The Properties palette is an essential tool. You can open it with the **PROPERTIES** command (enter **PR** in the Command window), you can press Ctrl + 1, or you can click the tiny arrow in the Properties panel on the Home tab whichever you prefer.

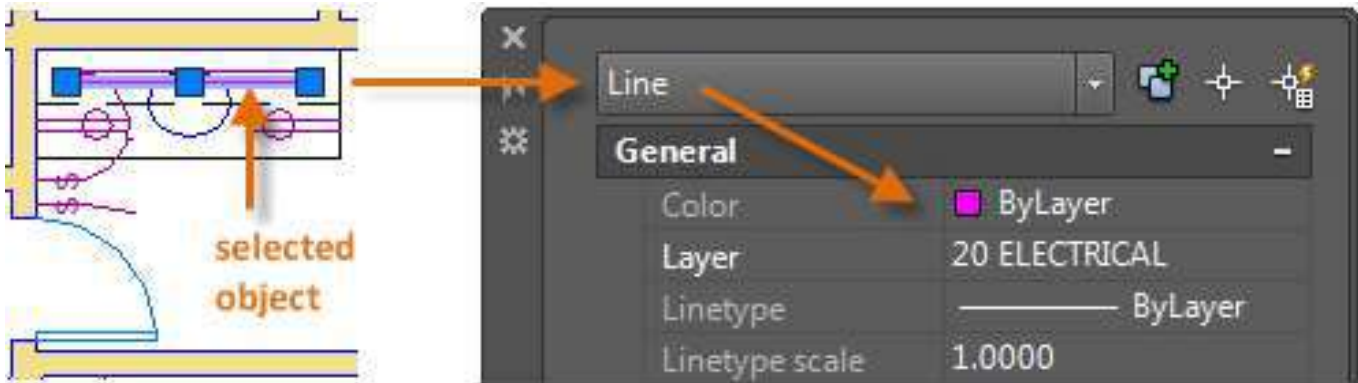


The Properties palette displays a list of all the important property settings. You can click any of the available fields to change the current settings. In the following example, if no objects are selected, the current color will be changed from ByLayer to Red and the UCS icon will be turned off.



## Verify and Change Object Properties

You can use the Properties palette to verify and change property settings for selected objects. If you click an object in your drawing to select it, here is what you might see in the Properties palette.



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**NOTE:** To clear the current selection, press Esc.

Notice that the current properties for the selected object are displayed in the palette. You can change any of these properties by clicking and changing the setting.

A property that is set to “ByLayer” inherits its setting from the layer. In the previous example, the objects that were created on the 20 ELECTRICAL layer are purple because that is the default color of the objects on that layer.

If you select several objects, only their common properties are listed in the Properties palette. If you change one of these properties, all the selected objects will change in one operation. Selecting objects is covered in more detail in the Modifying topic

## Quick Access to Property Settings

The Properties palette can take up a lot of space. For quick access to the most common properties, use the Properties panel. As you can see in this example, the listed properties will all be determined by the current layer.



The Properties panel works the same way as the Properties palette. When you select an object, the current property settings are replaced by the properties assigned to the selected object, and you can use this panel to easily change the properties of one or more selected objects.



Match the Properties of Objects

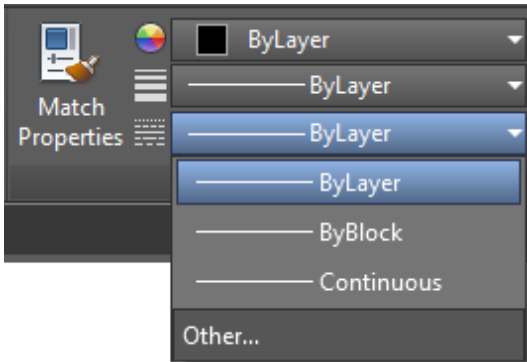
For a fast way to copy the properties of a selected object to other objects, use the Match Properties tool, or enter **MATCHPROP** or **MA** in the Command window.

Select the source object, and then select all of the objects that you want to modify.

### Linetypes

Dashed and other non-continuous linetypes are assigned from the Properties panel. You must first load a linetype before you can assign it.

In the Linetype drop-down list, click Other.



This action displays the Linetype Manager dialog box. Perform the following steps in order:

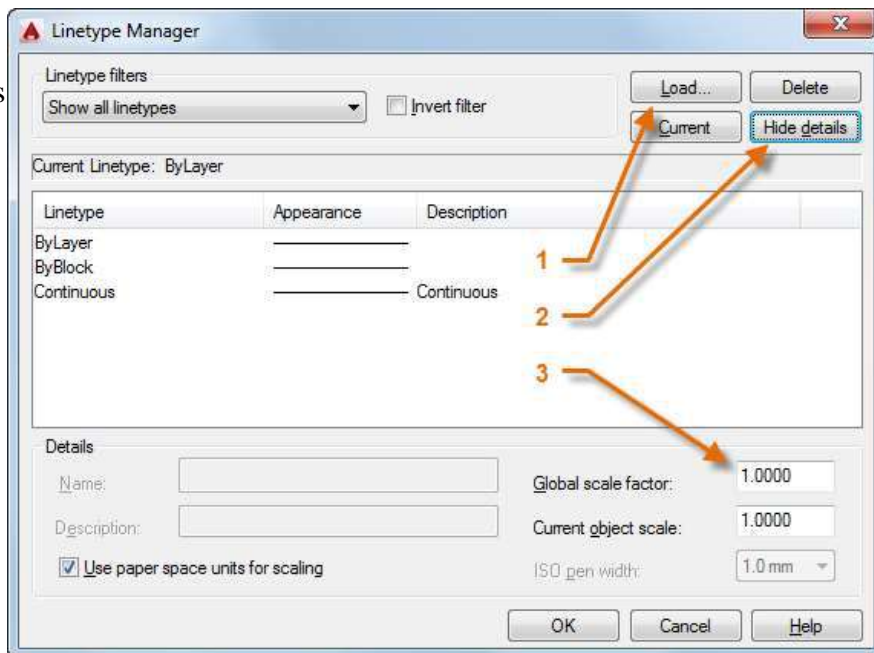
Click Load. Choose one or more linetypes that you want to use. Notice that dashed (non-continuous) linetypes come in several preset sizes.

Click Show/Hide details to display additional settings.

Specify a different “global scale factor” for all linetypes—the larger the value, the longer the dashes and spaces. Click OK.

Once you’ve loaded the linetypes that you plan to use, you can select any object and specify a linetype from the Properties panel or the Properties palette. Alternatively, you can specify a default linetype for any layer in the Layer

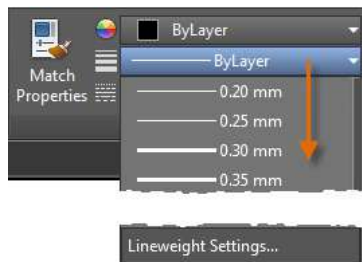
Properties





## Lineweights

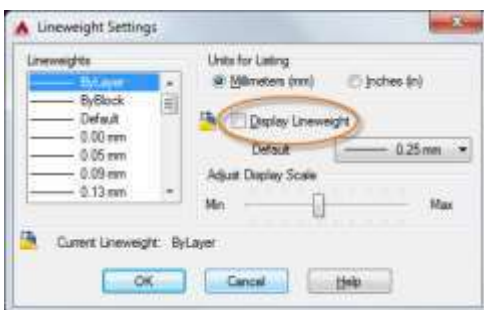
The Lineweight property provides a way to display different thicknesses for selected objects. The thickness of the lines remains constant regardless of the scale of the view. In a layout, lineweights are always displayed and printed in real-world units. Lineweights can also be assigned from the Properties panel.



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You can leave the lineweight set to ByLayer, or you can specify a value that overrides the layer's lineweight. In some cases, the lineweight previews look the same because they are displayed in approximated pixel widths on a monitor. However, they will print at the correct thickness.

To control the display of lineweights, click the Lineweight Settings button at the bottom of the lineweight list. In the Lineweight Settings dialog box, you can choose whether you want to display or hide lineweights.



Regardless of the display setting, lineweights will always be printed at the correct scale.

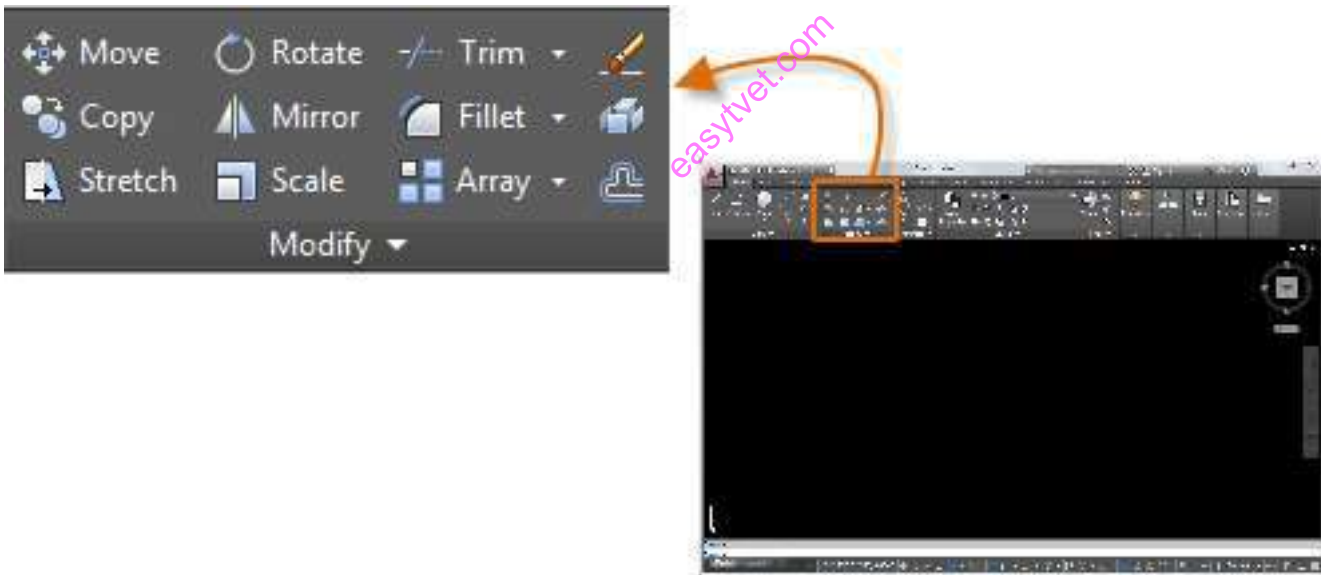
Here's a Tip:

It's usually best to leave lineweights turned off while you work. Heavy lineweights can obscure nearby objects when you use object snaps. You might want to turn

## Modifying

Perform editing operations such as erase, move, and trim on the objects in a drawing.

The most common modifying tools are located on the Modify panel of the Home tab. Take a minute to look through them.

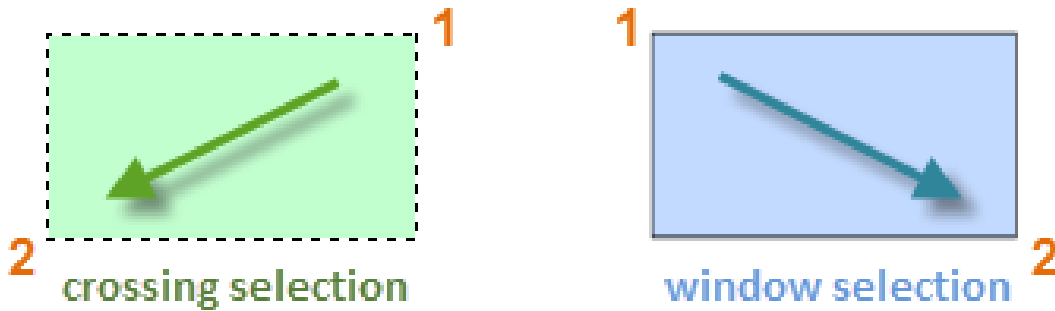


## Erase

To erase an object, use the **ERASE** command. You can enter **E** in the Command window, or click the Erase tool. When you see the cursor change to a square pickbox, click each object that you want to erase, and then press Enter or the Spacebar.

## Select Multiple Objects

Sometimes you may need to select a large number of objects. Instead of selecting each object individually, you can select the objects in an area by clicking an empty location (1), moving your cursor right or left, and then clicking a second time (2).



With a *crossing selection*, any objects within or touching the green area are selected.

With a *window selection*, only the objects completely contained within the blue area are selected.

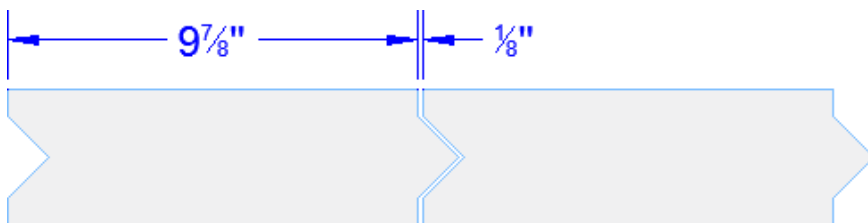
The result is called the *selection set*, which is the set of objects that will be processed by a command.

Here's a Tip:

You can easily remove objects from the selection set. For example, if you select 42 objects, and two of them should not have been

selected, hold down Shift and then select the two that you want to remove. Then, press Enter or the Spacebar, or right click to end the selection process.

### Move and Copy

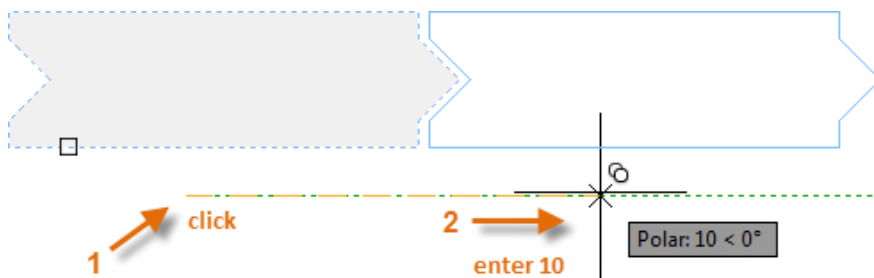


Here's how you would use the **COPY** command to lay out a row of decorative tiles. Starting with a polyline that represents its shape, you need to make copies that are  $\frac{1}{8}$ " apart.

Click the Copy tool or enter **CP** in the Command window to start the command. From here, you can choose between two methods, depending on which is more convenient. You will use these two methods frequently.

### The Distance Method

The second tile needs to be a total of  $9\text{-}7/8'' + 1/8'' = 10''$  to the right of the original tile. Start by selecting the tile, pressing Enter or the Spacebar to end your selection, and clicking anywhere in the drawing area (1). This point does not have to be located on the tile.

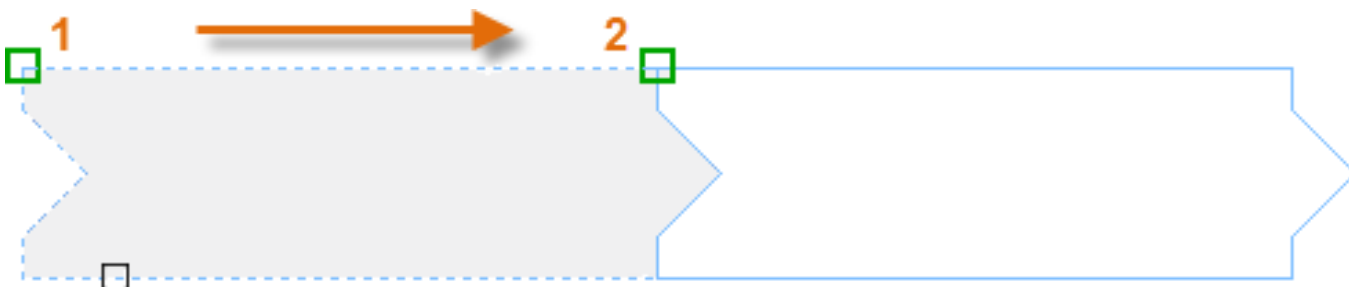


Next, move your cursor to the right, relying on the polar tracking angle to keep the direction horizontal, and then enter 10 for the distance. Press Enter or the Spacebar a second time to end the command.

### Move and Copy (continued)

### The Two Points Method

Another method, one that you will often use when you don't want to add numbers together, requires two steps. Enter the **COPY** command and select the tile as before, but this time click the two endpoints as shown. These two points also define a distance and direction.



Next, to add the 1/8" space between the tiles, click the Move tool or enter **M** in the Command window. The **MOVE** command is similar to the **COPY** command. Select the newly copied tile, and press Enter or the Spacebar. As before, click anywhere in the drawing area and move your cursor to the right. Enter 1/8 or .125 for the distance.

Here's a Tip:

The two points that define the distance and direction don't need to be located on the object that you want to copy. You can use two points specified anywhere in your

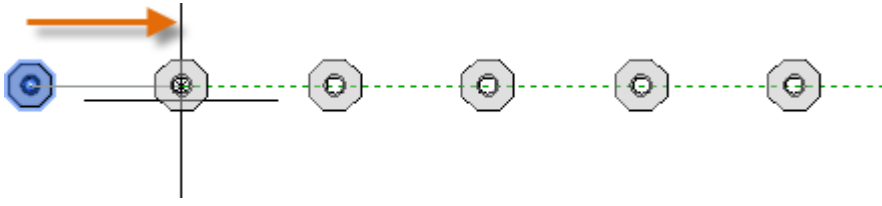
Create Multiple Copies

You can use the two-point method as a repeating sequence. Let's say that you want to make more copies of the circle at the same horizontal distance. Enter the **COPY** command and select the circle as shown.

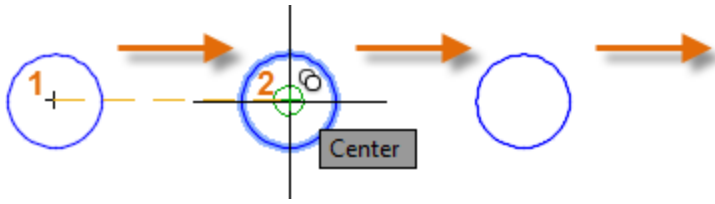


Then, using the Center object snap, click the center of circle 1, followed by the center of circle 2, and so on.

For larger numbers of copies, try experimenting with the Array option of the **COPY** command. For example, here's a linear arrangement of deep foundation piles. From a base point, you specify number of copies and the center-to-center distance.

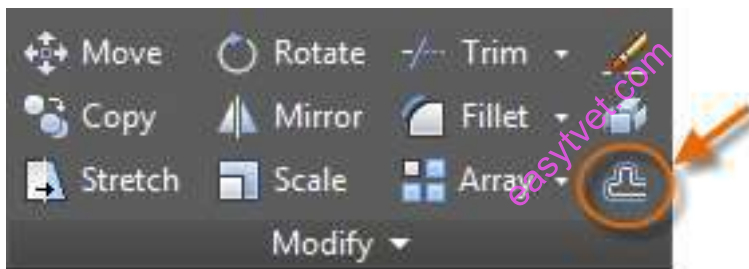


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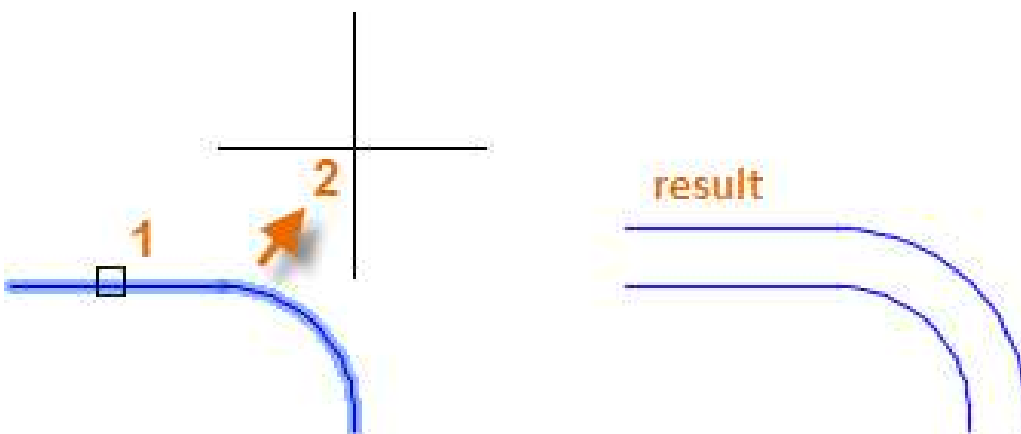


## Offset

Most models include a lot of parallel lines and curves. Creating them is easy and efficient with the **OFFSET** command. Click the **OFFSET** tool or enter **O** in the Command window



Select the object (1), specify the offset distance, and click to indicate on which side of the original that you want the result (2). Here is an example of offsetting a polyline.



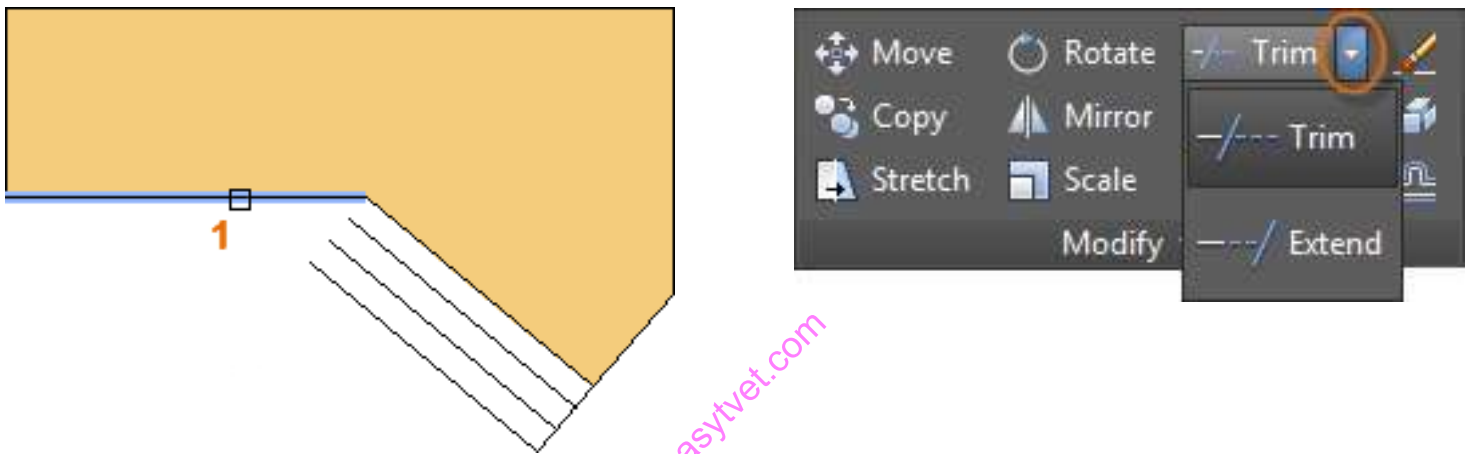
[easytvvet.com](http://easytvvet.com)



## Trim and Extend

A popular technique is to use the **OFFSET** command in combination with the **TRIM** and **EXTEND** commands. In the Command window, you can enter **TR** for **TRIM** or **EX** for **EXTEND**. Trimming and extending are some of the most commonly used operations.

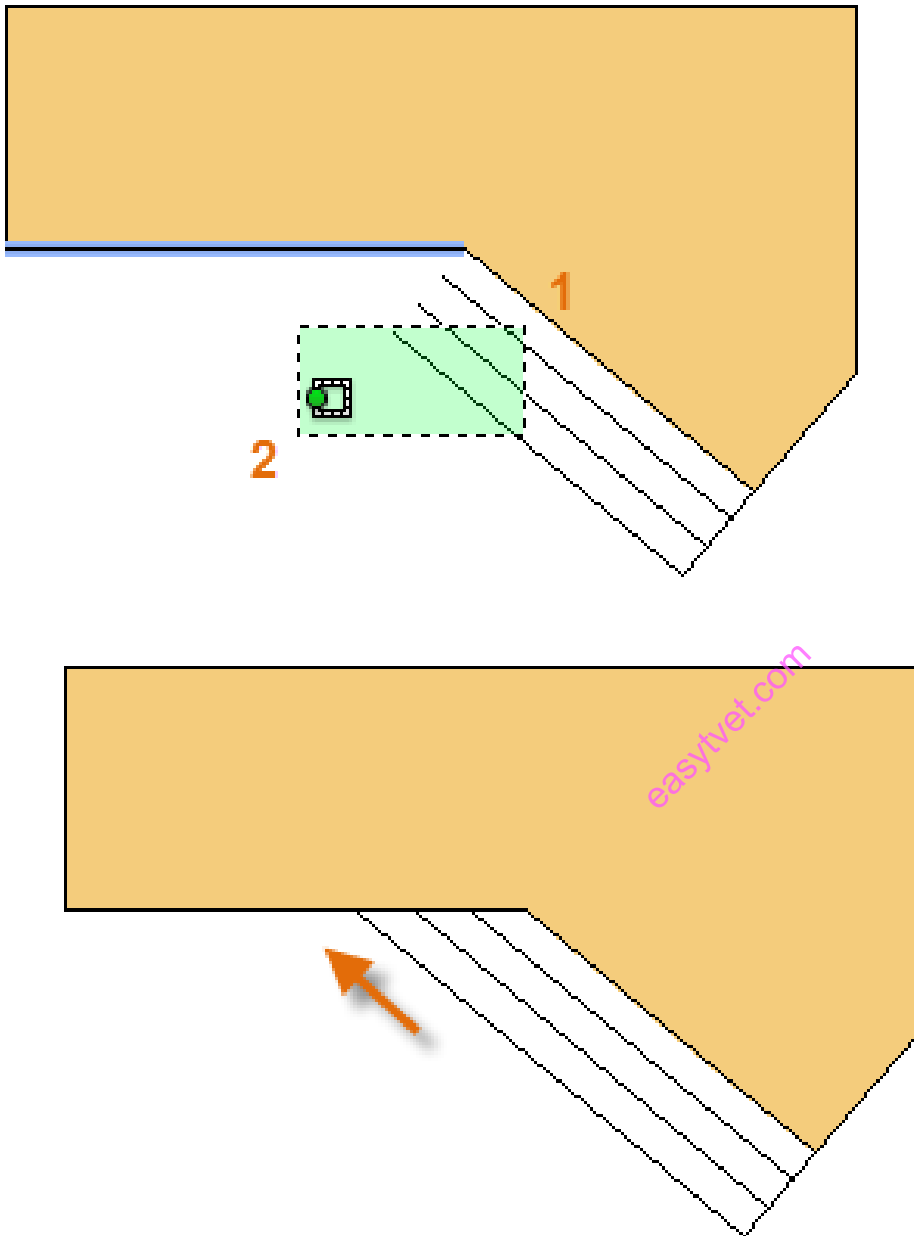
In the following illustration, you want to extend the lines that represent the steps for this deck. Enter the **EXTEND** command, select the boundary, and then press Enter or the Spacebar.



Pressing Enter or the Spacebar indicates that you've finished selecting the boundaries, and that you're now ready to select the objects to be extended. Here's a Tip:

A faster method is to press Enter or the Spacebar right away instead of selecting any boundary objects. The result is that all objects are available as possible boundaries

Next, select the objects to be extended (near the ends to be extended), and then press Enter or the Spacebar to end the command.

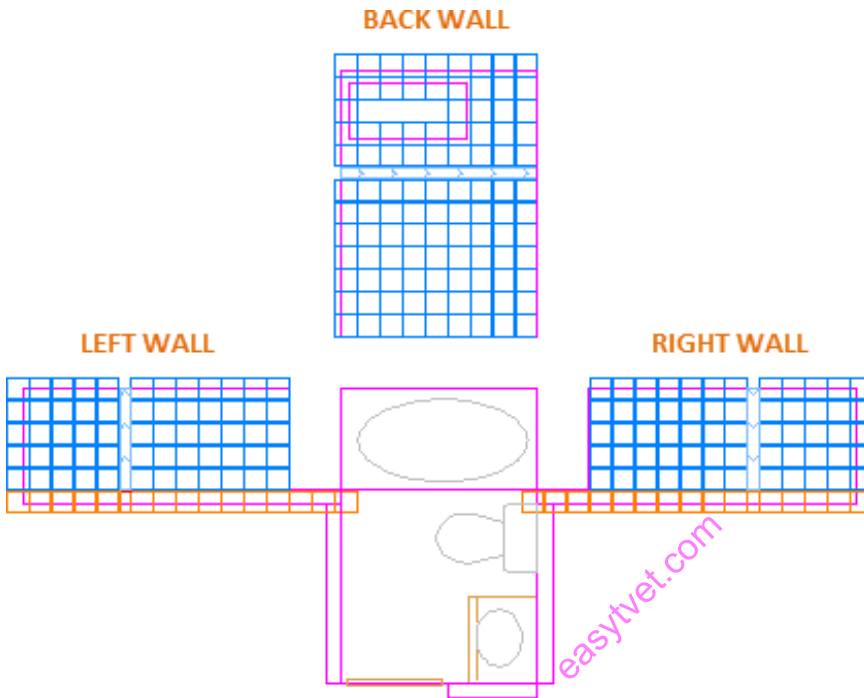


As you can see, the selected lines are extended to the boundary.

The **TRIM** command follows the same steps, except that when you select the objects to trim, you select the portions to trim away.

## Mirror

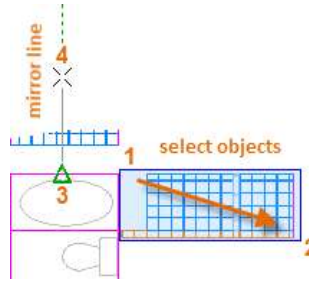
The following illustration comes from a tile project. The walls in this residential bathroom are flattened out to be able to lay out the tile pattern and estimate the number of tiles needed.



You can save a lot of work by taking advantage of the symmetry between the left and right walls. All you need to do is create the tiles on one wall and then mirror the wall across the center of the room. In the example below, begin the **MIRROR** command (or enter

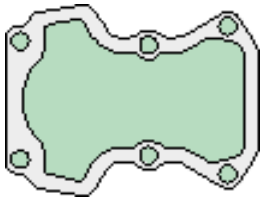
**MI** in the Command window), use window selection (1 and

2) to select the geometry on the right wall, press Enter or the Spacebar, and then specify a mirror line (3 and 4) corresponding to the centerline of the bathroom.

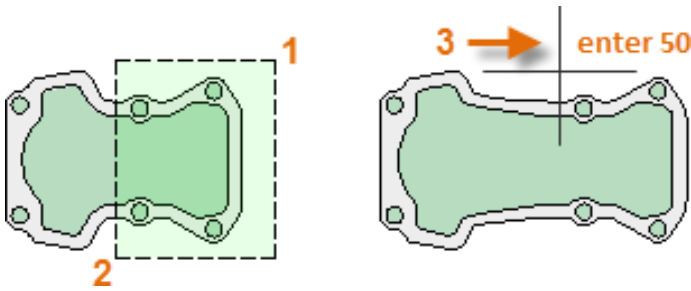


## Finally, Stretch

You can stretch most geometric objects. This lets you lengthen and shorten parts of your model. For example, this model might be a gasket or the design for a public park.



Use the **STRETCH** command (or enter **S** in the Command window) and select the objects with a crossing selection as shown below (1 and 2). The crossing selection is mandatory— only the geometry that is crossed by the crossing selection is stretched. Then click anywhere in the drawing area (3), move the cursor to the right, and enter 50 as the distance. This distance might represent millimeters or feet.

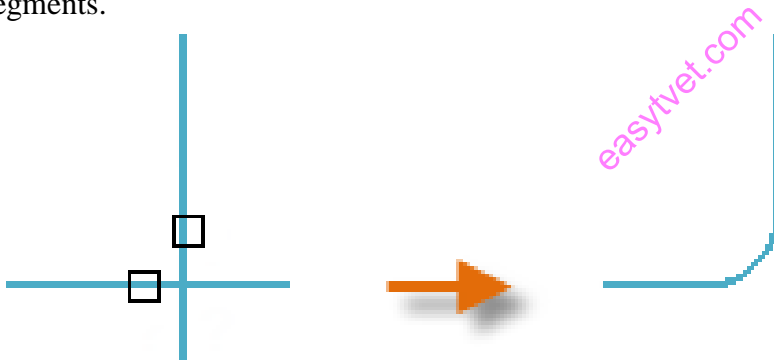


To shorten the model by a specified amount, you'd move your cursor to the left instead.

### Fillet

The **FILLET** command (enter **F** in the Command window) creates a rounded corner by creating an arc that is tangent to two selected objects. Notice that the fillet is created relative to where you select the objects.

You can create a fillet between most types of geometric objects, including lines, arcs, and polyline segments.



### Here's a Tip:

If you specify 0 (zero) as the radius of the fillet (imagine a circle shrinking to a radius of 0), the result trims or extends the selected objects to a sharp corner.

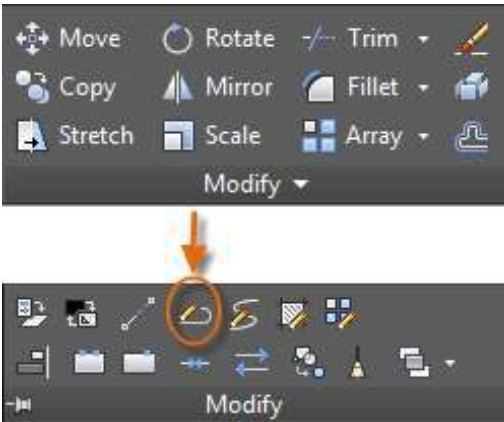
### Explode

The **EXPLODE** command (enter **X** in the Command window) disassociates a compound object into its component parts. You can explode objects such as polylines, hatches, and blocks (symbols).

After you explode a compound object, you can modify each resulting individual object.

## Edit Polylines

You can choose from several useful options when you want to modify a polyline. The **PEDIT** command (enter **PE** in the Command window) is located on the drop-down list of the Modify panel.



With this command, you can:

Join two polylines into a single polyline if they share a common endpoint

Convert lines and arcs into a polyline—simply enter **PEDIT** and select the line or arc

Change the width of a polyline

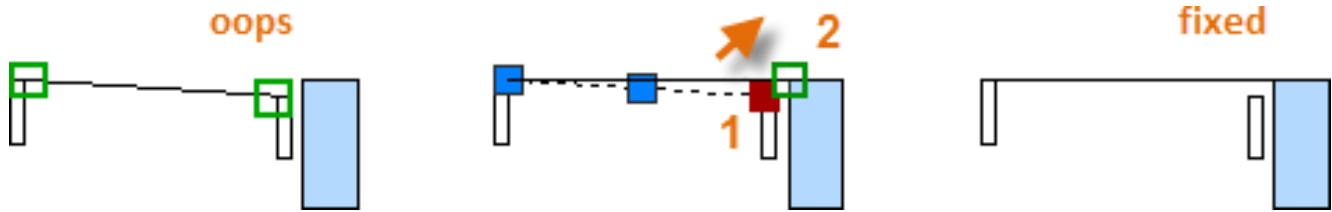
Here's a Tip:

In some cases, the easiest method to modify a polyline is to explode it, make the modifications, and then turn the objects back into a polyline using the Join option of the **PEDIT** command.

## Grips

Grips are displayed when you select an object without starting a command. Grips are often handy for light editing. For example, the line below accidentally snapped to the wrong endpoint. You can

\_\_\_\_\_ select the misaligned line, click on a grip and then click to specify the correct location.

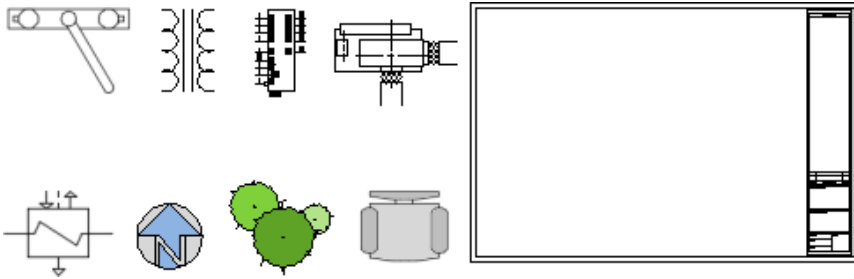


By default, when you click a grip, you automatically start in **\*\*STRETCH\*\*** mode as indicated in the Command window. If you want to explore other ways of editing

## Blocks

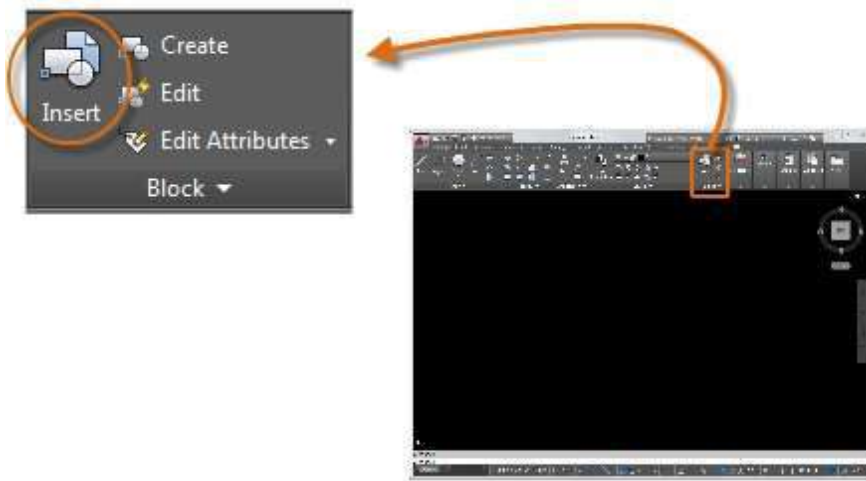
Insert symbols and details into your drawings from commercial online sources or from your own designs.

In AutoCAD, a *block* is a collection of objects that are combined into a single named object. The following are some sample blocks at various scales.



Some of these blocks are realistic representations of objects, some are symbols, and one of them is an architectural title block for a D-size drawing.

## Insert a Block

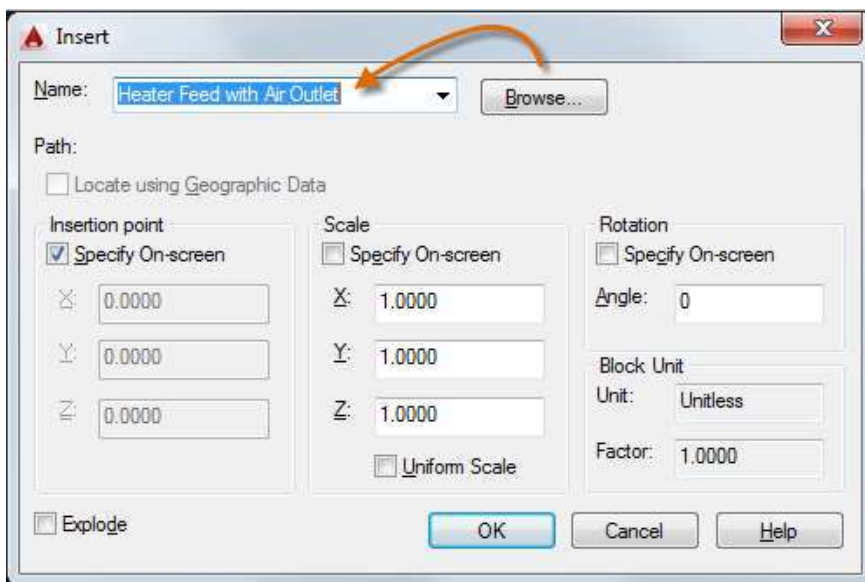




Typically, each of these blocks is an individual drawing file, perhaps saved in a folder with similar drawing files. When you need to insert one into your current drawing file, use the **INSERT** command (or enter **I** in the Command window).

### Insert a Block

The first time you insert the drawing as a block, you must click Browse to locate the drawing file. Make sure you organize your blocks into easy-to-find folders.

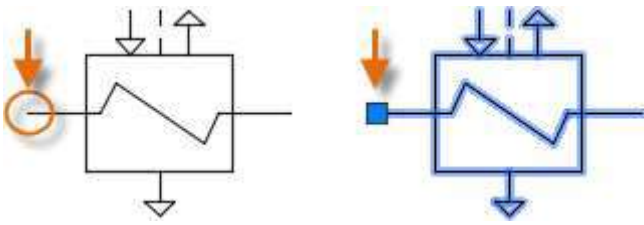


Once inserted, the *block definition* is stored in your current drawing. From then on, you can choose it from the Name drop-down list without needing to click the Browse button.

Here's a Tip:

The default settings in the Insert dialog box are usually acceptable. After you choose the block name, click OK, and then specify its location in your drawing. You can rotate it later, if necessary.

Notice that when you insert a block, it is attached to your cursor at the point indicated. This location is called the insertion point. By default, the insertion point is the origin point (0,0) of the original drawing.



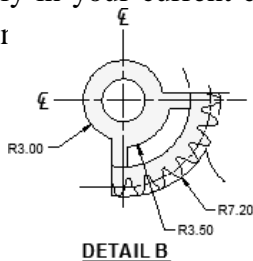
After inserting the block, you can select it and a grip appears. You can easily move and rotate this block using this grip.

In the following example, a drawing file is inserted into the current drawing to provide a standard detail view.

***NOTE:** Inserting a drawing file as a block provides a static reference to the specified drawing. For a reference that automatically updates, you can attach the drawing with the External References palette (**XREF** command) instead.*

### Create a Block Definition

Instead of creating a drawing file to be inserted as a block, you might want to create a block definition directly in your current drawing. Use this method if you do not plan to insert the block into any other drawing the **BLOCK** command to create the block definition.





For example, this is how you could create a module for a cubicle design.

Create the objects for the block.

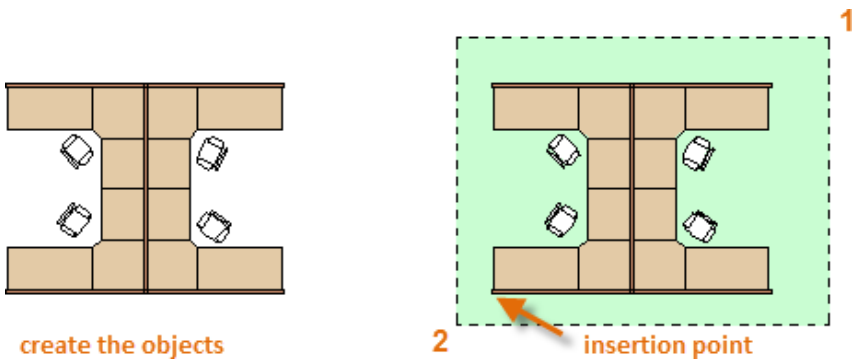
Start the **BLOCK** command.

Enter a name for the block, in this case Quad-Cube.

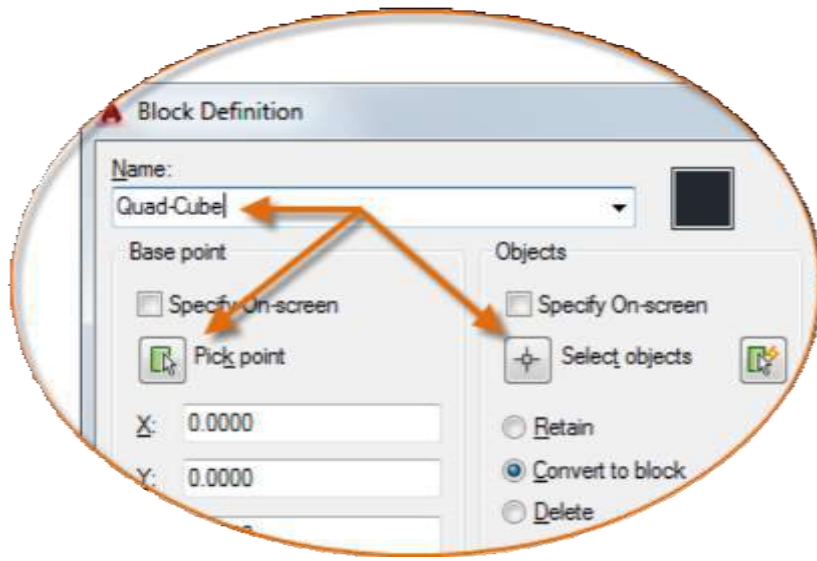
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Select the objects that you created for the block (click 1 and 2).

Specify the block insertion point.

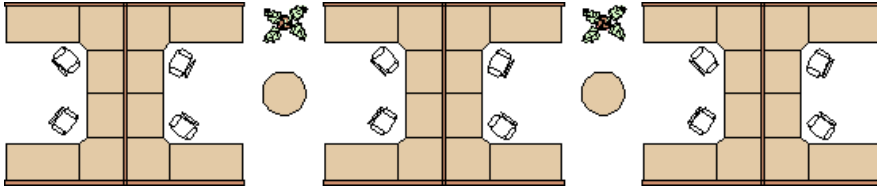


You can enter the information for steps 3, 4, and 5 into the Block Definition dialog box in any order.

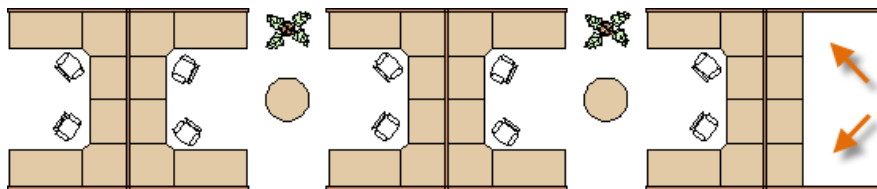


### Create a Block Definition (continued)

After creating the block definition, you can insert, copy, and rotate the block as needed.



Using the **EXPLODE** command, you can explode a block into its component objects if you need to make changes. In the illustration below, the cubicle on the right was exploded and modified.



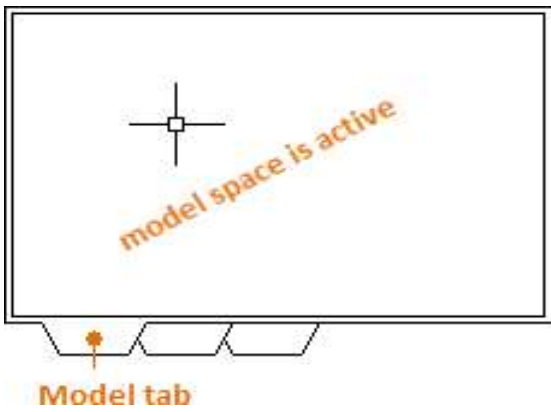
In this example, you would probably create a new block definition from the objects in the exploded block.

### Layouts

Display one or more scaled views of your design on a standard- size drawing sheet called a layout.

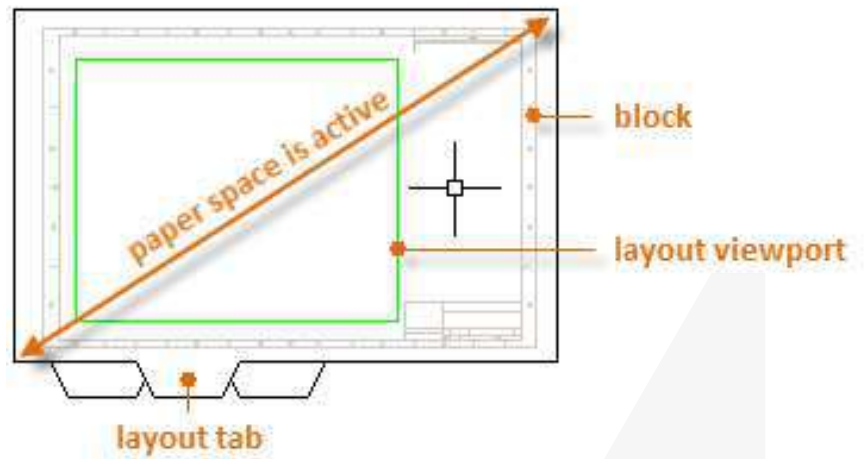
After you finish creating a model at full size, you can switch to a *paper space layout* to create scaled views of the model, and to add notes, labels, and dimensions. You can also specify different linetypes and line widths for display in paper space.

### Model Space and Paper Space



Originally, this was the only space available in AutoCAD. All notes, labels, dimensions, and the drawing border and title block were also created and scaled in the model space.

After *paper space* was introduced, you could click a layout tab to access a space designed specifically for layouts and scaling. In the following illustration, paper space is active. There are currently only two objects in paper space: a drawing border block, and a single *layout viewport*, which displays a view of model space.



## Four Methods for Scaling

There are four different methods in AutoCAD that are used to scale views, notes, labels, and dimensions. Each method has its advantages depending on how the drawing will be used.

Here's a brief summary of each of the methods:

**The Original Method:** You create geometry, annotate, and print from model space.

Dimensions, notes, and labels must all be scaled in reverse. You set the dimension scale to the inverse of the plot scale. With this method, scaling requires a little math. For example, a common scale used in architecture is  $1/4'' = 1'-0''$  which is 1:48 scale. If a note is to be printed  $1/4''$  high, then it must be created 48 times as large, or  $12''$  high in model space. The same scale factor also applies to dimensions, and an ARCH D drawing border at that scale is 144 feet long. When the drawing is printed as a D-size sheet, everything scales down to the correct size.

**The Layout Method:** You create geometry and annotate in model space, and print from the layout. Set the dimension scale to 0 and the dimensions will scale automatically.

**The Annotative Method:** You create geometry in model space, create *annotative* dimensions, notes, and labels (using a special annotative style) in model space from the layout, and you print from the layout. Annotative objects display only in layout viewports that share

***NOTE:** Many AutoCAD drawings were created with this method, and many companies still use it. Once everything is set up, the method works well for 2D drawings with single views and inserted details.*

the same scale. The dimension scale is automatically set to 0 and all annotative objects scale automatically.

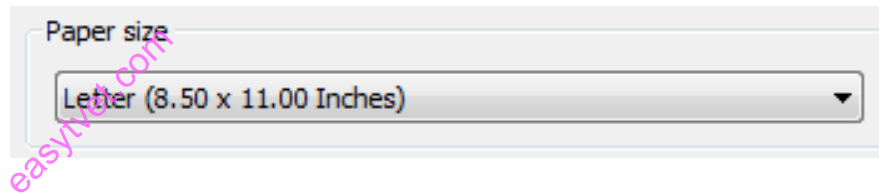
**The Trans-Spatial Method:** You create geometry in model space, create annotations in paper space on a layout with dimension scale set to 1, and you print from the layout. This is arguably the easiest, most direct method, and it is the method of choice for this guide.

Talk to other AutoCAD users in your discipline about these four methods and why they chose the method that they use.

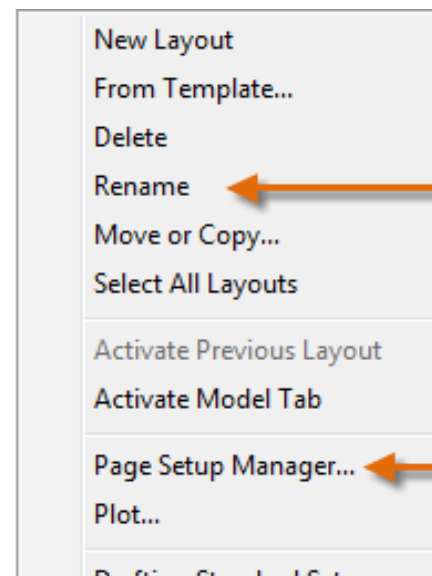
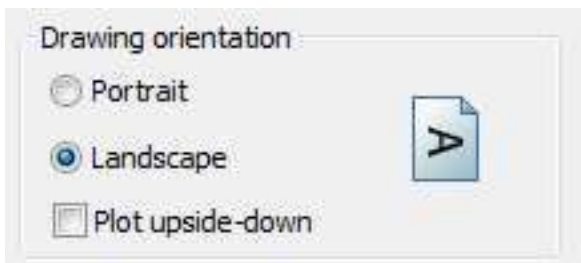
### Specifying the Paper Size of a Layout

The first thing you should do when you access a layout tab (1) is right-click the tab (2) and rename it (3) to something more specific than Layout 1. For a D-size layout, ARCH D or ANSI D might be good choices.

Next, open the Page Setup Manager (4) to change the paper size displayed in the layout tab.



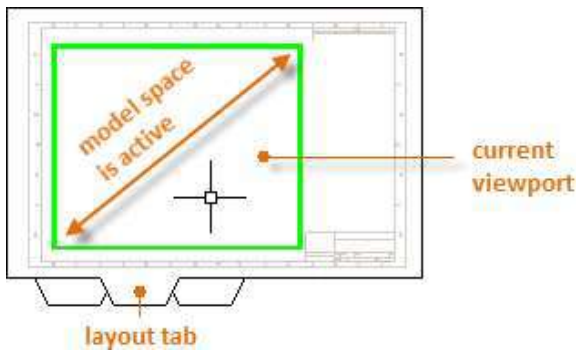
***NOTE:** You might be wondering why there are two entries in the list for every sheet size. This is because some printers and plotters do not recognize the drawing orientation setting.*



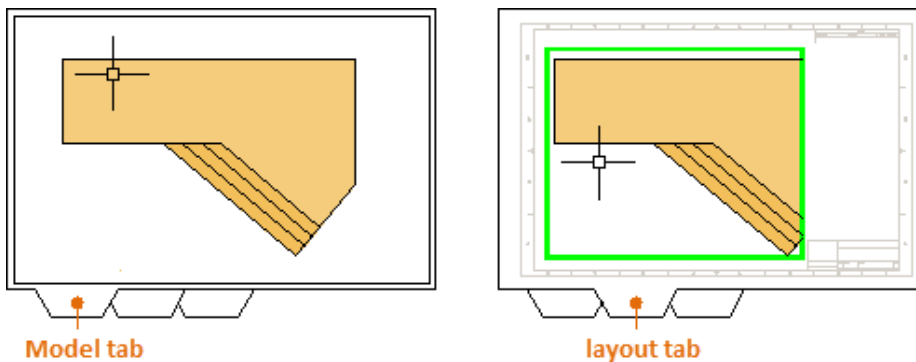


## Layout Viewports

A layout viewport is an object that is created in paper space to display a scaled view of model space. You can think of it as a closed-circuit TV monitor that displays part of model space. In the illustration, model space is active and accessible from within the current layout viewport



In a layout, when model space is active, you can pan and zoom, and anything else that you could do on the Model tab. For example, let's say that you created a backyard deck design in model space, and now you want to lay out and print your design from a layout tab.



The view in the layout viewport is not yet set to the correct scale.

Important:

You can switch between paper space and model space by double-clicking inside or outside the layout viewport.

**NOTE:** You can use the **MVIEW** (make view) command to create additional layout viewports in paper space. With several layout viewports, you can display several views of model space at the same or at different scales.

Here are the steps to follow if you use the trans-spatial method of annotating your drawing:

Click the layout tab. If you started the drawing with your own custom drawing template file, several tasks might already have been completed: the layout might already be set to

D-size, and the title block might already have been inserted in the layout.

By default, paper space is active, so double-click within the layout viewport to make the model space active. Notice that the edge of the layout viewport becomes thicker as a result of switching to model space.

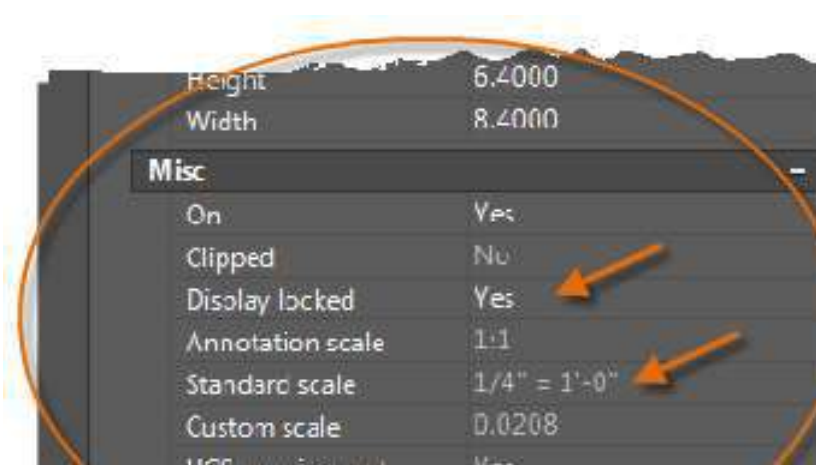
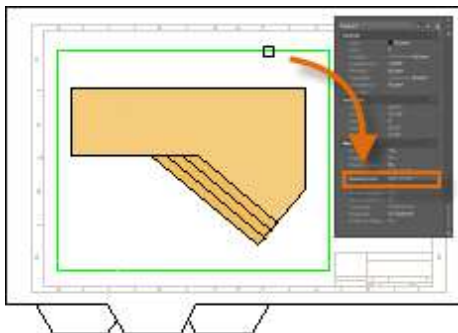
Zoom out and center the model space view by panning. Note that the displayed view will not yet be set to the correct scale.

Double-click outside the layout viewport to make paper space active again.

Open the Properties palette and then click to select the edge of the layout viewport.

In the Properties palette, specify a standard scale of 1/4" =

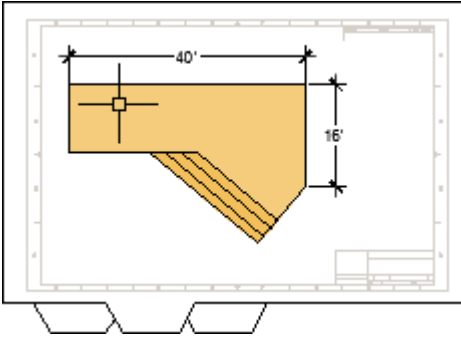
1'-0" from the drop-down list. This action scales your view of model space precisely to the D-size drawing. You should also set the Display Locked property from No to Yes, which will prevent any unintentional display changes to the view.



(continued)

Move the layout viewport as needed, and adjust its edges using grips.

Create notes, labels, and dimensions directly in paper space. They will automatically appear at the correct size.



Turn off the layer on which you created the layout viewport object. This hides the edges of the layout viewport as shown below.

Print the drawing to paper or as a DWF or PDF file.

**NOTE:** After you have finished dimensioning, you can use the *EXPORTLAYOUT* command to merge everything in model and paper space into the model space of a separate drawing file. This operation creates a drawing file that conforms to the original method of creating the model and all annotations in model space.

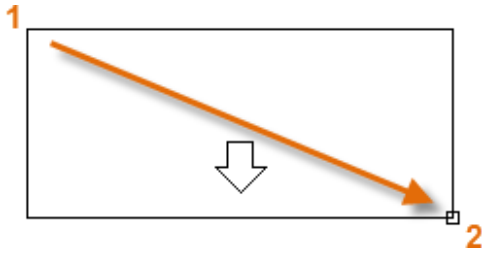
## Notes and Labels

Create notes, labels, bubbles, and callouts. Save and restore style settings by name.

You can create general notes using the **MTEXT** command (or enter **MT** in the Command window), which stands for *multiline text*. The multiline text tool is available on the Annotation panel.



After you start the **MTEXT** command, you are prompted to create a “text box” with two diagonal clicks.



### Create a Text Style

As with several other annotation features, multiline text provides a lot of settings. You can save these settings as a *text style*

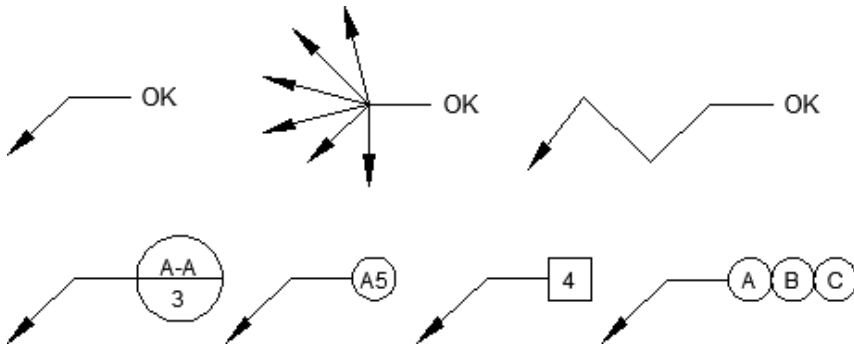
using the **STYLE** command, and then you can access the text styles you’ve saved by clicking the drop-down arrow on the Annotation panel. The current text style is displayed at the top of the drop-down list.

To create a new text style, click the Text Style control as shown.

### Multileaders

*Multileader* objects are used to create text with leader lines such as general labels, reference labels, bubbles, and callouts.

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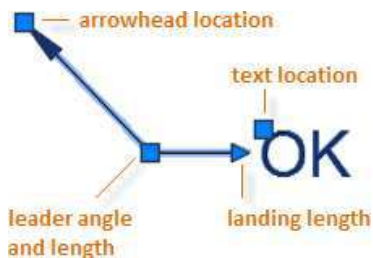
### Create a Multilayer

To create a multilayer, use the **MLEADER** command. Click the Multilayer tool in the Annotation panel or enter **MLD** in the Command window. Follow the prompts and options in the Command window. Feel free to experiment.

After you create a multilayer, select it and then modify it by clicking and moving its grips.

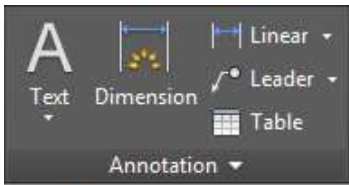
Grip menus appear when you hover over arrowhead and leader grips. From these menus, you can add leader segments or additional leaders.

You can edit the text in a multilayer by double-clicking it.



## Create a Multileader Style

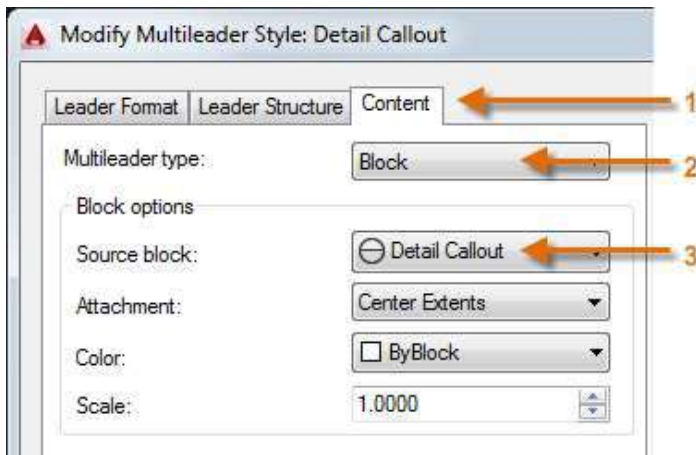
You can create your own multileader styles from the drop-down list in the expanded Annotation panel, or by entering **MLEADERSTYLE** in the Command window.



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For example, to create a “detail callout” style, start the **MLEADERSTYLE** command. In the Multileader Styles Manager, click New and choose a descriptive name for the new multileader style. Click the Content

tab, choose Block, and then Detail Callout as shown.

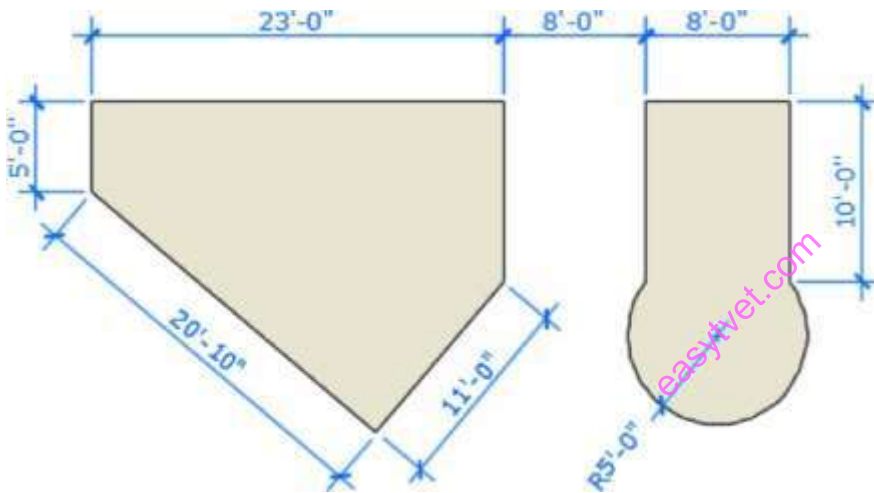


**NOTE:** As with text styles, once you create one or more multileader styles, save them in your drawing template files.

## Dimensions

Create several types of dimensions and save dimension settings by name.

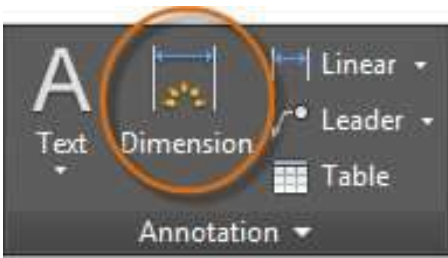
Here is an example of several types of dimensions using an architectural dimension style with imperial units.



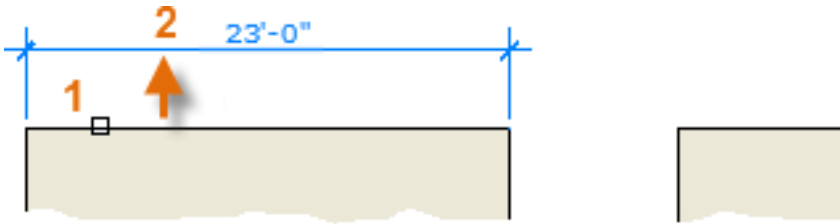
## Linear Dimensions

You can create horizontal, vertical, aligned, and radial dimensions with the **DIM** command. The type of dimension depends on the object that you select and the direction that you drag the dimension line.



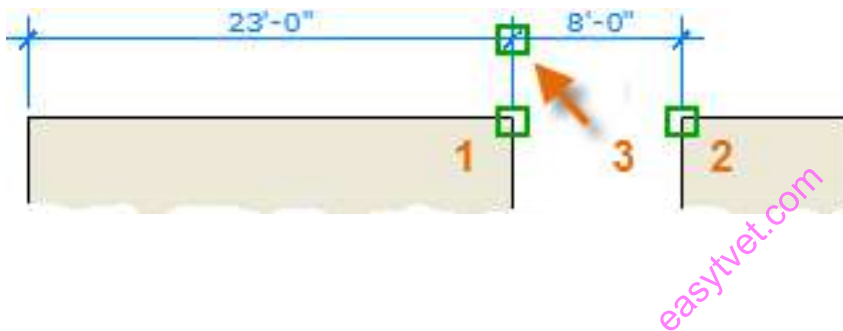


The following illustration demonstrates one method for using the **DIM** command. Once you start the command, press Enter or the Spacebar, select the line (1), and then click the location of the dimension line (2).



Linear Dimensions (continued)

For the 8'-0" dimension below, you use another method. You start the DIM command, click two endpoints (1 and 2) and then the location of the dimension line (3). To line up the dimension lines point 3 was snapped to the endpoint of the previously created dimension line.



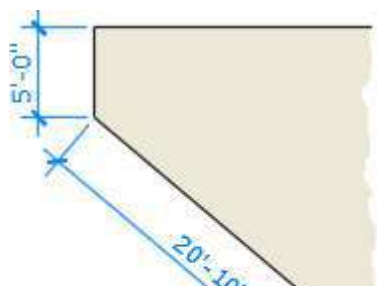
Use the **DIM** command to create dimensions that are parallel to an object by dragging the dimension line at an angle rather than horizontally or vertically.

Here's a Tip:

If points 1 and 2 are not on the same horizontal line, press Shift to force the dimension line to be horizontal. In addition, if the building or part being dimensioned is at an angle, enter **DIMROTATED** for that case.

Another Tip:

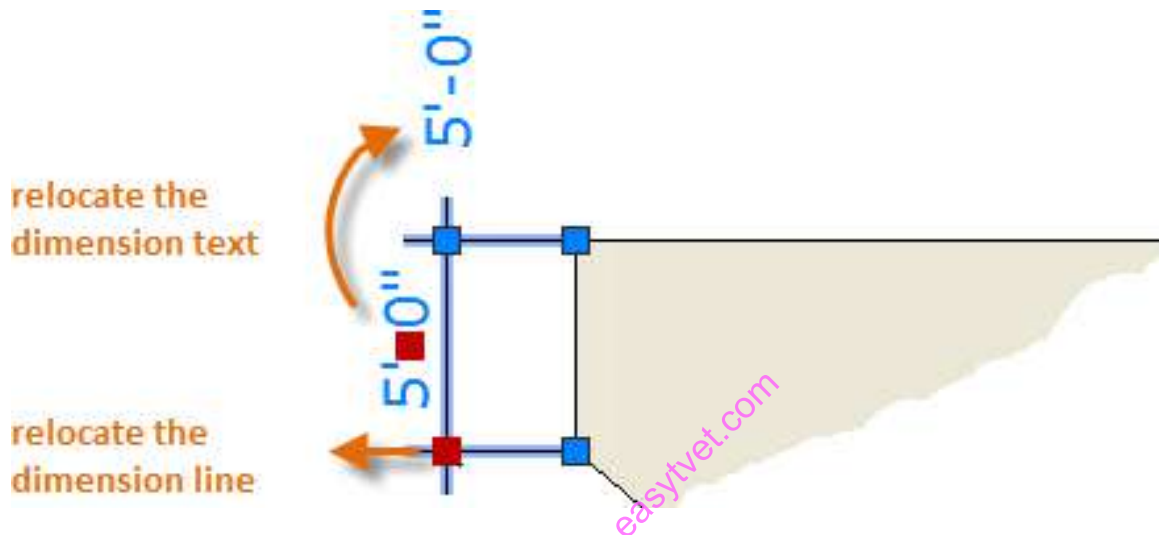
Because it is easy to accidentally snap to the wrong feature or part of a dimension object, be sure to zoom in closely enough to avoid mistakes.



## Modify Dimensions

For simple adjustments to dimensions, nothing is faster than using grips.

In this example, you select the dimension to display its grips. Next, click the grip on the dimension text and drag it to a new location, or click one of the grips at the end of the dimension line and drag the dimension line.



Here's a Tip:

If the changes are more complicated than this, it might be faster simply to delete and then recreate the dimension.

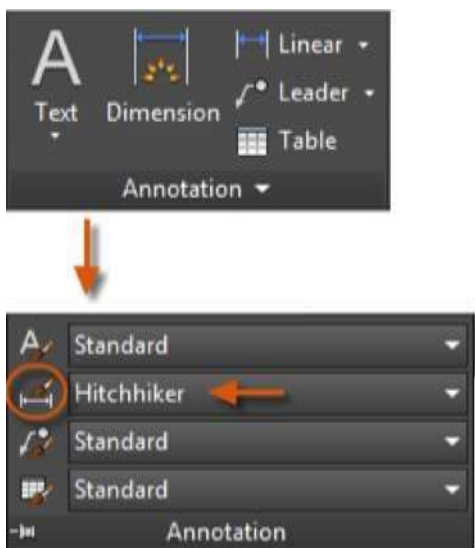
## Dimension Styles

Dimension styles help establish and enforce drafting standards. There are many dimension variables that can be set with the **DIMSTYLE** command to control virtually every nuance of the appearance and behavior of dimensions. All these settings are stored in each dimension style.

The default dimension style is named either Standard (imperial) or ISO-25 (metric). It is assigned to all dimensions until another style is set as the current dimension style.

The current dimension style name, Hitchhiker in this case, is displayed in the drop-down list of the Annotation panel.

To open the Dimension Style Manager, click the indicated button. You can create dimension styles that match nearly any standard, but you will need to invest time into specifying them completely. For this reason, you should save any dimension styles that you create in one or more drawing template files.



## Printing

Output a drawing layout to a printer, a plotter, or a file. Save and restore the printer settings for each layout.

Originally, people *printed* text from printers and *plotted* drawings from plotters. Now, you can perform both with either device, so this guide will use the terms 'print' and 'plot' interchangeably.

The command to output a drawing is **PLOT** and you can access it from the Quick Access toolbar.



To display all of the options in the Plot dialog box, click the More Options button.



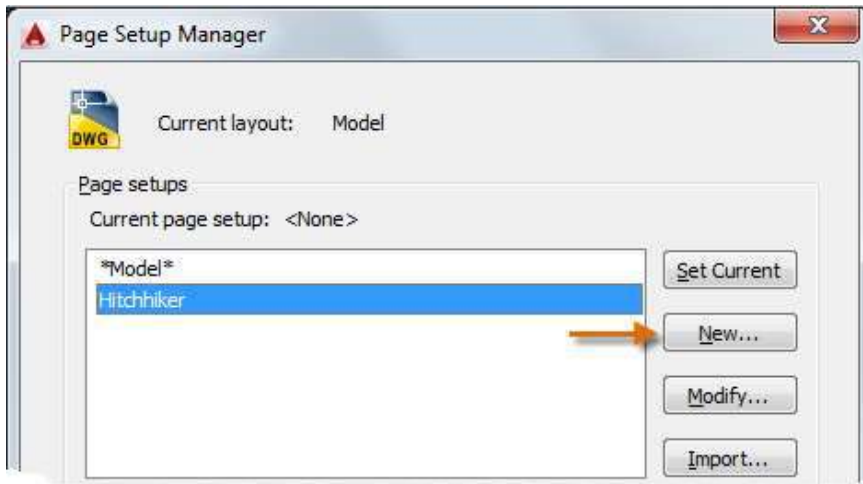
As you can see, there are many settings and options available.

For the sake of convenience, you can save and restore collections of these settings by name. These are called *page setups*. With page setups you can store the

### Create a Page Setup

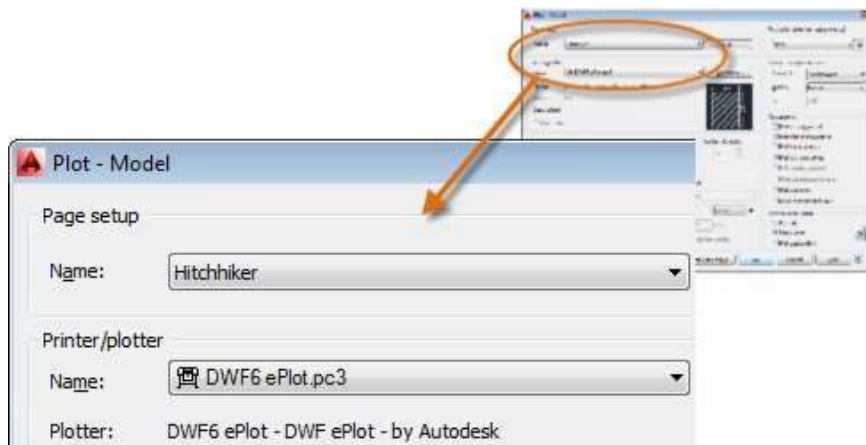
To open the Page Setup Manager, right-click on the Model tab or a layout tab and choose Page Setup Manager. The command is **PAGESETUP**.

Each layout tab in your drawing can have an associated page setup. This is convenient when you use more than one output device or format, or if you have several layouts with different sheet sizes in the same drawing.



To create a new page setup, click New and enter the name of the new page setup. The Page Setup dialog box that displays next looks like the Plot dialog box. Choose all the options and settings that you wish to save.

When you are ready to plot, simply specify the name of the page setup in the Plot dialog box, and all your plot settings will be restored. In the following illustration, the Plot dialog box is set to use the Hitchhiker page setup, which will output a DWF (Design Web Format) file rather than print to a plotter.



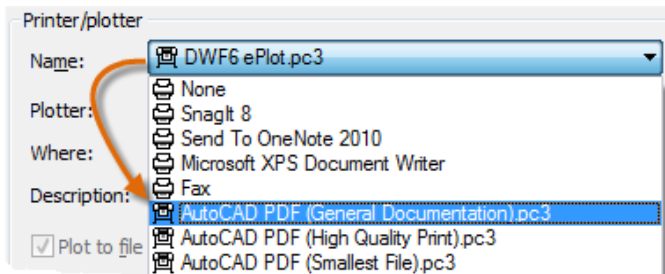
Here's a Tip:

You can

### Output to a PDF File

The following example shows you how to create a page setup for creating PDF files.

From the Printer/plotter drop-down list, choose *AutoCAD PDF (General Documentation).pc3*:



Next, choose the size and scale options that you want to use:

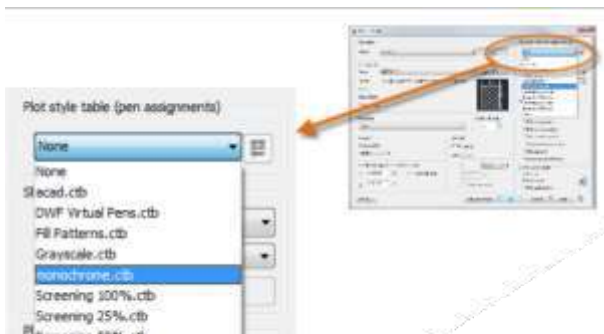
**Paper Size:** The orientation (portrait or landscape) is built into the choices in the drop-down list.

**Plot Area:** You can clip the area to be plotted with these options, but typically everything will be plotted.

**Plot Offset:** This setting changes based on your printer, plotter, or other output. Try centering the plot or adjusting the origin, but remember that printers and plotters have a built-in margin around the edges.

**Plot Scale:** Choose your plot scale from the drop-down list. A scale such as 1/4" = 1'-0" is meant for printing to scale from the Model tab. On a layout tab, you normally print at a 1:1 scale.

The plot style table provides information about processing colors. Colors that look good on your monitor might not be suitable for a PDF file or for printing. For example, you might want to create a drawing in color, but create monochrome output. Here is how you specify monochrome output:



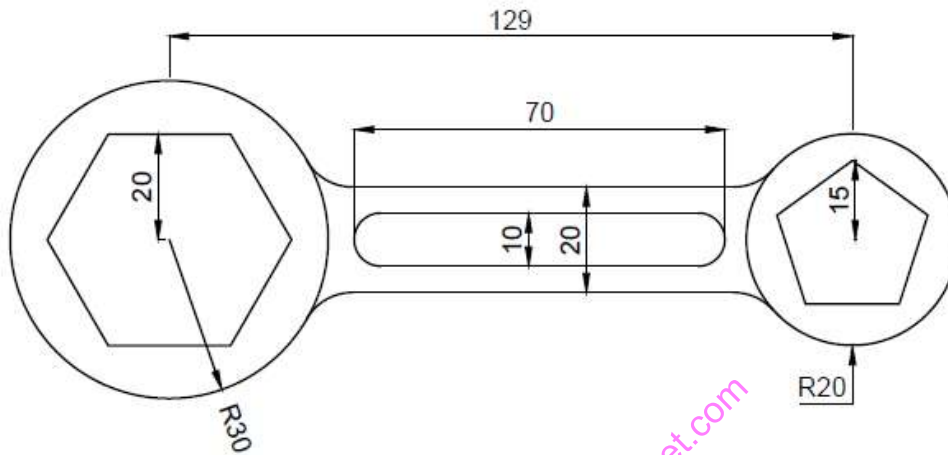
## Learning activities

### Learning activity 1: Apply CAD packages

The following figure is an orthographic view of a lever crank. Redraw the view using AutoCAD.

SET-UP INSTRUCTIONS: Using the UNITS command:

- i. Set UNITS to Decimal.
- ii. Set the accuracy to 2 decimal places.
- iii. Accept the defaults for the remaining prompts.



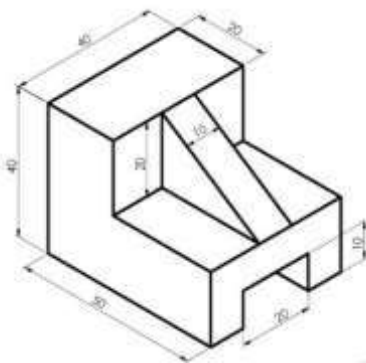
### Learning activity 2: Apply cad packages

The following figure is an ISOMETRIC view. Redraw the view using AutoCAD.

SET-UP INSTRUCTIONS:

Using the UNITS command:

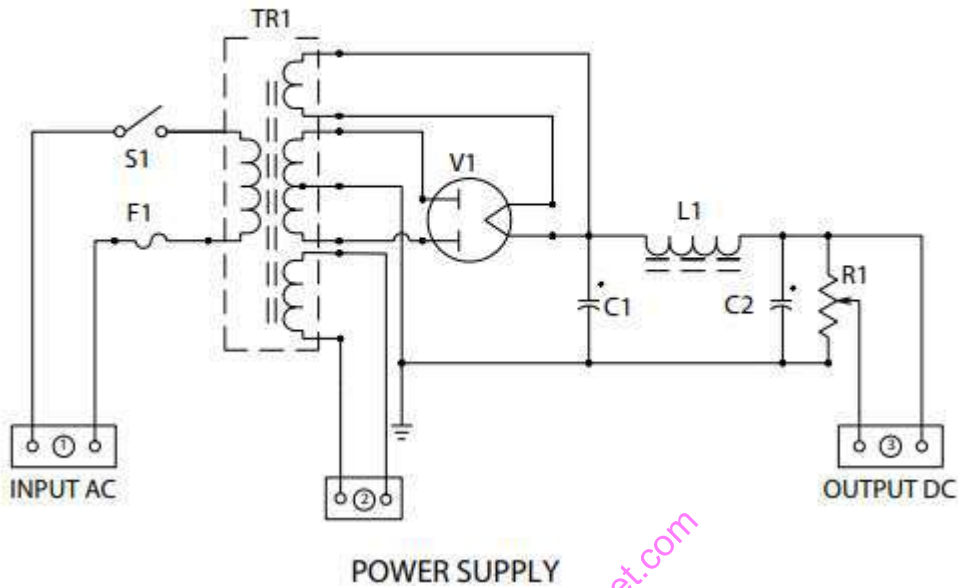
- i. Set UNITS to Decimal.
- ii. Set the accuracy to 2 decimal places.
- iii. Accept the defaults for the remaining prompts.





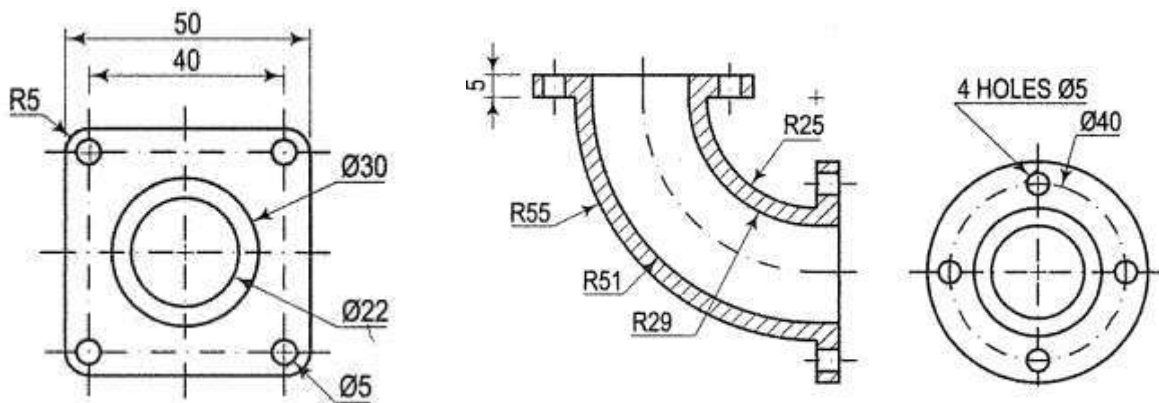
### Learning activity 3: Apply cad packages

Draw this circuit, using the techniques you have learned using AutoCAD.



### Learning activity 4: Apply cad packages

Draw the figure below using line, circle, rectangle, fillet, rectangular array, polar array, dimension, hatch, layer, hidden line, and center line etc., commands.



## Self-assessment

1. When creating your own blocks, it is important to avoid drawing any portion of the block in the \_\_\_\_\_ layer.
  - A. 0
  - B. center line
  - C. hatch
  - D. hidden line
2. An AutoCAD term that refers to a pre-drawn object which is stored in a drawing file and can be inserted into any other drawing file as needed is a \_\_\_\_\_.
  - A. Block
  - B. Brick
  - C. Balloon
  - D. none of the above
3. Before starting an isometric drawing in AutoCAD the drafter needs to \_\_\_\_\_.
  - A. set the grid to isometric
  - B. set the current layer to Defpoints
  - C. turn Object Snap off
  - D. turn Ortho off
4. When lettering a CAD drawing, for clarity you should limit the number of fonts to:
  - A. One
  - B. Two
  - C. Three
  - D. Any number
5. The same general concepts and drafting standards apply to CAD as to drawings created by hand.
  - A. True
  - B. False
6. The main difference between a CAD drawing and a freehand sketch is in the appearance of lines.
  - A. True
  - B. False
7. In a CAD system, you can draw an ellipse by specifying these:
  - A. The bounding lines
  - B. The midpoint and end points
  - C. The center and major and minor axes
  - D. The center and radius

8. When creating an isometric drawing in AutoCAD the drafter can utilize the Dynamic Input and Polar Coordinate system to place both vertical and horizontal lines. A line created from one point 3 inches at 180 degrees would be a \_\_\_\_\_ line.
- A. horizontal
  - B. vertical
  - C. inclined
  - D. none of the above
9. AutoCAD refers to isometric ellipses as \_\_\_\_\_.
- A. Ellipses
  - B. Isoellipses
  - C. Isocircles
  - D. circles
10. Drafters should use a \_\_\_\_\_ in a section view of a mechanical part that includes the cylindrical view of a threaded hole.
- A. Center line
  - B. Hatch line
  - C. Poly line
  - D. Dimension line
11. When filling an area with a hatch pattern in AutoCAD the drafter needs to be able to \_\_\_\_\_.
- A. See the entire bounding area to hatch
  - B. set Ortho on
  - C. turn ISO grid off
  - D. set the layer to Defpoints
12. The default position of the UCS icon is positioned at \_\_\_\_\_ on the AutoCAD grid.
- A. 0,0,0
  - B. 10,10,10
  - C. 20,20,20
  - D. None of the above
13. A cylinder can be created by drawing a rectangular shape then the \_\_\_\_\_ tool.
- A. Revolve
  - B. Sweep
  - C. Extrude
  - D. none of the above
14. The MASSPROP shortcut will provide the following information.
- A. mass
  - B. volume
  - C. bounding box

- D. all of the above
15. The 3-D commands on the Modeling toolbar include \_\_\_\_\_.
- A. box
  - B. sphere
  - C. extrude
  - D. all of the above
16. CAD programs which incorporate parametric modeling utilize a system in which the dimensions control the \_\_\_\_\_.
- A. size and shape of the model features
  - B. perspective of the model
  - C. shading used to render the model
  - D. all of the above
17. In order to create one solid model from two or more separate solid shapes the drafter will need to position them and then \_\_\_\_\_.
- A. use Union to join them
  - B. use the Join command
  - C. use the Add Parts tool
  - D. none of the above
18. The Conceptual Visual Style tool is located on the \_\_\_\_\_ toolbar.
- A. Visual Styles
  - B. Modify
  - C. 3-D Modeling
  - D. All of the above
19. Drawings created with commercial software are typically saved as:
- A. Rapid prototypes
  - B. Electronic files
  - C. Draft drawings
  - D. Change orders
20. Newer versions of AutoCAD utilize the \_\_\_\_\_ to make block library management very easy.
- A. File / find
  - B. Design Center
  - C. File / search
  - D. None of the above
21. Inserting blocks into a drawing file usually requires exacting placement. The drafter should insure that \_\_\_\_\_ is turned on.
- A. O Snaps
  - B. Ortho
  - C. Grid

- D. Dynamic Input
22. The command which identifies the points on drawing entities that are visible on screen is and this option allows the user to pick-up the points very accurately with respect to drawing displayed.
- A. OSNAP
  - B. TABSURF
  - C. SNAP
  - D. GRID
23. The commands Erase, Copy, Mirror, Trim, Extend, Break etc belongs to which tool bar?
- A. Layer tool bar
  - B. Style tool bar
  - C. Modify tool bar
  - D. Draw tool bar
24. The commands Donut, Block, Spline, Polygon, and Arc etc belong to which tool bar?
- A. Layer tool bar
  - B. Style tool bar
  - C. Modify tool bar
  - D. Draw tool bar
25. The command which works on two lines or a single poly line to create a beveled edge is
- A. Chamfer
  - B. Fillet
  - C. Stretch
  - D. Extend
26. The command which is used to create a round corner between two lines is
- A. Chamfer
  - B. Fillet
  - C. Stretch
  - D. Extend
27. The command 'Oops' is used to
- A. create one or more copies of selected objects at another location
  - B. creates mirror image of selected objects about specified line
  - C. retrieves all objects erased by the last erase
  - D. deletes the selected entities
28. The command 'pedit' is used for
- A. erases a portion of line, arc, circle or a 2D poly line between two selected points
  - B. reverses the effects of a series of previously used commands
  - C. breaking a poly line into individual segments
  - D. editing of poly line properties
29. The command 'break' is used for
- a) erases a portion of line, arc, circle or a 2D poly line between two selected points
  - b) reverses the effects of a series of previously used commands
  - c) breaking a poly line into individual segments
  - d) editing of poly line properties

30. The command 'U' is used for
- erases a portion of line, arc, circle or a 2D poly line between two selected points
  - reverses the effects of a series of previously used commands
  - breaking a poly line into individual segments
  - editing of poly line properties
31. The command 'Explode' is used for
- erases a portion of line, arc, circle or a 2D poly line between two selected points
  - reverses the effects of a series of previously used commands
  - breaking a poly line into individual segments
  - editing of poly line properties
32. The command which is used to set a new coordinate system by shifting the working XY plane to be desired location is?
- 3DFACE
  - VPOINT
  - UCS
  - ELEV
33. The command which is used for making planar unmeshed surfaces that have three or four sides is
- 3DFACE
  - VPOINT
  - UCS
  - ELEV
34. The command which is used to set the viewpoint in 3D space for viewing the 3D models is
- 3DFACE
  - VPOINT
  - UCS
  - ELEV
35. The command which is used to set elevation and thickness properties for 2D wireframe objects such as line, point, circle, polygon, arc is
- 3DFACE
  - VPOINT
  - UCS
  - ELEV

#### Tools, Equipment, Supplies and Materials

- Drawing tools
- Drawing set
- Drawing papers
- Erasers
- Series of pencils
- Drawing board

## References

1. *Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing : Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.*
2. *Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.*
3. *Narayana, K. L., Kanniah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.*
4. *Reddy, K. V. 2010. Textbook of Engineering Drawing . B.S. Publ., Hyderabad.*
5. *Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,*
6. *Learn about AutoCAD manual. An Introduction to AutoCAD for Beginners*

## 4.7 MODEL ANSWERS

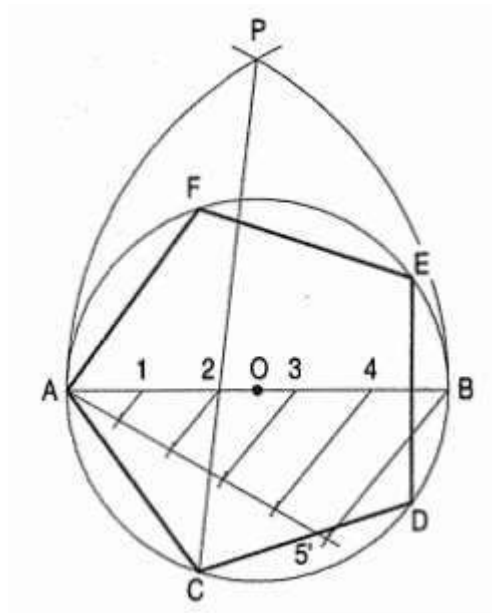
### Apply and Maintain Drawing Equipment and Materials

1. B
2. A
3. B
4. C
5. A
6. B
7. Why the drawing is called the language of Engineers?  
Engineering drawing teaches us to imagine and read the drawing, which is important in industrial or construction engineers to execute the construction with the help of a drawing and execute according to the drawing. Without drawing we can't construct in construction work
8. What is the Necessity of Dimension a Drawing?

## Learning activity 2: Produce plane geometry

### To inscribe a regular polygon of any number of sides, say 5, in a given circle

- vii. With centre  $O$ , draw the given circle.
- viii. Draw a diameter  $AB$  and divide it into five equal parts (same number of parts as the number of sides) and number them as shown.
- ix. With centres  $A$  and  $B$  and radius  $AB$ , draw arcs intersecting each other at  $P$ .
- x. Draw a line  $AP$  and produce it to meet the circle at  $C$ . Then  $AC$  is the length of the side of the pentagon.
- xi. Starting from  $C$ , step-off on the circle, divisions  $CD$ ,  $DE$  etc., equal to  $AC$ .
- xii. Draw lines  $CO$ ,  $DO$  etc., thus completing the pentagon.



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Produce Plane Geometry Drawings

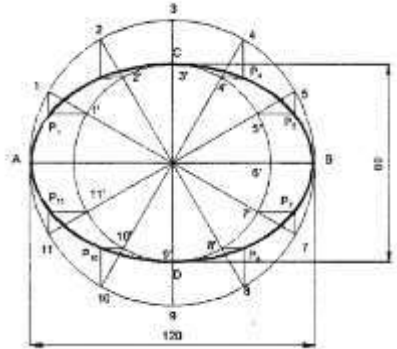
1. D 9

2. D

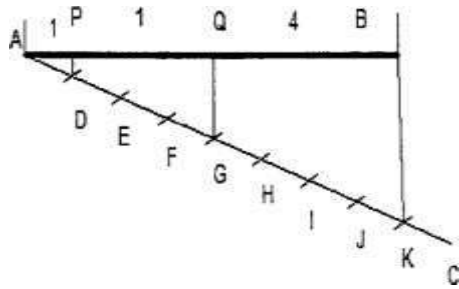
an

inscribed

3. Ellipse

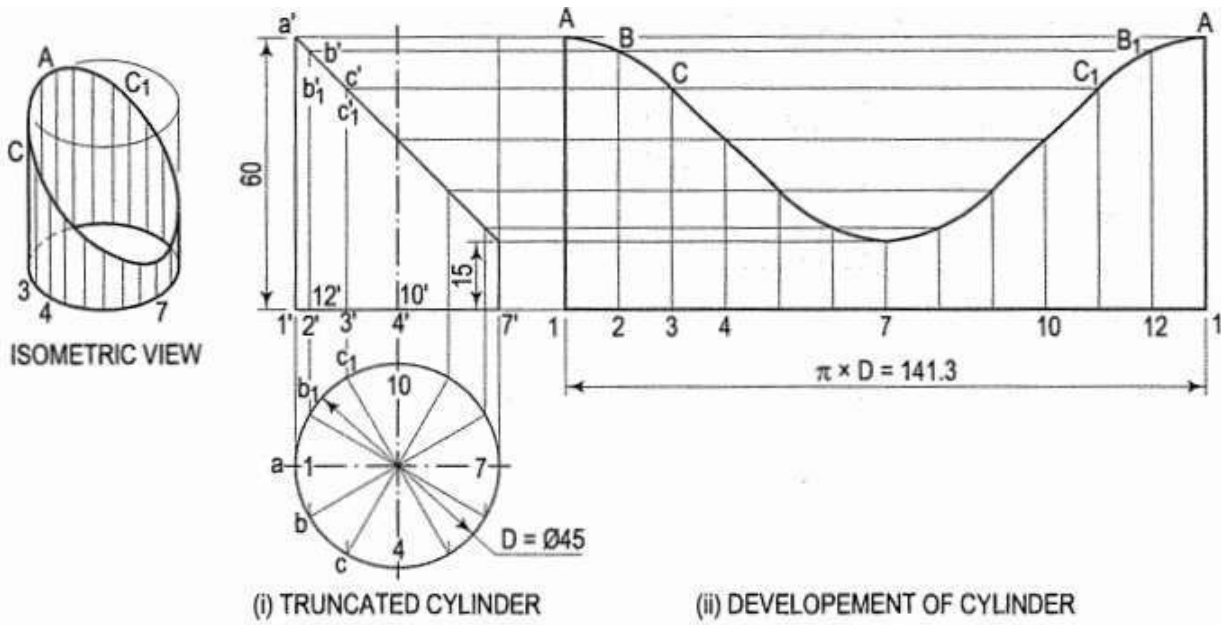


4.

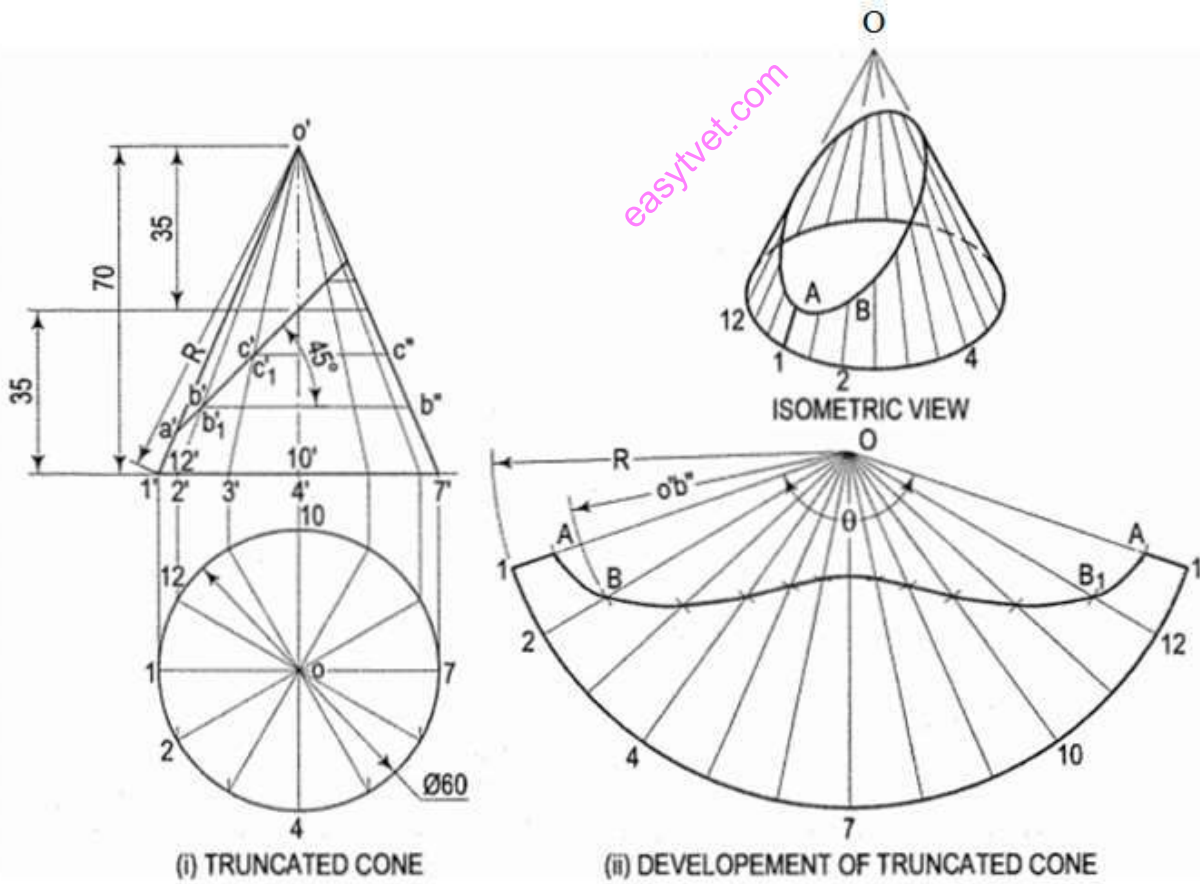


Add the ratios  $1+3+4 = 8$  and divide the line into 8 equal divisions.  
Obtain P and Q to divide the line AB in the ratio 1:3:4.

**Learning activity 1: Produce solid geometry drawings**  
**Develop the lateral surface of the truncated cylinder**



**Learning activity 2: Produce solid geometry drawings**  
**Draw the development of the of the truncated cone**



Produce Solid Geometry Drawings

1. A
2. C
3. B

4. What is the difference between regular and irregular polygons?

**Regular polygon – A regular polygon is a plane figure in which all the sides and angles are equal.**

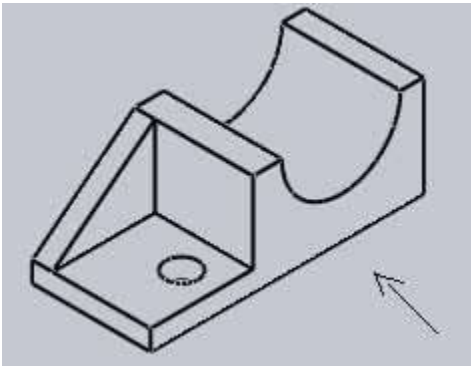
**Irregular polygon – An irregular polygon is a plane figure in which all the sides and angles are not equal.**

5. If an isometric drawing is made use of isometric scale then the drawings are called

Answer: A

Explanation: To avoid confusion, the view drawn with the true scale is called isometric drawing or isometric view, while that drawn with the use of isometric scale is called isometric projection.

6. Identify the front view of the below isometric view.



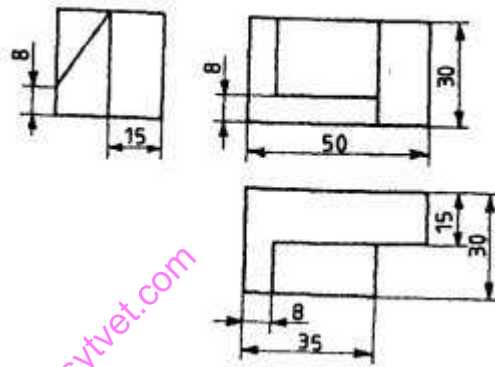
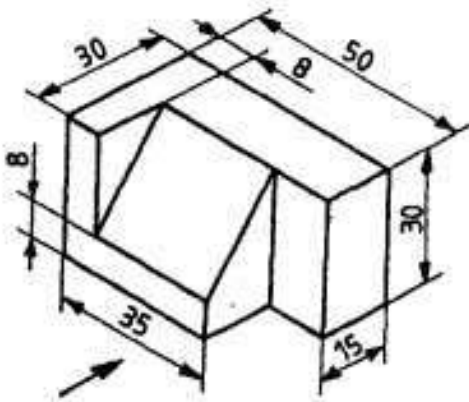
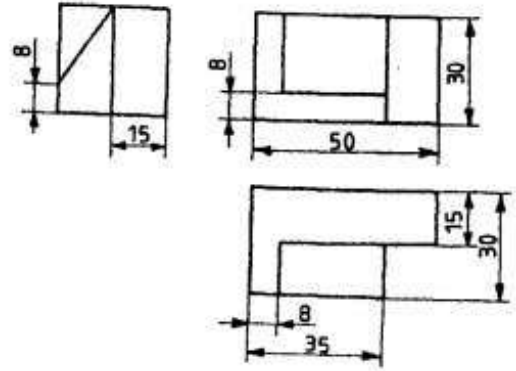
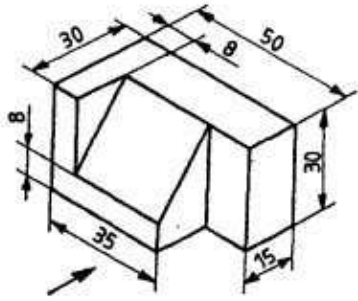
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Answer: a

Explanation: Here the isometric view of some example picture is given. Arrow in question represents the line of sight in case of front view from that we can get other view. Front view is asked which can be watched along the arrow.

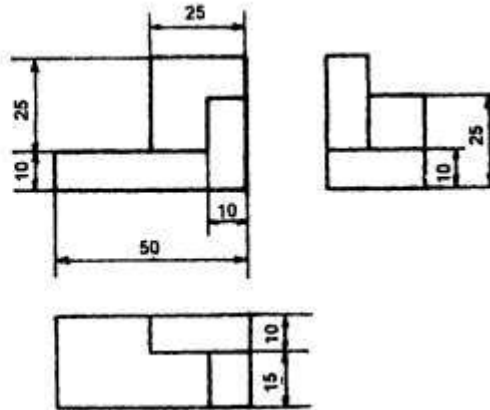
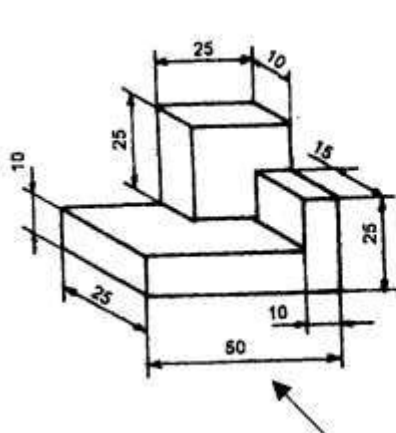
### LEARNING ACTIVITY 1: Produce orthographic and pictorial drawings

- i. The following figures are in isometric view. Draw the orthographic views in first angle.



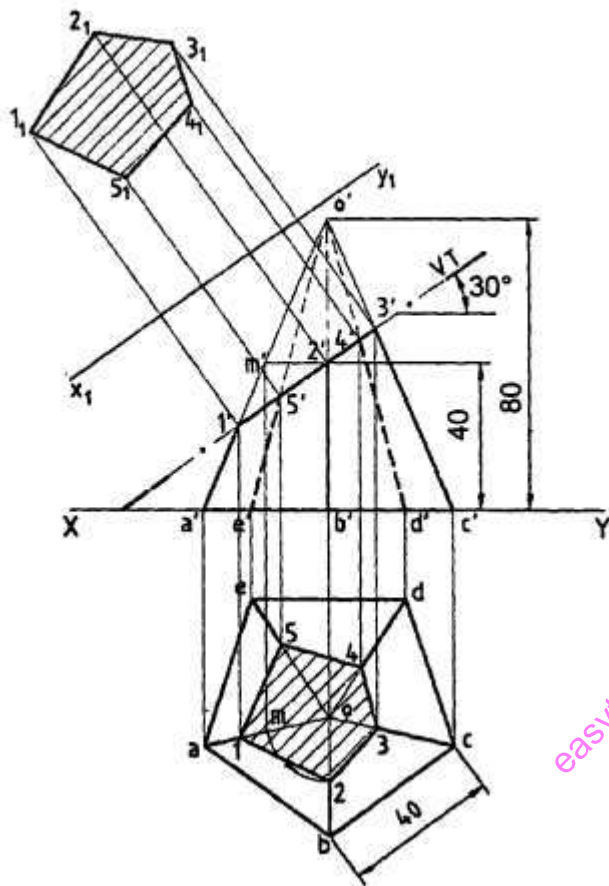
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ii. The following figures are in oblique view. Draw the orthographic views in first angle.



### Learning activity 2: Produce orthographic and pictorial drawings

A pentagonal pyramid of base side 40 mm and axis length 80mm is resting on HP on its base with one of its base side parallel to VP. It is cut by a plane inclined at 30° to HP and perpendicular to VP and is bisecting the axis. Draw its front view, sectional top view, and the true shape of section.



Produce Orthographic and Pictorial Drawings

1. D
2. B
3. B
4. A
5. A
6. B
7. A
8. B
9. C
10. A
11. D
12. D

### 13. C

Explanation: From the front view it is clear that the circle has diameter 20 mm. Hence its radius will be 10mm. The dimension 10mm in the side view is just a repetition of this information. Repetitive dimensions are redundant and they need to be avoided.

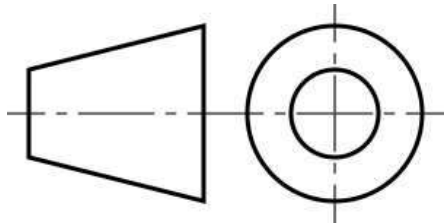
### 14. Views in an Orthographic Drawings

**Front view**

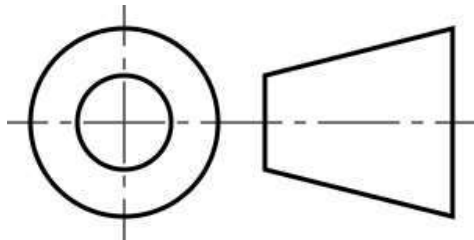
**Side view**

**Plan**

15. First angle projection:-In this projection the object is assumed to be situated in first quadrant, i.e. in front of V.P and above HP the projections obtained on these planes is called first angle projection. The symbol for the first angle projection is



Third angle projection: – In this Projection the object is assumed to be situated in the third quadrant that is below HP and behind VP .The front view comes below the XY line and the top view above it. The symbol for the third angle projection is



### First angle and third angle symbol in machine drawing

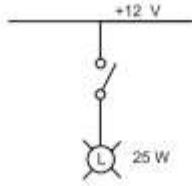
### Produce Electrical Drawings

1. Definitions;
  - i. Schematic diagram

Schematic diagram: a diagram that uses lines to represent the wires and symbols to represent components. It is used to show how the circuit functions.

ii. Line diagram

Line diagram: a one-line diagram or single-line diagram is a simplified notation for representing an electrical system. The one-line diagram is similar to a block diagram except that electrical elements such as switches, circuit breakers, transformers, and capacitors are shown by standardized schematic symbols.



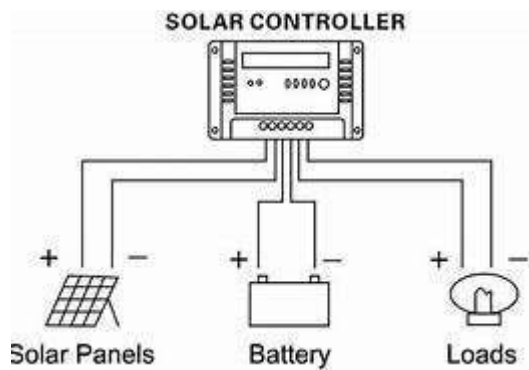
iii. Wiring diagram

A diagram which shows the connections of an installation or its component devices or parts. It may cover internal or external connections, or both, and contains such detail as is needed to make or trace connections that are involved.

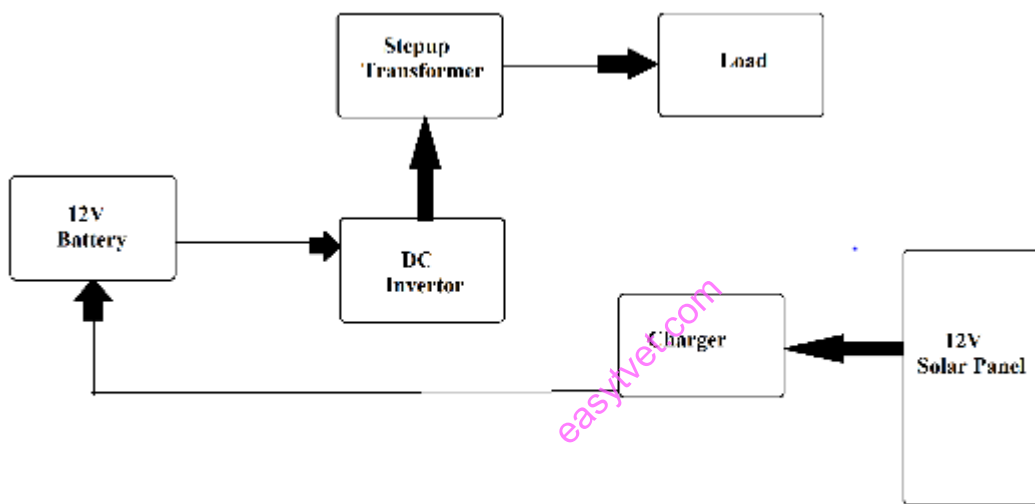
2. Indicate the meaning of the following symbols

| Symbol | Meaning                               |
|--------|---------------------------------------|
|        | 1 gang switched socket-outlet         |
|        | Battery                               |
|        | Inverter                              |
|        | Switch, general symbol                |
|        | <b>Filament lamp</b>                  |
|        | Semi-Conductor Diode - general symbol |

3. A pictorial diagram to show the connection of the solar panel, the battery, and the load to a charge controller.



**4. Block diagram of a solar system.**



Apply Cad Packages

1. A
2. A
3. A
4. B
5. A
6. A
7. C
8. B
9. C
10. A



11. A

12. A

13. A

14. D

**15. D**

16. A

17. A

18. A

19. B

20. B

21. A

22. Answer: a

Explanation: The command which identifies the points on drawing entities that are visible on screen is OSNAP. This option allows the user to pick-up the points very accurately with respect to drawing displayed.

23. Answer: c

Explanation: The commands Erase, Copy, Mirror, Trim, Extend, Break, Join, Scale, Array etc belongs to 'Modify tool bar'. The commands Donut, Block, Spline, Hatch, Rectangle, Ellipse, Polygon, and Arc etc belong to 'Draw tool bar'.

24. Answer: d

Explanation: The commands Erase, Copy, Mirror, Trim, Extend, Break, Join, Scale, Array etc belongs to 'Modify tool bar'. The commands Donut, Block, Spline, Hatch, Rectangle, Ellipse, Polygon, and Arc etc belong to 'Draw tool bar'.

25. Answer: a

Explanation: Chamfer works on two lines or a single poly line to create a beveled edge. Fillet is used to create a round corner between two lines. Stretch command can either lengthen entities or shorten them and thus their shapes.

26. Answer: b

Explanation: Fillet is used to create a round corner between two lines. Chamfer works on two lines or a single poly line to create a beveled edge. Stretch command can either lengthen entities or shorten them and thus their shapes.

27. Answer: c

Explanation: The command 'Oops' is used to retrieves all objects erased by the last erase. Mirror is used to creates mirror image of selected objects about specified line. Command copy creates one or more copies of selected objects at another location. The command 'pedit' is used for

28. Answer: d

Explanation: The command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands. Command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points.

29. Answer: a

Explanation: The command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points. Command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands.

30. Answer: b

Explanation: The command 'U' is used for reverses the effects of a series of previously used commands. Command 'pedit' is used for editing of poly line properties. Command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points.

31. Answer: c

Explanation: The command 'Explode' is used for breaking a poly line into individual segments. Command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands.

32. Answer: c

Explanation: UCS is used to set a new coordinate system by shifting the working XY plane to be desired location. 3DFACE is used for making planar unmeshed surfaces that have three or four sides. VPOINT is used to set the viewpoint in 3D space for viewing the 3D models.

33. Answer: a

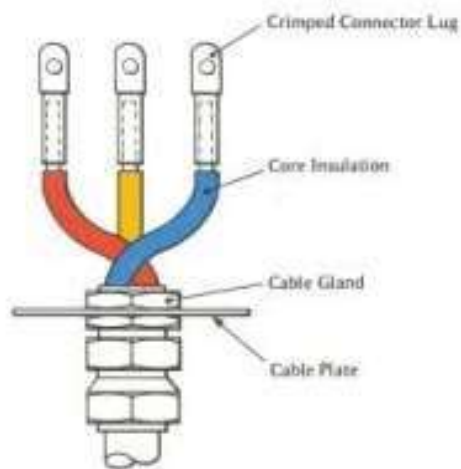
Explanation: 3DFACE is used for making planar unmeshed surfaces that have three or four sides. VPOINT is used to set the viewpoint in 3D space for viewing the 3D models. UCS is used to set a new coordinate system by shifting the working XY plane to be desired location.

34. Answer: b

Explanation: VPOINT is used to set the viewpoint in 3D space for viewing the 3D models. 3DFACE is used for making planar unmeshed surfaces that have three or four sides. UCS is used to set a new coordinate system by shifting the working XY plane to be desired location.

35. Answer: d

Explanation: ELEV is used to set elevation and thickness properties for 2D wireframe objects such as line, point, circle, polygon and arc. 3DFACE is used for making planar unmeshed surfaces that have three or four sides.



Cable termination

The methods used to terminate the cables vary according to;

- Type of cable,
- Type of connector and application.

- Outdoor or indoor use
- Voltage
- Current
- Overhead, or underground
- Type of Connector on the equipment where the cable will be connected.

The common type of terminations

- Crimp connection,
- Soldered connection,
- Compression termination, and wire-wrapping connection,
- Direct connection,
- Loop or eye connection.

### **Electrical power cable joints**

The cable joints are used to connect low, medium or high voltage cables. The type of cable joint sizes, shapes and configurations vary according to the voltage, structure, insulation and the number of cores of the cable to be jointed.

The joints provide electrical insulation as well as mechanical protection and strength. The electrical connection is made in various ways and can crimping, or use of mechanical connectors, soldering, etc.

*Voltage-* The joints are designed for low, medium or high voltages and it is important to match the capacity of the joint to voltage in the cable. Low power cable joint will fail if subjected to high current.

*Structure-* The cable joints are made according to how the cables are to be connected. The simple joints such as the straight through connectors are used to connect two power cables at one point while the other more advanced branch connectors may be used to accommodate a cable branching off the main line or several cables coming into one joint to form one main cable.

*Cores-* The cable joints are required to have the same number of cores to those of the cables to be joined.

*Insulation-* There are different cable insulations depending on the application of the cable and the cable joint must be compatible with the cable insulation. There are a variety of insulation procedures, and can be either heat or cold shrinkable insulation, molded type of insulation, or use of tape.

### **Types of electrical power cable joints**

There are about four commonly used types of joints; these differ in mechanical arrangement and where they are used. However, some manufacturers may provide custom designs to suit unique customer requirements.

**Straight through joints-** This is the mostly used type of a joint and is used to extend pieces of electrical cables.

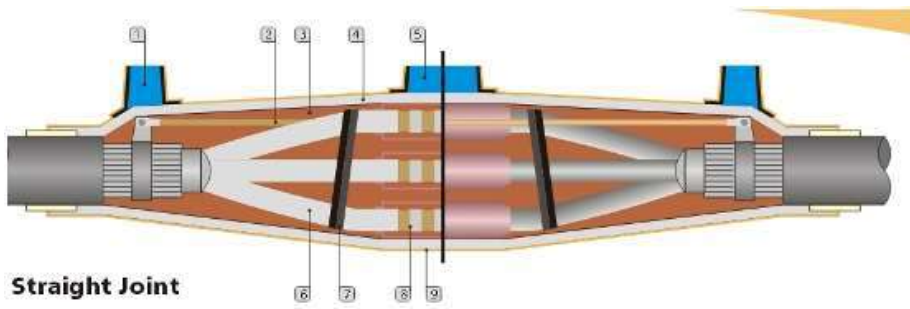


Figure 137: Cable joint:

1. Riser
2. Earth continuity connection
3. C.J compound
4. Plastinet
5. Pouring gate
6. Core Insulation
7. PVC (NA) Tape
8. Ferrule
9. BOPP Tape two layers each half overlapped over plastinet

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**Branch which can be a T or Y joint-** This is used to join low voltage, polymeric, non-shielded cables of between 1 and 5 cores. The branch jointing provides a reliable electrical connection, electrical insulation and mechanical protection. The connectors are either the compression or the mechanical type. The branch joints can be used for indoor, outdoor, submerged and underground cable jointing.



T or Y joint

**Pot End Joints-** The pot end joints are used at the live voltage cable ends. In a typical cable, each of the cores is sealed separately using a heat shrink cable end caps. A screen bandage is then applied to provide for earth fault protection and the combination is then covered with a thick wall of heat shrink cable cap. The pot ends

joints are suitable for temporary and permanent cable abandonment to provide safe termination of live power cables for indoor, outdoor as well as underground cables

Follow the link below to watch tutorials on cable terminations-

<https://www.youtube.com/watch?v=PgD2D2VnNg0>

- **Importance of termination**

- Provides electrical continuity in the circuit
- Provides mechanical support and physical protection to the cables
- Ensures safety of the circuit, the user and maintenance technician

### **Types of cable terminations**

**Soldering-** Flame soldering units can be used to automate the process. In a flame soldering application, the object is placed over a tiny flame, heated for a specified time and a precise amount of solder is applied. Some applications require the terminal to be soldered after it is crimped onto the end of the wire. This method is mainly used in electronics

**Insulation Displacement Connections-** Insulation displacement connectors (IDC) are probably the fastest way to terminate wires. The process can quickly and efficiently terminate the hundreds of wires in large patch panels. There is no need to strip the wires when using IDC. IDC tools are inexpensive and virtually error-proof. There are no chemicals to deal with and no insulation slugs to clean up. IDC applications are usually reserved for small, stranded wire up to 22 AWG.

**Crimping-** Crimping is the most commonly used method of wire termination, and is most efficient for high-volume wire termination. The terminations are fast, clean and mechanically strong. For low volume or fieldwork, loose terminals are applied with a plethora of handheld and benchtop crimping devices.

**Ultrasonic Welding-** Ultrasonic welding is used in various bonding applications, such as joining such dissimilar metals as copper, aluminum, nickel and brass. Ultrasonic welding is widely used in wire harness manufacturing, where welding multiple wires is required. The resulting molecular bonds are strong and can provide lower resistance than soldering or crimping. Ultrasonic welding can also bond wire to terminals. The advantage is the lower resistance. The disadvantage is that this process takes longer than crimping

**Cable lug-** A device attached to a conductor to permit connection to a terminal. It has provisions for attachment of wires or similar electrical conductors in order to establish an electrical connection and could require the use of tools for attachment of wire. A terminal may be attached to a wire by a number of methods including screw-on, press-on or crimp-on

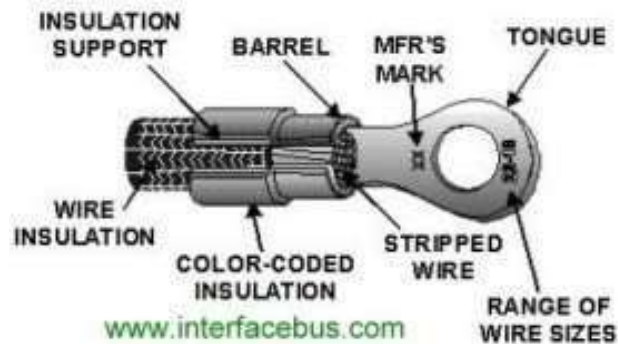


Figure 138: terminal lug (from [www.Interfacebus.com](http://www.Interfacebus.com)):

- **Cable labeling**

Letters, numbers, and wording on wiring labels tell you important information, such as the wire material, the size of the wire, and the type of insulation used on the conducting wires. Labels are found on both individual insulated wires and on insulated cable containing bundles of wires. Cables carry labels indicating the cable type or construction as well as the number of wires inside the cable.

A ground wire is indicated by "G," "w/G," or "with Ground." The wire material is indicated by "CU" for copper and "AL" for aluminum.

Example

- **14-2G:** Cable contains two insulated wires plus a ground wire; the wires are 14-gauge.
- **14-3G:** Cable contains three insulated wires plus a ground wire; the wires are 14-gauge.
- **12-2 w/G:** Cable contains two insulated wires plus a ground wire; the wires are 12-gauge.
- **12-3 w/G:** Cable contains three insulated wires plus a ground wire; the wires are 12-gauge.
- **600 V:** Cable is rated for a maximum of 600 volts; this is standard for residential NM cable.
- **TYPE NM-B:** Non-metallic type-B cable; this is the current standard for residential installations. "NM-B" cable is more heat-resistant than older "NM" cable.

### Underground Feeder Cable

Most NM cable is used in "dry," or interior, locations, where the cable is protected inside wall, ceiling, and floor cavities. Underground feeder (UF) cable is a special type of non-metallic cable that is suitable for "wet" locations, or for unprotected locations like direct burial in the ground. UF cable is usually gray (not white, yellow, orange, or black, like standard NM cable); it is labeled "UF-B" and may include "Sunlight Resistant" or similar wording. UF cable uses the same symbols as standard NM cable to indicate the number and gauge of wires.

### Labels on Individual Wires

Individual insulated wires are used in home wiring when an installation calls for conduit—a rigid or flexible protective pipe or tubing through which the wires are run. The important labeling on individual wires relates to the wire insulation—the plastic coating that covers the metal conducting wire. The most common types of wire used in home wiring include:

THHN, THWN, THW and XHHN where;

- **T:** Thermoplastic insulation, a fire-resistant material
- **H:** Heat-resistant; able to withstand temperatures up to 167 F.
- **HH:** Highly heat-resistant; able to withstand temperatures up to 194 F.
- **W:** "Wet," or approved for damp and wet locations; this wire is also suitable for dry locations
- **X:** Insulation made of a synthetic polymer that is flame-retardant
- **N:** Nylon-coated for resistance to oil and gasoline

### Labels on Low-Voltage and Thermostat Wires

Low-voltage wiring used around the home includes small non-metallic cable used for thermostats and other control devices and paired insulated wire used for landscape lighting systems. Wire for landscape lights usually is black and has labeling stamped into the wire insulation. Labels typically include:

- **Wire size:** Indicated by a number (such as 12, for 12-gauge) or a number followed by "AWG," for American Wire Gauge.
- **Number of wires:** Usually indicated by the number 2; landscape wiring typically has two insulated wires stuck together (similar to a lamp cord) and contains no ground wire.
- **Properties:** Wording indicating sunlight-resistance or suitability for underground installation.

Thermostat cable is similar to NM cable but contains four or more small insulated wires and no ground wire. The cable may or may not be labeled. Each wire has its own colour to help you connect to the appropriate terminal at the thermostat and the equipment it controls. Although colour coding is not universal, the lettering on the thermostat terminals is relatively standard:

**C:** Common wire; allows for continuous power flow from the R wire; not all thermostats use this terminal

- **R:** 24-volt power supply from the furnace transformer
- **Rc:** Calls for heat or cooling; there may be more than one Rc terminal
- **G:** Fan
- **W:** Heat
- **Y:** Air conditioner

Technicians in their line of work may also find it necessary to label cables especially in industrial installation, cabinets and automated systems for easy troubleshooting and safety.

- **Tools used for cable termination**

- Needle nose crimping pliers-They are applicable as small lug crimpers





Figure 11

Needle nose pliers

- Crimping tool- It is used for fixing a connector to the end of a cable

RJ-11 (6-Pin) and RJ-45 (8-Pin) Crimping Tool



- Snips- They are used to cut small cables and conductors, and to trim insulation.



Figure 12

- Wire stripper hole for 22- to 24-gauge wire- They are used to strip insulation from conductors. The adjusting screw should be used to prevent the cutting tips doing damage to the conductor. They may also

be used to remove the sheath from single core PVC / PVC cable, 1.5mm<sup>2</sup> and 2.5mm<sup>2</sup>, while leaving the insulation intact



Figure 13

➤ Automatic wire stripper- The automatic wire stripper is designed to remove insulation from a range of conductor sizes.



Figure 14

➤ Hack saw- It is used to cut the larger size cables, cut mini trunking and cut out openings in surface boxes for cable entry.



➤ Electrician's knife- Electrician's penknife is mainly used to remove the sheath from the various types of cables and flexible cords.

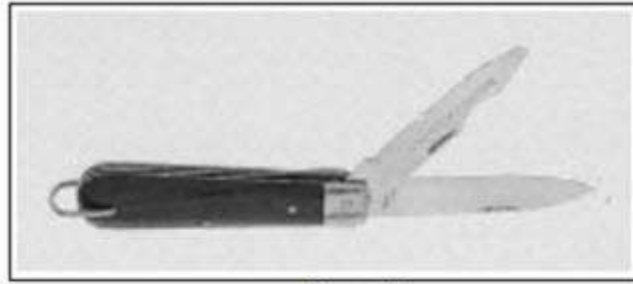


Figure 17

➤ Phase tester -It is a very useful tool when checking if a circuit is “live” or not. This ensures safety of the electrician



Figure 22

#### 1.2.6.1 Learning activities

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#### Practical activities

#### Field/Visit to an electrical Installation Sites

| Visit Objective/Aim  | Indicators   | Special Instruction   |
|--|--|---|
| To establish how to perform termination on electrical installation | Types of terminations<br>Cable labelling<br>Cable lugging<br>Tools used in termination | <ul style="list-style-type: none"> <li>• Observe keenly</li> <li>• Take notes</li> <li>• Ask questions</li> </ul> |

#### Industrial attachment

| Visit Objective/Aim                              | Indicators  | Special Instruction   |
|--|---|---|
| To experience how to terminate electrical cables | <ul style="list-style-type: none"> <li>• Demonstrate various methods of cable termination</li> <li>• Demonstrate methods of cable jointing</li> <li>• Use of various cable termination tools</li> </ul> | <ul style="list-style-type: none"> <li>• Participate actively</li> <li>• Take notes</li> <li>• Ask questions</li> </ul> |

### A case study

#### Carefully read the case study in the excerpt below and answer that follow

You are employed by ABC Company limited. The company which deals with electrical installation and consultancy. The company is required to install electrical power in a wheat grinding plant. The plant is powered by 3 phase 415V power to run grinding the machine. The company has assigned you responsibility to supervise installation process. Installation is complete and now you are required to terminate cables.

1. Explain how you would get 240V power from the 415V for lighting and socket outlets
2. Discuss various termination methods you will apply in the system
3. Give some considerations in selecting cable joints
4. Explain importance of termination in electrical installation
5. Names various tools and how they are applied in cable termination.

#### 1.2.6.2 Tools, Equipment, Supplies and Materials

- Functional workshop
- Tools equipment used in electrical installation e.g.
  - ✓ Pliers
  - ✓ Cable strippers
  - ✓ Crimping tools
  - ✓ Materials e.g.
    - ✓ Cables
    - ✓ Trunking
    - ✓ Conduits
    - ✓ Enclosures

Supplies and consumables e.g.

- ✓ Cable ties
- ✓ Silicon glue

- ✓ Connectors
- ✓ Switches
- ✓ circuit breakers

Computer

Stationery

Classroom and classroom resources

### 1.2.6.3 Self-Assessment

1. What are the factors you will consider before selecting the method of termination suitable for various parts of the installation?
2. Give various types of the terminations you will apply for the installation
3. Explain importance of termination
4. What are the factors you will consider when selecting types of cable joints to apply during installation?
5. Give various types of cable joints
6. Explain importance of cable labeling in electrical installation
7. Explain some tools used for performing various types of terminations

### 1.2.6.4 References

1. Technical Description, electrical installations by World Skills
2. Measurements on electrical installations Metrel measuring and regulating manufacturer
3. Electrical wiring components
4. Measurement and instrumentation principles third edition by Alan S Moris

## CHAPTER FOUR: TECHNICAL DRAWING

**Unit of learning code:** ENG/LG/MC/CC/04/5/A

Related Unit of Competency in Occupational Standard; Prepare and interpret technical drawings

Introduction to the unit of learning

### Unit Description

This unit covers the competencies required to prepare and interpret technical drawings. It involves competencies to select, applying and maintaining drawing equipment and materials, producing plane geometry drawings, producing solid geometry drawings, producing orthographic and pictorial drawings and applying CAD packages

### Summary of Learning Outcomes

6. Apply and maintain drawing equipment and materials
7. Produce plane geometry drawings
8. Produce solid geometry drawings
9. Produce orthographic and pictorial drawings
10. Apply CAD packages

## 4.1 Apply and Maintain Drawing Equipment and Materials

### Introduction to the learning outcome

**This learning outcome is intended to equip the trainee to be competent in** identifying, and gathering drawing and drawing materials according to task requirements. It also covers content on maintenance of drawings and drawing materials.

### Performance standard

- vii. **Drawings** are identified and gathered according to task requirements
- viii. Drawing materials are identified and gathered according to task requirements
- ix. Drawings are used and maintained as per manufacturer's instructions
- x. Drawing materials are used as per workplace procedures
- xi. Waste materials are disposed in accordance with workplace procedures and **environmental**
- xii. **Personal Protective** is used according to occupational safety and health regulations

Information sheet

### Identification and care of drawing equipment and materials

#### Basic Drawing Tools

A draftsman needs some basic tools to draw. These should include the following:

- xi. A range of pencils
- xii. Ruler
- xiii. Set squares
- xiv. Rubber
- xv. Compasses
- xvi. Dividers

- xvii. Drawing board
- xviii. T-square
- xix. Clips or tape
- xx. Emery board or fine sandpaper

**Pencils:** You will need a selection of pencils. A hard leaded pencil (6H) can be used for light lines, a softer pencil (2H) for the outlines and an even softer pencil (HB) for printing. (More than one pencil of each grade will save you from frequent re-sharpening.)

**Ruler:** It is advisable to have a transparent ruler.

**Set squares:** You will need at least two set squares: a 60 ° and a 45 ° set square. It will be also useful to have an adjustable set square, which will enable you to set the angle on the set square to anywhere between 0 ° and 90 °. If you have an adjustable set square you can manage without the other two.

**Rubber:** Choose a good quality rubber, one that does not smudge.

**Compasses:** You will need at least two compasses: a small spring bow compass for small circles and one for larger circles.

**Dividers:** A pair of dividers is essential.

**Drawing board and T-square:** Drawing boards for size A2 paper can be bought with a fitted horizontal square which slides up and down on rollers. A less expensive board is one that is used with a separate T-square which slides up and down on the side of the drawing board and has to be held in place when used.

**Clips or tape:** The best tape to use to hold paper on the drawing board is masking tape but metal drawing board clips are easier to use.

**Emery board or fine sandpaper:** This is used to ensure that the lead in the pencils is kept sharp.

### **Instruments for Drawing Straight Lines**

- T- Square
- Set- squares

### **Instruments for Drawing Curved Lines**

- Compass
- French curve

### **Instruments for Measuring Distance**

- Divider
- Scales

### **Instruments for Measuring Angles**

- Protractors

- Set-squares
- Special Tool
- Mini drafter

There are other instruments that will help you to draw quickly and accurately.

These include the following:

- e) French curves (for drawing non-circular curves accurately).
- f) Large spring bow compasses.
- g) Trammel (for drawing circles with very large diameters).
- h) Scales (rulers with special markings for drawing items bigger or smaller than they are in real life)

## Using the Equipment

First fix the paper to your board, using clips or tape.

Then sharpen your pencils, either to a point using a pencil sharpener, or to a chisel shape using the emery board and use this shape for drawing lines, drawing from the ends of each line to meet in the middle.

Use the emery board to sharpen your compass leads to a chisel point too. Finally, draw a frame on your paper if required.

## Precautions for Neatness in Drawing Work

8. The hands should be kept clean at all times during work.
9. All the drawing instruments should be kept clean by wiping with a cloth/towel.
10. Special emphasis is to be given to sliding instruments on the drawing sheet, such as T- square and set squares. These instruments must be cleaned properly every time.
11. Pencil should always be kept sharp and used properly. It should be sharpened away from the drawing sheet and other instruments.
12. Dirt and graphite particles from the pencil will make the drawing dirty. Hence, every care should be taken to remove them from the drawing sheet.
13. Direct contact of hand with the drawing sheet should be avoided.
14. Rubbing or erasing should be done properly with soft eraser.

## Identification and care of drawing materials

Drawing materials

These are consumable items used for technical drawing. They are consumable because they cannot be reused after being used.

The following are the necessary drawing materials.



## 7. Drawing paper

These are white papers on which drawing is done. The mostly used sizes are A2 to A4

## 8. Erasers

Erasers are rubber materials used to clean errors made. A good eraser should be able to clean errors without tearing the paper.

## 9. Handkerchief

It is a small clothing material used for cleaning and dusting.

## 10. Emery clothes/glass paper

They are materials used to maintain the sharpness of pencils at all times

## 11. Adhesives

It is commonly called callotape.it is used to fix drawing paper on the drawing board.

## 12. Drawing pencils

The drawing pencil is used for preparing the drawing on the drawing paper.

## Pencils

Pencils are the main drawing instruments used to draw the lines, circles, arcs, polygons, etc. with respect to the scale provided. Some of the pencils are hard and some of the pencils are smooth.

The hard pencils are used to draw the construction lines and the smooth pencils are used to draw the main lines.

### 5. H Grades:

H leads give cleaner lines and are also smudge resistant, making them perfect for outlining, technical drawings, painting with watercolors after the sketch and light sketches.

The only flip side is that as you move up the scale, the harder the leads will get and they tend to be scratchy. So make sure you practice and experiment before you begin on your actual art project.

### 2. HB:

The HB grade lies in the middle of the spectrum. HB is dark enough to be read clearly with minimal smudging and is therefore used mostly for writing.

### 3. B Grade:

B grades smudge easily, are smooth to write and draw with. But they are easily erasable. As you go higher up the scale with these pencils, artists can take advantage of the brush- like expressions that can result while using this grade of pencils. Animators in particular love using 10B on the animator paper as it writes so smoothly – like butter, creating quick, heavy lines without friction.

### 4. F Grade:

The F grade also lies in the middle of the spectrum. The letter 'F' stands for 'fine'. The lead with 'F' grade contains a limited amount of graphite and more amount of clay. It has a hard lead but gives a lighter shade when used.

Depending on the smooth and hard quality or the hardness, pencils are classified into 18 grades and they are as follows.

| Grade of Pencil | Hardness of Pencil        |
|-----------------|---------------------------|
| 9H              | Hardest                   |
| 6H, 5H, 4H      | Extremely Hard            |
| 3H              | Very hard                 |
| 2H              | Hard                      |
| H               | Moderately hard           |
| F               | Firm                      |
| HB              | Medium hard               |
| B               | Moderately soft and black |
| 2B              | Soft and black            |
| 3B              | Very soft and black       |
| 4B, 5B, 6B      | Very soft and very black  |
| 7B              | Softest                   |

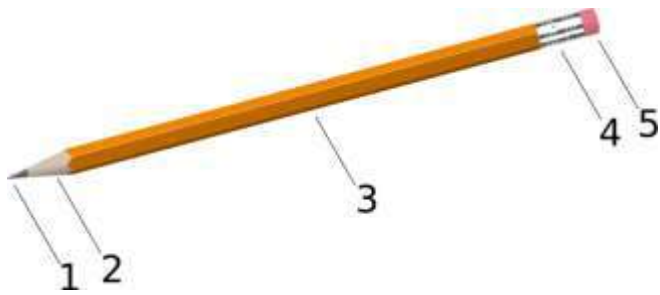
*Table 11: Grades of pencils*

Out of the above 18 grades of pencils, the following grades are used in engineering drawings.

| Grade of Pencil | Used to Draw   |
|-----------------|--|
| 3H              | Construction lines   |
| 2H              | Dimension lines, center lines, sectional lines, hidden lines |
| H               | Object lines, lettering                                      |

|    |                              |
|----|------------------------------|
| HB | Dimensioning, boundary lines |
|----|------------------------------|

Table 12: Continuation of grades of pencils



1. Solid pigment core (typically graphite, commonly called pencil lead).
2. Wood.
3. Painted body.
4. Ferrule.
5. Eraser.

### Care in handling and maintaining drawing instruments and materials

#### Drawing board

5. Do not use drawing board for any other purpose than for drawing
6. The surface of the drawing board must be in good condition. Do not using sharp object to cut on it.
7. Always clean the drawing board before use.
8. Cover drawing board surface with paper or cardboard after use

#### Tee square

4. Tee square should not be used as a walking stick.
5. The blade must be straight at angle  $90^0$  to the stock.
6. Always clean the tee square before using it.

#### Set of drawing instruments

4. Do not place heavy load on them to prevent breakage.
5. Do not use sharp objects to cut on their edges.
6. Store them in a safe place

#### Drawing pencil

3. Drawing pencil should be kept in a pencil packet after use.
4. Pencil points must be pointed

## Other instruments

All other instruments should be stored in a safe place to prevent damage

<http://schoolportalng.com/drawing-instruments-and-materials/>

## Title Block

The title block should lie within the drawing space at the bottom right hand corner of the sheet. The title block can have a maximum length of 170 mm providing the following information.

10. Title of the drawing
11. Drawing number
12. Scale
13. Symbol denoting the method of projection
14. Name of the firm
15. Initials of staff who have designed, checked and approved
16. Date when the drawing was finished
17. Name of the person who checked the drawing
18. Remarks

## Lettering

Lettering used in engineering drawing is referred to as a *Single Stroke, Commercial Gothic Hints on Lettering*

- To save time, use a guide lining device
- The recommended height of lettering is 3-mm
- During initial learning period, make a point of concentrating on hand control
- Endeavor to make your hand do what you want it to do and not otherwise. Remember your fingers are not used to such movements, so they have to be trained until hand control becomes effortless
- Do not guess at the construction of letters and numerals. Use the sample letter
- Make letters and numerals as wide as they are high with individual letters of a word almost touching
- Spacing between words is a matter of judgment and tends to improve with practice
- Lines of lettering should be spaced the same distance apart
- Do not attempt to erase guide lines after lettering has been completed

## Printing

Most notes on drawings are done in upper case (capital letters) although this is not always so. Two alphabets and numbers are shown below.

Most draftspersons develop great skills in printing by hand. If you need to print, try both standard and italic and develop a style that suits you.

## Standard print




A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

a b c d e f g h I j k l m n o p q r s t u v w x y z

1 2 3 4 5 6 7 8 9 0

## Lines

In Engineering Drawing, we make use of different lines and line styles to convey the desired message. These lines differ in (i) thickness and (ii) style

| Type of Line and Designation   | Applications   | Recommended line thickness [mm] |       |
|--|--|---------------------------------|-------|
|  |  | A3/A2                           | A1/A0 |
| <br>continuous thick line | 1. Object line<br>2. Dimensioning line   | 0.5                             | 0.7   |
| <br>continuous thin line  | 8. Dimensioning line<br>9. Projection or extension lines<br><i>used to project points from one view to another)</i><br>10. Hatching<br>11. Outlines of adjacent parts<br>12. Outline of revolved views or revolved sections<br>13. Leaders for notes<br>14. Imaginary outlines | 0.25                            | 0.35  |
| <br>continuous wavy line  | 1. Break line of part views and part sections when break lines are not center lines  | 0.25                            | 0.35  |


|  |   |   |      |
|--|---|---|------|
| <br>short thin dashes | <b>5. Non-visible outline (hidden)</b><br><i>3 – 4-mm strokes, 1 – 2-mm spaces)</i> | 5 | 0.35 |
|--|---|---|------|

Table 13: Types of lines in drawings

### Learning Activities

#### Learning activity 1: Apply and maintain drawing equipment and materials

Make a sketch of an A 1 size drawing sheet, showing in it, the border lines, margin lines, folding marks, zones and the title block. Give the untrimmed and trimmed sizes of this sheet.

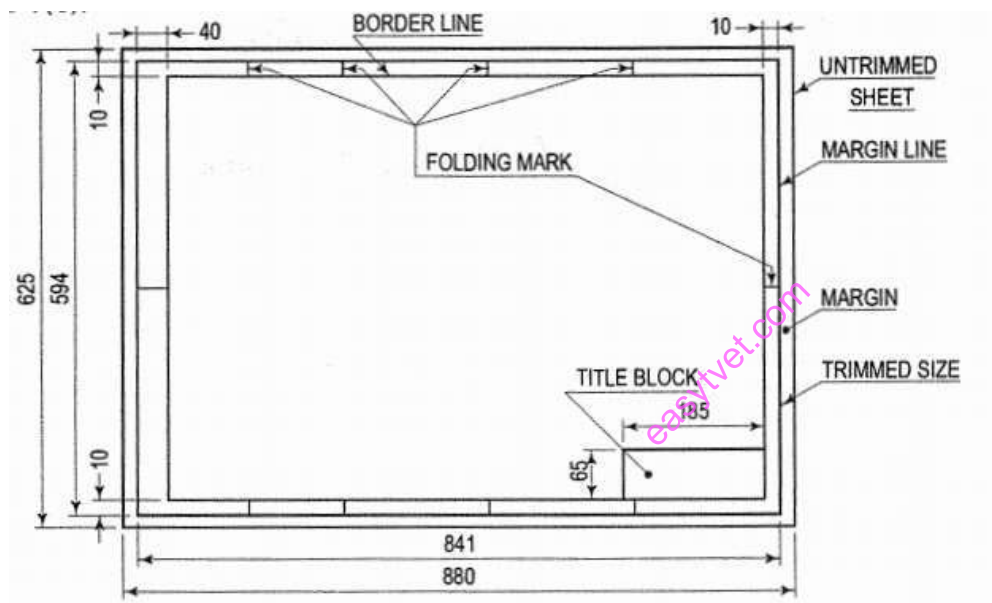


Figure 139: Drawing paper layout

#### Learning activity 2: Apply and maintain drawing equipment and materials

In an A3 size sheet, Copy the drawings below as per layout shown. [All dimensions are in mm.]

- iii. Draw the border lines as per the standards learnt.
- iv. Draw the title block as per the standards learnt.

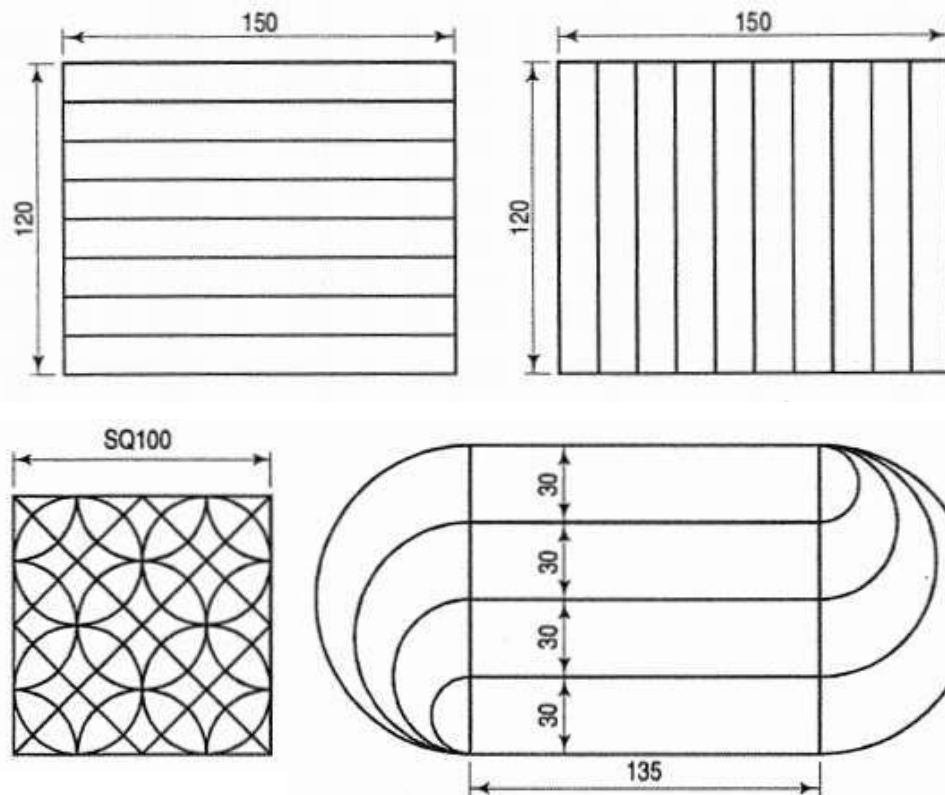


Figure 140: Patterns

### Learning activity 3: Apply and maintain drawing equipment and materials

Write freehand the following, using single stroke vertical (CAPITAL and lower-case) letters:

5. Alphabets (Upper-case & Lower-case) and Numerals 0 to 9 (h = 5 and 7 mm)
6. PRACTICE MAKES A PERSON PERFECT (h = 3.5 and 5)
7. BE A LEADER NOT A FOLLOWER (h = 5)
8. LETTERING SHOULD BE DONE FREEHAND WITH SPEED (h = 5)

### Self-assessment

10. What is a technical drawing?
  - E. A sketch
  - F. A detailed drawing with measurements
  - G. A brainstorming sketch
  - H. A drawing with labels
11. Once a drawing is determined to be complete, the title block is used to document the change from:
  - E. A draft to a finished drawing
  - F. A finished to a working drawing
  - G. An assembly to a finished drawing
  - H. A working drawing to a draft

12. Which of the following types of lines is used on construction line?
- E. Thick line
  - F. Thin line
  - G. Dash line
  - H. Wavy line
13. What is the size of an A3 drawing sheet?
- E. 1189 x 841mm
  - F. 594 x 420mm
  - G. 420mm x 297mm
  - H. 297 x 210mm
14. The primary unit of measurement for engineering drawings and design in the mechanical industries is the:
- E. Millimeter
  - F. Centimeter
  - G. Meter
  - H. Kilometer
15. With regard to lettering, the shapes of letters are not described as part of drawing standards.
- C. True
  - D. False
16. Scale is stated as a ratio of the number of drawing units to the number of actual units.
- C. True
  - D. False
17. Why the drawing is called the language of Engineers?
18. What is the Necessity of Dimension a Drawing?

#### Tools, Equipment, Supplies and Materials

- 7. Drawing tools
- 8. Drawing set
- 9. Drawing papers
- 10. Erasers
- 11. Series of pencils
- 12. Drawing board

#### References

- 6. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing : Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.
- 7. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
- 8. Narayana, K. L., Kannaiah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
- 9. Reddy, K. V. 2010. Textbook of Engineering Drawing . B.S. Publ., Hyderabad.



10. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,

easytvvet.com

## 5.2. Produce Plane Geometry Drawings

### Introduction to the learning outcome

This learning outcome is intended to equip the trainee to acquire the competence of producing plane geometry drawings.

### Performance Standard

- vii. Different types of lines used in drawing and their meanings are identified according to standard drawing conventions
- viii. Different types of *geometric forms* are constructed according to standard conventions
- ix. Different types of angles are constructed according to principles of trigonometry
- x. Different types of angles are measured using appropriate measuring tools
- xi. Angles are bisected according to standard conventions
- xii. Freehand sketching of different types of geometric forms, tools, , diagrams is conducted

Information sheet

### Construction of geometric forms and geometrical constructions

3. Dividing a straight line into equal parts

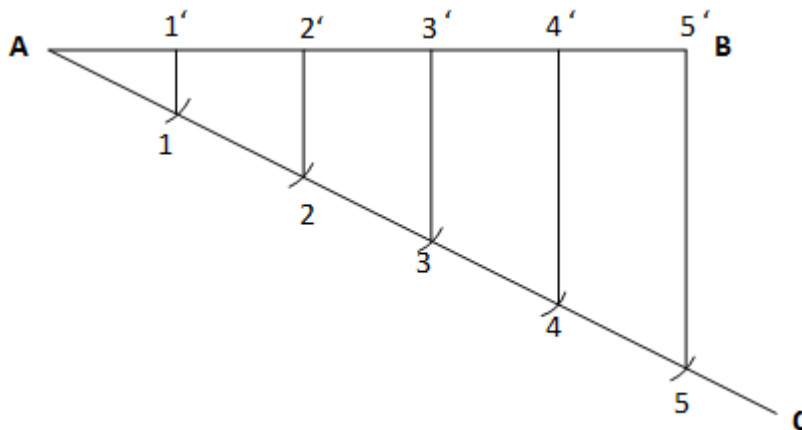


Figure 141: A line divided into equal parts

- i. Draw AC at any angle  $\theta$  to AB.
- ii. Construct the required number of equal parts of convenient length on AC like 1, 2, and 3.

- iii. Join the last point 5 to B
  - iv. Through 4, 3, 2, 1 draw lines parallel to 5B to intersect AB at 4', 3', 2' and 1'.
4. Dividing a line in ratios

Take the line to be divided in the ratio 1:3:4

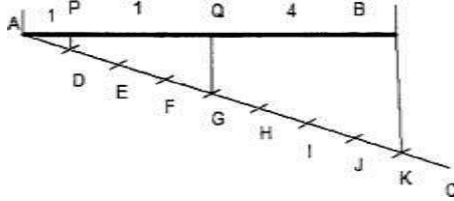


Figure 142: Line divided in ratio

- i. Add the ratios  $1+3+4 = 8$  and divide the line into 8 equal divisions.
- ii. Obtain P and Q to divide the line AB in the ratio 1:3:4.

### Construction of different types of triangles

#### Triangles

This is a plane figure bounded by three straight sides.

#### Types of triangles

- vi. Scalene triangle is a triangle with three unequal sides and three unequal angles.
- vii. Isosceles triangle is a triangle with two sides, and hence two angles, equal.
- viii. Equilateral triangle is a triangle with all the sides, and hence all the angles, equal.
- ix. Right-angled triangle is a triangle containing one right angle. The side opposite the right angle is called the 'hypotenuse'.
- x. Obtuse-angled triangle

#### Acute-angled triangle

Construct the different triangles given:

- viii. One of the sides
- ix. Perimeter and altitude
- x. Base angles and perimeter
- xi. Base, altitude and vertical angle
- xii. Perimeter and the ratio of the sides
- xiii. Perimeter, altitude and vertical angle
- xiv. Similar triangle with different perimeter

### Constructions of triangles

## 2. When all the three sides are given

To construct a  $\triangle ABC$  in which  $AB = 4$  cm;  $BC = 6$  cm and  $AC = 5$  cm.

- vi. Draw  $AB = 4$  cm.
- vii. With A as centre and radius 5 cm, draw an arc.
- viii. With B as centre and radius 6 cm, draw an arc.
- ix. The two arcs cut each other at point C.
- x. Join AC and BC to complete the triangle ABC.

Example:

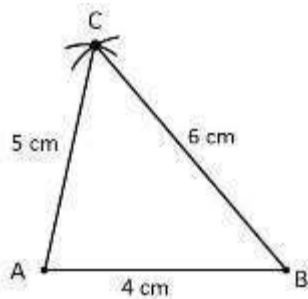


Figure 143: Triangle

## When Two Sides and an Angle are Given

To construct a  $\triangle ABC$  in which  $QP = 4$  cm;  $QR = 6.5$  cm and included angle  $Q = 60^\circ$

- Draw  $QR = 6.5$  cm
- Construct  $\angle XQR = 60^\circ$
- With Q as center and radius 4 cm, draw an arc to cut QX at P
- Join QP
- Thus,  $\triangle PQR$  is the required triangle

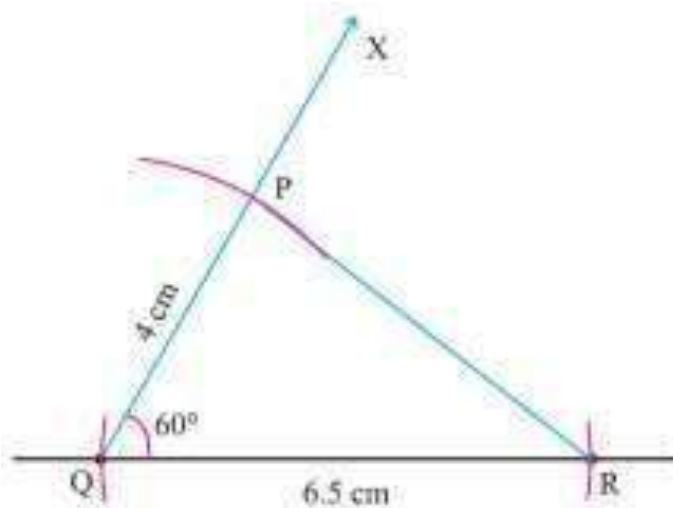


Figure 144: Construction Triangle

When two angles and their included side is given

To construct a  $\triangle ABC$  in which  $\angle B = 60^\circ$ ;  $\angle C = 45^\circ$  and their included side  $BC = 3\text{cm}$

- Draw  $BC = 3\text{cm}$
- Construct  $\angle BCQ = 45^\circ$
- Construct  $\angle PBC = 60^\circ$
- The lines  $BP$  and  $CQ$  at point  $A$
- Thus,  $\triangle ABC$  is the required triangle

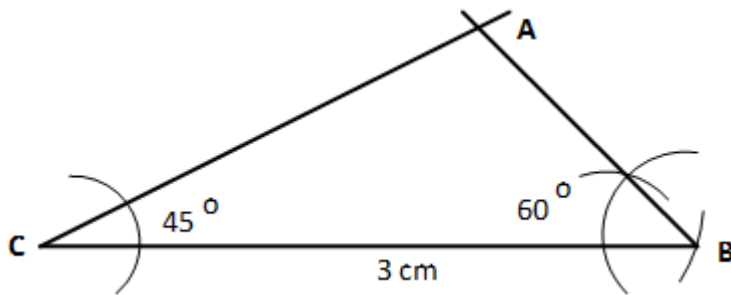


Figure 145: Construction of triangle

## Quadrilaterals

This is a plane figure bounded by four straight sides.

### Types of quadrilaterals

- vii. Square is a quadrilateral with all four sides of equal length and one of its angles (and hence the other three) a right angle.
- viii. Rectangle is a quadrilateral with its opposite sides of equal length and one of its angles (and hence the other three) a right angle.
- ix. Parallelogram is a quadrilateral with opposite sides equal and therefore parallel.
- x. Rhombus is a quadrilateral with all four sides equal.
- xi. Trapezium is a quadrilateral with one pair of opposite sides parallel.
- xii. Trapezoid is a quadrilateral with all four sides and angles unequal.

Steps to Construct a Rectangle:

**Step 1:** Draw a side of given length (say)  $QR = 4.8\text{ cm}$

**Step 2:** Draw side  $QP$  (say) of given length perpendicular to  $QR$  at  $Q$ .

**Step 3:** Draw side  $RS$  (say) of length equal to  $PQ$  and perpendicular to  $QR$  at  $R$ .

**Step 4:** Draw side  $PS$ .

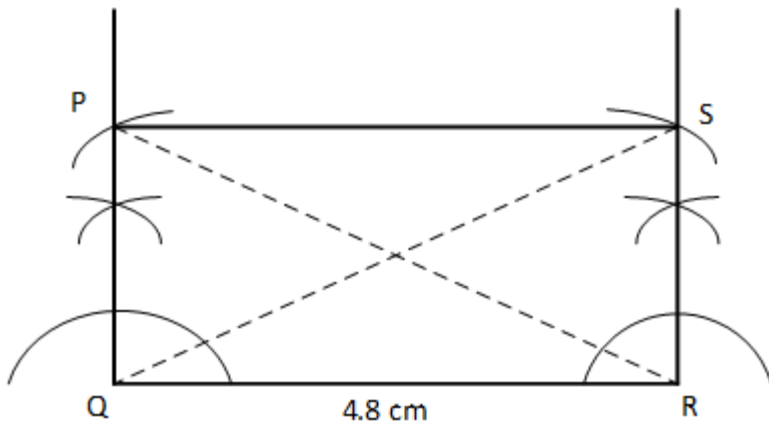


Figure 146: Construct a Rectangle

Steps to Construct a Kite:

**Step 1:** Draw diagonal (say) AY and its perpendicular bisector.

**Step 2:** Draw sides say AL and AZ of given length.

**Step 3:** Draw sides LY and YZ.

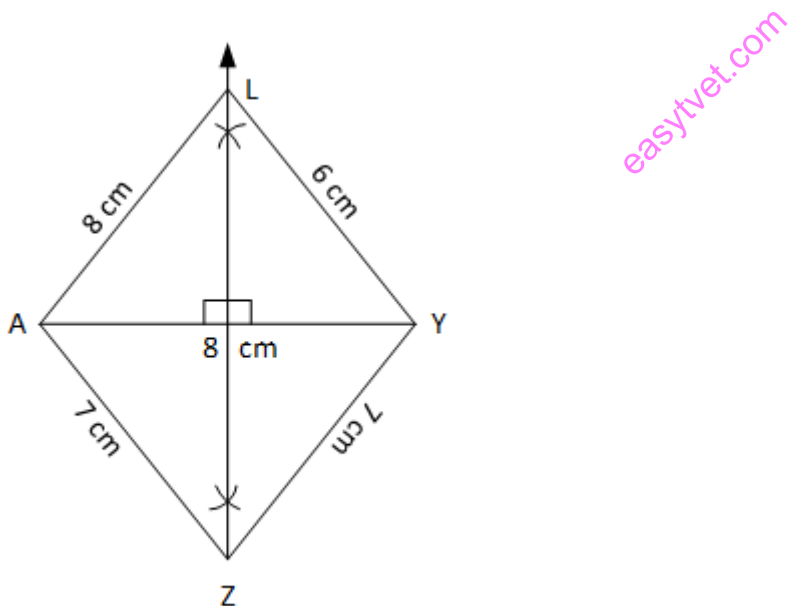


Figure 147: A Kite

### Construction of a Square

a) **Construct a square whose one side is given.**

Construct a square ABCD, given that  $AB = 3$  cm.

**Step 1:** Draw line segment  $AB = 3$  cm.

**Step 2:** Construct  $\angle ABX = 90^\circ$ .

**Step 3:** Draw an arc with B as the center and radius 5 cm, cutting ray BX at C.

**Step 4:** Draw an arc with C as the center and radius 5 cm.

**Step 5:** Draw another arc with A as the center and radius 5 cm, cutting the previous arc at D.

**Step 6:** Join points D, A and D, C. ABCD is the required square.

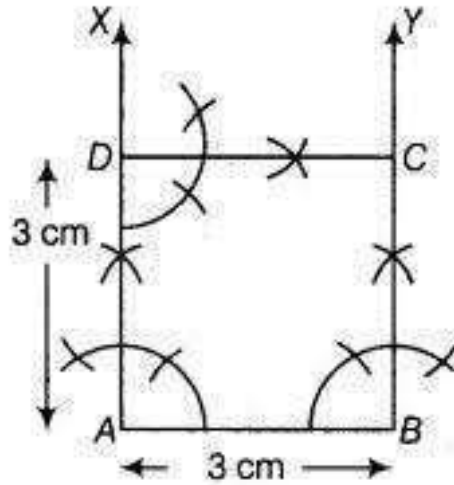


Figure 148: Square given one side

**b) Construct a square whose one diagonal is given.**

Construct a square ABCD, given that  $AC = 5$  cm.

**Step 1:** Draw diagonal  $AC = 5$  cm.

**Step 2:** Draw the perpendicular bisector of AC, meeting AC at O.

**Step 3:** Set the compass for a length equal to OA or OC.

**Step 4:** Draw arcs on the perpendicular bisector with O as the center, without changing the compass setting, cutting the perpendicular bisector at points B and D.

**Step 5:** Join points A, B; points A, D; points B, C and points C, D. ABCD is the required square.

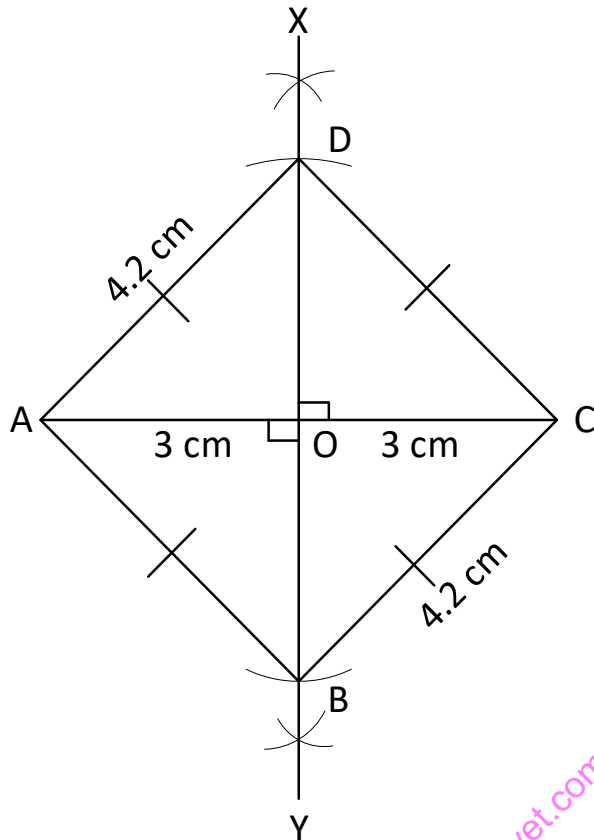


Figure 149: Construct a square whose one diagonal

### Construction of Parallelogram

**Construction of a parallelogram when both the diagonals and the angle between them are given.**

Construct a parallelogram ABCD in which diagonal AC = 8 cm, diagonal BC = 9.2 cm and the angle between them is  $50^\circ$ .

In a parallelogram, diagonals bisect each other:

$$AO = \frac{1}{2} AC = \frac{1}{2} \times 8 = 4 \text{ cm}$$

$$BO = \frac{1}{2} BD = \frac{1}{2} \times 9.2 = 4.6$$

cm

**Step 1:** Draw line segment AC = 8 cm

**Step 2:** Draw the perpendicular bisector of AC.

**Step 3:** Construct.  $\angle DAOX = 50^\circ$ . Extend XO to Y.

**Step 4:** With O as the centre and radius equal to 4.6 cm, draw an arc cutting OX at D, and OY at B.

**Step 5:** Join points A, B, points B, C, points C, D and points A, D. ABCD is the required parallelogram.



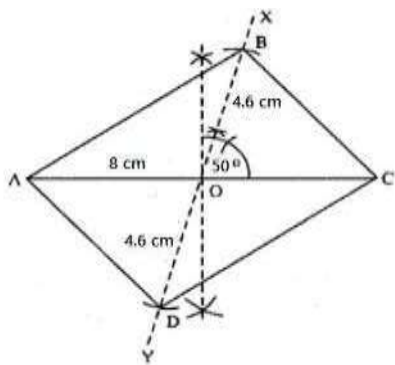


Figure 150: Parallelogram

**b) Construct a rhombus given one side and one angle**

Construct a rhombus ABCD in which AB = 6 cm and Angle A = 60° Steps of construction:

**Step 1:** Draw line segment AB = 6 cm.

**Step 2:** Construct Angle BAX = 60°.

**Step 3:** With A as the center and radius equal to 6 cm, draw an arc on ray AX.

**Step 4:** Mark the point of intersection as D.

**Step 5:** With D as the center and radius equal to 6 cm, draw an arc.

**Step 6:** With B as the center and the same radius, draw another arc such that it intersects the previous arc at C.

**Step 7:** Join points C, D and points C, B.

ABCD is the required rhombus.

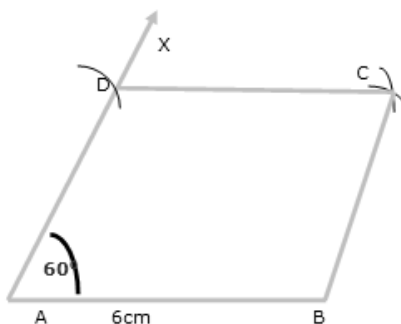


Figure 151: Rhombus

Construction a rhombus given one side and one diagonal:

Construct a rhombus ABCD in which AB = 5.4 cm and AC = 7.4 cm

**Step 1:** Draw line segment AB = 5.4 cm.

**Step 2:** With B as the center and radius equal to 5.4 cm, draw an arc.

**Step 3:** With A as the center and radius equal to 7.4 cm, draw another arc such that it intersects the

previous arc at C.

**Step 4:** Join points B, C and points A, C.

**Step 5:** With A as the center and radius equal to 5.4 cm, draw an arc.

**Step 6:** With C as the center and the same radius, draw another arc such that it intersects the previous arc at D.

**Step 7:** Join points D, A and points D, C.

ABCD is the required rhombus.

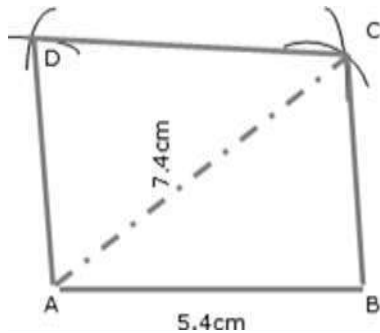


Figure 152: Rhombus

## CIRCLES

### Definition

A circle is a plane figure bounded by a curved line called the circumference, which is always equidistant from the center.

### PROPERTIES OF A CIRCLE

- x. A diameter is a straight line drawn through the center meeting the circumference at both ends.
- xi. A radius is a straight line drawn from the center to the circumference.
- xii. An arc is part of the circumference.
- xiii. A chord is any straight line drawn across the circle meeting the circumference at both ends.
- xiv. A tangent is a straight line which touches the circumference. It is always at right angles to the radius.
- xv. A segment is part of a circle bounded by an arc and a chord.
- xvi. A sector is a part of a circle bounded by two radii and an arc.
- xvii. A quadrant is part of a circle bounded by two radii at right angles and an arc.
- xviii. Concentric circles are circles of the same center but different radii

Eccentric circles are circles of different centers

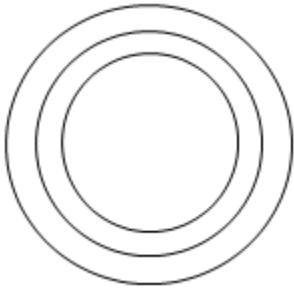


Figure 153: Concentric circles

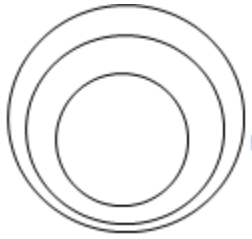


Figure 154: Eccentric circles

## POLYGONS

### Definitions

A polygon is a plane figure bounded by more than four straight sides. Polygons are frequently referred to have particular names. Some of these are listed below

### Polygons

8. A pentagon is a plane figure bounded by five sides
9. A hexagon is a plane figure bounded by six sides
10. A heptagon is a plane figure bounded by seven sides
11. An octagon is a plane figure bounded by eight sides
12. A nonagon is a plane figure bounded by nine sides
13. A decagon is a plane figure bounded by ten sides.
14. A regular polygon is one that has all its sides equal and therefore all its exterior angles equal and all its interior angles equal.

The diameter of that circle is called the diameter of the polygon.

The diagonal of a polygon is the distance from one corner to the corner furthest away from it.

### To construct a regular octagon given the diagonal, i.e. within a given circle Steps

4. Draw the circle and insert a diameter AE.
5. Construct another diagonal CG, perpendicular to the first diagonal.

6. Bisect the four quadrants thus produced to cut the circle in B, D, F, and H. ABCDEFGH is the required octagon.

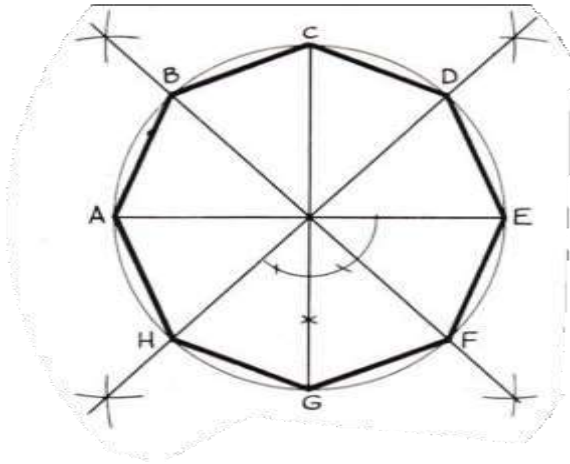


Figure 156: Regular octagon

To construct a rectangular octagon; given the diameter, i.e, within a given square.

4. Construct a square PQSR, length of side equal to the diameter.
5. Draw the diagonals SQ and PR to intersect in T.
6. With centres P, Q, R, and S draw four arcs, radius PT ( $=QT = RT = ST$ ) to cut the square in A, B, C, D, E, F, G and H.

ABCDEFGH is the required octagon.

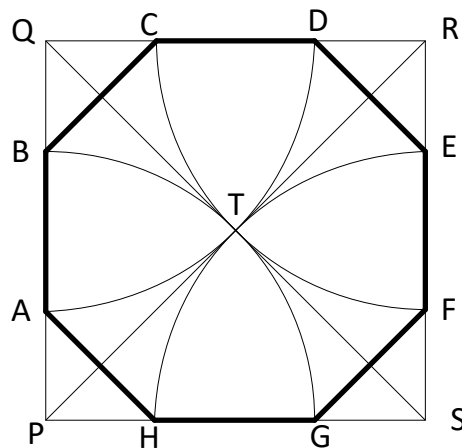


Figure 157: Rectangular octagon

### To construct any given polygon; given the length of a side.

There are three fairly simple way of constructing a regular polygon. Two methods require a simple calculation and the third requires very careful construction if it is to be exact. All three methods are shown. The constructions work for any polygon, and a heptagon (seven sides) has been chosen to illustrate them

#### Method 1

7. Draw a line AB equal in length to one of the sides and produce AB to P.
8. Calculate the exterior angle of the polygon by dividing  $360^{\circ}/7 = 51\ 3^{\circ}/7$ .
9. Draw the exterior angle PBC so that  $BC = AB$ .
10. Bisect AB and BC to intersect in O.
11. Draw a circle, centre O and Radius OA ( $=OB = OC$ ).
12. Step off the sides of the figure from C to D, D to E, etc.  
ABCDEFG is required heptagon.

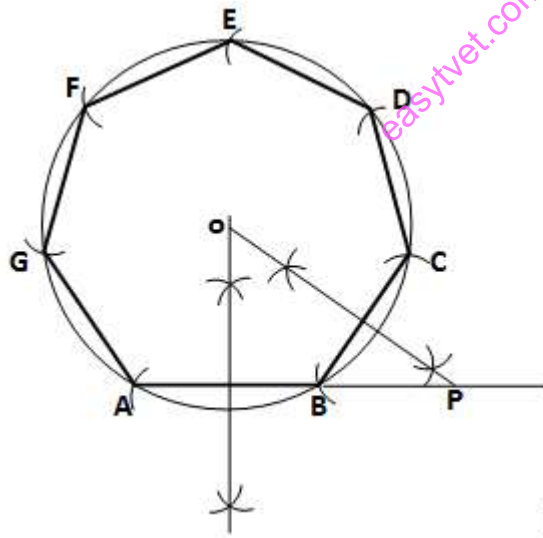


Figure 158: Construction of polygon given the length of a side

#### Method 2

8. Draw a line AB equal in length to one of the sides
9. From a, erect a semi-circle, radius AB to meet BA produced in P.
10. Divide the semi-circle into the same number of equal parts as the proposed polygon has sides. This may be done by trial and error or by calculation ( $180^{\circ}/7 = 25\ 5^{\circ}/7$  for each arc).

11. Draw a line from A to point 2 (For all polygons). This forms a second side to the polygon.
12. Bisect AB and A2 to intersect in O.
13. With center O draw a circle, radius OB (=OA = O2).
14. Step off the sides of the figure from B to C, C to D etc. ABCDEFG is the required heptagon.

### Method 3

9. Draw a line GA equal in length to one of the sides
10. Bisect GA
11. From A construct an angle of  $45^{\circ}$  to intersect the bisector at point 4.
12. From G construct an angle of  $60^{\circ}$  to intersect the bisector at point 6.
13. Bisect between points 4 and 6 to get point 5. Point 4 is the center of the circle containing a square. Point 5 is the center of a circle containing a pentagon. Point 6 is the center of a circle containing a hexagon. By marking off points at similar distance the centers of circles containing any regular polygon can be obtained.
14. Mark off point 7 so that 6 to 7 = 5 to 6 and =4 to 5.
15. With center at point 7 draw a circle, radius 7 to A (=7toG).
16. Step of the sides of the figure from A to B, B to C, etc. ABCDEFG is the required heptagon

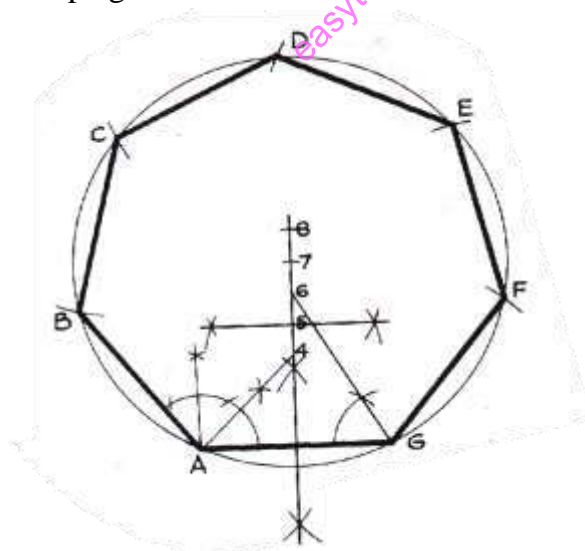


Figure 159: To construction Polygon by 45-60 degrees

To construct a regular polygon given a diagonal i.e. within a given circle

13. Draw the given circle and insert a diameter AM.
14. Divide the diameter into the same number of divisions as the polygon has sides.

15. With center M draw an arc, radius MA. With center A draw another arc of the same radius to intersect the first arc in N.
16. Draw N2 and produce to intersect the circle in B (for any polygon).
17. AB is the first side of the polygon. Step out the other sides BC, CD, etc.
18. ABCDE is the required polygon.
19. draw the given circumference AB
20. Bisect AB in C.
21. With center C, and radius CA, Draw a semi –circle.
22. With center B and radius BC, draw an arc to cut the semi-circle in D.
23. From D draw perpendicular to AB, to cut AB in E.
24. With center E and radius ED draw an arc to cut AB in F. AF is the required diameter. The rest of this chapter shows the construction for finding circles drawn to satisfy certain gain conditions.

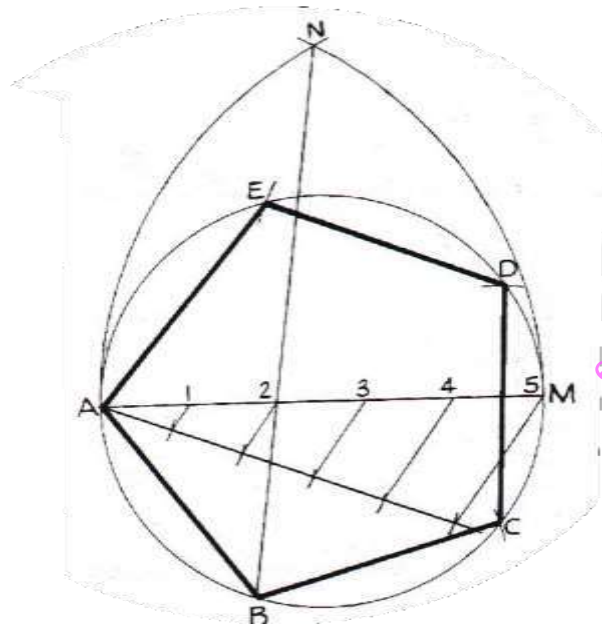


Figure 160: To construct a regular polygon given a diagonal

## Tangency

A tangent to a circle is a straight line that touches the circle at one point.

Construct the different conditions of tangency

5. Common tangent to two equal circles
6. Common interior tangent to two equal circles
7. Common tangent between two unequal circles
8. Common internal tangent between two unequal circles

Construct the following conditions Inscribed, Circumscribed and Escribed

#### iv. Inscribed Circle

Bisect any two of the interior angles to intersect in O. (If the third angle is bisected it should also pass through O.)

O is the center of the inscribed circle. This center is called the in center.

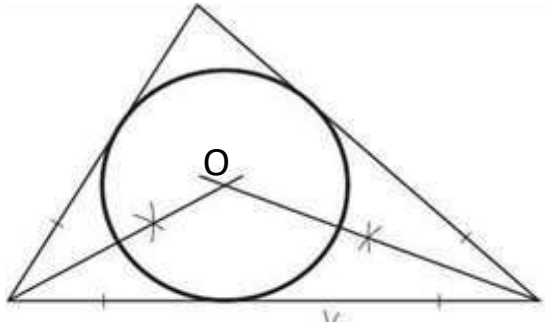


Figure 161: Inscribed Circle

#### v. Circumscribed Circle

Perpendicularly bisect any two sides to intersect in O. (If the third side is bisected it should also pass through O). O is the centre of the circumscribed circle. This centre is called the circumcenter.

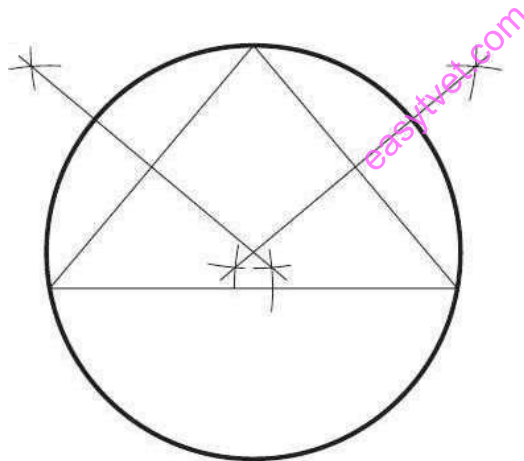


Figure 162: Circumscribed Circle

#### vi. Escribed Circle

An escribed circle is a circle that touches a side and the two adjacent sides produced. Thus, the first step is to produce the adjacent sides.

Bisect the exterior angles thus formed to intersect in O. O is the centre of the escribed circle



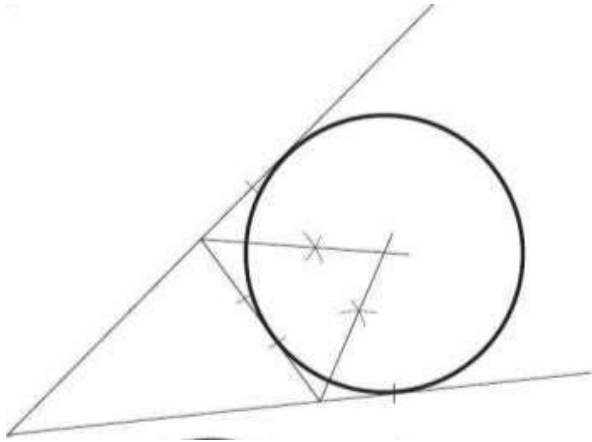


Figure 163: Escribed Circle

## Construction of different angles

### Construction of an angle using compass and ruler

#### To draw an angle equal to a given angle

In this section, we will learn how to construct angles of  $60^\circ$ ,  $30^\circ$ ,  $90^\circ$ ,  $45^\circ$  and  $120^\circ$  with the using a ruler and compasses only.

Construction of some standard angles

#### Construction of an angle of $60^\circ$

In order to construct an angle of  $60^\circ$  with the help of ruler and compasses only, we follow the following steps:

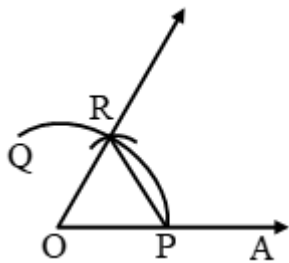


Figure 164: angle of  $60^\circ$

#### Steps of Construction

**Step 1:** Draw a ray OA.

**Step 2:** With centre O and any radius draw an arc PQ with the help of compasses, cutting the ray OA

at P.

**Step 3:** With centre P and the same radius draw an arc cutting the arc PQ at R.

**Step 4:** Join OR and produce it to obtain ray OB.

The angle  $\angle AOB$  so obtained is the angle of measure  $60^\circ$ .

**Justification:** In the above figure, join PR.  
In  $\triangle OPR$ , we have  
 $OP = OR = PR$   
 $\Rightarrow \triangle OPR$  is an equilateral triangle.  
 $\Rightarrow \angle POR = 60^\circ$   
 $\Rightarrow \angle AOB = 60^\circ$  [ $\because \angle POR = \angle AOB$ ]

(ii) **Construction of an Angle of  $30^\circ$**

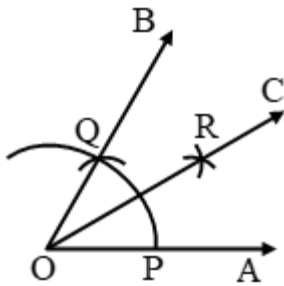


Figure 165: Angle of  $30^\circ$

easytvet.com

**Steps of Construction:**

**Step 1:** Draw  $\angle AOB = 60^\circ$  by using the steps mentioned above.

**Step 2:** With centre O and any convenient radius draw an arc cutting OA and OB at P and Q respectively.

**Step 3:** With centre P and radius more than  $\frac{1}{2}(PQ)$ , draw an arc in the interior of  $\angle AOB$ .

**Step 4:** With centre Q and the same radius, as in step III, draw another arc intersecting the arc in step III at R.

**Step 5:** Join OR and produce it to any point C.

**Step 6:** The angle  $\angle AOC$  is the angle of measure  $30^\circ$ .

(iii) Construction of An Angle of  $90^{\circ}$

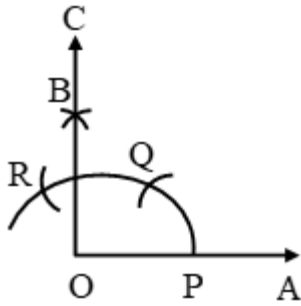


Figure 166: An Angle of  $90^{\circ}$

**Steps of Construction:**

**Step 1:** Draw a ray OA.

**Step 2:** With O as centre and any convenient radius, draw an arc, cutting OA at P.

**Step 3:** With P as centre and the same radius, an arc cutting the arc drawn in step 2 at Q.

**Step 4:** With Q as centre and the same radius as in steps 2 and 3, draw an arc, cutting the arc drawn in step 2 at R.

**Step 5:** With R as centre and the same radius, draw an arc.

**Step 6:** With Q as centre and the same radius, draw an arc, cutting the arc drawn in step 5 at B.

**Step 7:** Draw OB and produce it to C.  $\angle AOC$  is the angle of measure  $90^{\circ}$ .

(iv) Construction of An Angle of  $45^{\circ}$

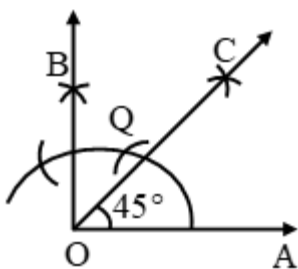


Figure 167: An Angle of  $45^{\circ}$

**Steps of Construction:**

**Step 1:** Draw  $\angle AOB = 90^{\circ}$  by following the steps given above.

**Step 2:** Draw OC, the bisector of  $\angle AOB$ .

The angle  $\angle AOC$  so obtained is the required angle of measure  $45^{\circ}$ .

(v) Construction of An Angle of  $120^{\circ}$

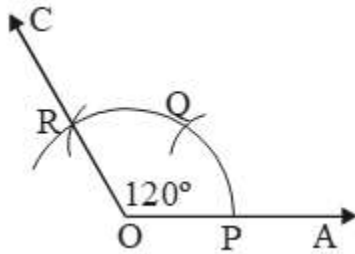


Figure 168: An Angle of  $120^{\circ}$

**Steps of Construction:**

- Step 1:** Draw a ray OA.
- Step 2:** With O as centre and any convenient radius, draw an arc cutting OA at P.
- Step 3:** With P as centre and the same radius draw an arc, cutting the first arc at Q.
- Step 4:** With Q as centre and the same radius, draw an arc, cutting the arc drawn in step II at R.
- Step 5:** Join OR and produce it to any point C.  $\angle AOC$  so obtained is the angle of measure  $120^{\circ}$

<https://www.aplustopper.com/construction-of-angles-using-compass-ruler/>

**Measurement of different angles**

**Different types of angles**

**Angle:**

Two rays with a common end point form an angle. OA, OB is rays & O is end point.

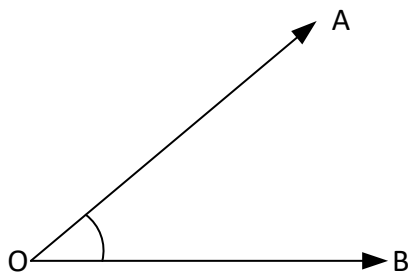


Figure 169: Rays & end point of an angle

**Types of Angles**

In geometry, angles can be classified according to the size (or magnitude) of the angle.

- 8. **Right angle:** An angle, whose measure is  $90^{\circ}$ , is called a right angle. Two lines that meet at a right angle are said to be perpendicular.

9. **Acute angle:** An angle, whose measure is less than  $90^\circ$ , is called an acute angle.
10. **Obtuse angle:** An angle, whose measure is greater than  $90^\circ$  and less than  $180^\circ$ , is called an obtuse angle.
11. **Straight angle:** An angle whose measure is  $180^\circ$  is called a straight angle.
12. **Reflex angle:** An angle, whose measure is more than  $180^\circ$  but less than  $360^\circ$ , is called a reflex angle.
13. **Complete angle:** An angle whose measure is  $360^\circ$  is called a complete angle.
14. **Zero angles:** An angle whose measure is  $0^\circ$  is called a zero angle.

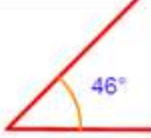
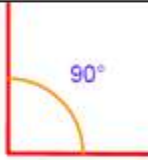
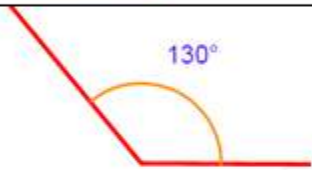
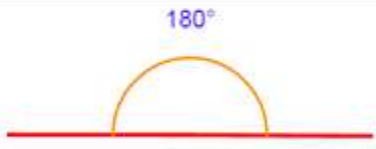
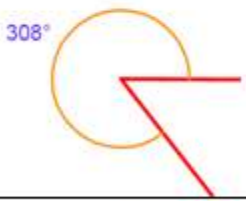
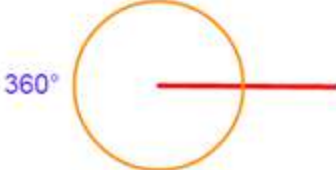
| Type of Angle  | Description   | Example   |
|----------------|---|---|
| Acute Angle    | An angle that is less than $90^\circ$                               |  A diagram showing an acute angle of $46^\circ$ formed by two rays meeting at a vertex. The angle is marked with a yellow arc and the value $46^\circ$ in blue text.  |
| Right Angle    | An angle that is exactly $90^\circ$                                 |  A diagram showing a right angle of $90^\circ$ formed by two perpendicular rays meeting at a vertex. The angle is marked with a yellow arc and the value $90^\circ$ in blue text.   |
| Obtuse Angle   | An angle that is greater than $90^\circ$ and less than $180^\circ$  |  A diagram showing an obtuse angle of $130^\circ$ formed by two rays meeting at a vertex. The angle is marked with a yellow arc and the value $130^\circ$ in blue text.  |
| Straight Angle | An angle that is exactly $180^\circ$                                |  A diagram showing a straight angle of $180^\circ$ formed by two rays meeting at a vertex and extending in opposite directions to form a straight line. The angle is marked with a yellow arc and the value $180^\circ$ in blue text. |
| Reflex Angle   | An angle that is greater than $180^\circ$ and less than $360^\circ$ |  A diagram showing a reflex angle of $308^\circ$ formed by two rays meeting at a vertex. The angle is marked with a yellow arc and the value $308^\circ$ in blue text.  |
| Full Angle     | An angle that is exactly $360^\circ$                                |  A diagram showing a full angle of $360^\circ$ formed by two rays meeting at a vertex and extending in opposite directions to form a complete circle. The angle is marked with a yellow arc and the value $360^\circ$ in blue text.   |

Table 14: types of angles

**Measure of an angle:**  
 The amount of turning from OA to OB is called the measure of  $\angle AOB$ , written as  $m \angle AOB$ . An angle is measured in degrees denoted by  $^{\circ}$ .

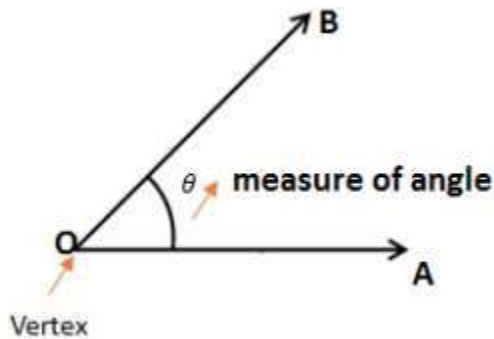


Figure 170: Measure of an angle

**An angle of  $360^{\circ}$ :**

If a ray OA starting from its original position OA, rotates about O, in the anticlockwise direction and after making a complete revolution it comes back to its original position, we say that it has rotated through 360 degrees, written as  $360^{\circ}$ .

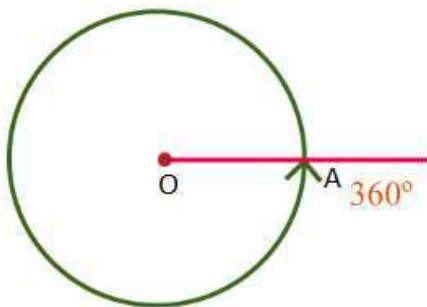


Figure 171: Angle of  $360^{\circ}$

<https://www.aplustopper.com/different-types-of-angles/>

## A PROTRACTOR

**Protractor:** The Protractor is a circular or semi-circular tool for measuring angles. The units of measurement used are degrees. Some protractors are simple half-discs. More advanced protractors

usually have one or two swinging arms, which can be used to help measuring angles.

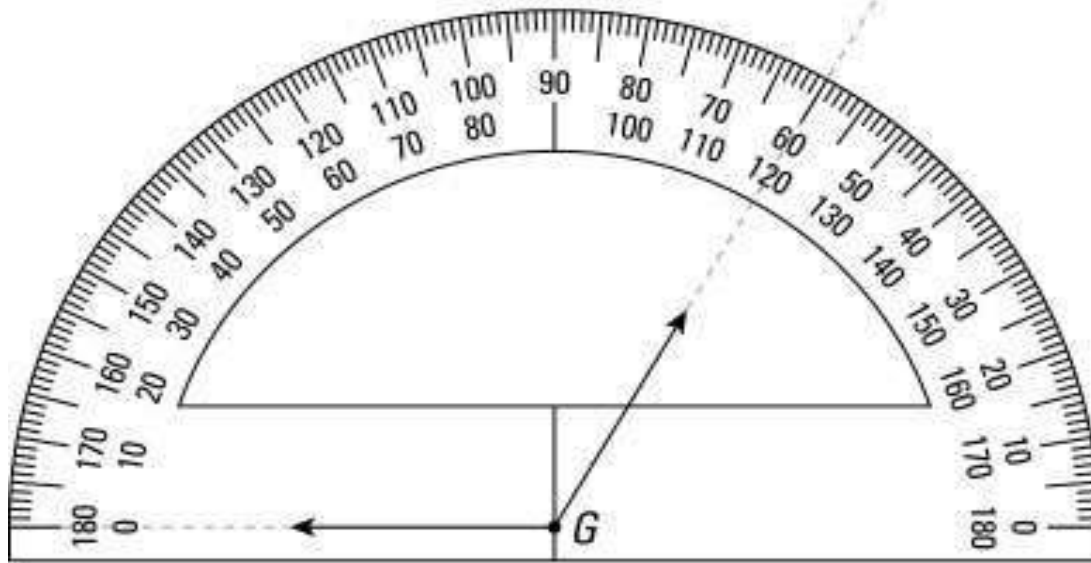


Figure 172: The handy-dandy protractor.

### How to use a protractor

1. Place the notch or center point of your protractor at the point where the sides of the angle meet (the vertex).
2. Place the protractor so that one of the lines of the angle you want to measure reads zero (that's actually  $0^\circ$ ).
3. Read the number off the protractor where the second side of the angle meets the protractor.

### Bisection of different angles and lines

2. Bisect a given angle

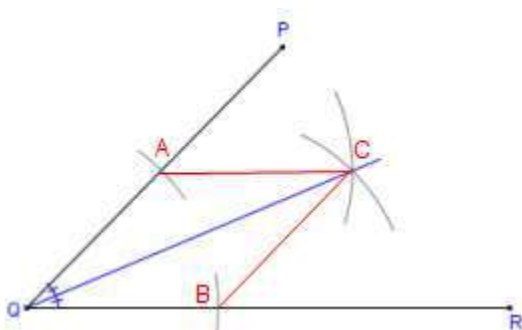


Figure 173: Bisection of an angle

- i. Draw line QP and QR making the given angle.

- ii. With centre Q and any convenient radius R draw an arc intersecting the sides at A and B.
- iii. With centres A and B and radius larger than half the chord length AC, draw arcs intersecting at C.
- iv. Join QC,  $\angle PQC = \angle RQC$

### Bisecting a Line

Draw a line segment AB of the desired length by using a graduated ruler.

4. With A as centre and radius more than half of AB, draw arcs, one on each side of AB.
5. With B as centre and the same radius as in step 2, draw arcs cutting the arcs drawn in step 2 at C and E respectively.
6. Draw the line segment with C and E as end-points. Suppose it meets AB at D. Then bisects the line segment AB.

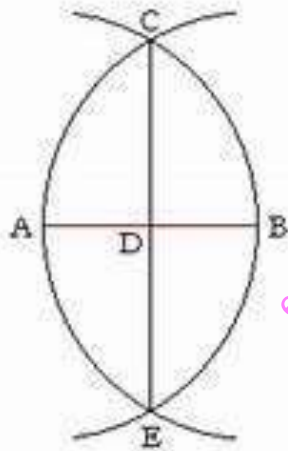


Figure 174: Bisection of line

### Standard drawing conventions

In the construction industry all drawings are carried out to a British Standard referred to as BS 1192.



## Dimensioning

Drawing of a component, in addition to providing complete shape description, must also furnish information regarding the size description. These are provided through the distances between the surfaces, location of holes, nature of surface finish, type of material, etc. The expression of these features on a drawing, using lines, symbols, figures and notes is called dimensioning.

## Principles of Dimensioning

Some of the basic principles of dimensioning are given below.

14. All dimensional information necessary to describe a component clearly and completely shall be written directly on a drawing.
15. Each feature shall be dimensioned once only on a drawing, i.e. dimension marked in one view need not be repeated in another view. Never repeat a dimension.
16. Dimension should be placed on the view where the shape is best seen
17. As far as possible, dimensions should be expressed in one unit only preferably in millimeters, without showing the unit symbol (mm).
18. As far as possible dimensions should be placed outside the view.
19. Dimensions should be taken from visible outlines rather than from hidden lines.
20. No gap should be left between the feature and the start of the extension line.
21. Crossing of center lines should be done by a long dash and not a short dash.
22. Circles are usually dimensioned using the measurement of their diameter.
23. There are dimension lines and projection lines. Projection lines are thin lines, which begin 1mm from the drawing and extend beyond the last dimension line by 2mm. They define the area being dimensioned and never touch the actual object. Dimension lines are also thin lines with arrows placed at each end that touch the projection line.
24. Each dimension line starts 10mm from the object and is then 10mm apart. The smaller dimensions are placed closer to the object. Longest dimension lines are furthest away from a view (for example, total height).
25. Each Dimension Line has an arrowhead that can be open or closed. Arrowheads touch (but do not cross) projection lines.
26. Dimension numbers can be written vertically or horizontally. The selection of vertical or horizontal writing must be consistent throughout the drawing.

*Dimensions should be shown as follows:*

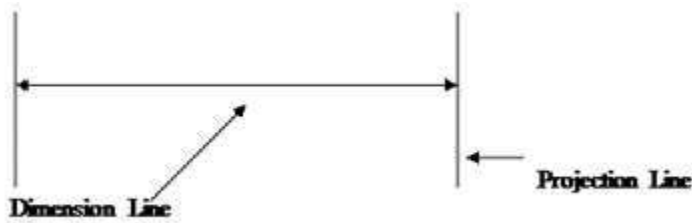


Figure 175: Dimension line and projection line

**The conventions relating to dimensions are as follows:**

- State dimensions once only.
- Place in the most appropriate view.
- Keep related dimensions on the same view.
- Select the functional dimensions.
- Avoid redundant dimensions.

Give metric dimensions to the least number of significant figures, for example;

2.5 not 2.50

3 not 3.0

Dimensions less than 1 are expressed with a zero preceding the decimal point; 0.5 not 5

Letters and Numbers

*All drawings require some form of lettering and numbers. The principles to remember are:*

They should be legible and clear – especially numbers, as they often have to be read on their own.

They should be of a suitable size and not less than 3mm tall. Title blocks and relative information are usually larger.

They should be correctly spaced and positioned. Notes and captions should be placed so that they can be read in the same direction as in the title block. In other words it should not be necessary to turn a drawing on its side to read the information.

Notes should be grouped together and not spread over the drawing.

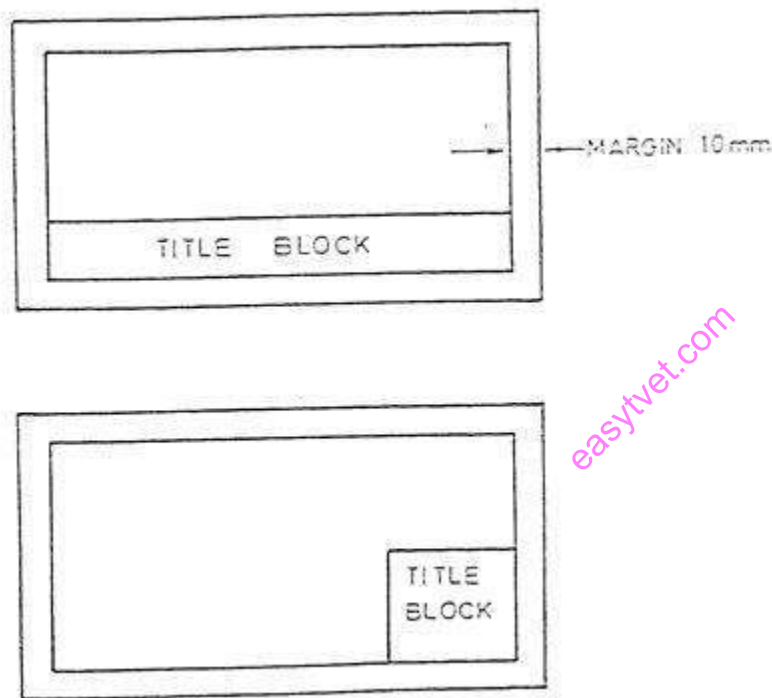
Underlining is not recommended.

Borders and Title Blocks

*One of the most important features of any drawing is the border and title block. The border (or margin) is a line which follows the outer edge of the drawing and is usually 10 or 20mm inside it. This margin is very important because everything inside it forms part of any contract. The 'Title Block' is locked within the boarder and contains information such as:*

- x. Project title
- xi. The subject
- xii. The date of the original drawing.
- xiii. Dates of any revisions.
- xiv. Job Number.
- xv. Drawing Number.
- xvi. Scale.
- xvii. The name of the person who drew up the drawing.
- xviii. Name of architects, consultant engineers or surveyors.

*Title Blocks are usually located along the bottom or sides of drawings as shown below:*



*Figure 176: Title block styles*

### **Scales**

A scale can be used to increase the detail of a small object or to accurately represent a large object on a smaller piece of paper. The majority of scaled work done in the construction industry is to reduce objects to a smaller more suitable size that will fit on a sheet of paper. The list below shows the scales used in BS 1192:

**Block Plans** 1:2500. These show the outlines of buildings and may also indicate roads, railway lines or rivers.

**Site Plans:** Between 1:500 and 1:2500 .Although often drawn at the same scale as the block plan site plans only give details relevant to the actual project. These details could relate to landscaping arrangements or show underground drainage pipe-work.

**General Location Drawings** 1:200 or 1:100. These drawings can show pipe runs within the building and the location of radiators and sanitary fixtures.

When details of boiler houses or plant rooms are given the scale may increase to 1:50. This enables greater detail to be shown. Where particular detail is necessary the scale could be as high as 1:20 or 1:10. This could be in the case of a bracket or support for a piece of equipment.

## LOCI

A locus (Plural loci) is the path traced out by a point which moves under given definite conditions or rules. You may not have been aware of it, but you have met loci many times before. One of the most common loci is that of a point which moves so that its distance from another fixed point remains constant: this produces a circle. Another locus that you know is that of a point which moves so that its distance from a line remains constant: this produces parallel lines.

The problems of loci can take several different forms. One important practical application in building is in the setting out of curves such as parabolic, hyperbolic and circular curves. Another important application of loci in engineering is finding the path traced out by points on mechanisms. This may be simply to see if there is sufficient clearance around a mechanism.

## ELLIPSE

### Definition

An ellipse is the locus of a point which moves so that distance from a fixed point (called the focus) bears a constant ratio, always less than 1, to its perpendicular distance from a straight line called the directrix). An ellipse has two foci and two and two directrices. Figure 3 shows how to draw an ellipse given the relative positions of and the directrix, and the eccentricity. In this case the focus and the directrix are 20mm apart and the eccentricity is  $\frac{4}{3}$

The first point to plot is the one that lies between the focus and the directrix. This is done by dividing DF in the same ratio as the eccentricity  $\frac{4}{3}$ . The other end of the ellipse, point is found by working out the simple algebraic sum shown on

The condition for the locus is that it is always  $\frac{3}{4}$  as far from the focus as it is from the directrix. It is therefore  $\frac{3}{4}$  as far from the directrix as it is from the focus. Thus. If the point is 30mm from F, it is  $40\frac{3}{4}$ mm from the directrix; if the point is 20mm from F, it is  $\frac{3}{4} \times 20$ mm from the directrix; if the

point is 30mm from F, it is  $\frac{3}{4} \times 30\text{mm}$  from the directrix. The intersections of radii drawn from F and line drawn parallel to the directrix, their distance from the directrix being proportional to the radii, give the outline of the ellipse. These points are joined together with a neat freehand curve.

### General method of construction of an ellipse

To construct an ellipse when the distance of the focus from the directrix is equal to 50 mm and eccentricity is  $\frac{2}{3}$

- xi. Draw any vertical line AB as directrix.
  - xii. At any point C on it, draw the axis perpendicular to the AB (directrix).
  - xiii. Mark a focus F on the axis such that  $CF = 50 \text{ mm}$ .
  - xiv. Divide CF into 5 equal divisions (sum of numerator and denominator of the eccentricity
  - xv. Mark the vertex V on the third division-point from C.  
Thus, eccentricity,  $e = VF/VC = \frac{2}{3}$
  - xvi. A scale may now be constructed on the axis (as explained below), which will directly give the distances in the required ratio
  - xvii. At V, draw a perpendicular VE equal to VF. Draw a line joining C and E.  
thus, in triangle CVE,  $VE/VC = VF/VC = \frac{2}{3}$
  - xviii. Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at  $1'$ .
  - xix. With centre F and radius equal to  $1-1'$ , draw arcs to intersect the perpendicular through 1 at points  $P_1$  and  $P'_1$ . These are the points on the ellipse, because the distance of  $P_1$  from AB is equal to  $C1$ ,
  - xx.  $P_1F = 1 - 1'$
- and

$$\frac{1 - 1'}{C1} = \frac{VF}{VC} = \frac{2}{3}$$

Similarly, mark points 2, 3 etc. on the axis and obtain points  $P_2$  and  $P'_2$ ,  $P_3$  and  $P'_3$  etc. (x)

### Exercise

Draw the ellipse through these points. It is a closed curve having two foci and two directrices.

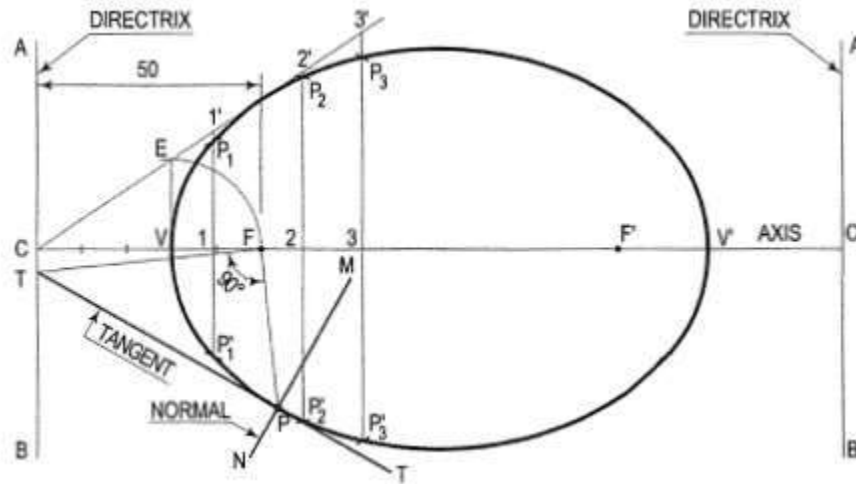


Figure 177: General method of construction of an ellipse

**To construct an ellipse, given the major and minor axes.**

The ellipse is drawn by, first determining a number of points through which it is known to pass and then, drawing a smooth curve through them, either freehand or with a french curve. Larger the number of points, more accurate the curve will be.

**Concentric circles method**

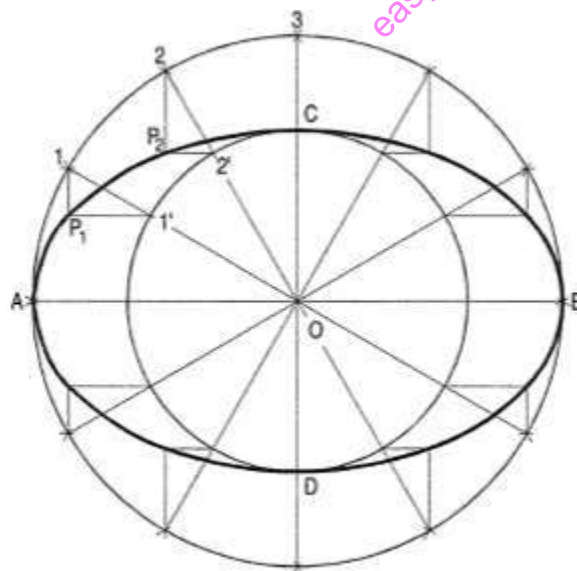


Figure 178: Concentric circle method

**Concentric circle method**

- vii. Draw the major axis AB and the minor axis CD intersecting each other at O.

- viii. With centre O and diameters AB and CD respectively, draw two circles.
- ix. Divide the major-axis-circle into a number of equal divisions, say 12 and mark points 1, 2 etc. as shown.
- x. Draw lines joining these points with the centre O and cutting the minor-axis-circle at points 1', 2' etc. (v) Through point 1 on the major-axis-circle, draw a line parallel to CD, the minor axis.
- xi. Through point 1' on the minor-axis-circle, draw a line parallel to AB, the major axis. The point P<sub>1</sub>, where these two lines intersect is on the required ellipse.
- xii. Repeat the construction through all the points. Draw the ellipse through A, P<sub>1</sub>, P<sub>2</sub> ..... etc.

**Oblong method**

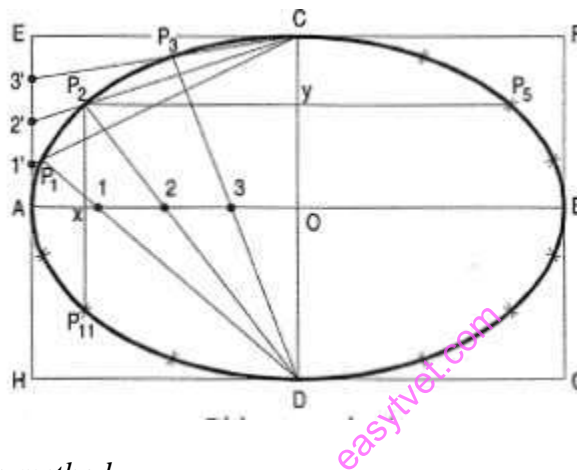


Figure 179: Oblong method

- (viii) Draw the two axes AB and CD intersecting each other at O.
- (ix) Construct the oblong EFGH having its sides equal to the two axes.
- (x) Divide the semi-major-axis AO into a number of equal parts, say 4, and AE into the same number of equal parts, numbering them from A as shown.
- (xi) Draw lines joining 1', 2' and 3' with C.
- (xii) From D, draw lines through 1, 2 and 3 intersecting C<sub>1</sub>, C<sub>2</sub> and C<sub>3</sub> at points P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> respectively.
- (xiii) Draw the curve through A, P<sub>1</sub> ..... C. It will be one quarter of the ellipse.
- (xiv) Complete the curve by the same construction in each of the three remaining quadrants.

As the curve is symmetrical about the two axes, points in the remaining quadrants may be located by drawing perpendiculars and horizontals from P<sub>1</sub>, P<sub>2</sub> etc. and making each of them of equal length on both the sides of the two axes. For example, P<sub>2</sub>x = x P<sub>11</sub> and P<sub>2</sub>y = yP<sub>5</sub>.

## Trammel method

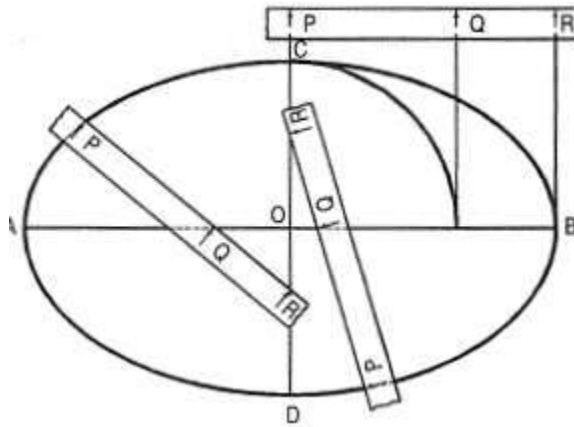
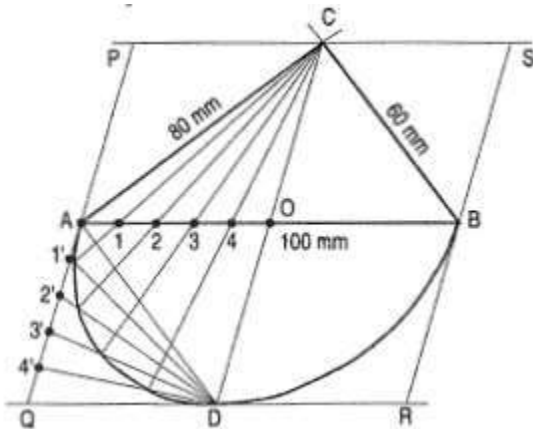


Figure 180: Trammel method

- iii. Draw the two axes AB and CD intersecting each other at O. Along the edge of a strip of paper which may be used as a trammel, mark PQ equal to half the minor axis and PR equal to half the major axis.
- iv. Place the trammel so that R is on the minor axis CD and Q on the major axis AB. Then P will be on the required ellipse. By moving the trammel to new positions, always keeping R on CD and Q on AB, obtain other points. Draw the ellipse through these points.

## Learning activity

2. ABC is a triangle such that AB = 100 mm, AC = 80 mm and BC = 60 mm. Draw an ellipse passing through points A, B and C. (figure below)



- vi. Draw horizontal line AB = 100 mm. Take A as centre draw an arc of 80 mm. Similarly B as centre and the radius equal to 60 mm, draw the arc such that it intersects previously drawn arc at the point C. Join ABC to complete triangle.
- vii. Mark the mid point of AB such that OA = OB = 50 mm. Join OC and extend CO such that CO = OD.



- viii. Draw parallel lines from C and D to the line AB. Similarly draw parallel lines from A and B to the line CD and complete the rhombus (PQRS).
- ix. Divide AO into convenient number of equal parts  $A1 = 12 = 23 = 34 = 40$  and AQ to same number of equal parts  $A1' = 1' 2' = 2' 3' = 3' 4' = 4' Q$ . Join A, 1', 2', 3', 4' with D. Join C1 and extend it to intersect line 01'. Similarly join C2, C3, C4 and extend it to intersect 02', 03', 04' respective. Draw smooth curve passing through all intersection.
- x. Complete the ellipse by above method for the remaining part.

## PARABOLA

Use of parabolic curves is made in arches, bridges, sound reflectors, light reflectors etc. Mathematically a parabola can be described by an equation  $y^2 = 4ax$  or  $x^2 = 4ay$ .

### General method of construction of a parabola

To construct a parabola when the distance of the Focus from the directrix is 50 mm.

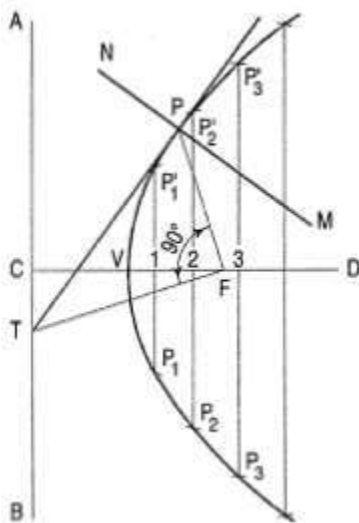


Figure 181: Parabola

Directrix and focus

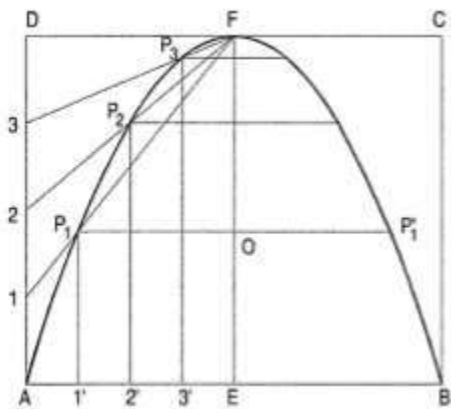
- vii. Draw the directrix AB and the axis CD.
- viii. Mark focus F on CD, 50 mm from C.
- ix. Bisect CF in V the vertex (because eccentricity = 1).
- x. Mark a number of points 1, 2, 3 etc. on the axis and through them, draw perpendiculars to it.
- xi. With centre F and radius equal to C1, draw arcs cutting the perpendicular through 1 at P<sub>1</sub> and P'<sub>1</sub>.  
Similarly, locate points P<sub>2</sub> and P'<sub>2</sub>, P<sub>3</sub> and P'<sub>3</sub> etc. on both the sides of the axis.

- xii. Draw a smooth curve through these points. This curve is the required parabola. It is an open curve.

#### Rectangle method

To construct a parabola given the base and the axis.

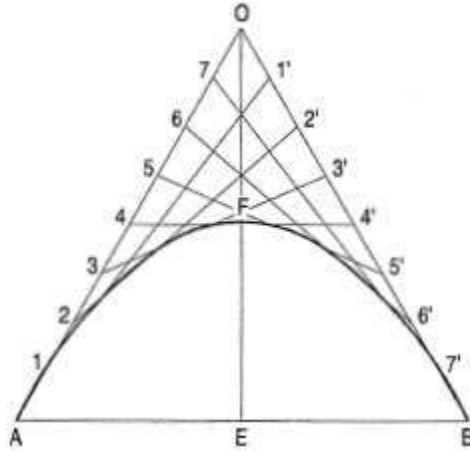
- (vii) Draw the base AB.
- (viii) At its mid-point E, draw the axis ff at right angles to AB.
- (ix) Construct a rectangle ABCD, making side BC equal to ff.
- (x) Divide AE and AD into the same number of equal parts and name them as shown (starting from A).
- (xi) Draw lines joining F with points 1, 2 and 3. Through 1', 2' and 3', draw perpendiculars to AB intersecting F1, F2 and F3 at points P1, P2 and P3 respectively.
- (xii) Draw a curve through A, P1, P2 etc. It will be a half parabola. Repeat the same construction in the other half of the rectangle to complete the parabola. Or, locate the points by drawing lines through the points P1, P2 etc. parallel to the base and making each of them of equal length c on both the sides of ff, e.g. P1O = OP'1. AB and EF are called the base and the axis respectively of the parabola.



Rectangular method

#### Tangent method

- (v) Draw the base AB and the axis ff. (These are taken different from those in method I.)
- (vi) Produce ff to O so that EF = FO.
- (vii) Join O with A and B. Divide lines OA and OB into the same number of equal parts, say 8.
  - (iv) Mark the division-points as shown in the figure.
- (viii) Draw lines joining 1 with 1', 2 with 2' etc. Draw a curve starting from A and tangent to lines 1-1', 2-2' etc. This curve is the required parabola.



*Figure 182: Tangent method of constructing parabola*

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## HYPERBOLA

### Definition

A hyperbola is the locus of a point which moves so that its distance from a fixed point (called the focus) bears a constant ratio, always greater than 1, to its perpendicular distance from a straight line (called the directrix).

Figure 45 shows how to draw a hyperbola given the relative positions of the focus and the directrix and the eccentricity ( $3/2$ ). The first point to plot is the one that lies between the focus and the directrix.

This is done by dividing the distance between them in the same ratio as the eccentricity.  $3:2$ .

The condition for the locus is that it is always  $2/3$  as far from the directrix as it is from the focus. Thus, if the point is 15mm from the focus, it is  $2/3 \times 15\text{mm}$  from the directrix; if it is 20mm from the focus, it is  $2/3 \times 20\text{mm}$  from the directrix. This is continued for as many points as may be required.

Use of hyperbolic curves is made in cooling towers, water channels etc.

### Rectangular hyperbola

It is a curve traced out by a point moving in such a way that the product of its distances from two fixed lines at right angles to each other is a constant. The fixed lines are called asymptotes.

This curve graphically represents the Boyle's Law, viz.  $P \times V = a$ ,  $P$  = pressure,  $V$  = volume and  $a$  is constant. It is also useful in design of water channels.

### General method of construction of a hyperbola

Mathematically, we can describe a hyperbola by  $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$

(figure 44): Construct a hyperbola, from the directrix is 65 mm and eccentricity is  $f$

- iv. Draw the directrix AB and the axis CD.
- v. Mark the focus F on CD and 65 mm from C.
- vi. Divide CF into 5 equal divisions and mark V the vertex, on the second division from C.

$$\text{Thus, eccentricity} = \frac{VF}{VC} = \frac{3}{2}$$

**To construct the scale for the ratio draw a line VE perpendicular to CD such that VE = VF. Join C with E.**

$$\text{Thus, in triangle CVE, } \frac{VE}{VC} = \frac{VF}{VC} = \frac{3}{2}$$

- v. Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at 1

- vi. With centre F and radius equal to 1-1', draw arcs intersecting the perpendicular through 1 at P<sub>1</sub> and P'<sub>1</sub>.
- vii. Similarly, mark a number of points 2, 3 etc. and obtain points P<sub>2</sub> and P'<sub>2</sub>, P<sub>3</sub> and P'<sub>3</sub> etc.
- viii. Draw the hyperbola through these points.

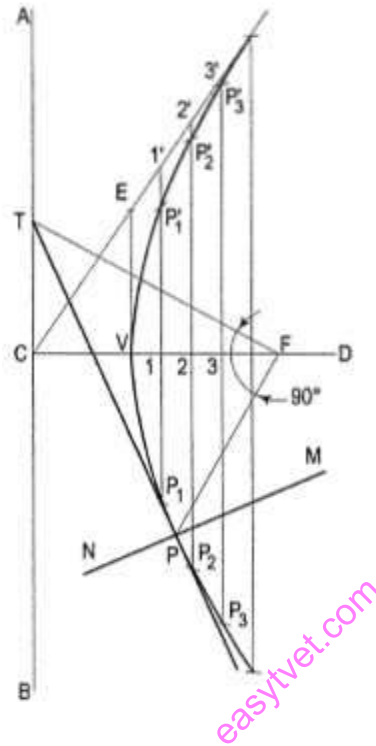
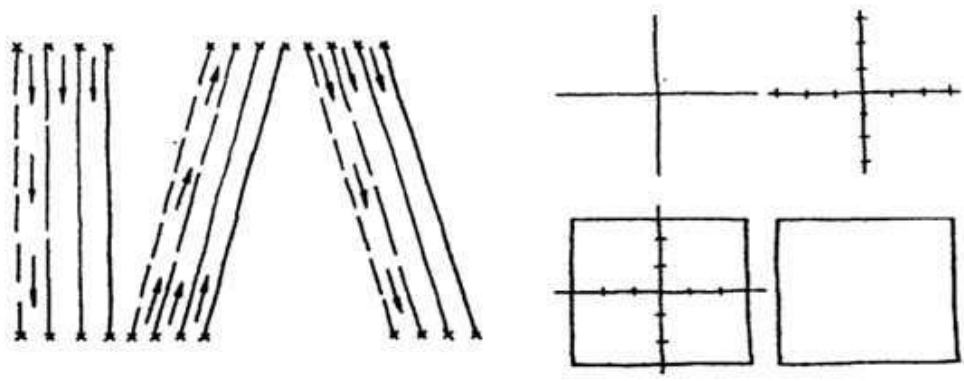


Figure 183

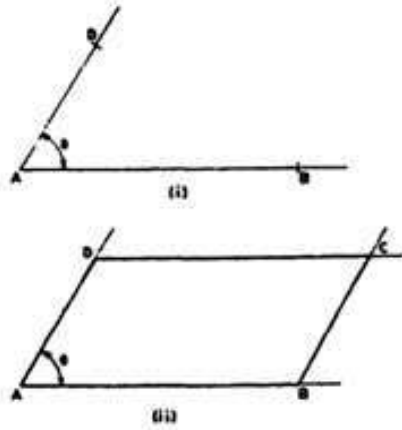
### Freehand Sketching

Freehand sketching is one of the effective methods to communicate ideas irrespective of the branch of study. The basic principles of drawing used in freehand sketching are similar to those used in drawings made with instruments.

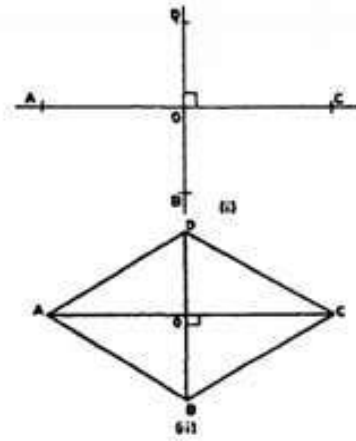


Sketching a Square

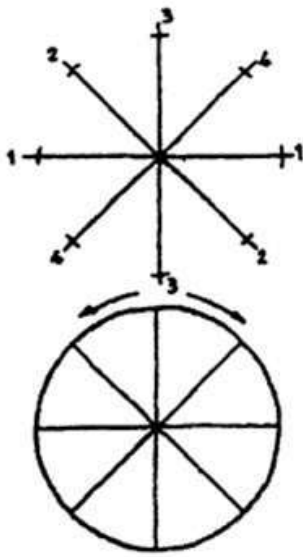
Sketching Straight Lines



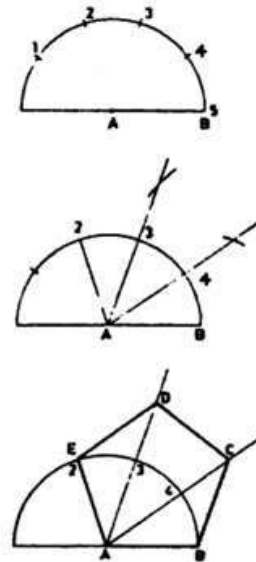
Sketching a Rhombus



Sketching a Parallelogram

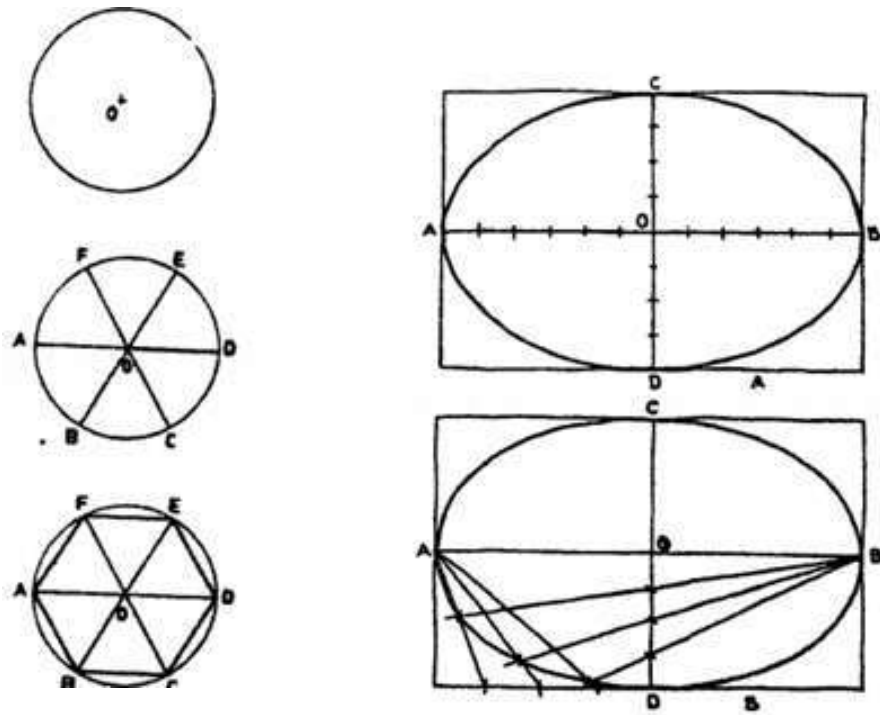


Sketching a Pentagon



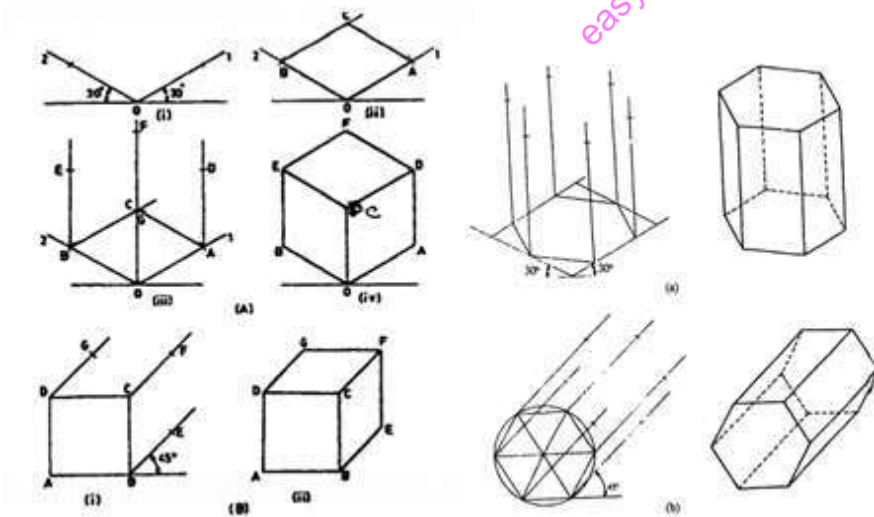
Sketching a Circle

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Sketching an Ellipse

Sketching a Hexagon



Sketching a Hexagonal Prism

Sketching a Cube

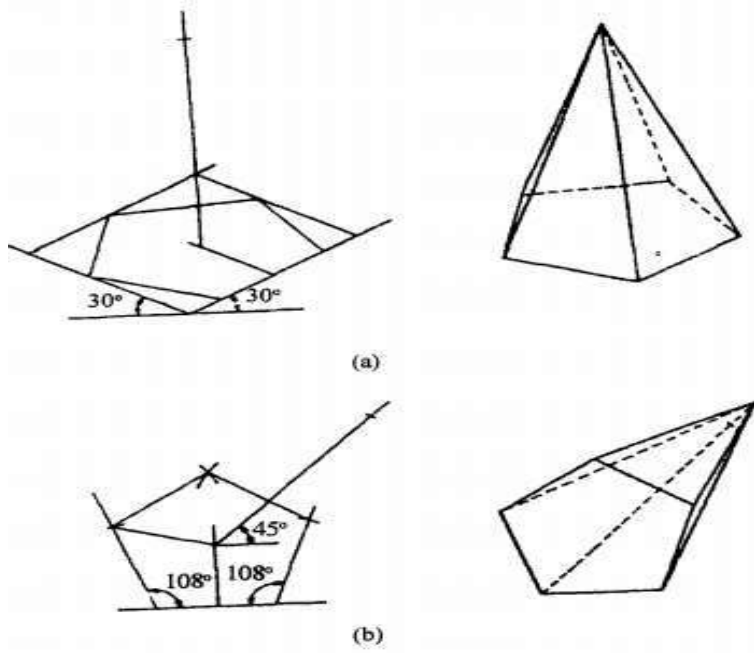
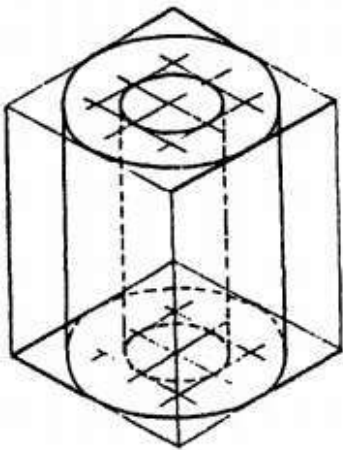
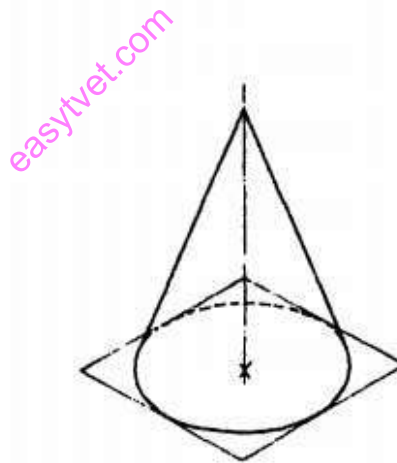


Figure 184: Sketching a Pentagonal Pyramid

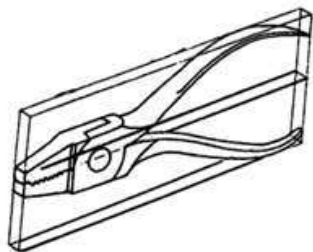


Sketching a Cone

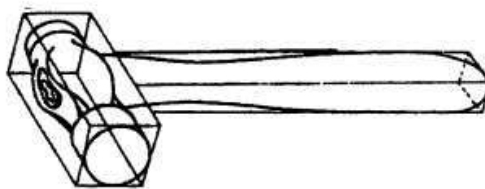


Sketching a Hollow Cylinder





*Sketching a Ball Peen Hammer*



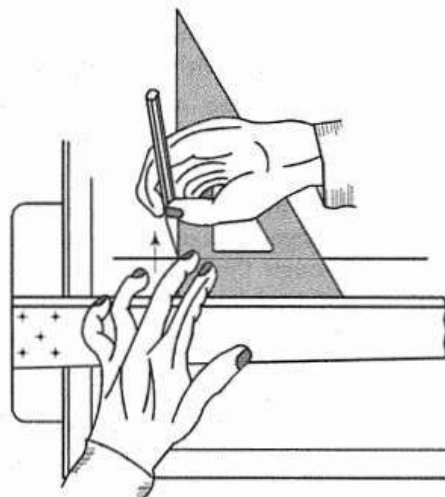
*Sketching a Cutting Plier*

### Learning activities

#### **Learning activity 1: Produce plane geometry**

To draw a fine perpendicular to a given horizontal line from a given point within it.

- v. Place the T-square a little below the given line
- vi. Arrange any one set-square with one of the edges containing the right angle touching the working edge of the T-square, and the other edge passing through the given point.
- vii. Hold the T-square and the set-square in this position firmly with the left hand.
- viii. With the right hand, draw the required line through the given point in the upward direction as shown by the arrow. The pencil point should always be in contact with the edge of the set-square. A perpendicular from any given point outside the line can also be drawn in the same manner. Vertical parallel lines may be drawn by sliding the set-square along the edge of the T-square to the required positions.



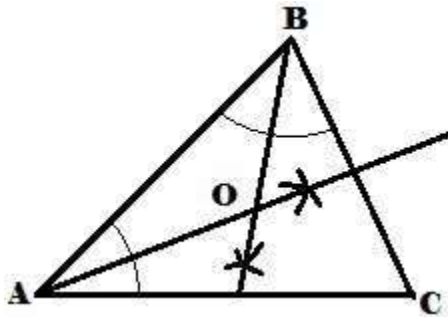
## Learning activity 2: Produce plane geometry

### To inscribe a regular polygon of any number of sides, say 5, in a given circle

- xiii. With centre O, draw the given circle.
- xiv. Draw a diameter AB and divide it into five equal parts (same number of parts as the number of sides) and number them as shown.
- xv. With centres A and B and radius AB, draw arcs intersecting each other at P.
- xvi. Draw a line P2 and produce it to meet the circle at C. Then AC is the length of the side of the pentagon.
- xvii. Starting from C, step-off on the circle, divisions CD, DE etc., equal to AC.
- xviii. Draw lines CO, DE etc., thus completing the pentagon.

### Self-assessment

8. How many sides have a regular nonagon?
  - E. 12
  - F. 11
  - G. 10
  - H. 9
9. When the construction is completed, the figure drawn describes \_\_\_\_\_ circle.



- A. a circumscribed
  - B. a concentric
  - C. an eccentric
  - D. an escribed
  - E. an inscribed
10. Draw a parabola by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 1:1.
  11. Draw a hyperbola by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 2:3.
  12. Draw an ellipse by locus of a point method such that the distance between the focus and the directrix is 40mm and the eccentricity is 3:2.

13. A ground is in the shape of a rectangle 120 m X 60m. Inscribe an elliptical lawn in it to a suitable scale by concentric circle method.
14. Divide a line of 40 mm in ratio 1:3:4

#### Tools, Equipment, Supplies and Materials

7. Drawing tools
8. Drawing set
9. Drawing papers
10. Erasers
11. Series of pencils
12. Drawing board

#### References

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### 4.3 Produce Solid Geometry Drawings

#### Introduction to the Learning Outcome

This learning outcome is intended to equip the trainee with competence on how to produce solid geometry drawings. Knowledge on how to develop and interpret patterns is learnt and exercised in this learning outcome

#### Performance Standard

- iv. Drawings of patterns are interpreted according to standard conventions
- v. Patterns are developed in accordance with standard conventions
- vi. Interpretation of sketches and drawings of patterns e.g. cylinders, prisms and pyramids

#### Information sheet

## Concept of developing surfaces

A layout of the complete surface of a three-dimensional object on a plane is called the development of the surface or flat pattern of the object. The development of surfaces is very important in the fabrication of articles made of sheet metal.

### *Methods of development*

The method to be followed for making the development of a solid depends upon the nature of its lateral surfaces. Based on the classification of solids, the following are the methods of development.

#### **i. Parallel-line Development**

It is used for developing prisms and single curved surfaces like cylinders in which all the edges / generators of lateral surfaces are parallel to each other.

#### **ii. Radial-line Development**

It is employed for pyramids and single curved surfaces like cones in which the apex is taken as center and the slant edge or generator (which are the true lengths) as radius for its development.

### *Orthographic views*

## Development of surfaces of pyramids

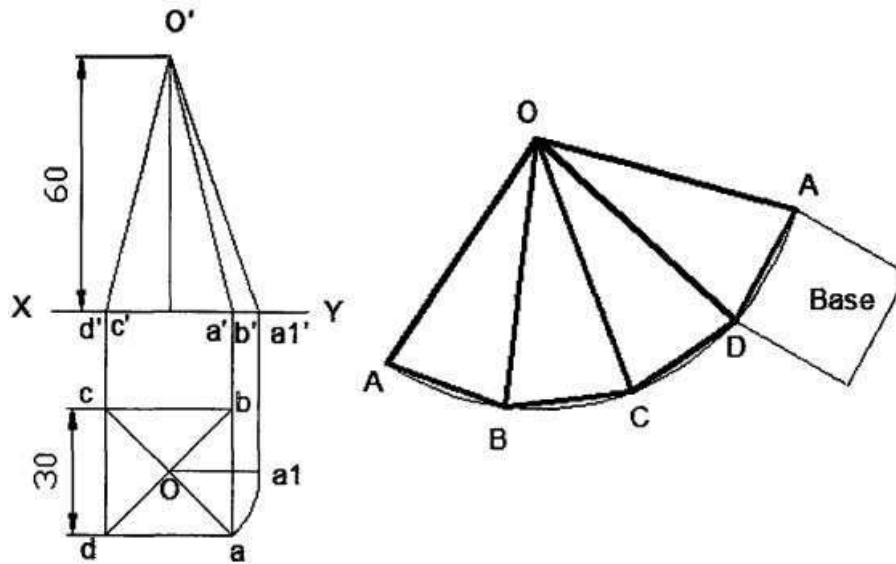


Figure 185: Development of surfaces of pyramids

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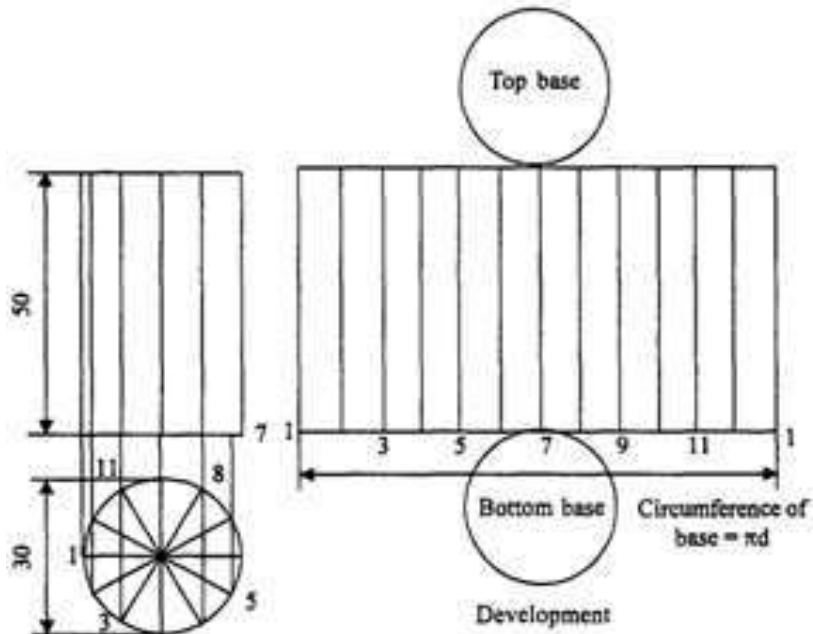


Figure 186: Development of cylinder surfaces

### Development of surfaces of cones

The development of the lateral surface of a cone is a sector of a circle. The radius and length of the arc are equal to the slant height and circumference of the base of the cone respectively. The included angle of the sector is given by  $(r / s) \times 360^\circ$ , where  $r$  is the radius of the base of the cone and  $s$  is the true length.

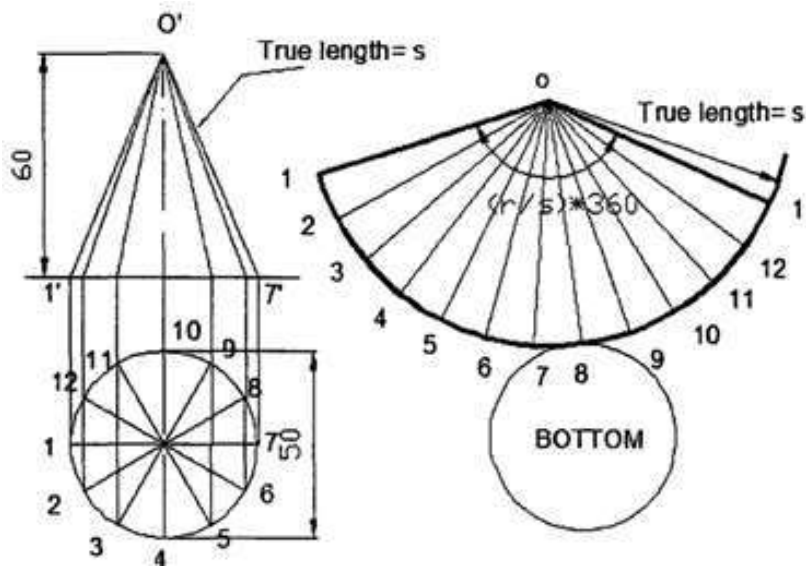


Figure 187: Development and interpenetrations of solids

## Development and interpenetrations of solids

### Intersection of regular solids

Ducts, pipe joints, smoke stacks, boilers, containers, machine castings etc., involve intersection of surfaces. Sheet metal work required for the fabrication of the above objects necessitates the preparation of the development of the joints objects. Orthographic drawings of lines and curves of intersection of surfaces must be prepared first for the accurate development of objects.

### Intersection of cylinder and cylinder

Case I: Cylinders of Same size

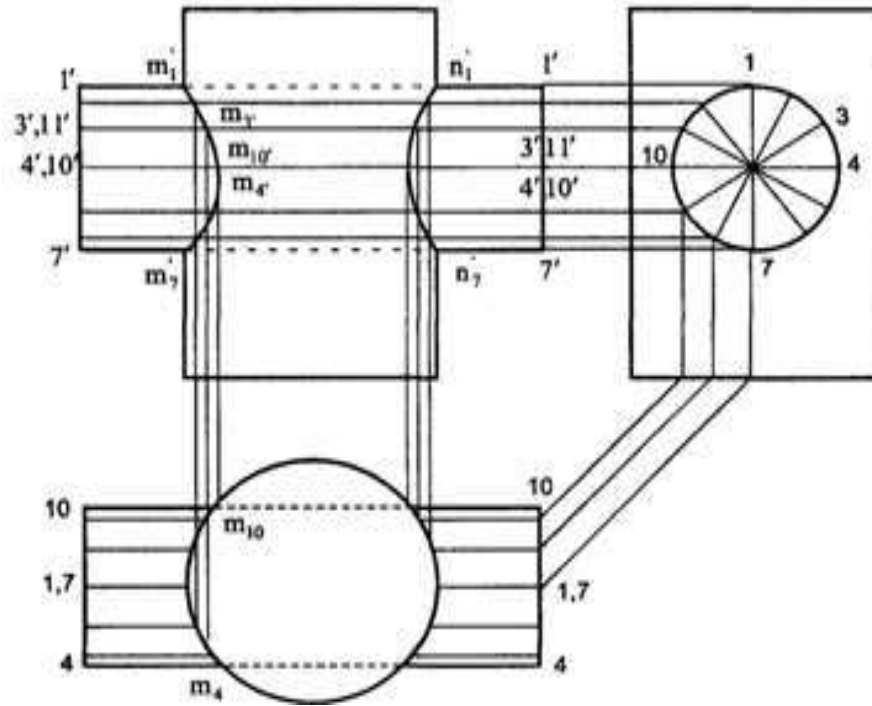
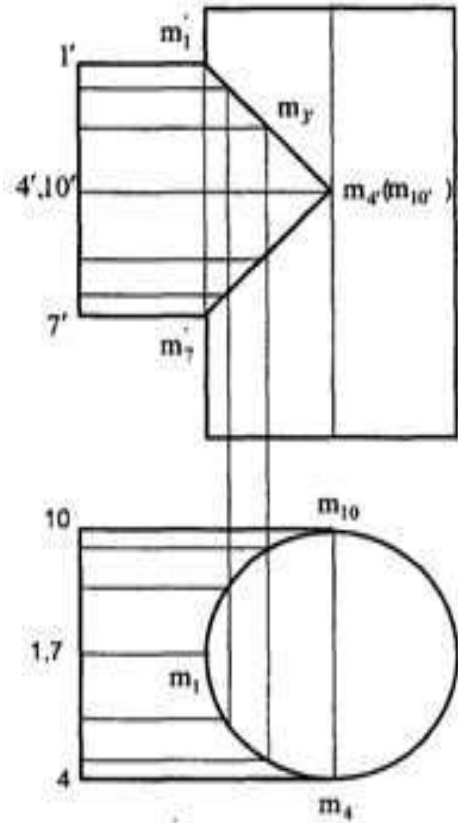


Figure 188: Cylinders of Same size

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Case II: Cylinders of Same size



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Figure 189: Cylinders of Same size

## Intersection of prism and prism

When a prism penetrates another prism, plane surface of one prism intersects the plane surfaces of another prism and hence the lines of intersection will be straight lines. In these cases, lines on the surface of one of the solids need not necessarily be drawn as it is done with cylinders. Instead, the points of intersections of the edges with the surface are located by mere inspection. These points are projected in the other view and the lines of intersection obtained.

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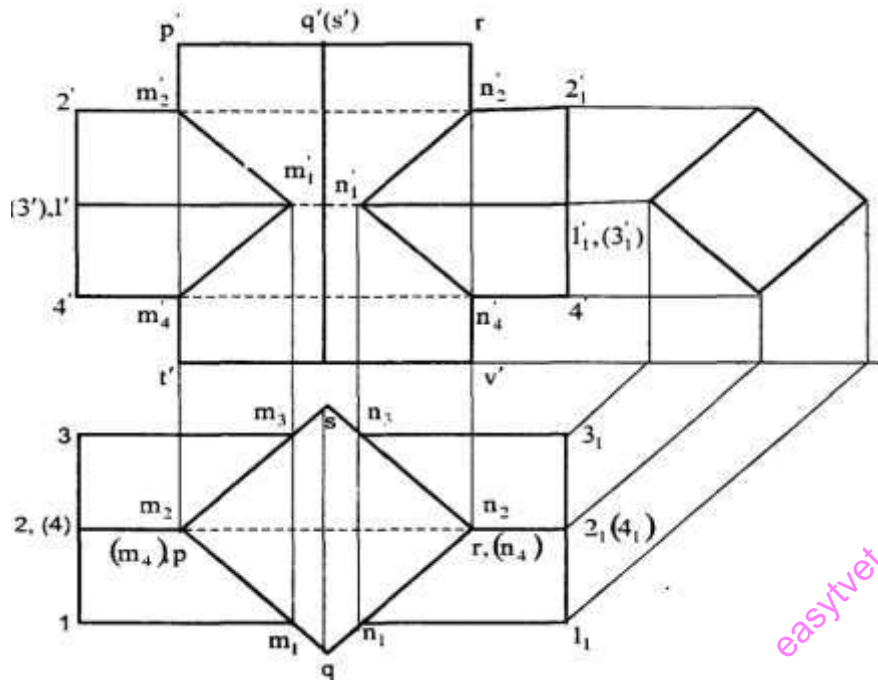


Figure 190: Intersection of prism and prism

Learning activities

**Learning activity 1:** Produce solid geometry drawings

**Develop the lateral surface of the truncated cylinder**

- iv. Divide the circle in the top view into twelve equal parts. Project the division points to the front view and draw the generators. Mark points a', b' and b'<sub>1</sub>, c' and c'<sub>1</sub> etc. in which the generators are cut.

- v. Draw the development of the lateral surface of the whole cylinder along with the generators. The length of the line 1-1 is equal to  $\pi \times D$  (circumference of the circle). This length can also be marked approximately by stepping off with a bow divider, twelve divisions, each equal to the chord-length  $ab$ . (The length thus obtained is about 1 % shorter than the exact length; but this is permitted in drawing work.)
- vi. Draw horizontal lines through points  $a'$ ,  $b'$  and  $b'1$  etc. to cut the corresponding generators in points  $A$ ,  $B$  and  $B1$  etc. Draw a smooth curve through the points thus obtained. The figure 1-A-A-1 is the required development.

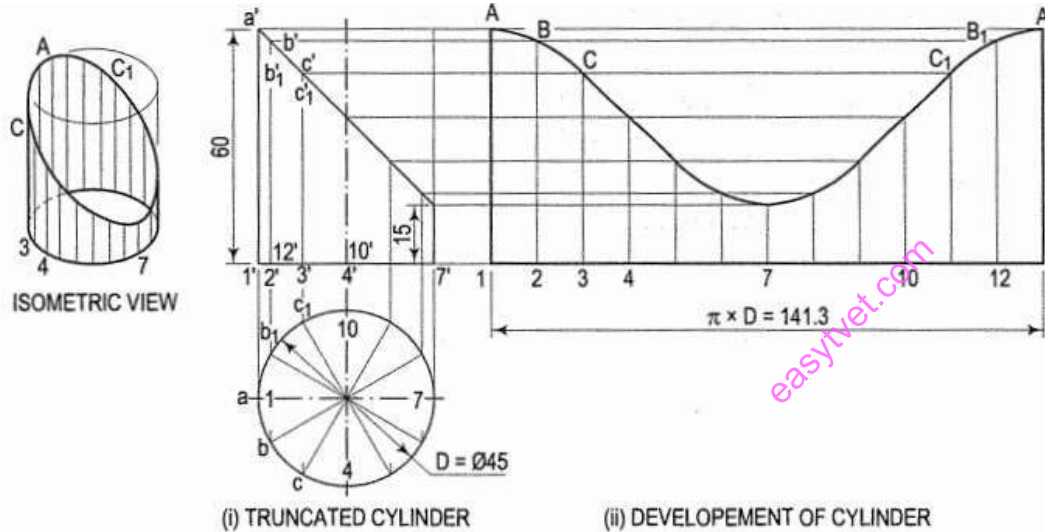


Figure 191: Lateral surface of the truncated cylinder

### Learning activity 2: Produce solid geometry drawings

#### Draw the development of the of the truncated cone

Assuming the cone to be whole, let us draw its development.

- viii. Draw the base-circle in the top view and divide it into twelve equal parts.
- ix. With any point O as centre and radius equal to o'1' or o'7', draw an arc of the circle. The length of this arc should be equal to the circumference of the base circle. This can be determined in two ways.
- x. Calculate the subtended angle  $\Theta$  by the formula,

$$\Theta = 3600 \times \frac{\text{radius of the base circle}}{\text{slant height}}$$

Cut-off the arc so that it subtends the angle  $\Theta$  at the centre and divide it into twelve equal parts.

- xi. Step-off with a bow-divider, twelve equal divisions on the arc, each equal to one of the divisions of the base-circle. (This will give an approximate length of the circumference. Note that the base-circle should not be divided into less than twelve equal parts.)
- xii. Join the division-points with O, thus completing the development of the whole cone with twelve generators shown
- xiii. The truncated portion of the cone may be deducted from this development by marking the positions of points at which generators are cut and then drawing a curve through them. For example, generators o'2' and o'12' in the front view are cut at points b' and b'1 which coincide with each other. The true length of o' b' may be obtained by drawing a line through b', parallel to the base and cutting o'7' at b". Then o'b" is the true length of o'b'.
- xiv. Mark points B and B<sub>1</sub> on generators O2 and O-12 respectively, such that OB = OB<sub>1</sub> = o' b". Locate all points in the same way and draw a smooth curve through them. The figure enclosed this curve and the arc is the development of the truncated cone.

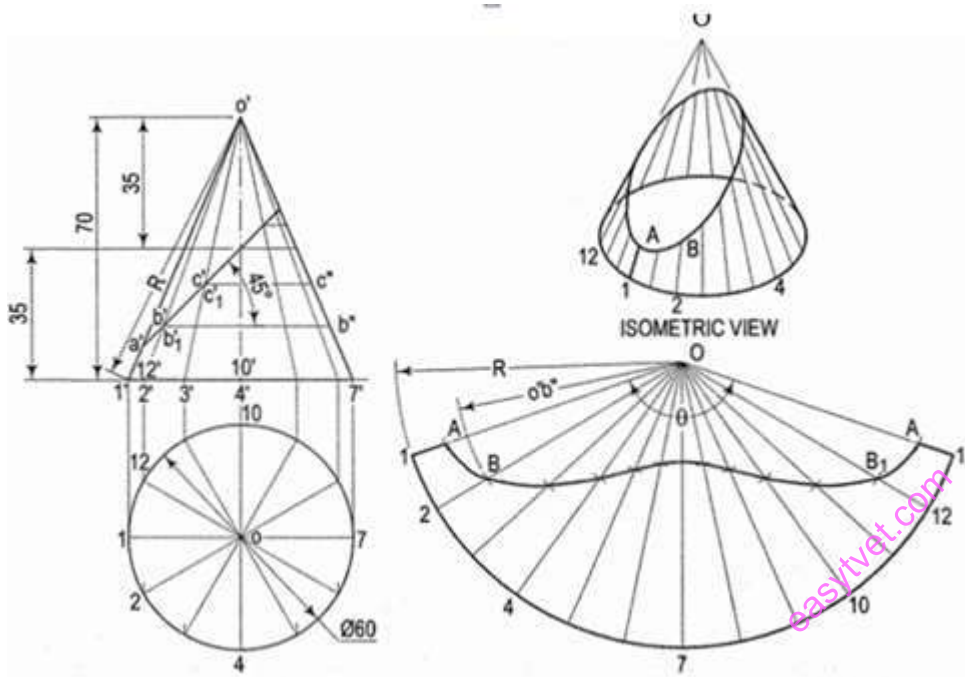


Figure 192: Truncated cone and surface development

### Self-assessment

7. The bounding box method for setting up an isometric drawing helps the drafter \_\_\_\_\_.

- E. confines the isometric drawing to its maximum size
- F. figure what lines are to be illustrated vertical and horizontal
- G. position the isometric drawing in paper space
- H. none of the above

8. This type of section is limited by a break line:

- E. Removed section
- F. Revolved section
- G. Broken-out section
- H. Half section

9. In the section view, the areas that would have been in actual contact with the cutting plane are shown with:

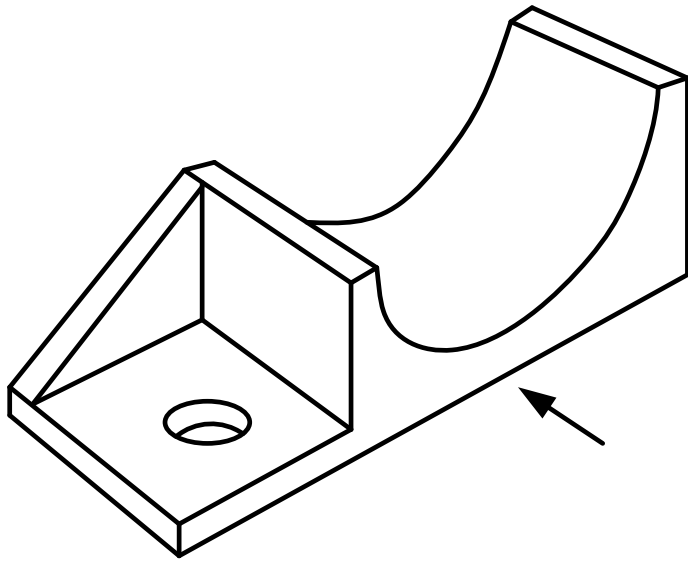
- A. A cutting plane line
- B. Section lining
- C. Visible lines
- D. Lines and arrows

10. What is the difference between regular and irregular polygons?

11. If an isometric drawing is made use of isometric scale then the drawings are called

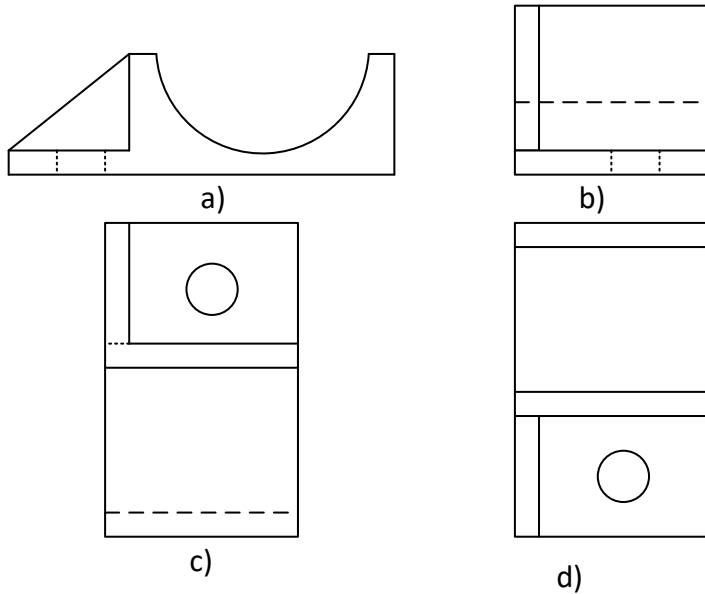
- E. Isometric projection
- F. Isometric view
- G. Isometric perception
- H. Orthographic view

12. Identify the front view of the pictorial drawing below.



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### Tools, Equipment, Supplies and Materials

- vii. Drawing tools
- viii. Drawing set
- ix. Drawing papers
- x. Erasers
- xi. Series of pencils
- xii. Drawing board

### References

6. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing: Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.
7. Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.
8. Narayana, K. L., Kannaiah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.
9. Reddy, K. V. 2010. Textbook of Engineering Drawing. B.S. Publ., Hyderabad.
10. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,

#### **4.4 Produce Orthographic and Pictorial Drawings**

##### **Introduction to the learning outcome**

This learning outcome is intended to equip the trainee with competence on how to produce orthographic and pictorial drawings.

##### **Performance Standard**

- vi. Symbols and abbreviations are identified and their meaning interpreted according to standard drawing conventions
- vii. First and third angle orthographic drawings are interpreted and produced in accordance with the standard conventions
- viii. Orthographic elevations are dimensioned in accordance with standard conventions
- ix. Isometric drawings are interpreted and produced in accordance with standard conventions
- x. Assembly drawing is produced and interpreted in line with the operating standards

Information sheet

##### **Definitions**

##### **Projections**

The technique of representing an object in a drawn form is referred to as projection. Projection can be divided into pictorial (3- dimensional) projection and orthographic (2- dimensional) projection. Pictorial projection is further divided into isometric, oblique and perspective projections; while the orthographic projection is divided into 1<sup>st</sup> angle and 3<sup>rd</sup> angle projection is referred to as projection. Projection can be divided into pictorial (3- dimensional) projection and orthographic (2- dimensional) projection. Pictorial projection is further divided into isometric, oblique and perspective projections; while the orthographic projection is divided into 1<sup>st</sup> angle and 3<sup>rd</sup>

angle projection.

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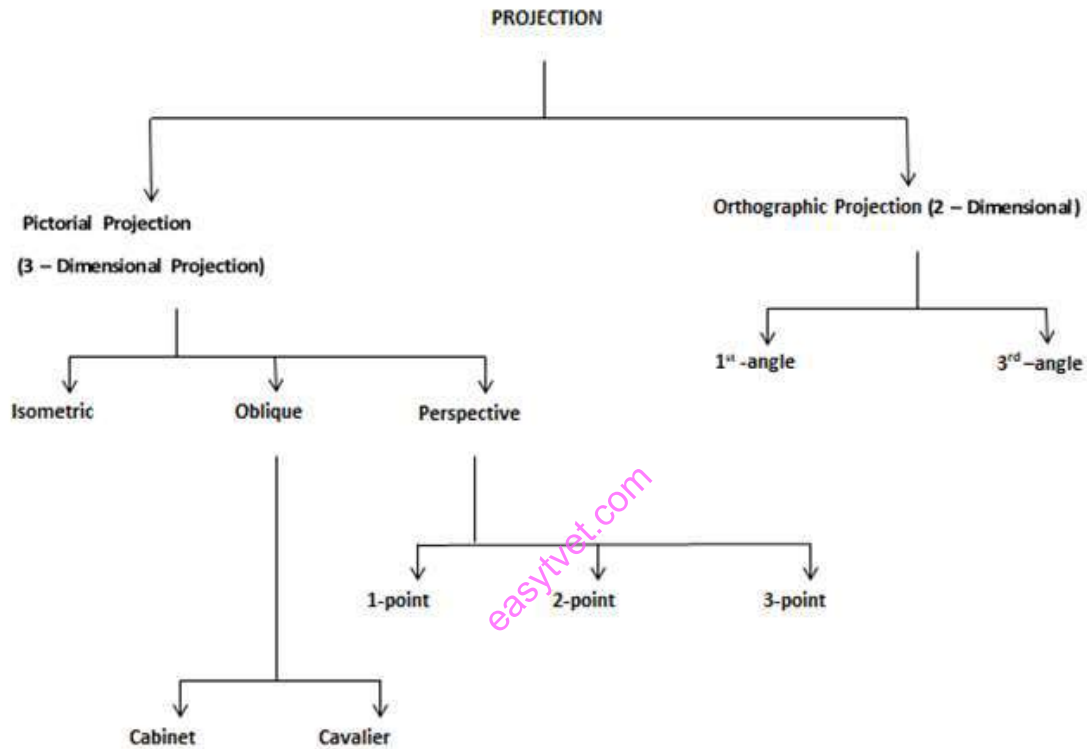


Figure 193: Types of projections

### Orthographic Drawing

'ORTHO' means right angle and orthographic means right angled drawing. When the projectors are perpendicular to the plane on which the projection is obtained, it is known as orthographic projection. It is in two dimensions (2D). It uses multiple views of the object, from points of view rotated about the object's center through increments of 90°. The views are positioned relative

to each other according to either of two schemes: *first- Angle* or *third-Angle* projection. In each, the appearances of views may be thought of as being *projected* onto planes that form a transparent "box" around the object.

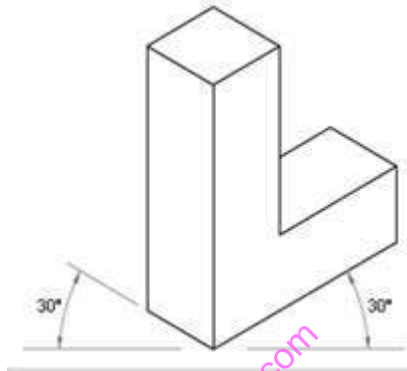


Figure 194: Isometric drawing

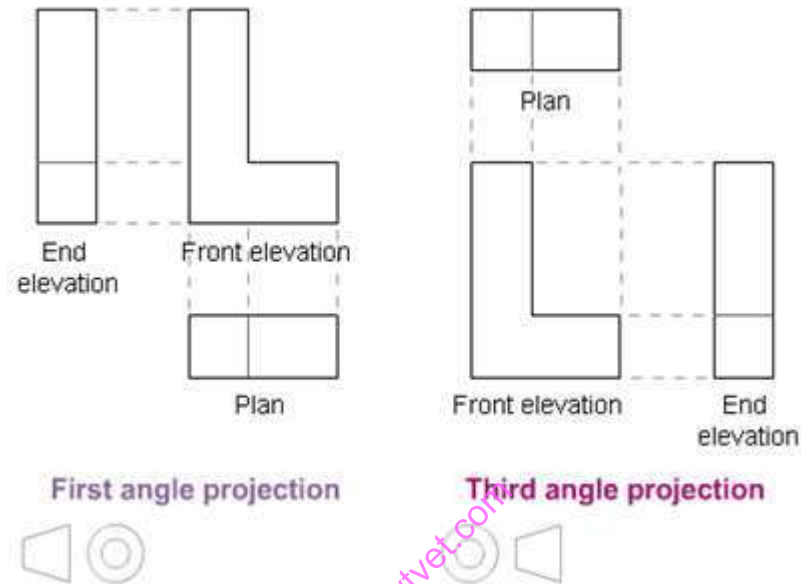
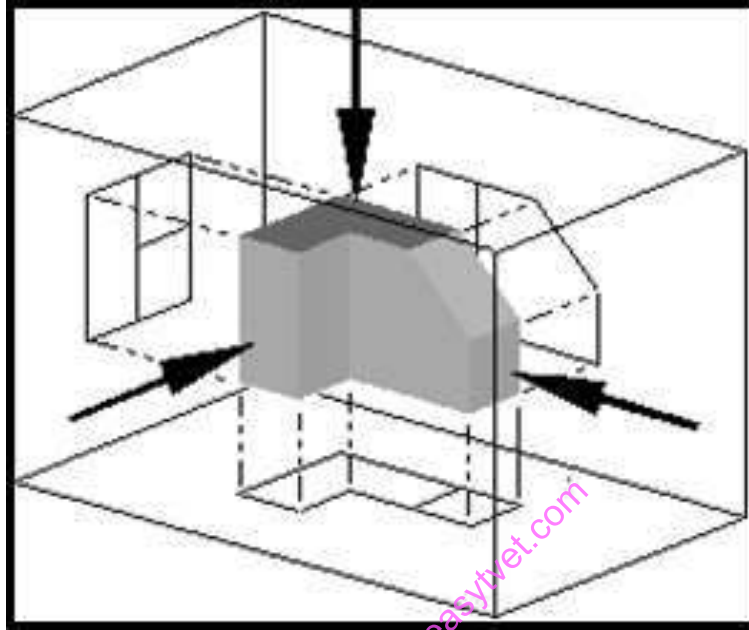


Figure 195: Illustrating the difference between 1st. and 3rd. angles projection

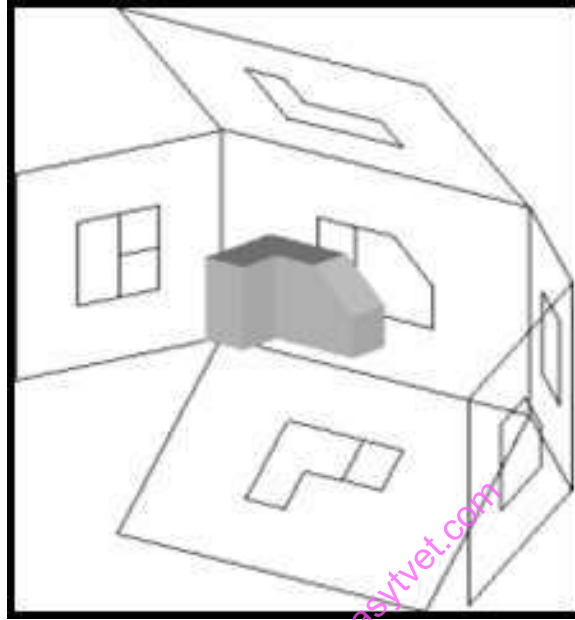
## The Differences between 1st & 3rd Angle Projection

### First-Angle Projection

In **first-angle projection**, each view of the object is projected in the direction (sense) of sight of the object, onto the interior walls of the box



A two-dimensional representation of the object is then created by "unfolding" the box, to view all of the *interior* walls



*Figure 196: unfolding*



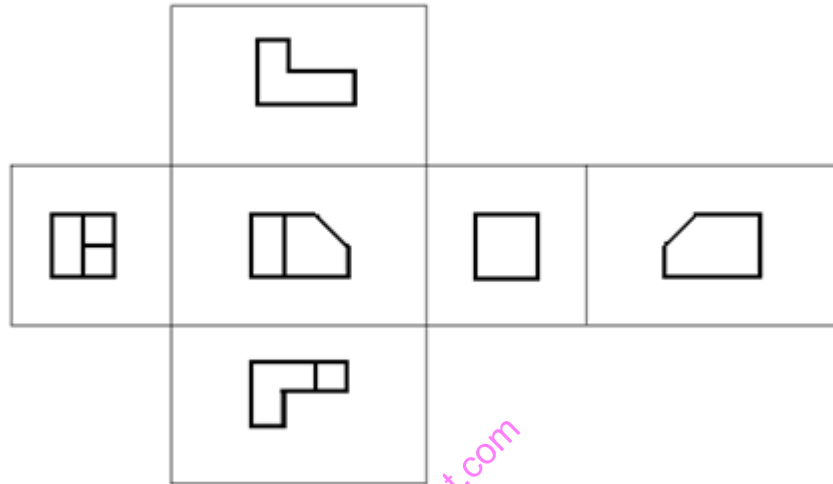


Figure 197: unfolded views

### Third-Angle Projection

In **third-angle projection**, each view of the object is projected opposite to the direction (sense) of sight, onto the (transparent) exterior walls of the box in the figure below.

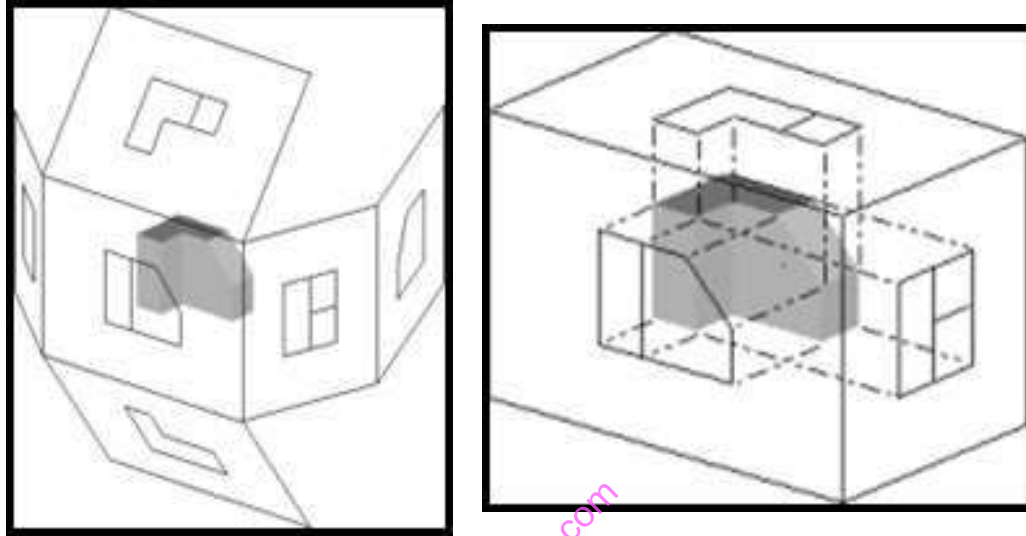
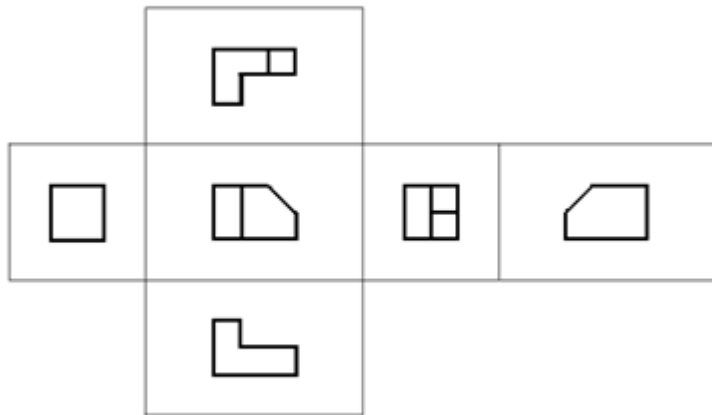
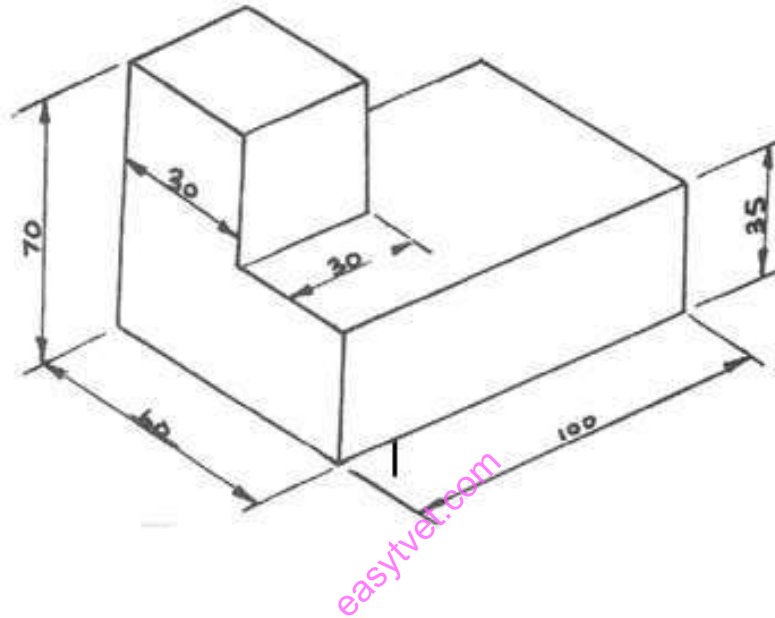


Figure 198: unfolding



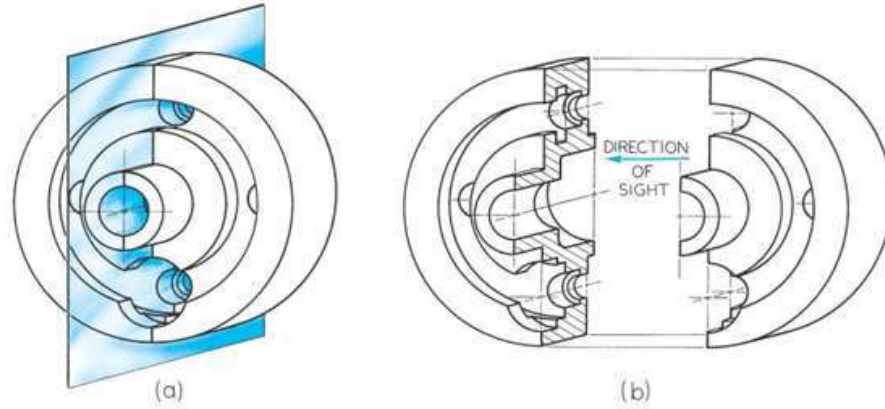
*Figure 199: unfolding views*

A two-dimensional representation of the object is then created by unfolding the box, to view all of the *exterior* walls. Before starting drawing the views of the component shown in Figure below, it is necessary to decide the best Angle to project on the component; good decision will make the reading of the details of the views much easier afterwards.



## SECTIONING

To produce a sectional view, a cutting plane is imagined cutting through the part, as shown in fig. (a). Picture the two halves of the object pulled apart, exposing the interior construction, as shown in fig. (b). In this case, we will look toward the left half of the object in the section view. This sectional view replaces the right-side view.



*Figure 200: Cutting plane*

### **Full Sections**

The section produced by cutting through the entire object is called a full Section, as shown in fig. (c) below.

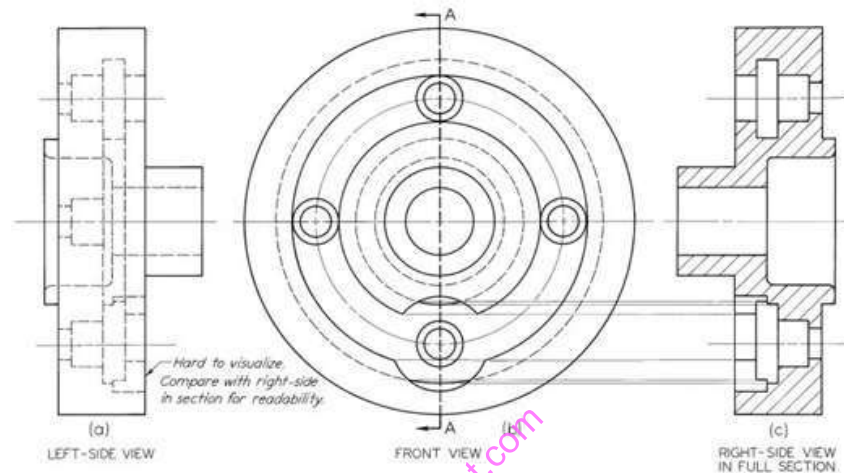


Figure 201: Full Sections

## The Cutting Plane

The cutting-plane line is shown as a special pattern. The arrows at the ends of the cutting plane line indicate the direction of sight for the section view. We can think the cutting-plane line as showing the edge view of the cutting plane.

When a cutting-plane line coincides with a centerline, the cutting-plane line takes precedence.

## Cutting-Plane Line Patterns

Figures below show two line patterns used to show the cutting-plane line. Arrowheads indicate the direction in which the cut object is viewed.

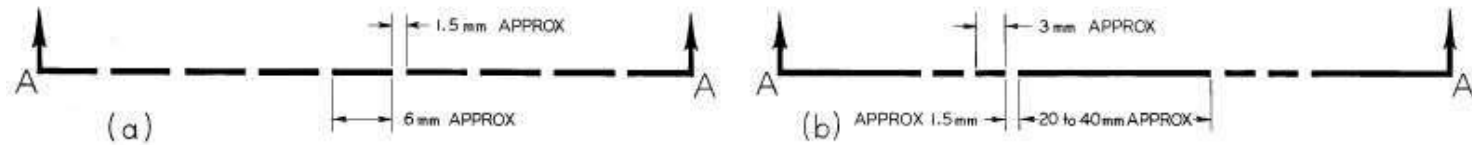


Figure 202: Cutting-Plane Line Patterns

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## Interpreting Cutting Planes and Sections

Sectional views often replace standard views. As figures shown, the cutting plane is a frontal plane and appears as a line in the top view. The arrows at the ends of cutting-plane line point in the direction of sight for front section. The result is called a front section, or front view in section, since it replaces the front view in the drawing.

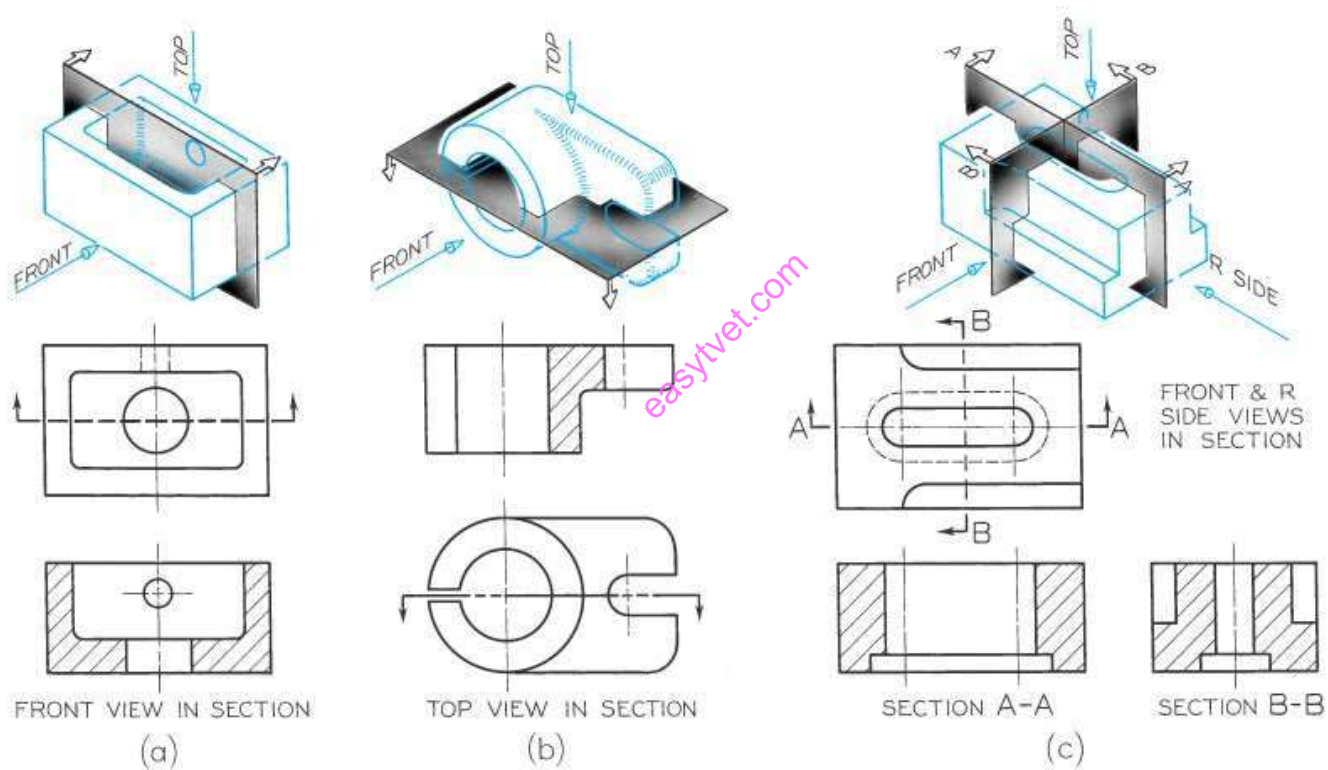
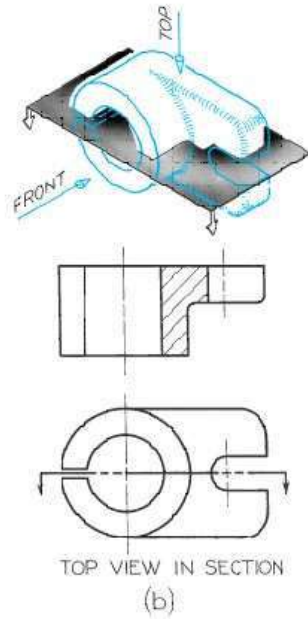


Figure 203: Cutting Planes and Sections



As shown in figures, the cutting plane is a horizontal plane, appearing as a line in the front view. The arrows point toward the lower half in the same direction of sight as for a top view. This result is top view in section.



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Figure 204: sectional views

Figures below show two cutting planes - one a frontal plane, the other a profile plane - and both appear on edge in the top view. Each section is completely independent of the other and drawn as if the other were not present.

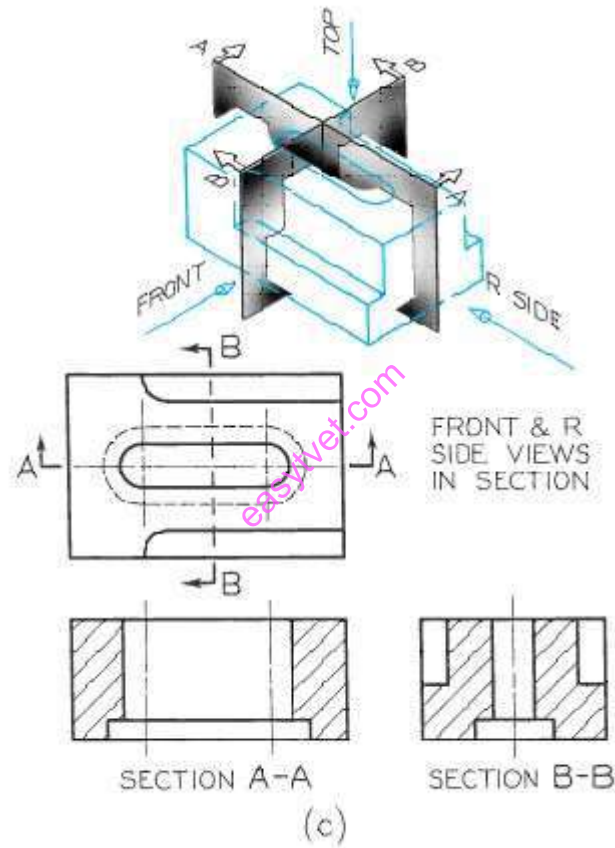
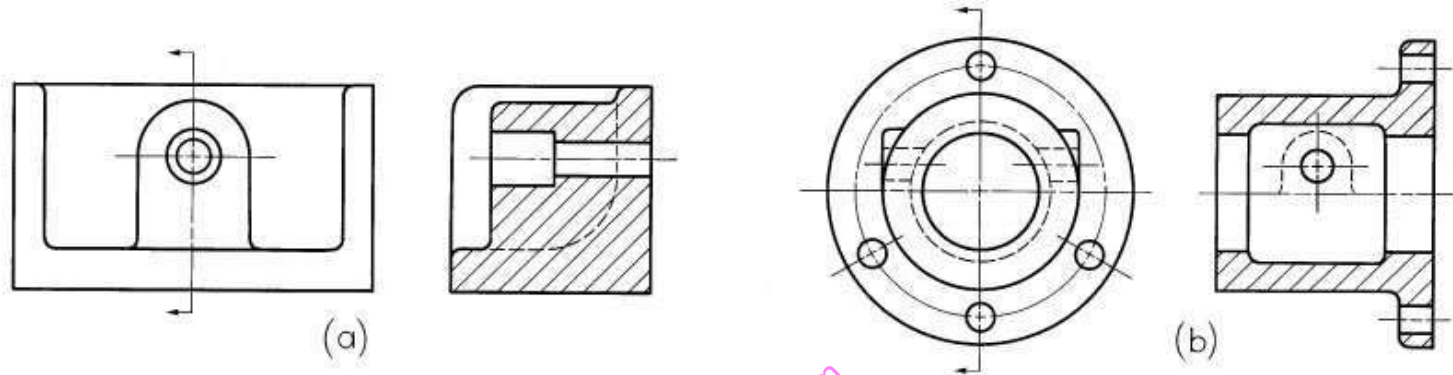


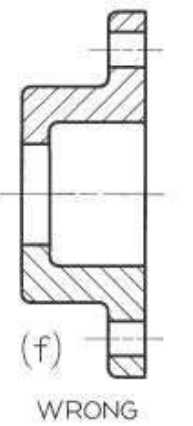
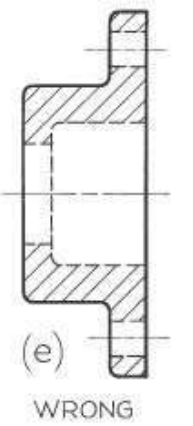
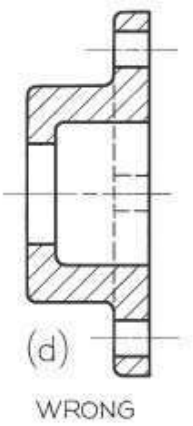
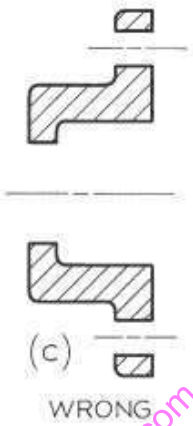
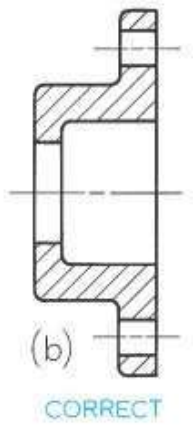
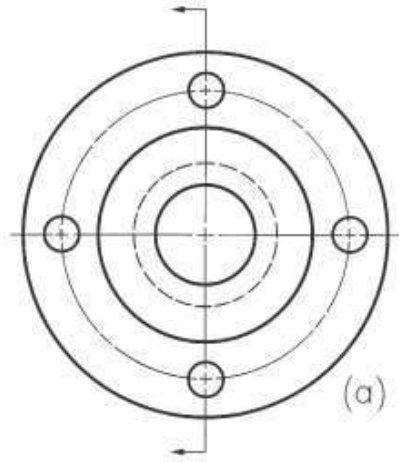
Figure 205:Sectional views

Keep the following things in mind when drawing sectional views. Visible edges and contours behind the cutting plane should be as shown in figure (a) below. Hidden lines should be omitted in section views unless they are necessary, as in figure (b).



A section-lined area is always completely bounded by a visible outline never by a hidden line. The cross hatching in all hatched areas must be parallel in a sectional view of a single object, along or in assembly.

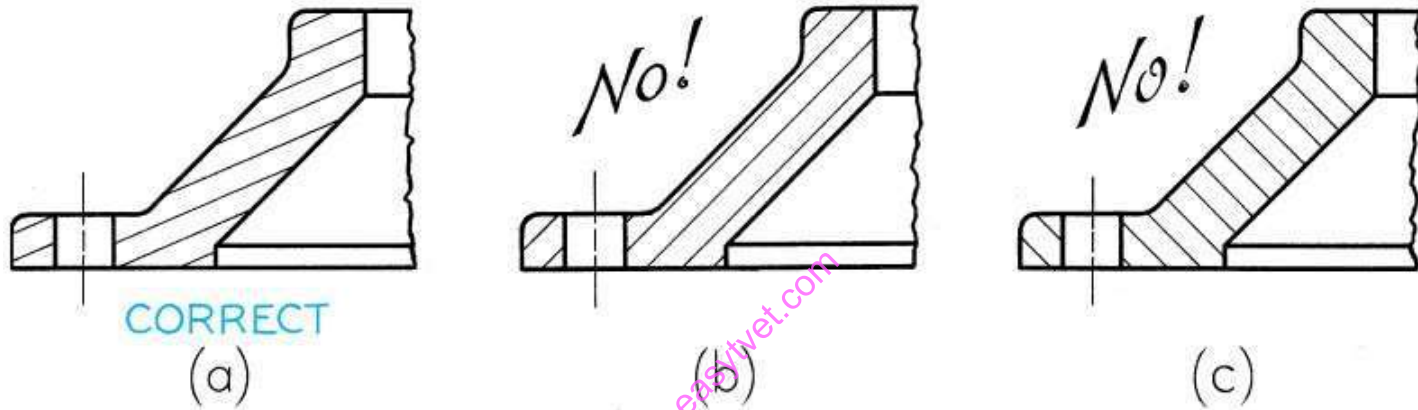
### Find the errors in section views



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## Cross-Hatching

Cross-hatching patterns, shown in Fig. 7.6 are used to present general material types. Make hatching lines at 45 degrees with horizontal, unless they look better at a different angle.

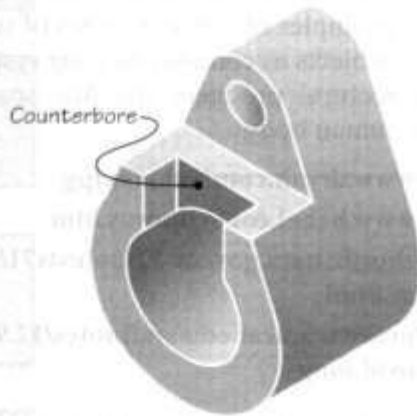


In figures above, cross-hatching at 45 degrees with horizontal would be nearly parallel or nearly perpendicular to a prominent feature. In this case, the hatching appears better drawn at 30 degrees, 60 degrees, or some other angle.

## Step by Step Visualizing of a full section

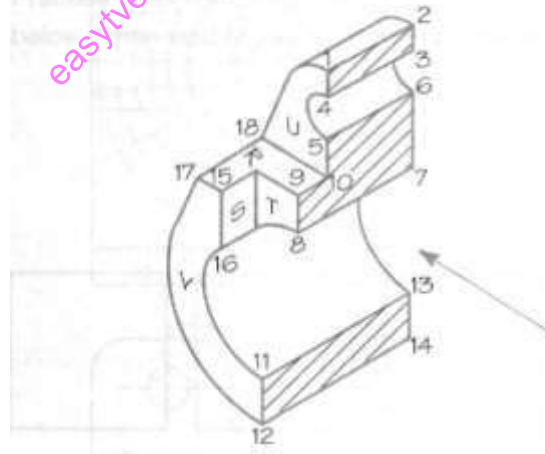
### STEP 1: CHOOSE A CUTTING PLANE

The illustration below shows two views of a collar to be sectioned. It has a drilled and counterbored hole. To produce a clear section showing both the counterbored hole and the smaller hole near the top of the object, choose the cutting plane to pass through the vertical center line in the front view and imagine the right half of the object removed.

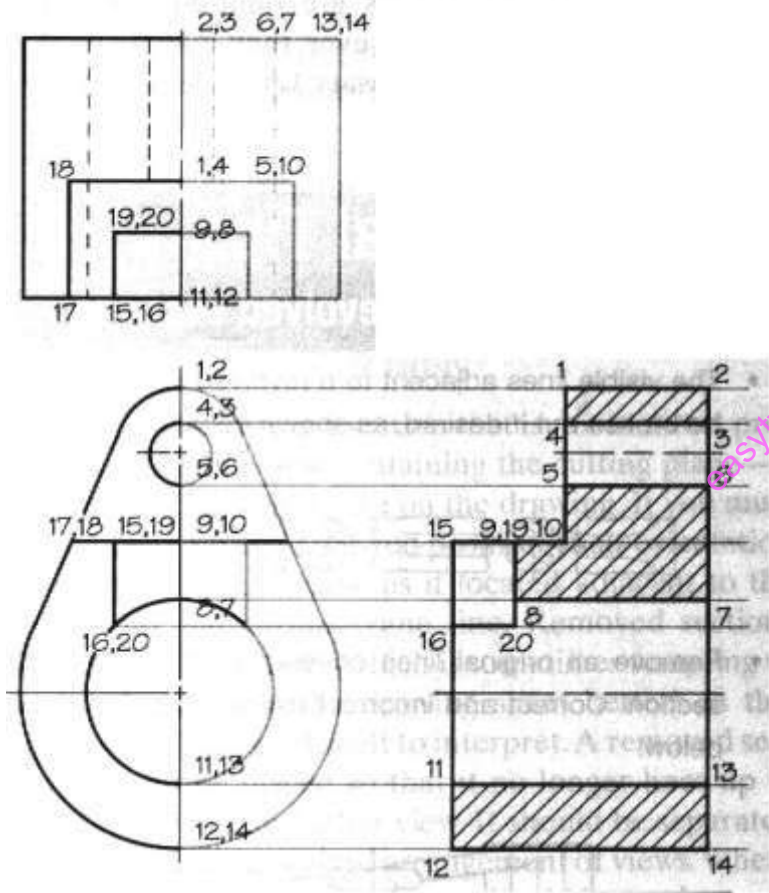


### STEP 2: IDENTIFY THE SURFACES

Below is a pictorial drawing of the remaining half. The first step in projecting the section view is making sure that you interpret the object correctly. Identifying the surfaces on the object can help. Surfaces R, S, T, U and V have been labeled on the given views and the pictorial view. Which surface is R in the front view? Which surface is U in the top view? Are they normal, inclined, or oblique surfaces. Can you identify the counterbore in each view?



### STEP 3: DRAWING THE SECTION VIEW



### STEP 4: PROJECTING THE VISIBLE LINES

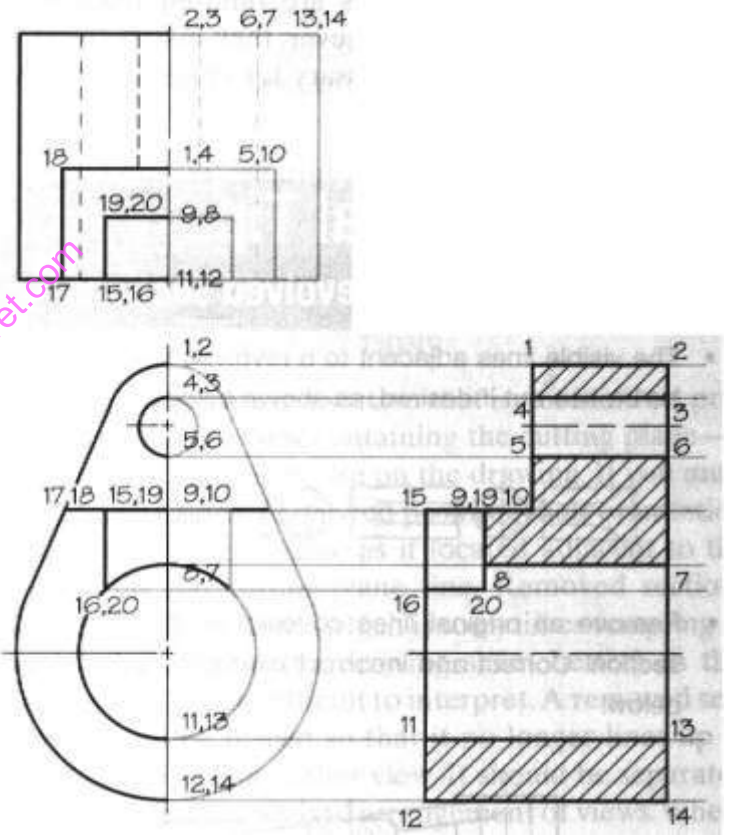


Figure 206: Drawing the sectional view

## Half Sections

Symmetrical objects can be sectioned using a cutting plane passing halfway through an object, resulting in a half section. A half section exposes the interior of one half of the object and still shows the exterior of the other half. Half sections are very useful in undimensioned assembly drawing since they show both internal and external construction on the same view.

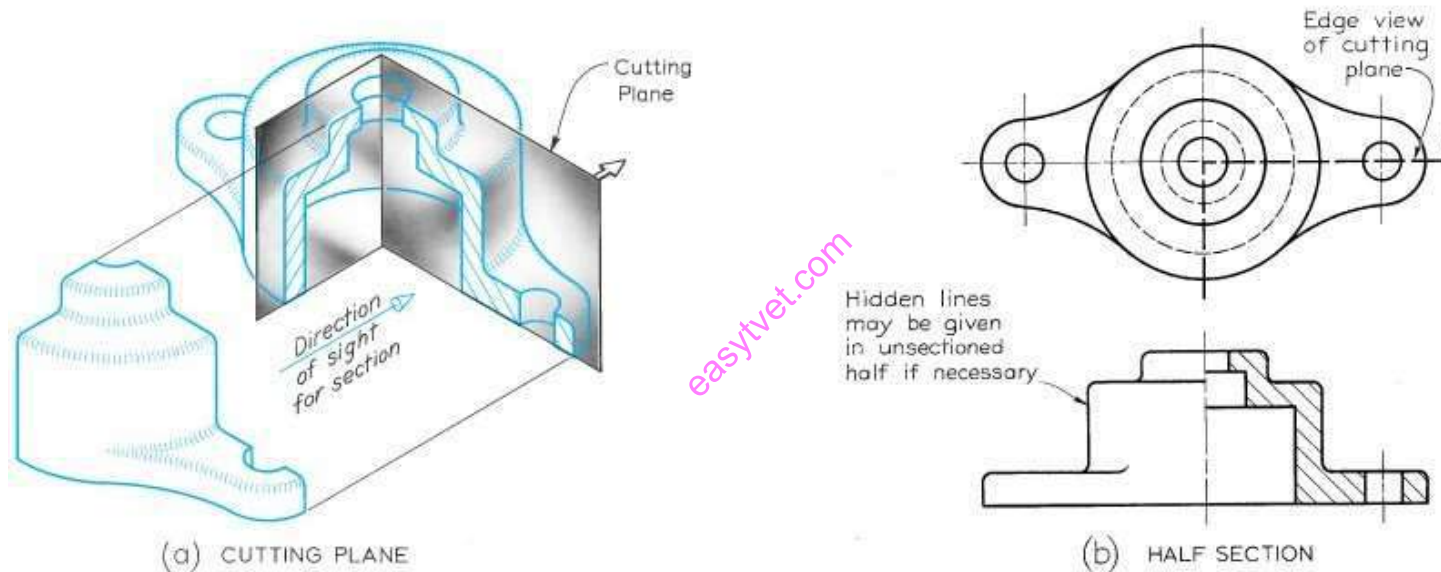


Figure 207: Half Sections

In general, hidden lines are omitted from both halves of a half section. However, they may be used in the unsectioned half if necessary for dimensioning.



## Broken-out Sections

Often, only a partial section of a view is needed to expose interior shapes. Such a section, limited by a break line, is called a broken-out section. In the first figure, a full or half section is not necessary. A broken-out section is sufficient to explain the construction.

In the second figure, a half section would have caused the removal of half the keyway. The keyway is preserved by breaking out around it. In this case, the section is limited partly by a break line and partly by a centerline (i.e., break-around keyway).

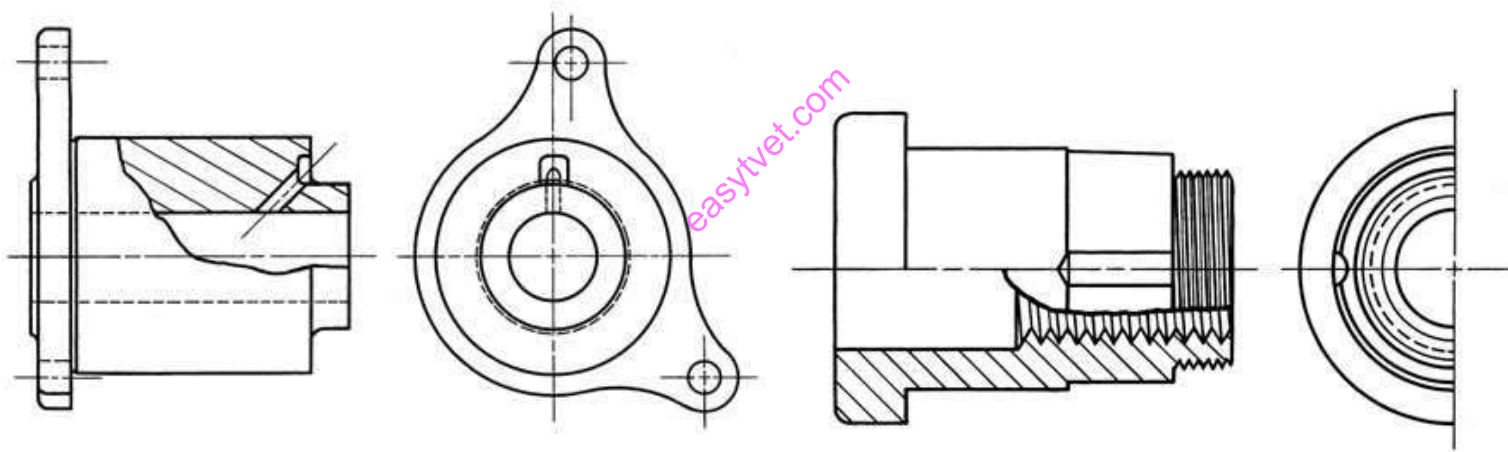


Figure 208: Broken-out Sections

## Revolved Sections

The shape of the cross-section of a bar, arm, spoke, or other elongated object may be shown by means of a revolved section.

Revolved sections are made by assuming a plane perpendicular to the centerline or axis of the bar or other object, and then revolving the plane through 90 degrees about a centerline at right angles to the axis.

The figure below depicts the process of creating a revolved section.

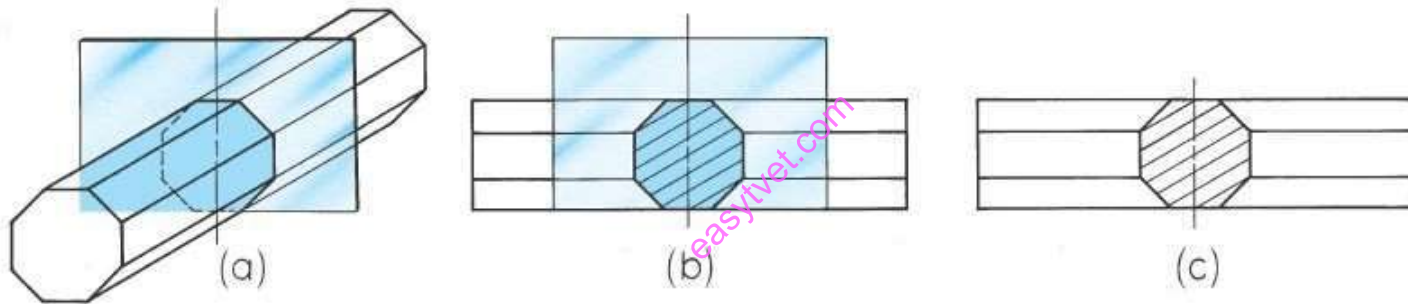
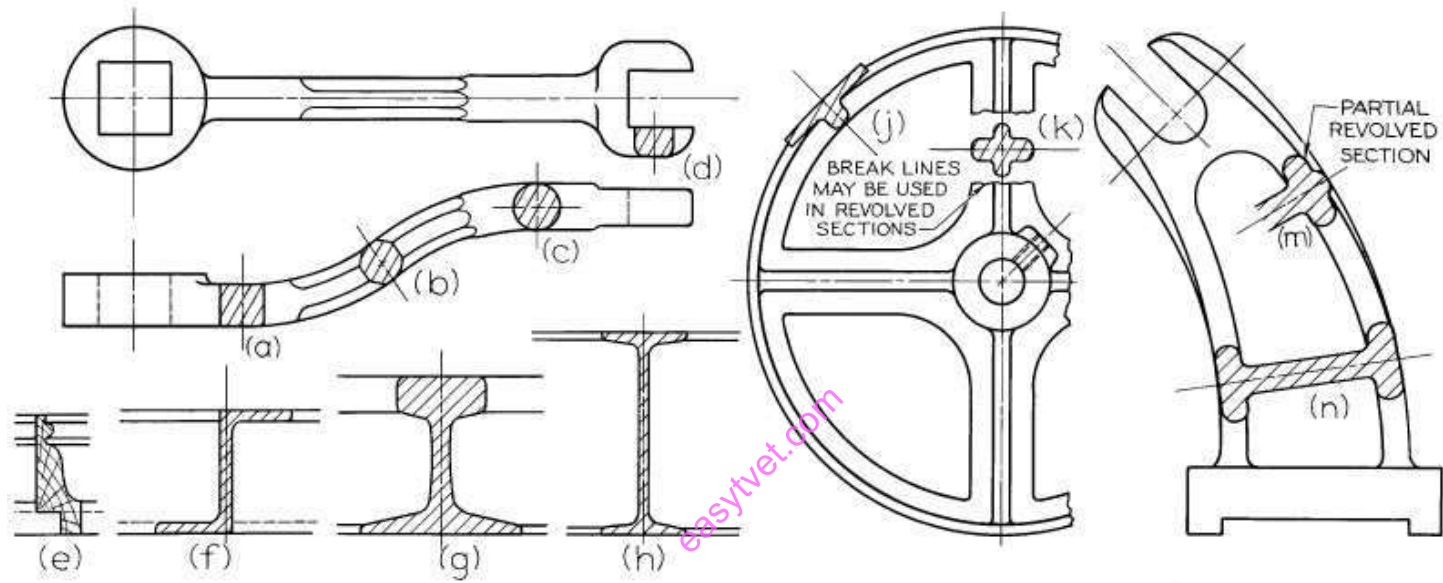


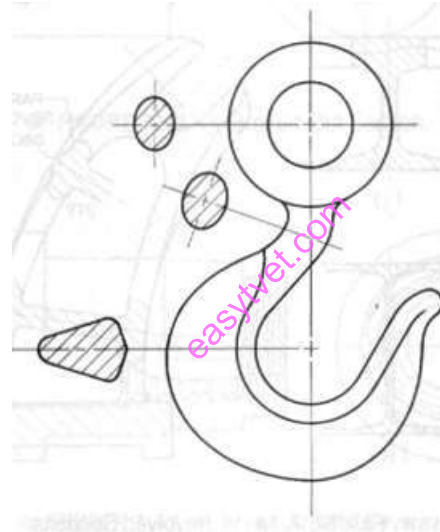
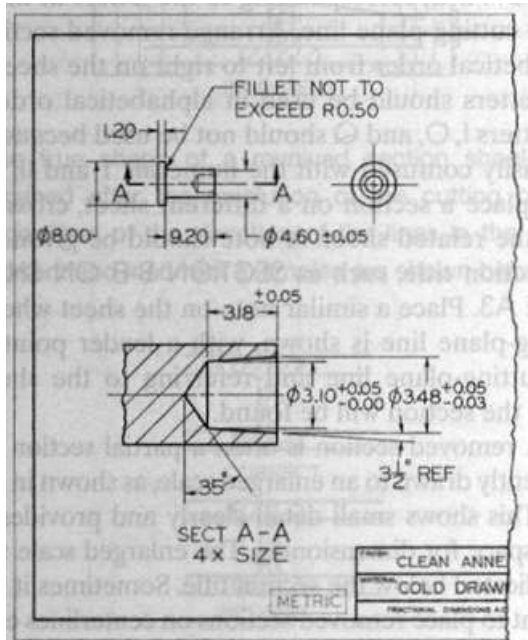
Figure 209: Revolved Sections

A number of examples of revolved sections are shown below.



## Removed Sections

A removed section is a section that is not direct projection from the view containing the cutting plane – it is located somewhere else in the drawing.



Removed sections

Figure 210: Removed Sections

## Offset Sections

In sectioning irregular objects, we may show features that do not lie in a straight line by offsetting, or bending the cutting plane. Such a section is called an offset section.

In figure (a) the cutting plane is offset in several places to include the hole at the left end, one of the parallel slots, the rectangular recess, and one of the holes at the right end.

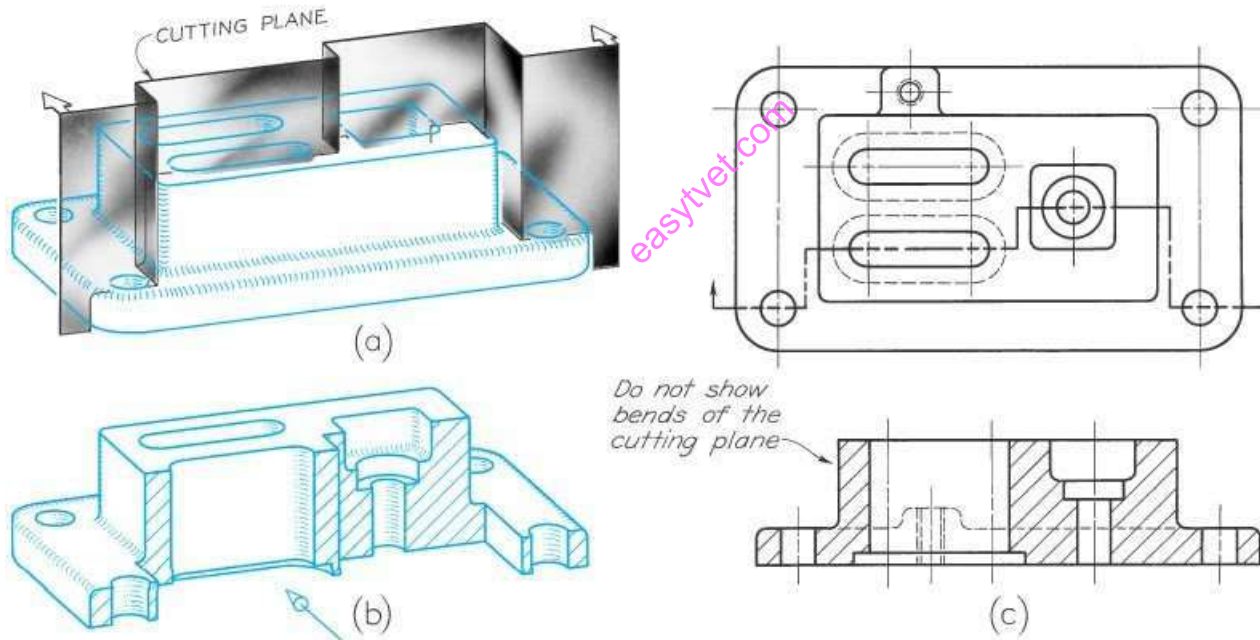


Figure 211: Offset Sections

The front portion of the object is then imagined to be removed, as shown in fig. (b). The path of the cutting plane is shown by the cutting-plane line in the top view of fig. (c), and the resulting offset section is shown in the front view. The offsets or bends in the cutting plane are all 90 degrees. Figure (c) also illustrates how hidden lines in a section eliminate the need for an additional view. If the hidden lines were not shown, an extra view would be needed to show the small boss on the back.

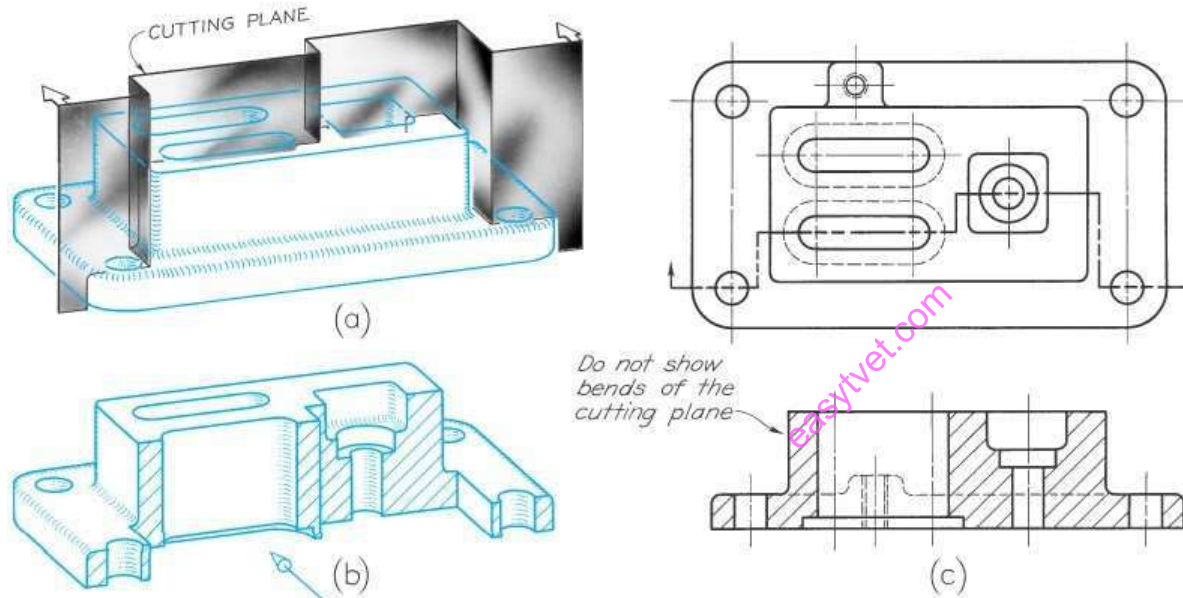
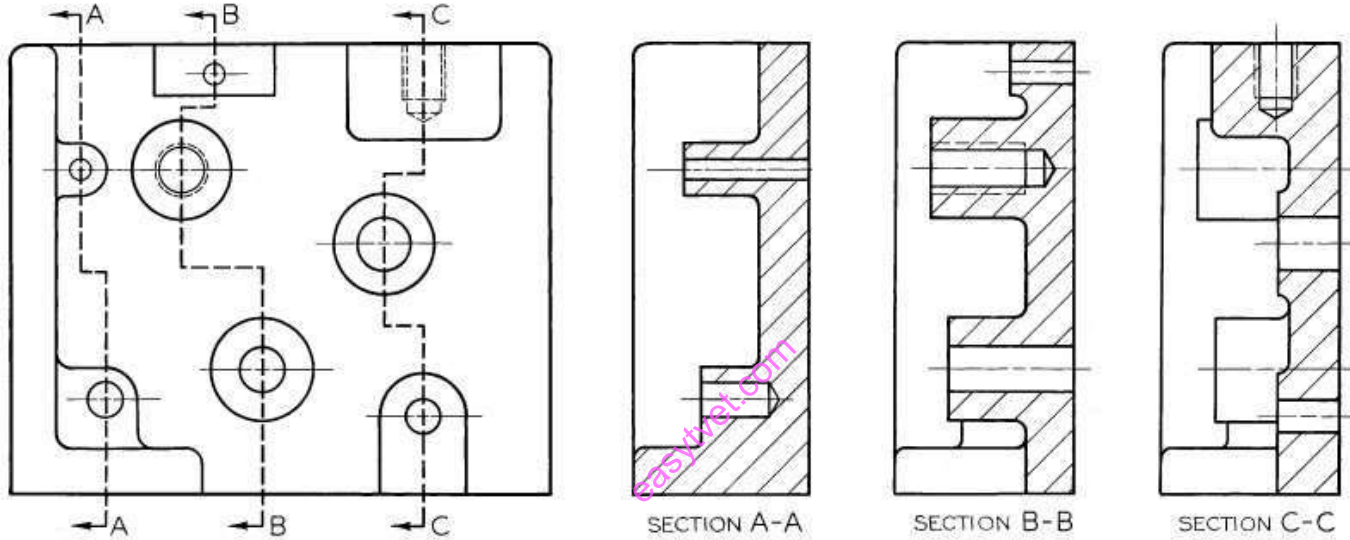


Figure below shows an example of multiple offset sections. Notice that the visible background shapes without hidden lines, appear in each sectional view.

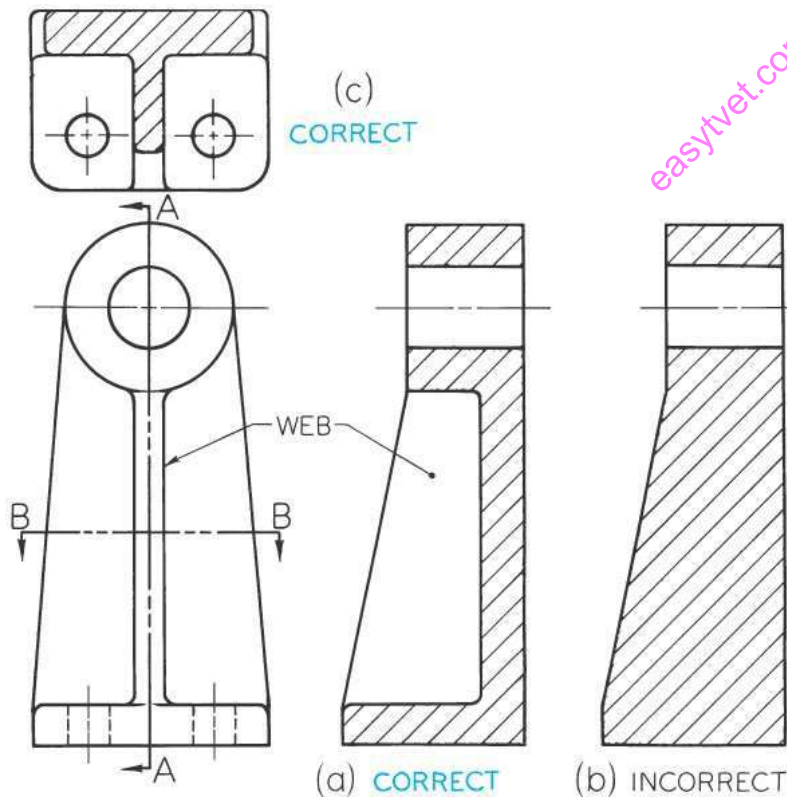


## Ribs in Sections

To avoid a false impression of thickness and solidity, ribs, webs, gear teeth, and other similar flat features are not sectioned, even though the cutting plane passes along the center plane of the feature.

For example, in figure at right the cutting plane A-A passes through the long dimension of the vertical web, or rib, but as figure a shows, the web is not section lined. Such thin features should not be section lined, even though the cutting plane passes through them.

Figure b shows an incorrect drawing.



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## Aligned Sections

To include in a section certain angled features, the cutting plane may be bent to pass through those features. The plane and features are then imagined to revolve into the original plane.

For example, in figure below the cutting plane bends to pass through the angled arm and then is aligned to a vertical position, where it is projected to the sectional view.

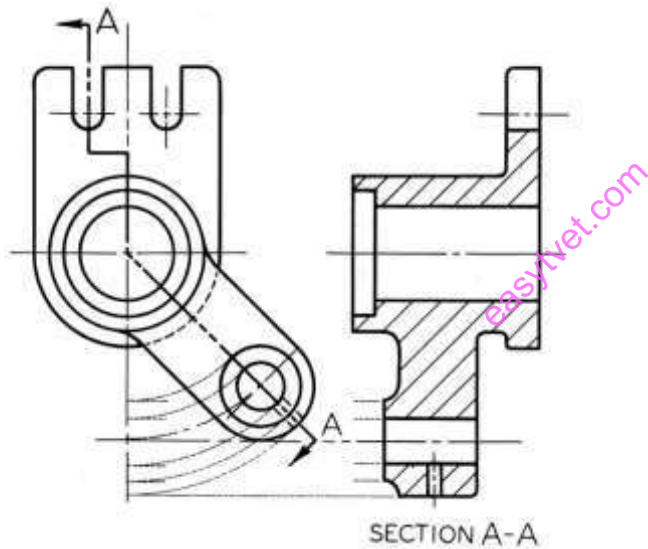
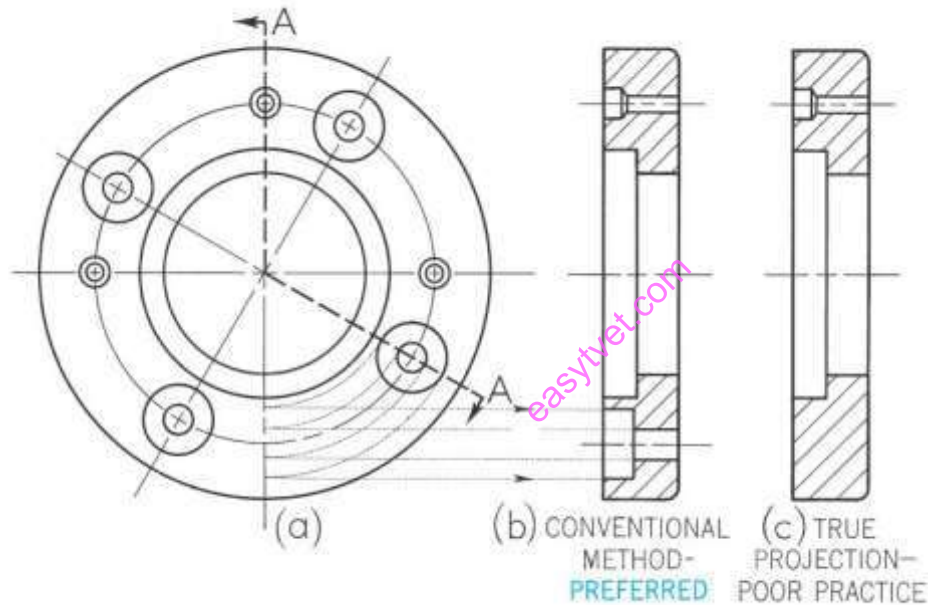
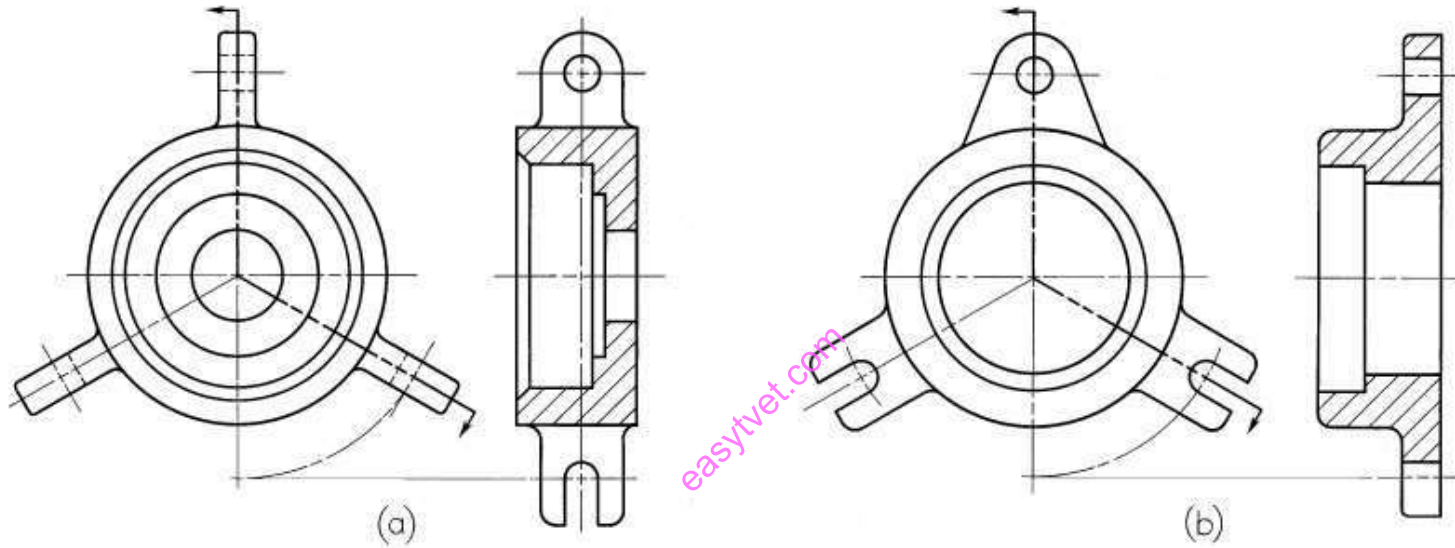


Figure 212: Aligned Sections

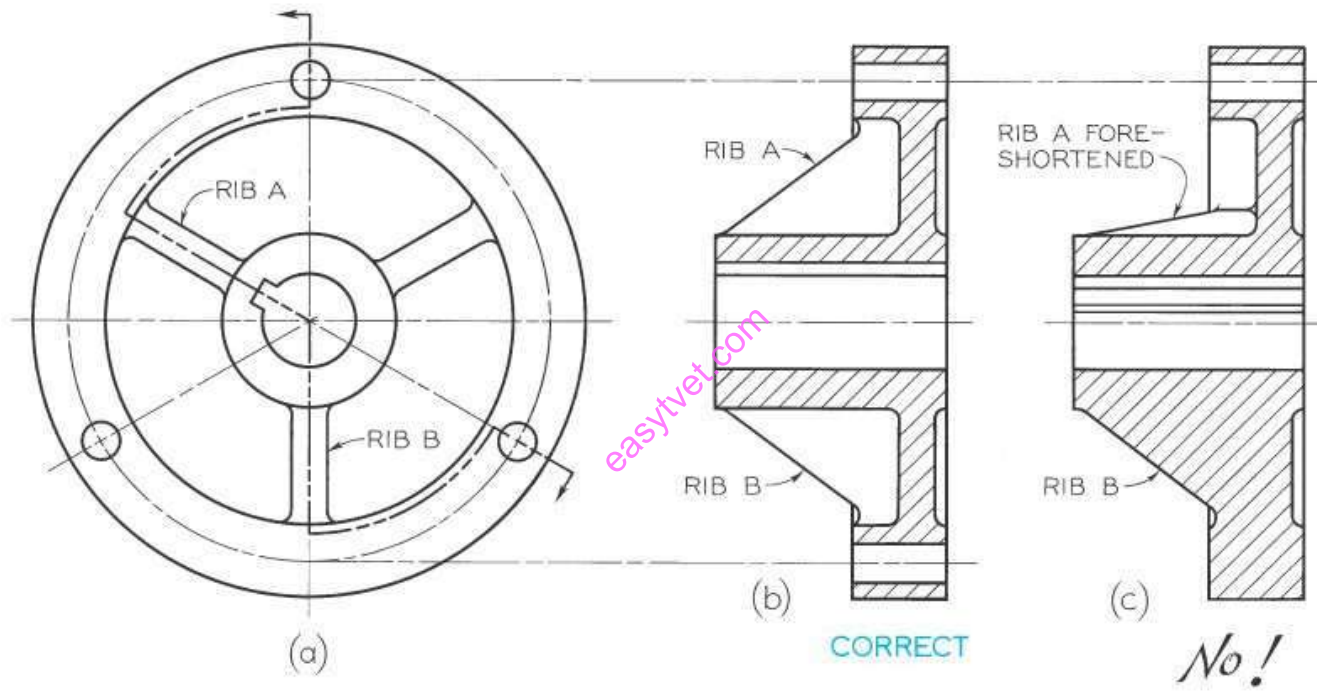
In the figure below, the cutting plane is bent so that both a drilled and a counterbored hole will be included in the sectional view. The correct sectional view, shown in fig. (b), is clearer and more complete than a full section, shown in fig. (c). The angle of revolution should always be less than 90 degree.



In figure (a) the projecting lugs are not sectioned for the same reason that ribs are not sectioned. In figure (b) the projecting lugs are located so that the cutting plane passes through them crosswise; therefore, they are sectioned.



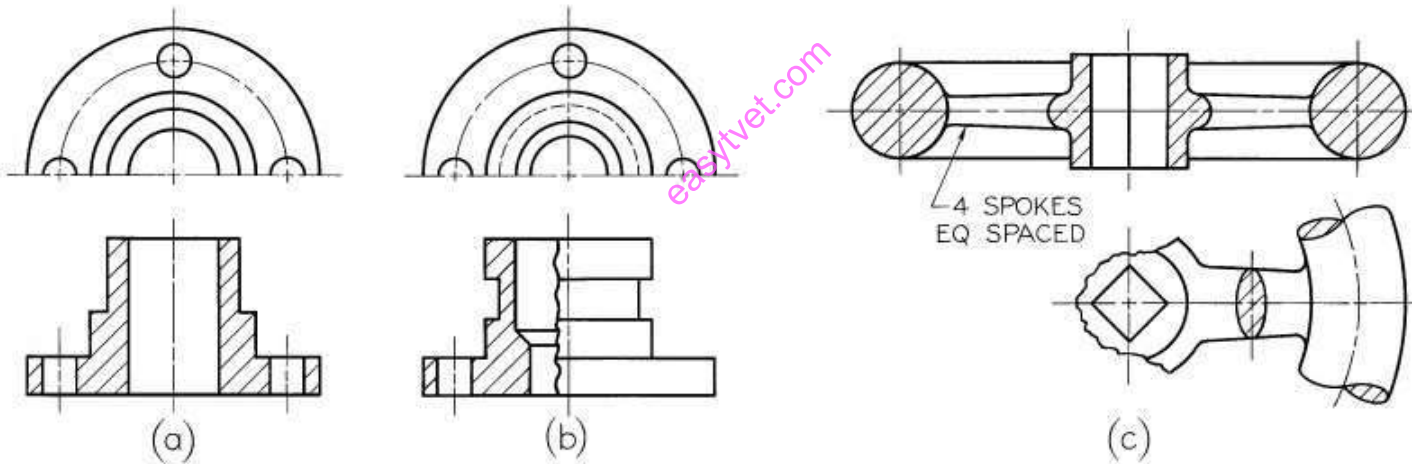
Another example involving rib sections and aligned sectioning is shown below.



## Partial Views

If space is limited on the paper or to save drafting time, partial views may be used in connection with sectioning. Figures (a) and (b) only show half views of the top view. In each case the back half of the object in the circular view is shown to expose the back portion of the object for viewing in section.

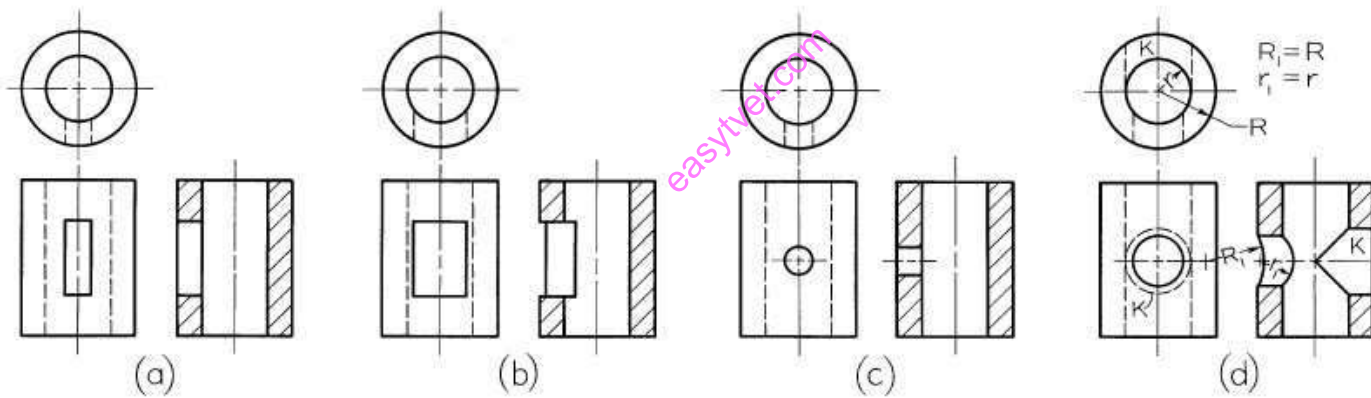
Another method of drawing a partial view is to break out much of the circular view, retaining only those features that are needed for minimum representation, as shown in figure (c).



## Intersections in Sectioning

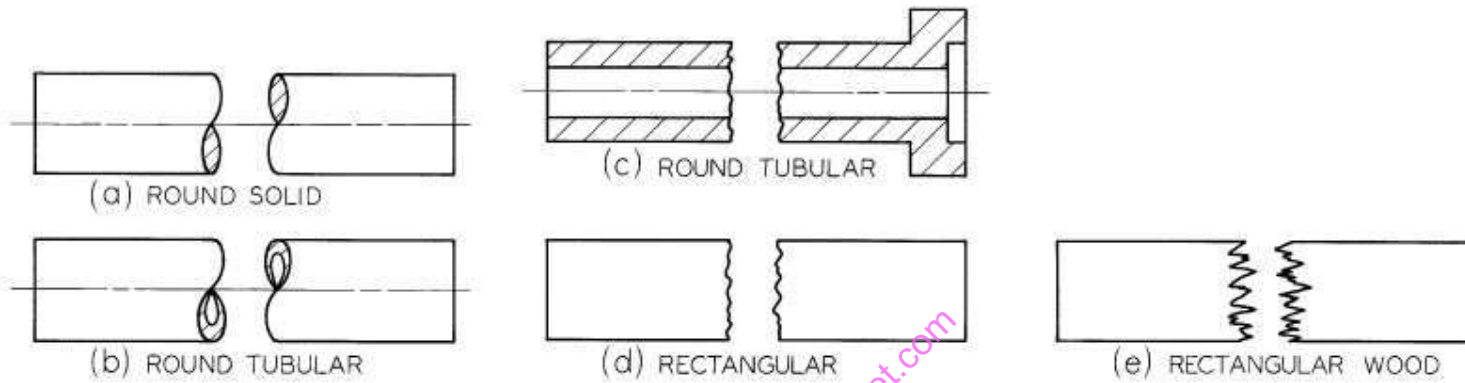
Where an intersection is small or unimportant in a section, it is standard practice to disregard the true projection of the figure of intersection, as shown in a and c. Larger figures of intersection may be projected, as shown in fig. (b), or approximated by circular arcs, as shown for the smaller hole in fig. (d).

Note that the larger hole K is the same diameter as the vertical hole. In such cases the curves of intersection, or ellipses, appear as straight lines, as shown.

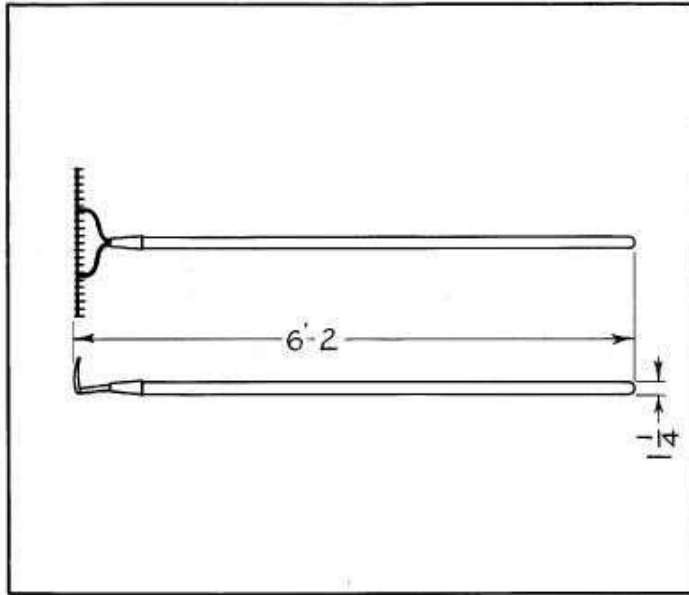


## Conventional Breaks

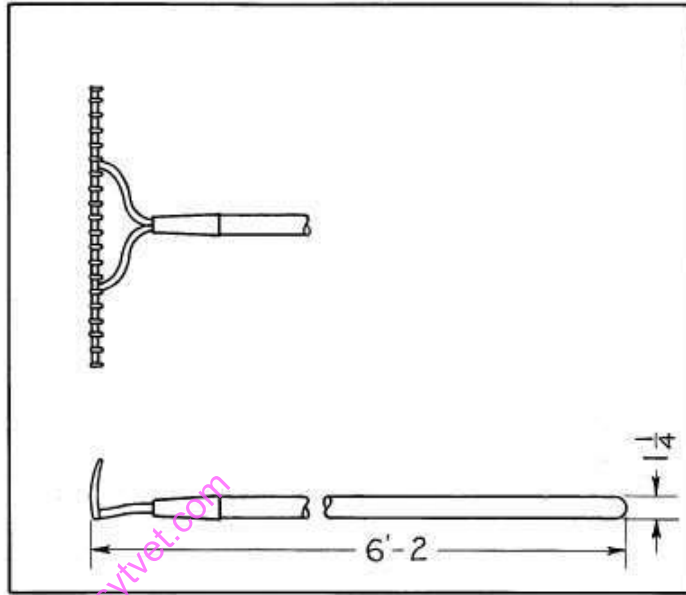
To shorten a view of an elongated object, whether in section or not, conventional breaks are recommended, as shown below.



Another example of conventional breaks is shown below.



(a)

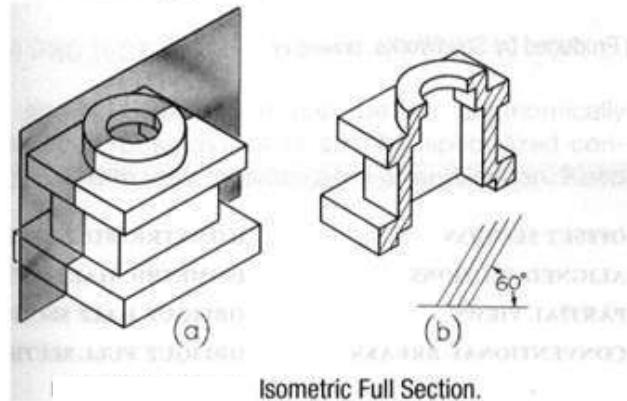


(b)



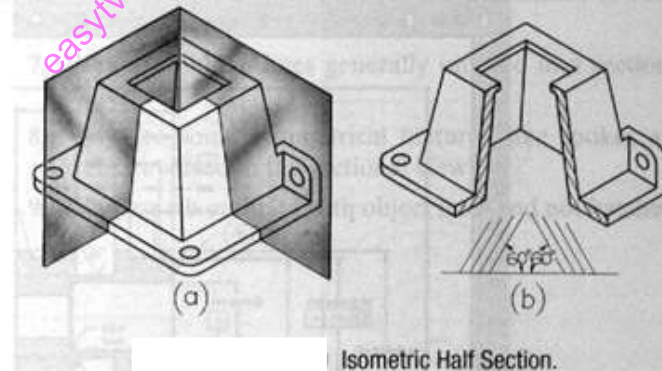
## Isometric Sectioning

You can create pictorial sectional views by showing the cut object in an isometric or oblique view and hatching the cut surfaces. An *isometric full section* is shown in Figure 7.32. It is usually best to draw the cut surface first and then to draw the portion of the object that lies behind the cutting plane.

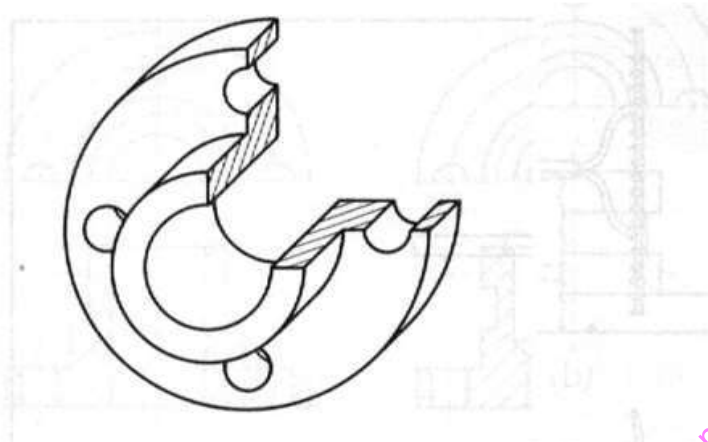


An *isometric half section* is shown in Figure 7.33. To sketch isometric half-sections, it is usually easiest to first sketch the entire object and then the cut surfaces. Since only a quarter of the object is removed in a half section, the resulting pictorial sketch is more useful than a full section to show both the exterior and interior shapes. Isometric broken-out sections are also sometimes used.

Hatching in an isometric sketch is similar to that in a multiview sketch. Showing it at an angle of 60 degrees with horizontal is recommended, but the direction should be changed if this would be parallel to major visible lines.

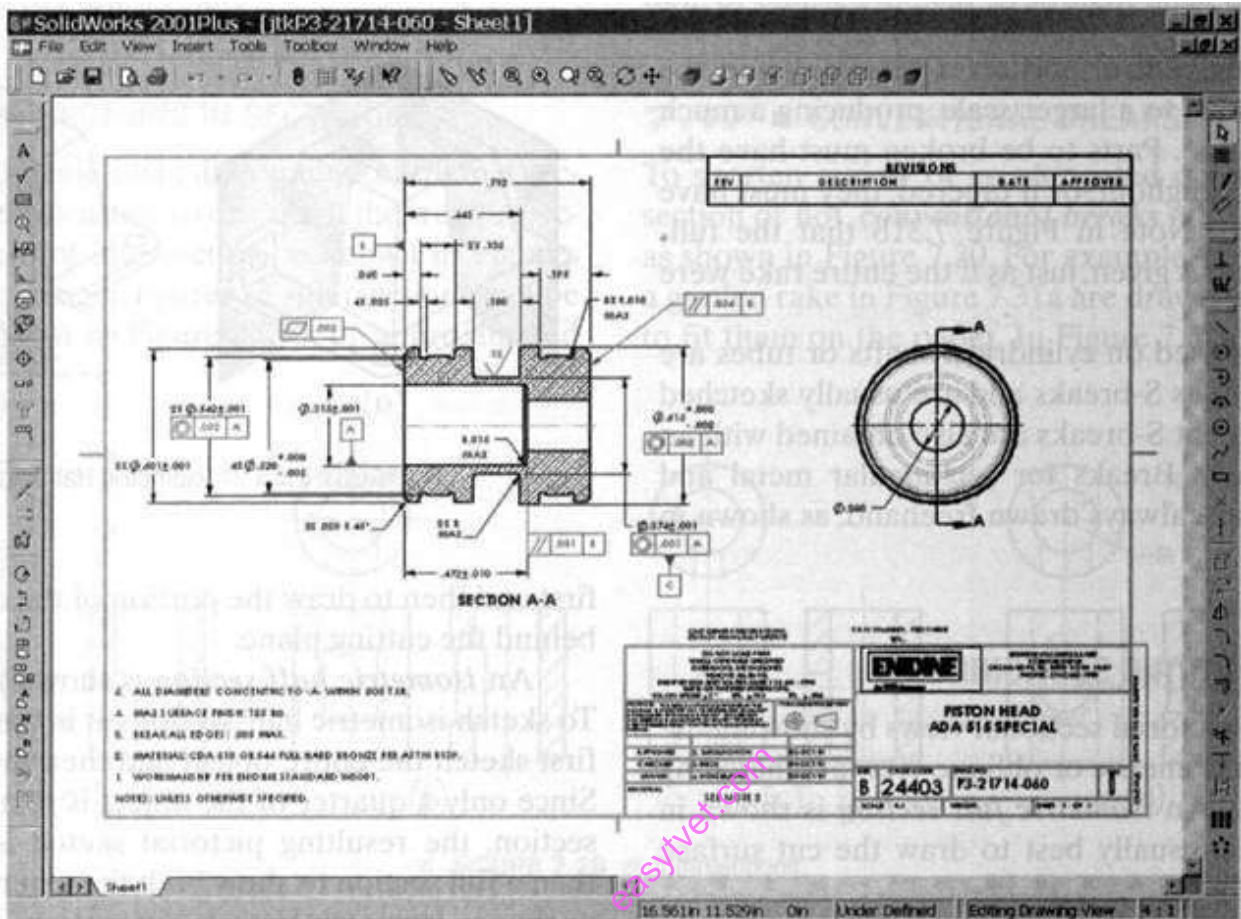


## Oblique Sections



Oblique Half Section.

You can also show pictorial sections in oblique view, especially to show interior shapes. An **oblique half section** is shown in Figure . . . . . **Oblique full sections** are seldom used because they do not show enough of the exterior shapes. In general, oblique sections are similar to isometric sections.



## Assembly drawings

### Introduction

A drawing which displays the parts of a machine or a machine unit assembled in their relative working positions is known as assembly drawing.

The assembly drawing would be such that it should satisfy:

- (iv) Manufacturing requirements
- (v) Operational requirements
- (vi) Maintenance requirements.

### **Designed assembly**

This assembly drawing is prepared at the design-stage on a larger scale.

### **Layout assembly**

This is an assembly drawing showing how the parts are assembled with their basic proportions (dimensions).

### **Installation assembly**

This is prepared for the installation or erection of a machine. This is also sometimes known as an outline assembly.

### **Working drawing assembly**

A complete set of working drawings of a machine comprises of detailed drawings, giving all necessary information for the production of individual parts and assembly drawing showing the location of each part. The assembly drawing should be ready before the detailed drawings are accepted as finished and the blue-prints are made.

### **General assembly**

It comprises of the detailed drawings of the individual parts, sub-assembly and the assembly drawings of the machine

Norms to be observed in preparing assembly drawings

- (vi) Selection of views: The main or important view which is usually in section should show all the individual parts and their relative locations. Additional views are shown only when they add necessary information.
- (vii) Sectioning: The parts should be sectioned according to the requirements (i.e. half-section or partial section) to show important assembly details. Code of the BIS ( SP:46-1988) for general engineering drawings must be observed
- (viii) Dotted lines: The dotted lines should be omitted from the assembly drawing when a proper section is taken. If the view of a part is drawn by the half-section, then in un section portion of the view, the dotted lines may be drawn to clarify details of the part.
- (ix) Dimensions: The overall dimensions and centre-to centre distances showing the relationship of parts to the machine as a whole, are sometimes shown.
- (x) Detailed dimensions are given on working assembly drawings when the detailed drawings are not prepared.

### **Bill of Materials**

Bill of materials: Each part of the machine is identified on assembly drawing by the leader line and number, which are used in the detail drawing and in the bill of material. The height of the number may be

approximately 5 mm and encircled by 9 mm diameter. Leader lines are drawn radially touching the respective parts.

The bill of materials also shows the following:

- h) Number of parts
- i) Material of parts required for one unit
- j) Shop processes
- k) Name of the company
- l) Standard norm for standard components
- m) Designed by, drawn by and checked by
- n) Scale
- (i) Any special remark.

The table containing above information must be prepared as shown in the illustrative problems.

### **Suggested approach**

- 3. Preparing an assembly form exploded view is easy task as clue to the position and sequence is available
- 4. For preparing from orthographic view of the individual components some skill is needed

### **The suggested approach is**

- 4. Functional Matching or Mapping
- 5. Geometrical mapping
- 6. Dimensional mapping

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### **Sequences of preparing the assembly drawing**

- (xii) Study functional requirements of each component and their inter relationship. • Learn the actual working of a machine.
- (xiii) Study carefully the views of each component in the detail drawing and decide the relative location of each part for the proper functioning of the machine.
- (xiv) Decide the mating dimensions between two components which are required to be assembled.
- (xv) Prepare free-hand sketch of the main view or an important view (generally front-elevation). Add additional views, if necessary.
- (xvi) Select a suitable scale for the entire assembly drawing.
- (xvii) Lay out the views of the assembly drawing so that it become easier to understand.
- (xviii) Prepare the bill of materials.
- (xix) Label each component by the leader-line and number it.
  
- (xx) Show overall dimensions.
- (xxi) Draw the section-lines according to the convention

(xxii) Show required fits and tolerances between the two mating components.

### Classification of Drawings

#### Machine drawing

It is pertaining to machine parts or components. It is presented through a number of orthographic views, so that the size and shape of the component is fully understood. Part drawings and assembly drawings belong to this classification. An example of a machine drawing is given in the figure below.

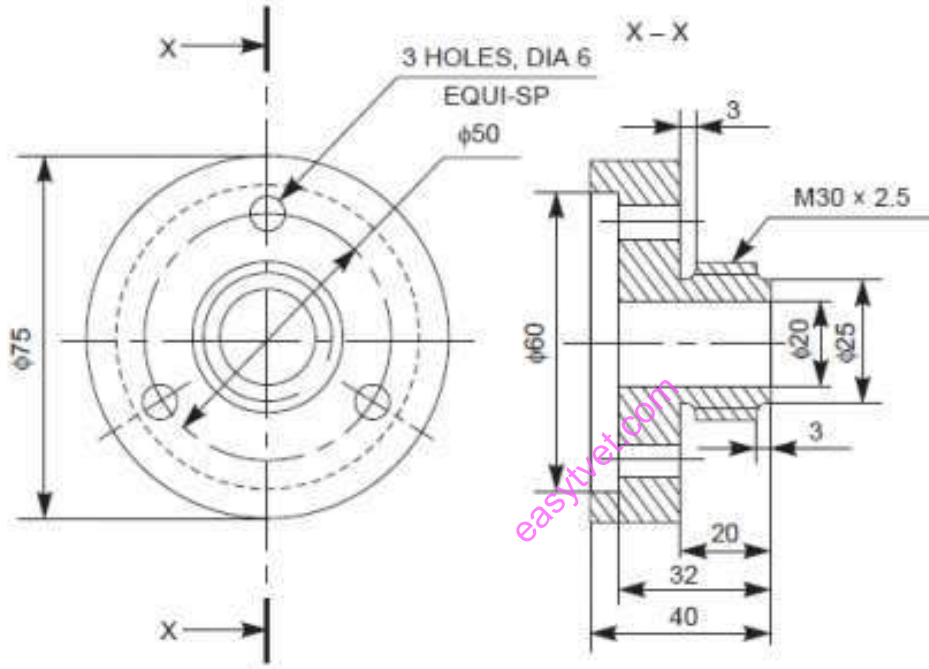


Figure 213: Machine drawing.

#### Production drawing

A production drawing, also referred to as working drawing, should furnish all the dimensions, limits and special finishing processes such as heat treatment, honing, lapping, surface finish, etc., to guide the craftsman on the shop floor in producing the component. The title should also mention the material used for the product, number of parts required for the assembled unit, etc. Since a craftsman will ordinarily make one component at a time, it is advisable to prepare the production drawing of each component on a separate sheet. However, in some cases the drawings of related components may be given on the same sheet. Figure below represents an example of a production drawing.

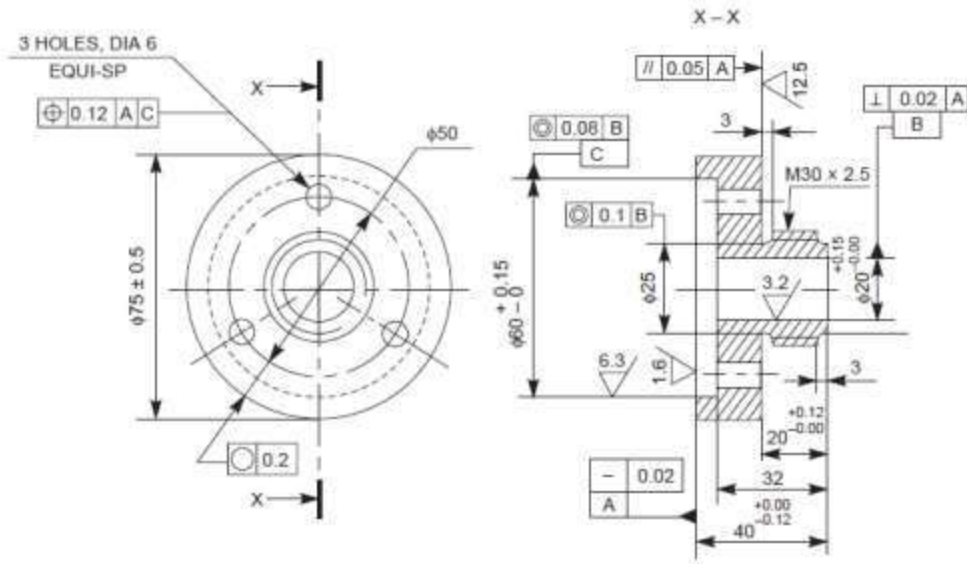


Figure 214: Production drawing.

### Assembly drawing

A drawing that shows the various parts of a machine in their correct working locations is an assembly drawing as shown in the figure below. There are several types of such drawings.

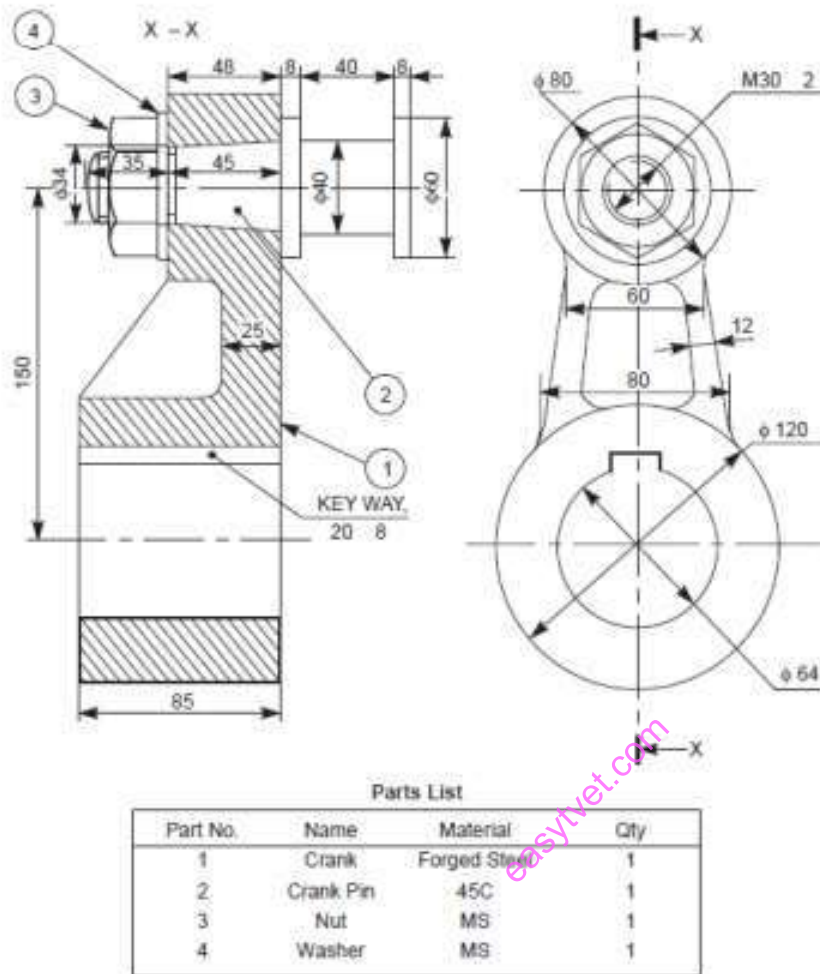


Figure 215: Assembly drawing.

Design Assembly Drawing When a machine is designed, an assembly drawing or a design layout is first drawn to clearly visualise the performance, shape and clearances of various parts comprising the machine.

### Detailed Assembly Drawing

It is usually made for simple machines, comprising of a relatively smaller number of simple parts. All the dimensions and information necessary for the construction of such parts and for the assembly of the parts are given directly on the assembly drawing. Separate views of specific parts in enlargements, showing the fitting of parts together, may also be drawn in addition to the regular assembly drawing.

### Sub- Assembly Drawing

Many assemblies such as an automobile, lathe, etc., are assembled with many pre-assembled components as well as individual parts. These pre-assembled units are known as sub-assemblies. A sub-assembly drawing is an



assembly drawing of a group of related parts, that form a part in a more complicated machine. Examples of such drawings are: lathe tail-stock, diesel engine fuel pump, carburettor, etc.

### **Installation Assembly Drawing**

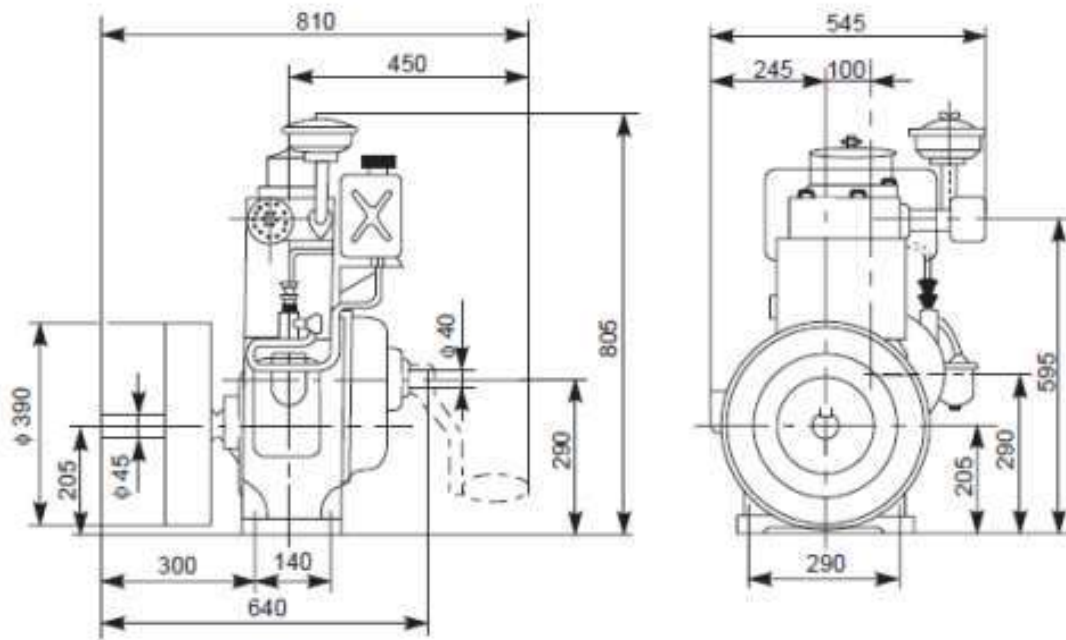
On this drawing, the location and dimensions of few important parts and overall dimensions of the assembled unit are indicated. This drawing provides useful information for assembling the machine, as this drawing reveals all parts of a machine in their correct working position.

### **Assembly Drawings for catalogues**

Special assembly drawings are prepared for company catalogues. These drawings show only the pertinent details and dimensions that would interest the potential buyer. Fig. 1.4 shows a typical catalogue drawing, showing the overall and principal dimensions. Assembly Drawings for instruction manuals These drawings in the form of assembly drawings, are to be used when a machine, shipped away in assembled condition, is knocked down in order to check all the parts before reassembly and installation elsewhere. These drawings have each component numbered on the job. Figure below shows a typical example of such a drawing.

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### **Assembly Drawings for instruction manuals**



These drawings in the form of assembly drawings, are to be used when a machine, shipped away in assembled condition, is knocked down in order to check all the parts before reassembly and installation elsewhere. These drawings have each component numbered on the job. Figure below shows a typical example of such a drawing.

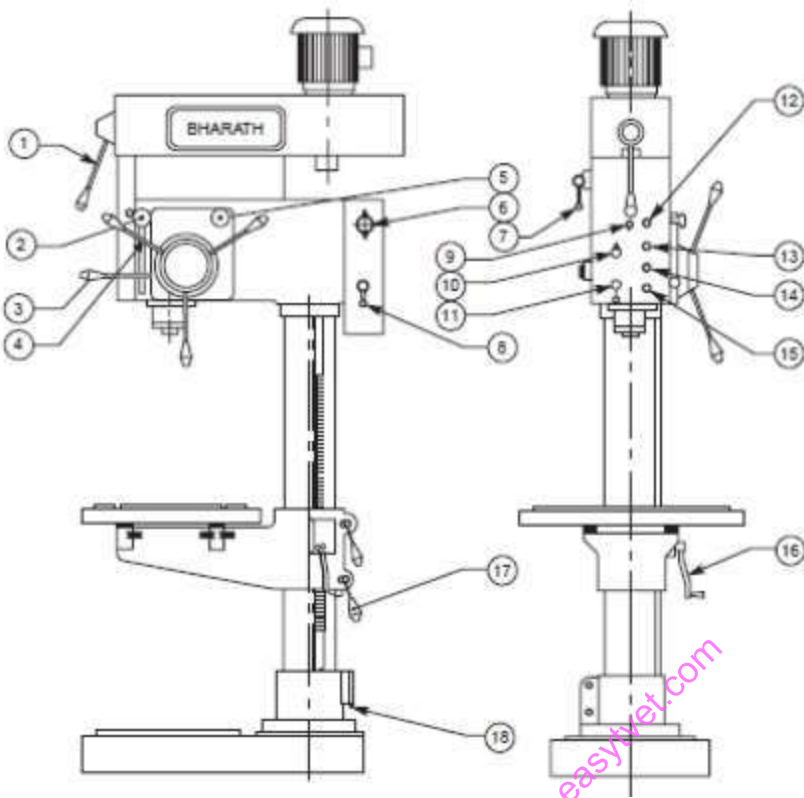


Figure 216: Assembly drawing for instruction manuals

Speed change lever (1)

Selector switch (10)

Depth adjusting knob (2)

Forward switch (11)

Mech. Feed engagement lever (3)

Pilot lamp (12)

Hand free lever (4)

Feed disengagement push button (13)

Feed change knob (5)

Start push button (14)

Switch for tapping(6)

Emergency stop (15)

Gear shifting lever (7)

Elevating handle (16)

Main switch(8)

Clamping handle(17)

Lamp switch(9)

Supply inlet (18)

### **Exploded Assembly Drawing**

In some cases, exploded pictorial views are supplied to meet instruction manual requirements. These drawings generally find a place in the parts list section of a company instruction manual. Figure shows drawings of this type which may be easily understood even by those with less experience in the reading of drawings; because in these exploded views, the parts are positioned in the sequence of assembly, but separated from each other.

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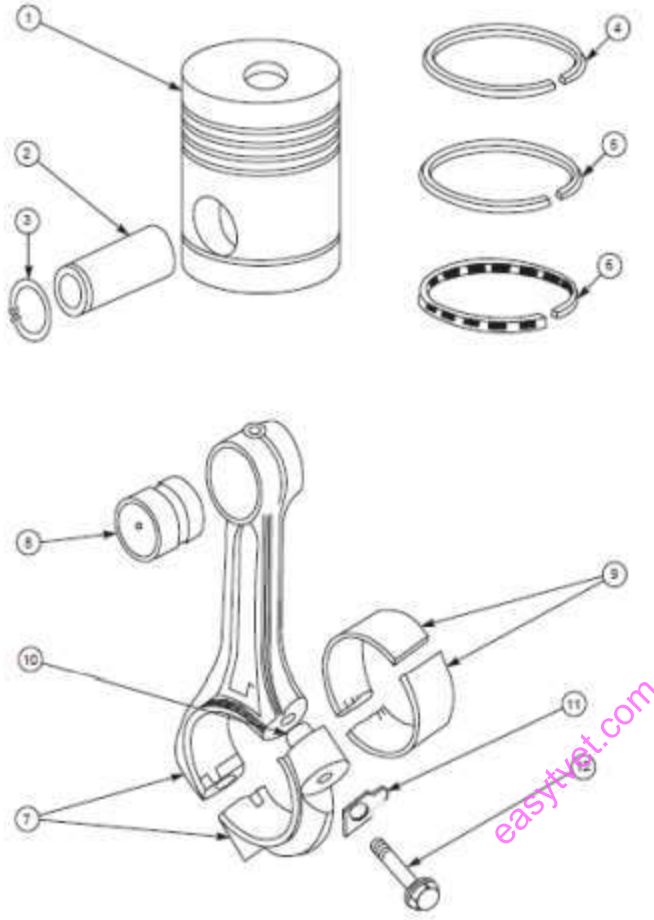


Figure 217: Exploded assembly drawing.

Schematic Assembly Drawing It is very difficult to understand the operating principles of complicated machinery, merely from the assembly drawings. Schematic representation of the unit facilitates easy understanding of its operating principle. It is a simplified illustration of the machine or of a system, replacing all the elements, by their respective conventional representations. The figure below shows the schematic representation of a gearing diagram.

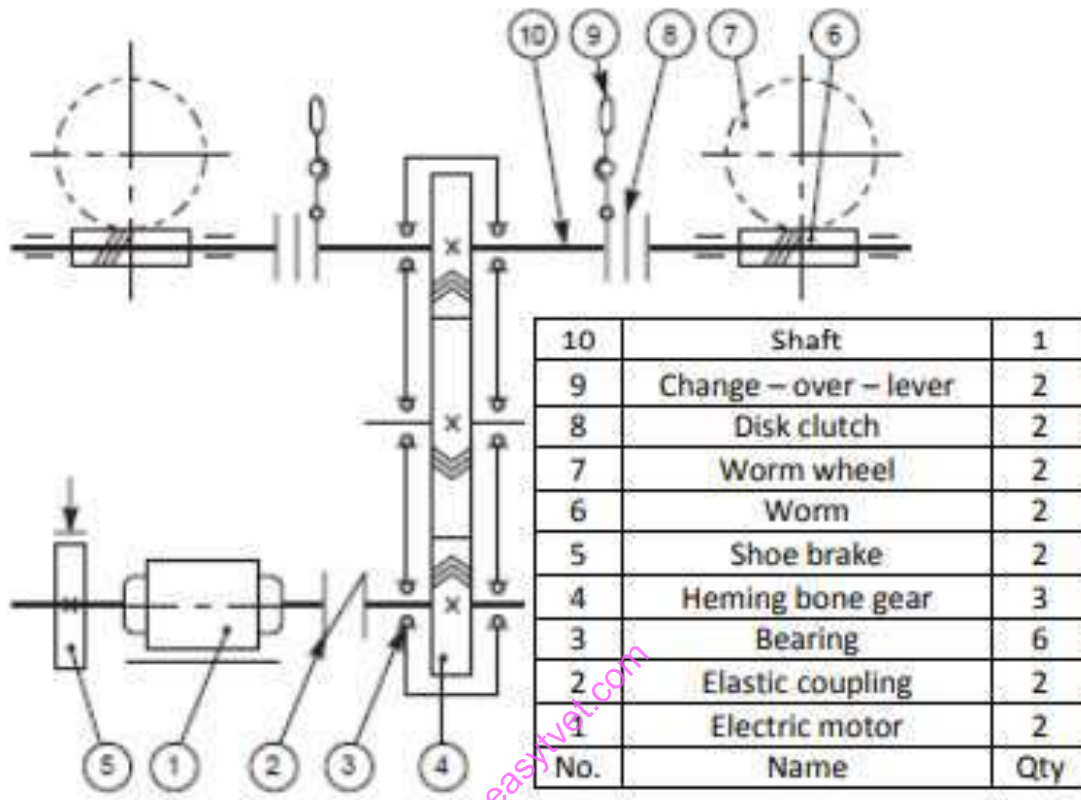


Figure 218: Schematic assembly drawing

### Machine Shop Drawing

Rough castings and forgings are sent to the machine shop for finishing operation. Since the machinist is not interested in the dimensions and information of the previous stages, a machine shop shown in figure below. Schematic assembly drawing.

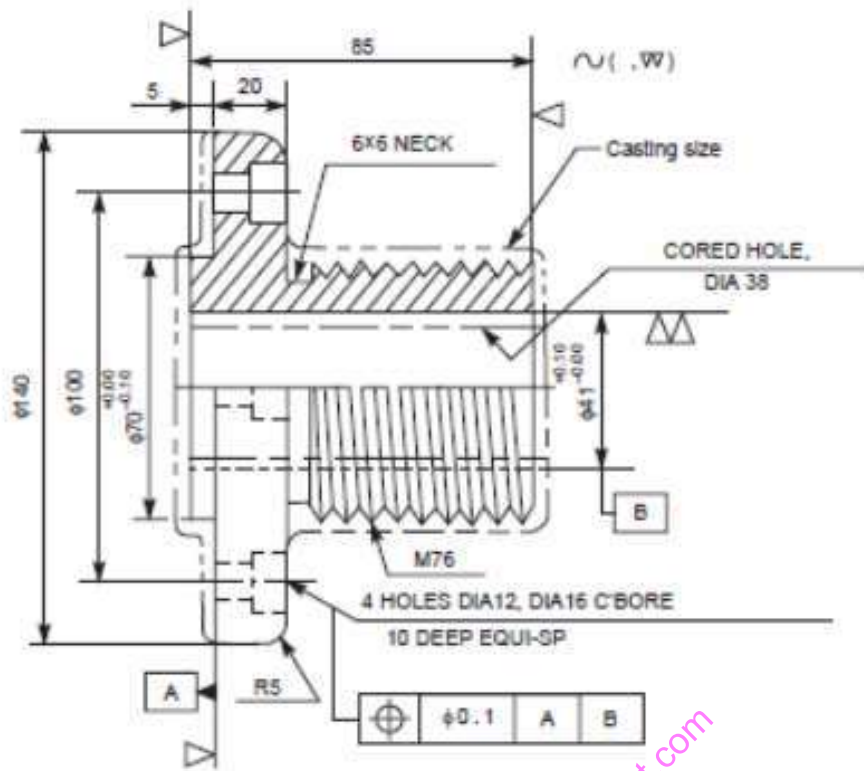


Figure 219: Machine Shop drawing.

Representation of external thread (Stud bolt)

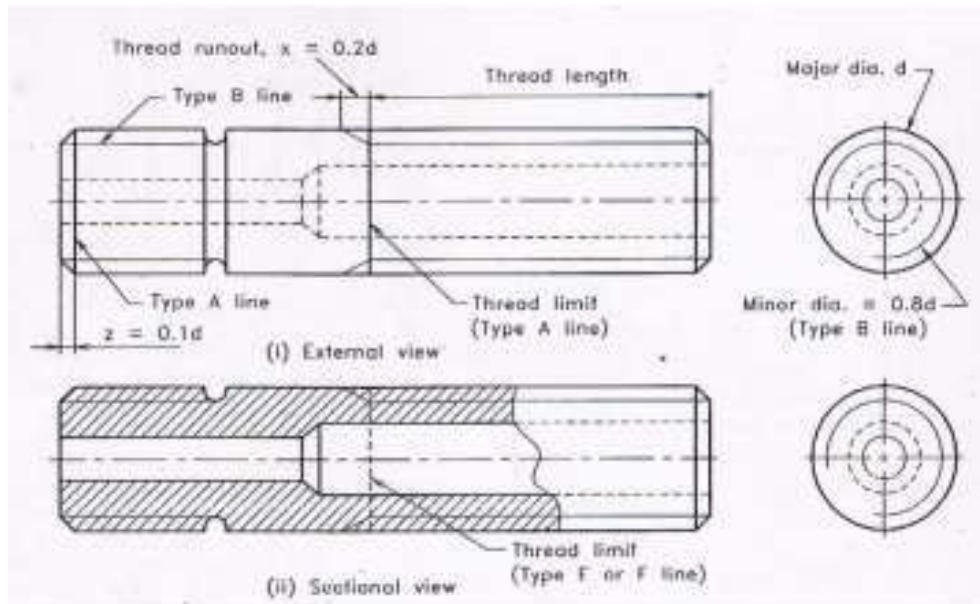


Figure 220: Representation of external thread.

### Representation of internal thread

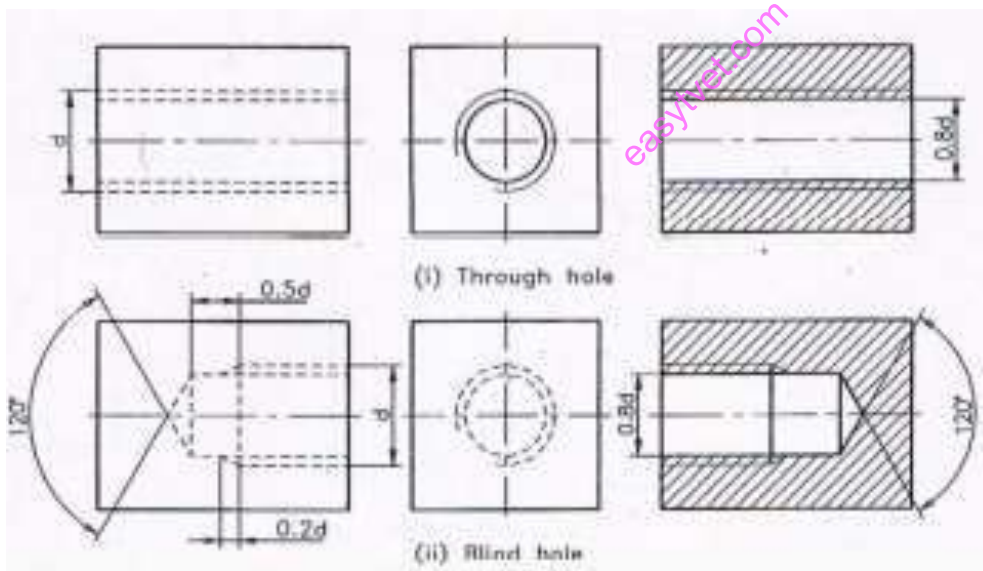


Figure 221:Representation of internal thread

### Terminology of bolt and nut



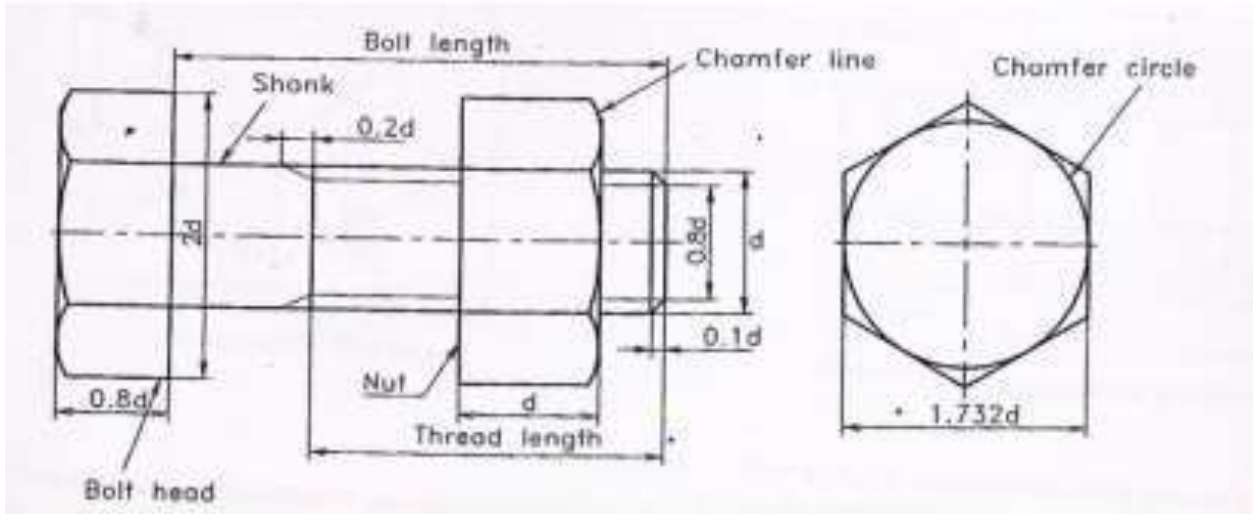


Figure 222: Terminology of bolt and nut

Figure: Terminology of bolt and nut.

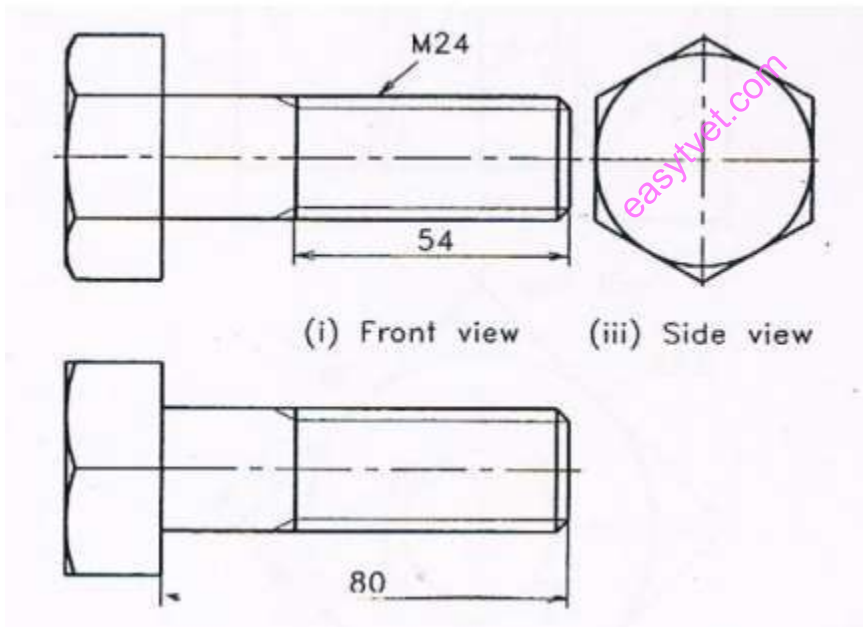


Figure 223: Hexagonal headed bolt

## Pictorial Drawing

Isometric Drawing

It is a pictorial orthographic projection of an object in which a transparent cube containing the object is tilted until one of the solid diagonals of the cube becomes perpendicular to the vertical plane and the three axes are equally inclined to this vertical plane.

#### *Types of isometric drawing*

- Cavalier
- Cabinet

#### *Lines in Isometric Projection*

The following are the relations between the lines in isometric projection

- The lines that are parallel on the object are parallel in the isometric projection.
- Vertical lines on the object appear vertical in the isometric projection.
- Horizontal lines on the object are drawn at an angle of  $30^\circ$  with the horizontal in the isometric projection.
- A line parallel to an isometric axis is called an isometric line and it is fore shortened to 82%.
- A line which is not parallel to any isometric axis is called non-isometric line and the extent of foreshortening of non-isometric lines are different if their inclinations with the vertical planes are different.

#### *Isometric drawing methods*

- Box construction
- Four center method

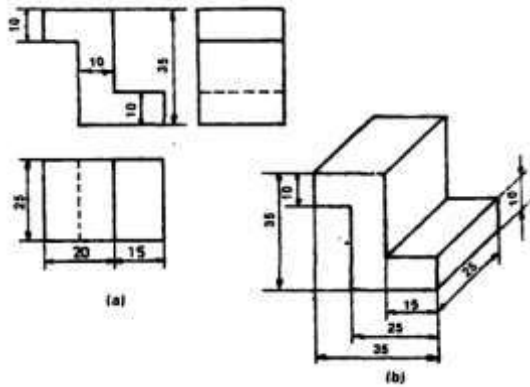
#### *Oblique Drawing*

##### *Characteristics of an oblique drawing*

In oblique projection, the front face of the object appears in its true size and shape, as it is placed parallel to the picture plane. The receding lines representing the other two faces are usually drawn at  $30^\circ$ ,  $45^\circ$  or  $60^\circ$  to the horizontal,  $45^\circ$  being the most common practice.

Oblique projections are classified as cavalier, cabinet.

##### *Draw an oblique box*



## Isometric and Oblique Circles

### *Construction of Isometric circles using the method of points*

- i. Enclose the circle in a square 1-2-3-4 and draw diagonals. Also draw lines YA horizontally and XA vertically.
- ii. To draw the isometric view of the square 1-2-3-4
- iii. Mark the mid points of the sides of the square as B, D, F and H.
- iv. Locate the points X and Y on lines 1-4 and 1-2 respectively.
- v. Through the point X, draw AX parallel to line 1-2 to get point A on the diagonal 1-3. The point A can be obtained also by drawing YA through the point Y and parallel to the line 1-4.
- vi. Similarly obtain other points C, E and G
- vii. Draw a smooth curve passing through all the points to obtain the required isometric view of the horizontal circular plane.
- viii. Similarly obtain isometric view of the vertical circular plane

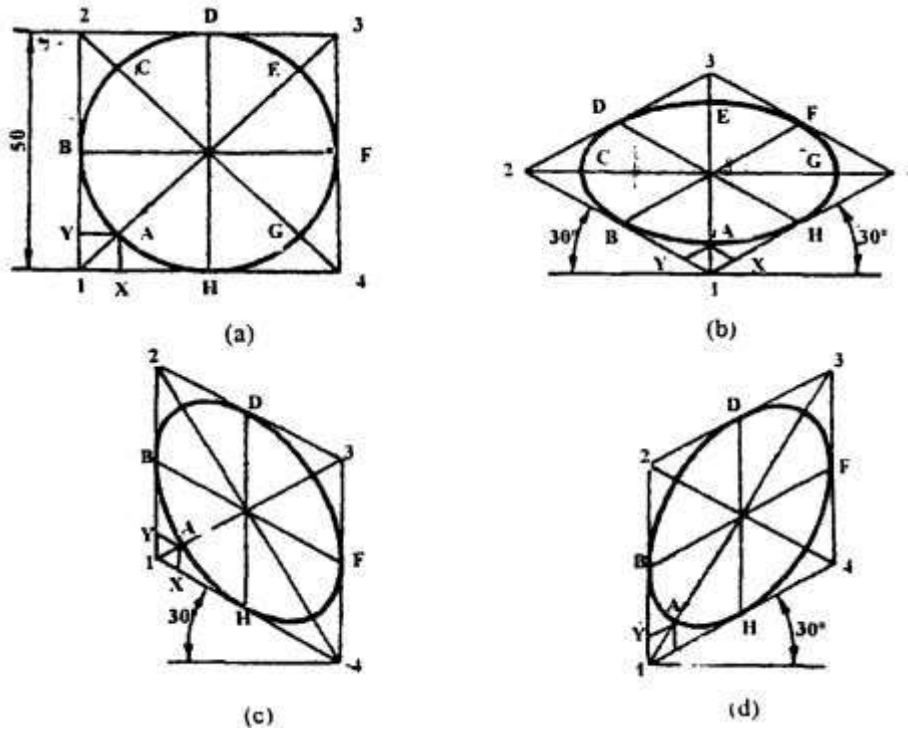


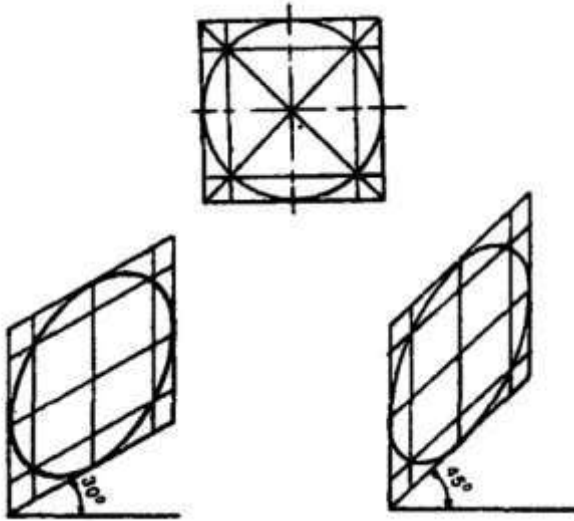
Figure 224: Angles, Circles and Curves in Oblique Projection

As already mentioned, angles, circles and irregular curves on the surfaces, parallel to the picture plane, appear in true size and shape. However, when they are located on receding faces, the construction methods, similar to isometric drawing may be followed.

For example, the method of representing a circle on an oblique face may be carried out by offset method and the four center method cannot be used. In case of cabinet oblique, the method and the result is the same as that of isometric drawing, since the angle of the receding axis can be the same as that of isometric axis.

Shows circles of same size in both isometric and oblique projections using  $45^\circ$  for the receding axis for oblique projections.

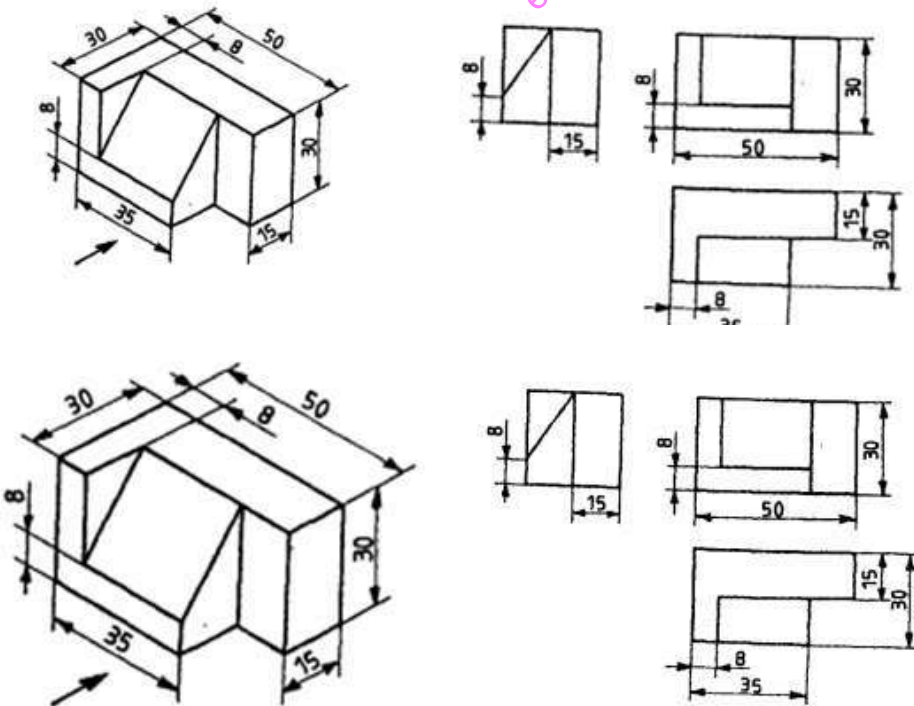
Curved features of all sorts on the receding faces or inclined surfaces may be plotted either by the off-set or co-ordinate methods as shown in the figure below.



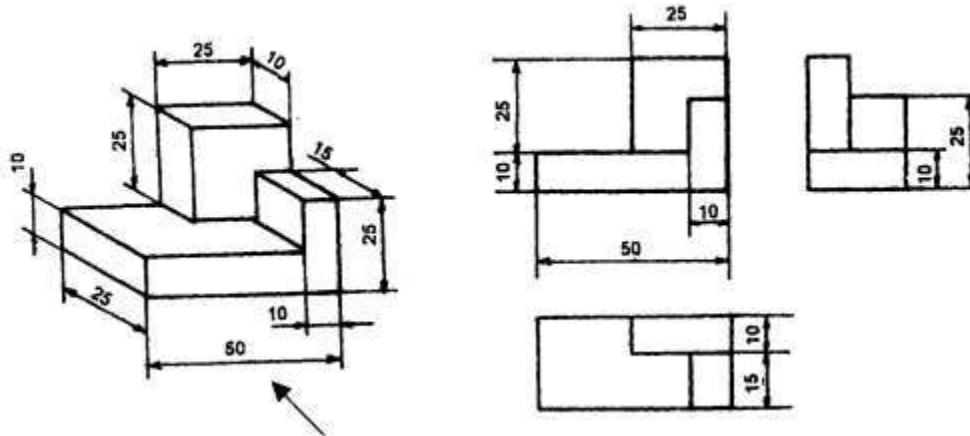
Learning activities

**LEARNING ACTIVITY 1: Produce orthographic and pictorial drawings**

iii. The following figures are in isometric view. Draw the orthographic views in first angle.



iv. The following figures are in oblique view. Draw the orthographic views in first angle.



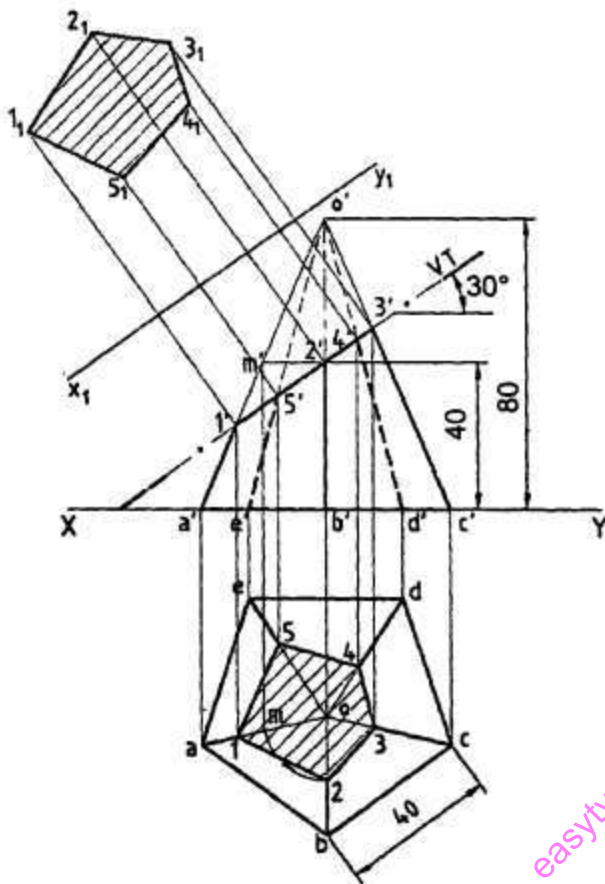
### Learning activity 2: Produce orthographic and pictorial drawings

A pentagonal pyramid of base side 40 mm and axis length 80mm is resting on HP on its base with one of its base side parallel to VP. It is cut by a plane inclined at  $30^\circ$  to HP and perpendicular to VP and is bisecting the axis. Draw its front view, sectional top view, and the true shape of section.

Draw the projection of the pyramid in the given position. The top view is drawn and the front view is projected.

To draw the cutting plane, front view and sectional top view

1. Draw the VT of the cutting plane inclined at  $30^\circ$  to XY line and passing through the midpoint of J the axis.
2. As a result of cutting, new comers 1', 2', 3', 4' and 5' are obtained on slant edges a '0', b '0', c '0', d'o' and e '0' respectively.
3. Show the remaining portion in front view by drawing dark lines.
4. Project the new points to get 1,2,3,4 and 5 in the top view on the respective slant edges.
5. Note that 2' is extended horizontally to meet the extreme slant edge a '0 ' at m', it is projected to meet ao in top view at m. Considering 0 as centre, om as radius, draw an arc to get 2 on bo



6. Join these points and show the sectional top view by drawing hatching lines.

To draw true shape of section.

II. Draw the new reference. Line  $x_1 y_1$  parallel to VT of the cutting plane.

1.2.3.4 Projectors from  $1', 2'$  etc. are drawn perpendicular to  $x_1 y_1$  line.

1.2.3.5 The distance of point 1 in top view from XY line is measured and marked from  $x_1 y_1$  in the projector passing through  $1'$  to get  $1'1$ . This is repeated to get  $2'1, 3'1$  etc.

II. Join these points and draw hatching lines to show the true shape of section.

### Learning activity 3

Assemble the following parts and Draw full sectional view of the assembly for the following:

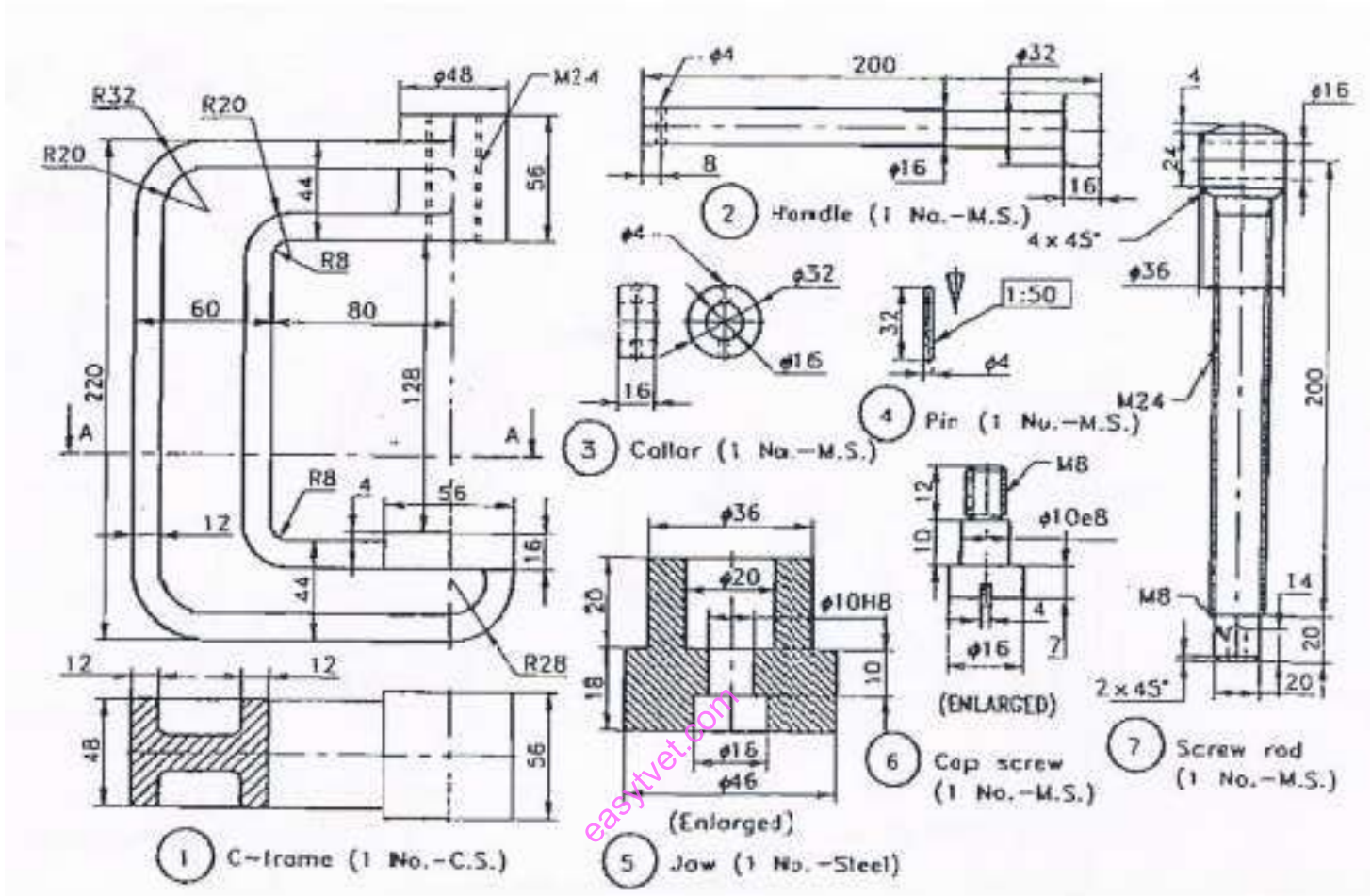


Figure: C-clamp parts.

**The assembled clamp**



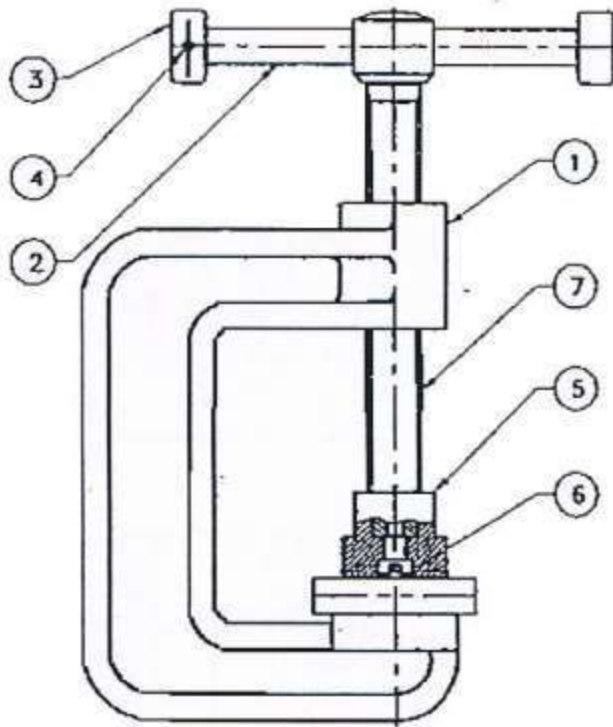


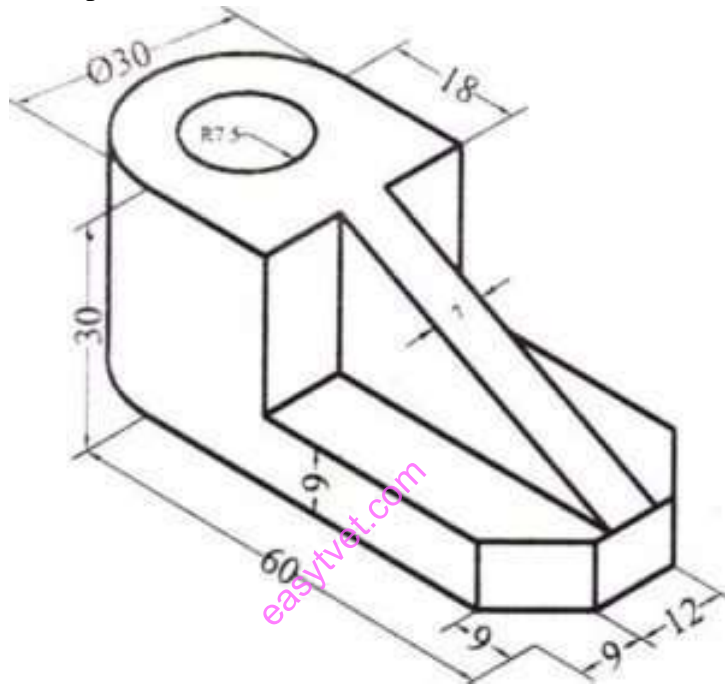
Figure: C-clamp assembly.

|     |              |          |       |   |
|-----|--------------|----------|-------|---|
| 7   | Screw rode   | M.S.     |       | 1 |
| 6   | Cap screw    | M.S.     |       | 1 |
| 5   | Jaw          | Steel    |       | 1 |
| 4   | Pin          | M.S.     |       | 1 |
| 3   | Collar       | M.S.     |       | 1 |
| 2   | Handle       | M.S.     |       | 1 |
| 1   | C-frame      | C.S.     |       | 1 |
| No. | Name of part | Material | Notes | Q |

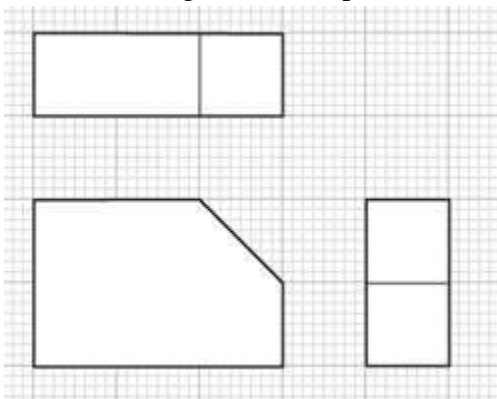
#### Self-assessment

16. What are the types of orthographic projections?
17. Isometric drawings are often used by \_\_\_\_\_ to help illustrate complex designs.
  - A. mechanical engineers
  - B. piping drafters
  - C. aerospace engineers
  - D. all of the above

18. When the receding lines are true length, and the projectors are at 45 degrees to the plane of projection, the oblique drawing is called this:
- E. Cabinet projection
  - F. Cavalier projection
  - G. Axonometric projection
  - H. Isometric projection
19. This drawing is an example of:



- E. An orthographic drawing
  - F. An isometric drawing
  - G. A perspective drawing
  - H. An oblique drawing
20. This drawing is an example of:

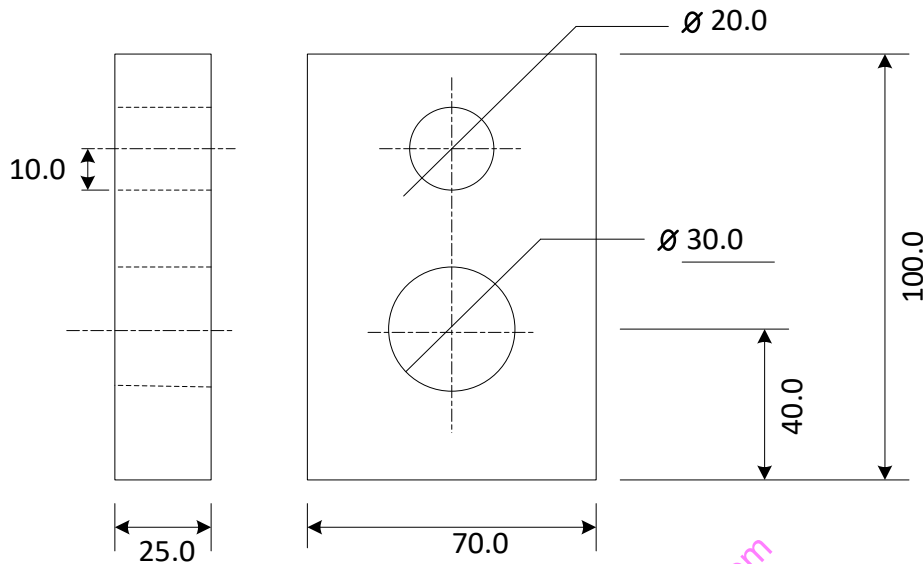


- E. An orthographic drawing
- F. An isometric drawing

- G. A perspective drawing
  - H. An oblique drawing
21. This type of projection is when projectors are parallel to each other, but is at an angle other than 90 degrees to the plane of projection:
- E. Oblique projection
  - F. Perpendicular projection
  - G. Aesthetic projection
  - H. Angular projection
22. Name the views in an Orthographic Drawings
23. The top, front, and bottom views align in this manner:
- E. Horizontally
  - F. Vertically
  - G. According to the planar views
  - H. Parallel to the frontal plane
24. If a plane is parallel to the plane of projection, it appears:
- E. True size
  - F. As a line or edge
  - G. Foreshortened
  - H. As an oblique surface
25. Three systems are used to arrange orthographic views: first, second, and third angle projection.
- C. True
  - D. False
26. This line pattern is composed of three dashes, one long dash on each end with a short dash in the middle:
- E. Object
  - F. Hidden
  - G. Center
  - H. Phantom
27. This is the plane upon which the top view is projected:
- E. Horizontal
  - F. Frontal
  - G. Profile
  - H. Base
28. An advantage of this type of view is that each view shows the object all the way through as if it were transparent:
- E. Planar
  - F. Horizontal
  - G. Auxiliary
  - H. Orthographic
29. This type of surface is tipped to all principal planes of projection and does not appear true size in any standard view:

- E. Foreshortened
- F. Parallel
- G. Orthographic
- H. Oblique

30. From the following figure, which is the repetitive dimension?



- E. 30
- F. 70
- G. 10
- H. 20

#### Tools, Equipment, Supplies and Materials

- 7. Drawing tools
- 8. Drawing set
- 9. Drawing papers
- 10. Erasers
- 11. Series of pencils
- 12. Drawing board

#### References

- 6. Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing: Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.
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10. Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical

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## 4.6 Apply Cad Packages

### Introduction to the learning outcome

This learning outcome is intended to equip the trainee with competence on how to apply CAD packages.

In this learning outcome AutoCAD has been selected to be the dominant CAD software to be learnt.

### Performance Standard

- iii. CAD packages are selected according to task requirements
- iv. CAD packages are applied in production of electrical drawings

Information sheet

### Identification of CAD packages

#### Computer-Aided Design (CAD) Software

Computer-Aided Design (CAD) is the use of an application to help create or optimize a design. Therefore, CAD software allows engineers, architects, designers, and others to create precision drawings or technical illustrations in 2D or 3D. This category of software can increase productivity, improve quality, and maximize organization by creating a documentation database for manufacturing.

CAD software has a host of applications, including the design of manufacturing parts, electronic circuit boards, prototypes for 3D printers, and buildings. Typically, this software uses either traditional vector-based graphics or raster graphics which show how finished objects would actually look.

CAD software can also facilitate the flow from the design process to the manufacturing process. This software can simulate the movement of a part through the manufacturing process in three dimensions. As this software becomes ever better at simulating the manufacturing process, specialized software for designing the manufacturing process and controlling machine tools called Computer-Aided Manufacturing (CAM) has become integrated with CAD as a single platform.

Computer-Aided Design (CAD) Features & Capabilities

#### AutoCAD

## DEFINITION OF TERMS

### Basics

This section reviews the basic AutoCAD controls.

## **Viewing**

Pan and zoom in a drawing, and control the order of overlapping objects.

## **Geometry**

Create basic geometric objects such as lines, circles, and hatched areas.

## **Precision**

Ensure the precision required for your models.

## **Layers**

Organize your drawing by assigning objects to layers.

## **Properties**

You can assign properties such as color and linetype to individual objects, or as default properties assigned to layers.

## **Modifying**

Perform editing operations such as erase, move, and trim on the objects in a drawing.

## **Blocks**

Insert symbols and details into your drawings from commercial online sources or from your own designs.

## **Layouts**

Display one or more scaled views of your design on a standard-size drawing sheet called a layout.

## **Notes and Labels**

Create notes, labels, bubbles, and callouts. Save and restore style settings by name

## **Dimensions**

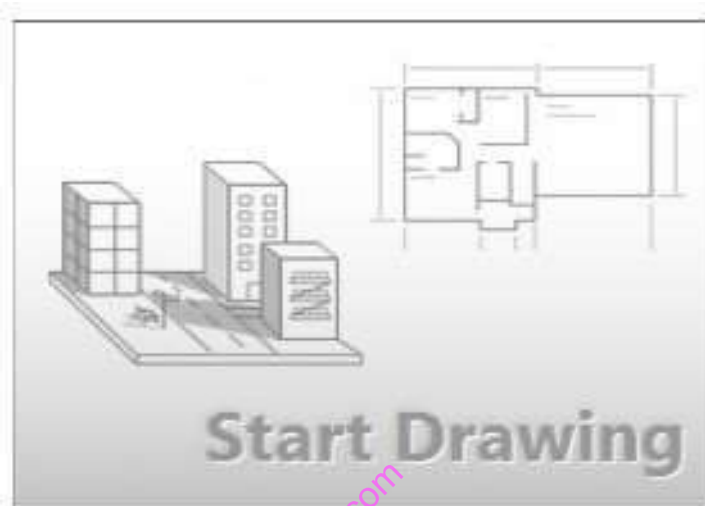
Create several types of dimensions and save dimension settings by name.

## **Printing**

Output a drawing layout to a printer, a plotter, or a file. Save and restore the printer settings for each layout.

## Basics

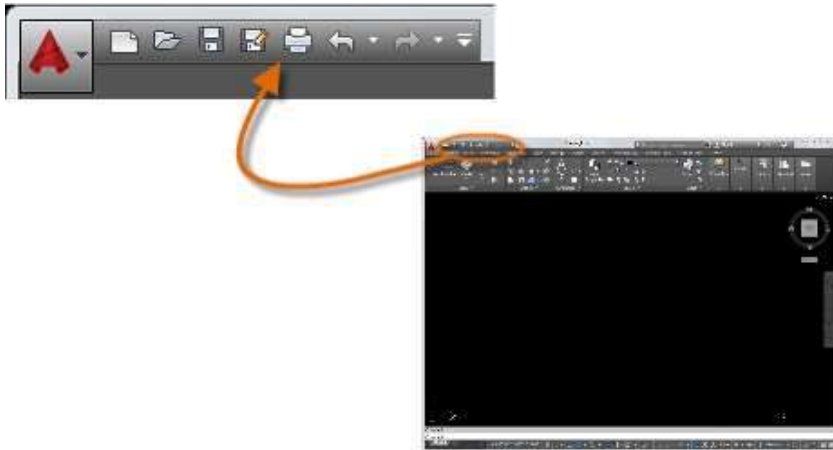
Review the basic AutoCAD controls. After you launch AutoCAD, click the Start Drawing button to begin a new drawing.





AutoCAD includes a standard tabbed ribbon across the top of the drawing area. You can access nearly all the commands presented in this guide from the **Home** tab. In addition, the Quick Access toolbar shown below includes familiar commands

such as New, Open, Save, Print, Undo, and so on.



### The Command Window

At the heart of AutoCAD is the Command window, which is normally docked at the bottom of the application window. The Command window displays prompts, options, and messages.

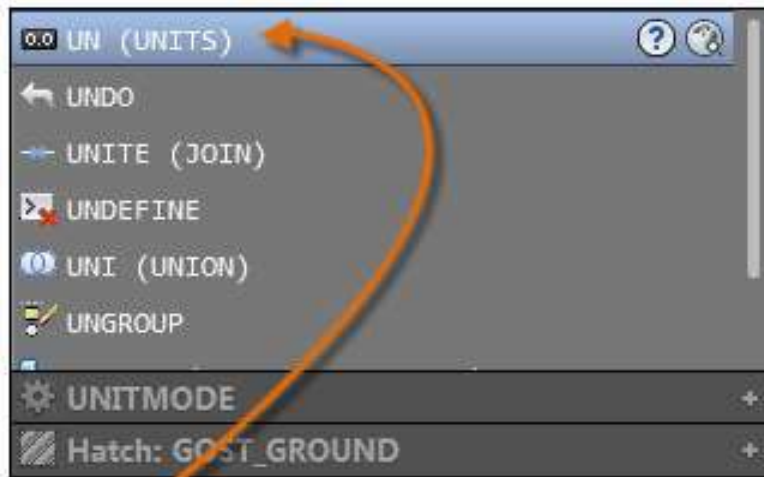


You can enter commands directly in the Command window instead of using the ribbon, toolbars, and menus.

Many long- time AutoCAD users prefer this method.

Notice that as you start to type a command, an autocomplete menu appears.

When several options are available, such as in the example below, make your choice by clicking the correct option or using the arrow keys and then pressing Enter or the Spacebar to confirm your selection.



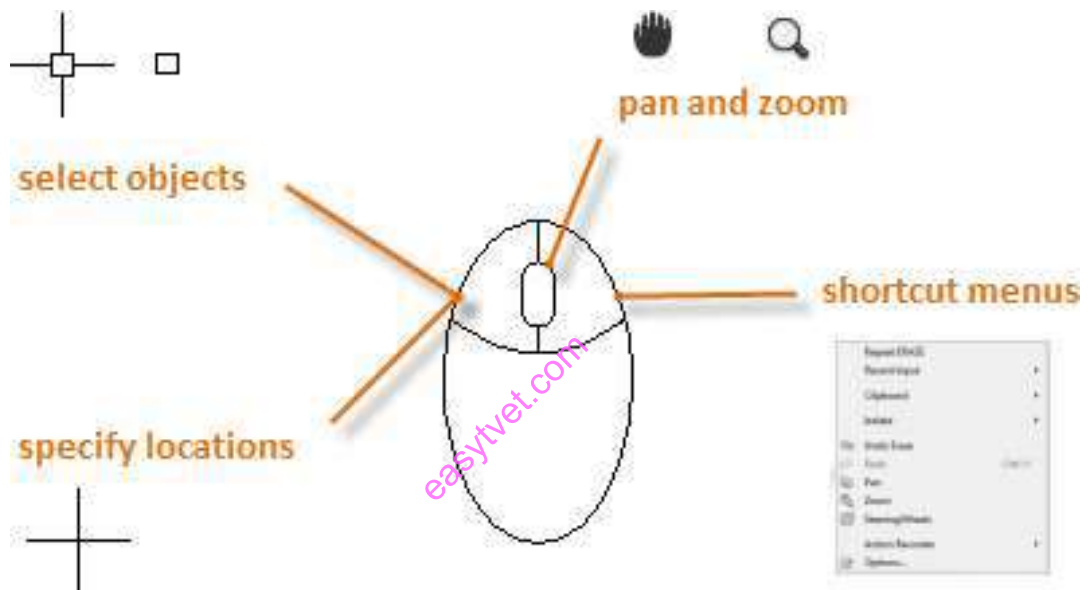
## The Mouse

Most people use a mouse as their pointing device, but other devices have equivalent controls.

Here's a Tip:

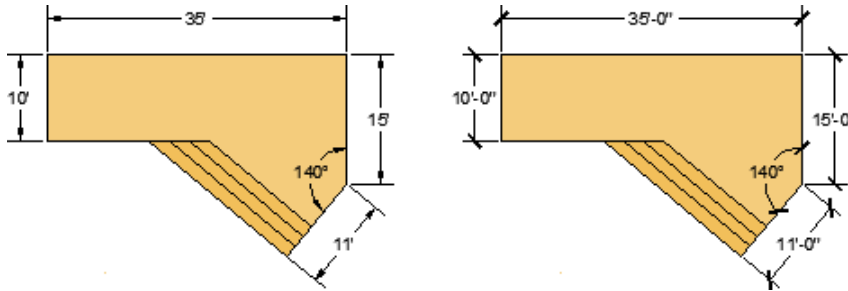
When looking for a command or option, try right-clicking.

Depending on where your cursor is located, different menus will display relevant commands and options.



## New Drawings

You can easily conform to industry or company standards by specifying settings for text, dimensions, linetypes, and several other features. For example, this backyard deck design displays two different dimension styles.



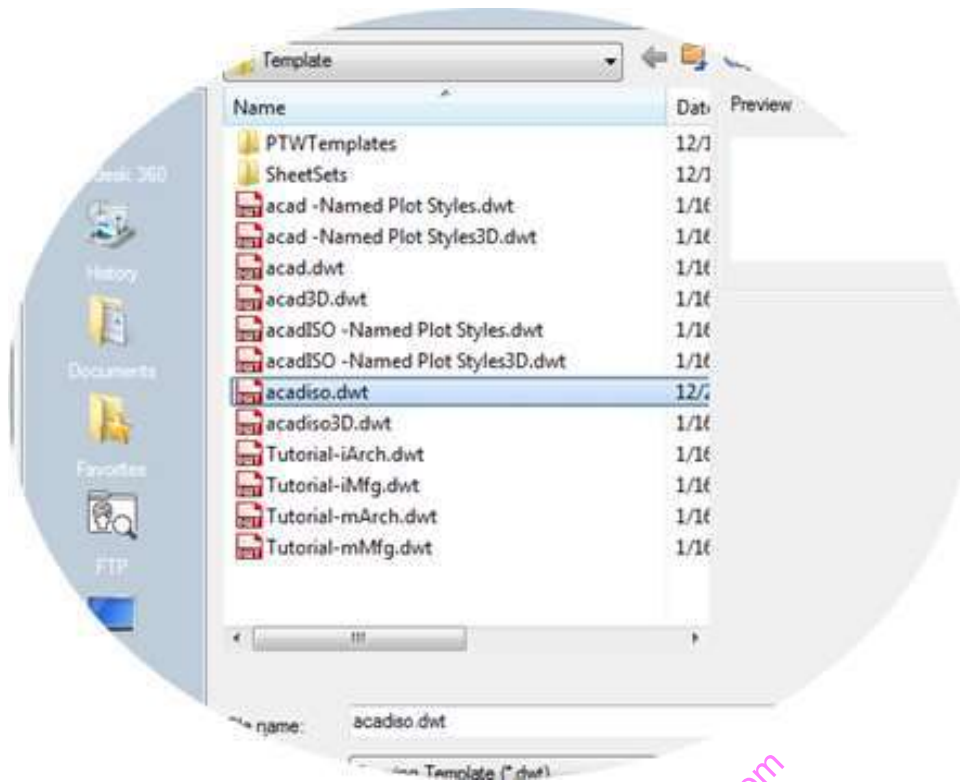
All these settings can be saved in a *drawing template* file. Click New to choose from several drawing



### Template files:

For imperial drawings that assume your units are inches, use *acad.dwt* or *acadlt.dwt*.

For metric units that assume your units are millimeters, use *acadiso.dwt* or *acadltiso.dwt*.



The “Tutorial” template files in the list are examples of the architectural or mechanical design templates using both imperial (i) and metric (m) measurements.

You might want to experiment with them.

Most companies use drawing template files that conform to company standards, and they will often use different drawing template files depending on the project or client.

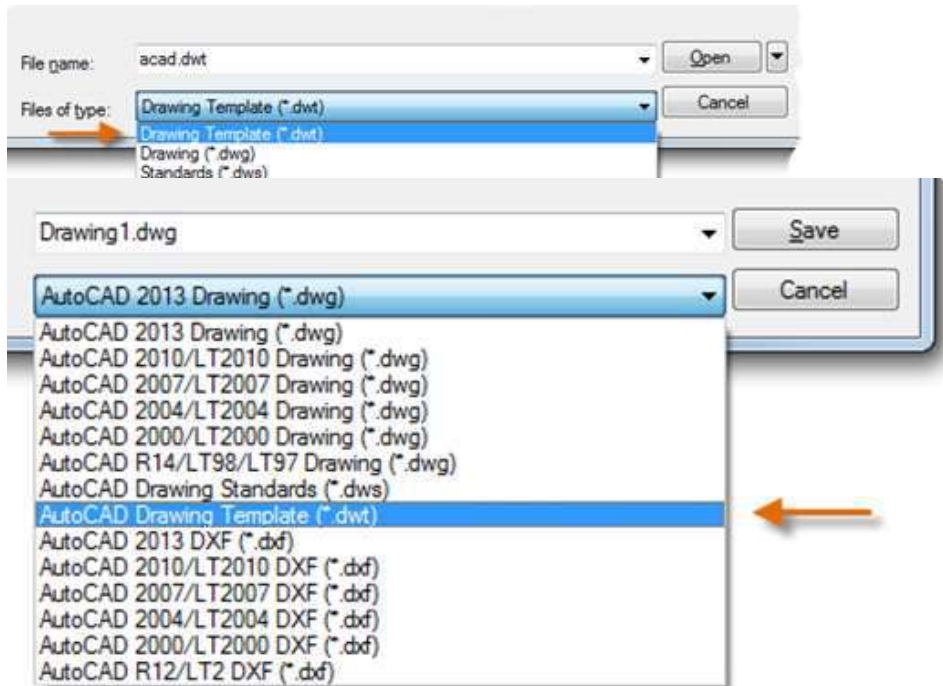
### Create Your Own Drawing Template File

You can save any drawing (.*dwg*) file as a drawing template (.*dwt*) file. You can also open any existing drawing template

If you work independently, you can develop your drawing template files to suit your working preferences, adding settings for additional features as you become familiar with them.

To modify an existing drawing template file, click Open, specify Drawing Template (\*.*dwt*) in the Select File dialog box, and choose the template file. Important:

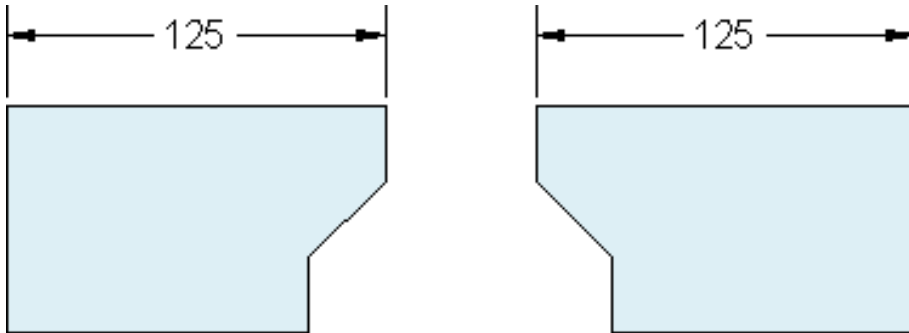
If your company has already established a set of drawing template files, check with your CAD manager before modifying any of them.



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## Units

When you first start a drawing, you need to decide what the length of one unit represents an inch, a foot, a centimeter, a kilometer, or some other unit of length. For example, the objects below could represent two buildings that are each 125 feet long, or they could represent a section from a mechanical part that is measured in millimeters.



## Unit Display Settings

After you decide what unit of length that you want to use, the **UNITS** command lets you control several unit display settings including the following:

**Format (or Type):** For example, a decimal length of 6.5 can be set to display as a fractional length of 6-1/2 instead.

**Precision:** For example, a decimal length of 6.5 can be set to display as 6.50, 6.500, or 6.5000.

If you plan to work in feet and inches, use the **UNITS** command to set the unit type to Architectural, and then when you create objects, specify their lengths in inches. If you plan to use metric units, leave the unit type set to Decimal. Changing the unit format and precision does not affect the internal precision of your drawing, it affects only how lengths, angles, and coordinates are displayed in the user interface

Here's a Tip:

If you need to change the **UNITS** settings, make sure that you save the drawing as a drawing template file (.dwt). Otherwise, you will need to change the **UNITS**

## Model Scale

Always create your models at full size (1:1 scale). The term *model* refers to the geometry of your design. A *drawing* includes the model geometry along with the views, notes, dimensions, callouts, tables, and the title block displayed in the *layout*.

You can specify the scaling that is necessary to print a drawing on a standard-sized sheet later, when you create the layout.

### Recommendations

To open **Help** for information about the command in progress, press F1.

To **repeat** the previous command, press Enter or the Spacebar.

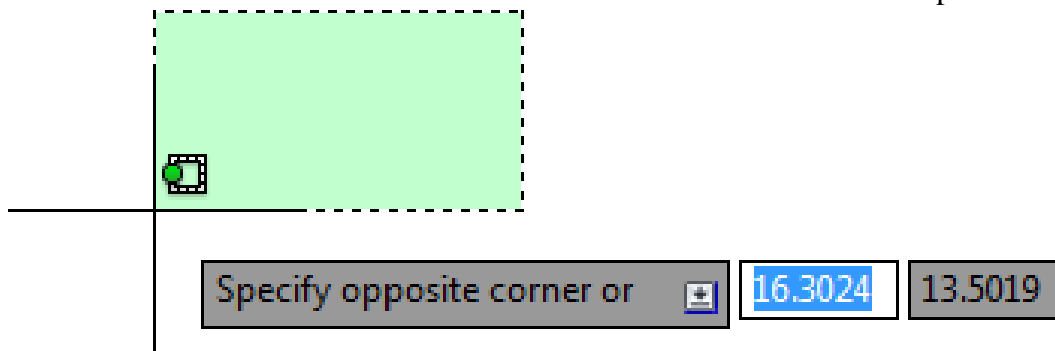
To see various **options**, select an object and right-click or right-click a user interface element.

To **cancel** a command in progress or if you ever feel stuck, press Esc.

For example GUIDE TO AUTOCAD BASICS: PRINTING e, if you click in the drawing area before entering a command, you will see something like the following:

Here's a Tip:

Press Esc to cancel this preselection operation.



## Viewing

Zoom in on a drawing to better control the order of overlapping objects. The easiest way to change your view is by using the mouse wheel.

Zoom in or out by rolling the wheel.

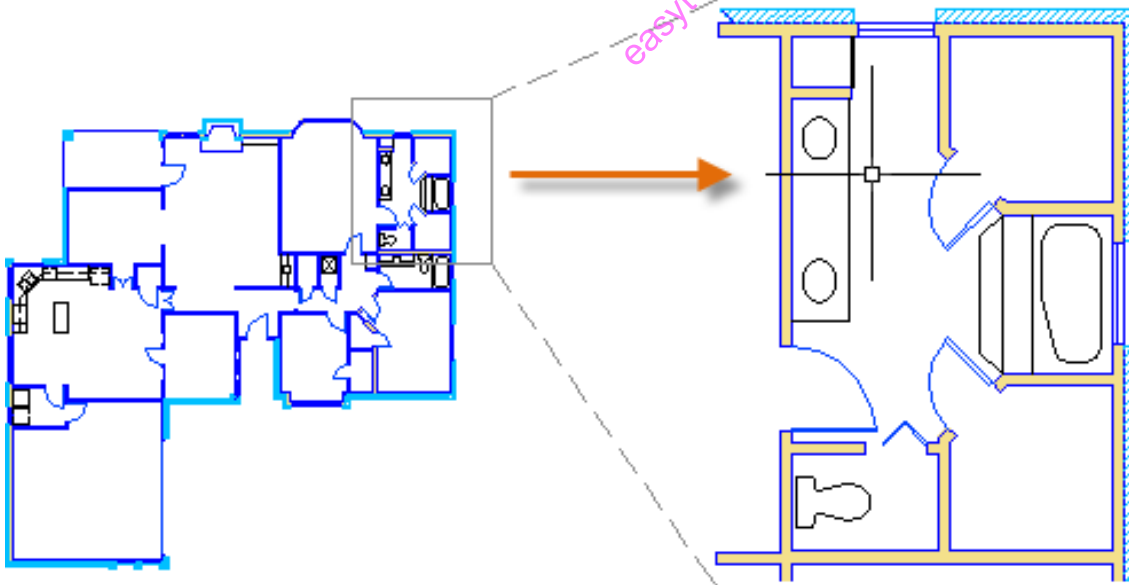
Pan a view in any direction by holding the wheel down while moving your mouse.

Zoom in on a specific area for greater detail holding your mouse over the area and clicking the wheel twice.

Here's a Tip:

When you zoom in or out, the location of the cursor is important. Think of your cursor as a magnifying glass. For example, if you position the cursor in the upper-right area of the floor plan as shown below, zooming in magnifies the dressing room without shifting the view.

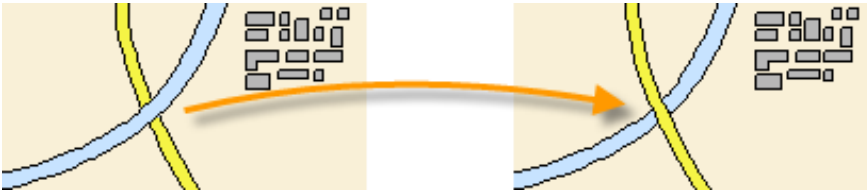
**NOTE:** If you cannot zoom or pan any more, type **REGEN** in the Command window and press Enter. This command regenerates the drawing display and resets the extents available for panning and z





## Overlapping Objects

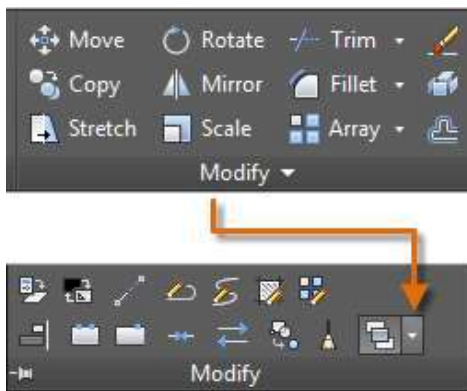
If you create objects that overlap, you might need to change which objects are displayed on top or in front of the others. For example, if you want the yellow highway to cross the blue river rather than the other way around,



use the **DRAWORDER** command to reorder the objects.

You can access several draw order options from the Modify panel on the ribbon. Click to expand the Modify panel, and then click the down-arrow as shown below.

The draw order options that are listed include sending all hatches to the back, all text to the front, and so on.



## Geometry

Create basic geometric objects such as lines, circles, and hatched areas.

You can create many different types of geometric objects in AutoCAD, but you only need to know a few of them for most 2D drawings.

**NOTE:** If you want to simplify the display while creating geometric objects, press *F12* to turn off dynamic input.

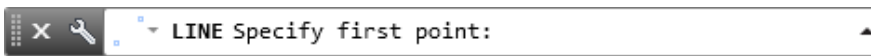
## Lines

The line is the most basic and common object in AutoCAD drawings. To draw a line, click the Line tool.



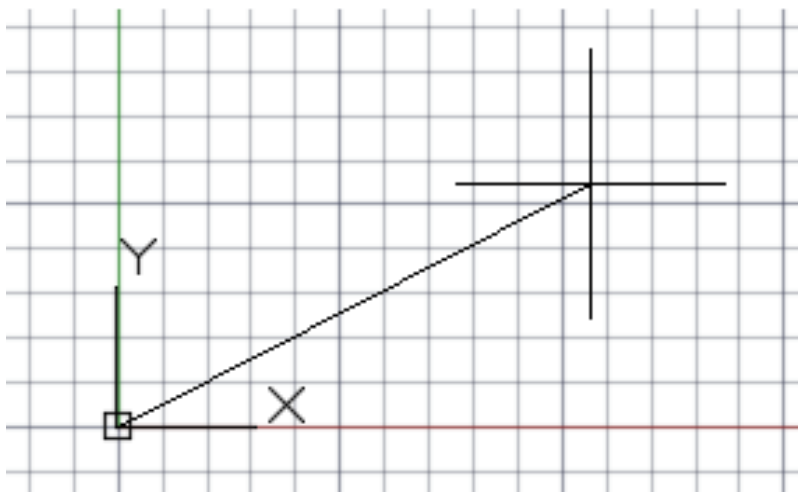
Alternatively, you can type **LINE** or just **L** in the Command window, and then press Enter or the Spacebar.

Notice the prompt in the Command window for a point location.



To specify the starting point for this line, you would type in the coordinates 0,0. It is a good idea to locate one corner of your model at 0,0, which is called the origin point. To locate additional points, you could specify additional X,Y coordinate

locations in the drawing area, however more efficient methods for specifying points are available, and will be presented in the Precision topic.

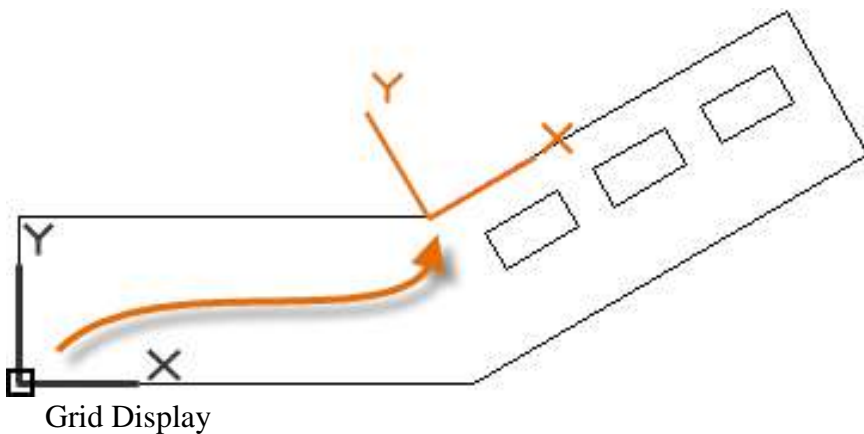


**After you specify the next point, the LINE command automatically repeats itself, and it keeps prompting you for additional points.**

**Press Enter or the Spacebar to end the sequence.**

### The User Coordinate System

The user coordinate system (UCS) icon indicates the direction of the positive X and Y axis for any coordinates that you enter, and it also defines the horizontal and vertical directions in a drawing. In some 2D drawings, it can be convenient to click, drag, and rotate the UCS to change the origin point, and the horizontal and vertical directions.



Some people like working with grid lines as a reference, while others prefer working in a blank area. To turn off the grid display, press F7. Even with the grid turned off, you can force your cursor to snap to grid increments by pressing F9.

### Lines as Construction Aids

Lines can serve as reference and construction geometry such as:

### Property line setbacks

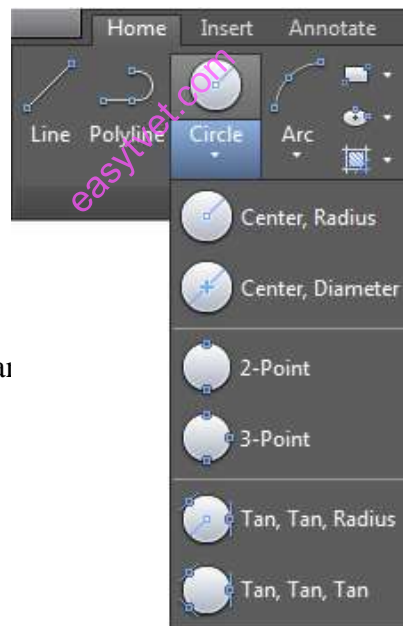
The mirror line of a symmetrical mechanical part

Clearance lines to avoid interferences

Traversal path lines

Circles

The default option of the **CIRCLE** command

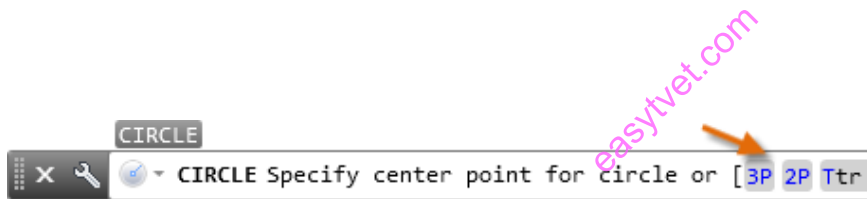


ter point and a radius.

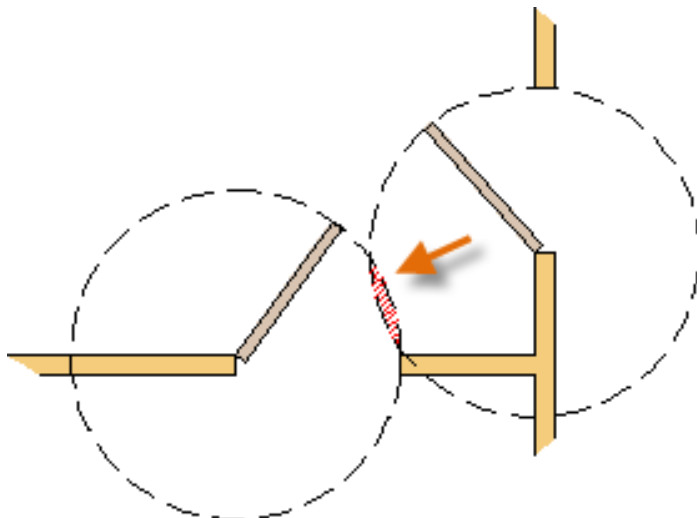


The other circle options are available from the drop-down:

Alternatively, you can also enter **CIRCLE** or just **C** in the Command window and click to choose an option. If you do, you can specify a center point, or you can click one of the highlighted command options as shown below.



Circles can be useful as reference geometry. For example, you can see that the two doors in the illustration can interfere with each other.



## Polylines and Rectangles

A polyline is a connected sequence of line or arc segments that is created as a single object.



Use the **PLINE** command to create open or closed polylines for:

Geometry that requires fixed-width segments

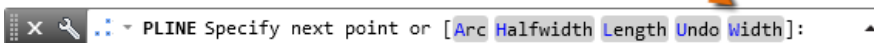
Continuous paths for which you need to know the total length

Contour lines for topographic maps and isobaric data

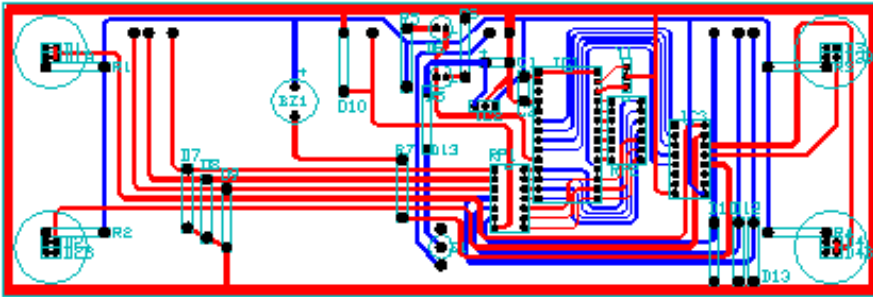
Wiring diagrams and traces on printed circuit boards

Process and piping diagrams

Polylines can have a constant width or they can have different starting and ending widths. After you specify the first point of the polyline, you can use the Width option to specify the width of all subsequently created segments. You can change the width value at any time, even as you create new segments.



Here is an example of a printed



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## Polylines and Rectangles

Polylines can have different starting and ending widths for each segment as shown here:



A fast way to create closed rectangular polylines is to use the **RECTANG** command (enter **REC** in the Command window).

Simply click two diagonal points for the rectangle as illustrated. If you use this method, turn on grid snap (F9) for precision.



## Hatches and Fills



In AutoCAD, a hatch is a single, compound object that covers a specified area with a pattern of lines, dots, shapes, a solid fill color, or a gradient fill.



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When you start the **HATCH** command, the ribbon temporarily displays the Hatch Creation tab. On this



tab, you can choose from over 70 industry-standard imperial and ISO hatch patterns along with many specialized options.

The simplest procedure is to choose a hatch pattern and scale from the ribbon, and click within any area that is completely enclosed by objects. You must specify the scale factor for the hatch in order to control its size and spacing.

After you create a hatch, you can move the bounding objects to adjust the hatch area, or you can delete one or more of the bounding objects to create partially bounded hatches:

Here's a Tip:

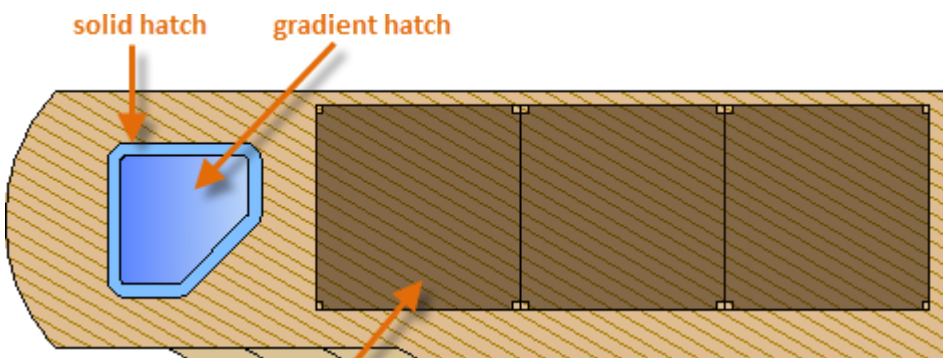
If you set a solid or gradient fill hatch pattern, also consider setting a transparency level on the Hatch Creation tab for interesting overlap effects.

### Hatches and Fills (continued)

Here are some examples of how you can use solid-fill hatches:

Here's a Tip:

If you need to align the pattern in a hatch, which might be the case with the decking boards above, use the Set Origin option to specify an alignment point.



## Precision

Ensure the precision required for your models.

There are several precision features available, including:

**Polar tracking:** Snap to the closest preset angle and specify a distance along that angle.

**Locking angles:** Lock to a single, specified angle and specify a distance along that angle.

**Object snaps:** Snap to precise locations on existing objects, such as an endpoint of a polyline, the midpoint of a line, or the center point of a circle.

**Grid snaps:** Snap to increments on a rectangular grid

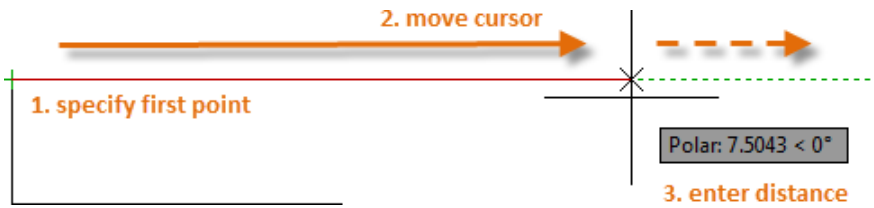
**Coordinate entry:** Specify a location by its Cartesian or polar coordinates, either absolute or relative.

The three most commonly used features are polar tracking, locking angles, and object snaps.

### Polar Tracking

When you need to specify a point, such as when you create a line, you can use polar tracking to guide the movement of your cursor in certain directions.

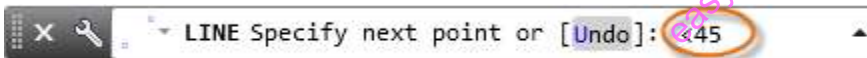
For example, after you specify the first point of the line below, move your cursor to the right, and then enter a distance in the Command window to specify a precise horizontal length for the line.



By default, polar tracking is turned on and guides your cursor in a horizontal or vertical direction (0 or 90 degrees).

### Locking Angles

If you need to draw a line at a specified angle, you can lock the angle for the next point. For example, if the second point of a line needs to be created at a 45 degree angle, you would enter '<45' in the Command window.

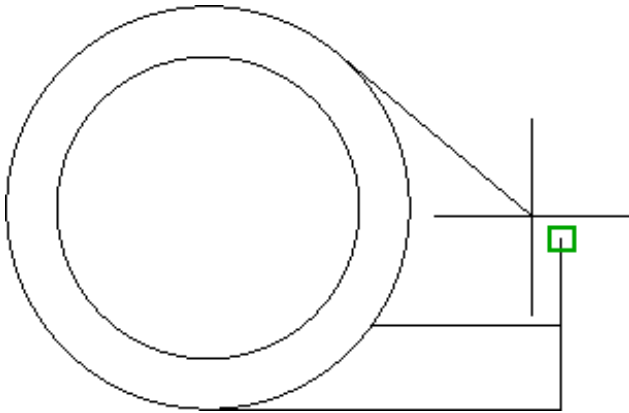


After you move your cursor in the desired direction along the 45-degree angle, you can enter the length of the line.

### Object Snaps

By far, the most important way for you to specify precise locations on objects is to use object snaps. In the following illustration, several different kinds of object snaps are represented by markers.

Object snaps become available during a command whenever AutoCAD prompts you to specify a point. For example, if you start a new line and move your cursor near the endpoint of an existing line, the cursor will automatically snap to it.



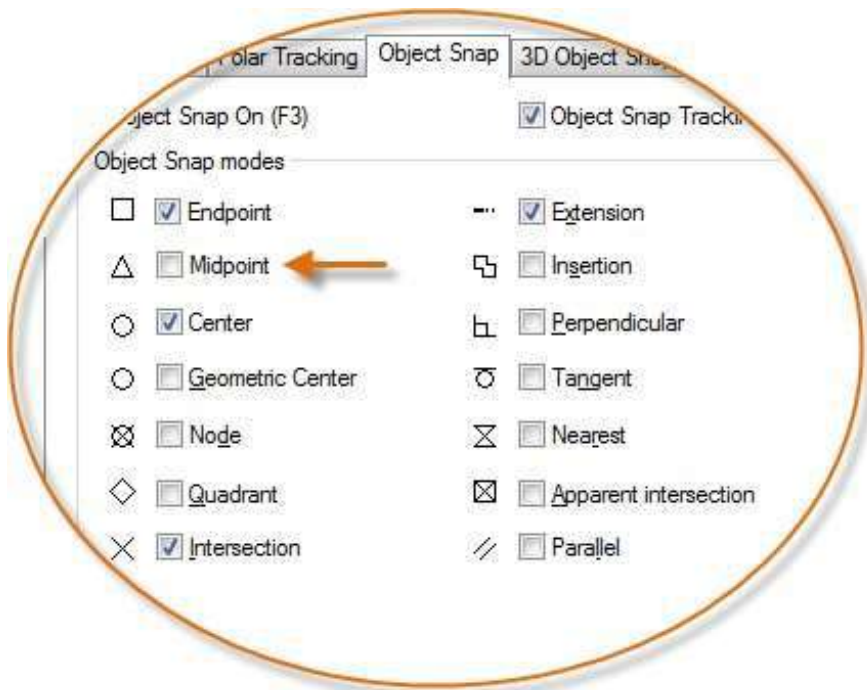
### Set Default Object Snaps

Enter the **OSNAP** command to set the default object snaps, which are also called “running” object snaps. For example, you might find it useful to turn on the Midpoint object snap by default.

### Recommendations

At any prompt for a point, you can specify a single object snap that overrides all other object snap settings. Hold down Shift, right-click in the drawing area, and choose an object snap from the Object Snap menu. Then move the cursor to select a location on an object.

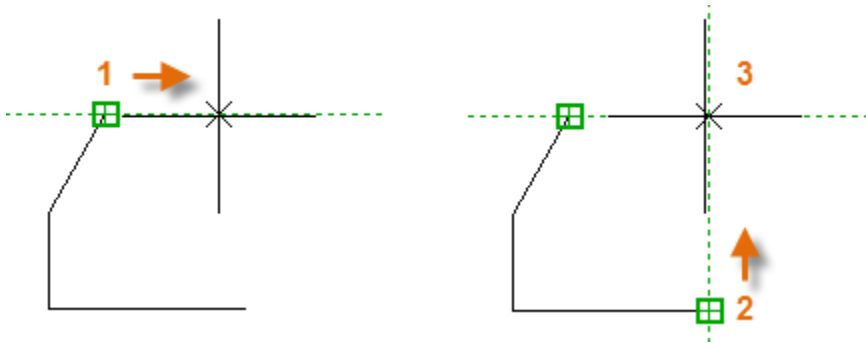
Make sure that you zoom in close enough to avoid mistakes. In a densely populated model, snapping to the wrong object will result in an error that can propagate throughout your model.



## Object Snap Tracking

During a command, you can align points both horizontally and vertically from object snap locations. In the following illustration, you first hover over endpoint 1 and then hover over endpoint

2. When you move your cursor near location 3, the cursor locks into the horizontal and vertical location shown.



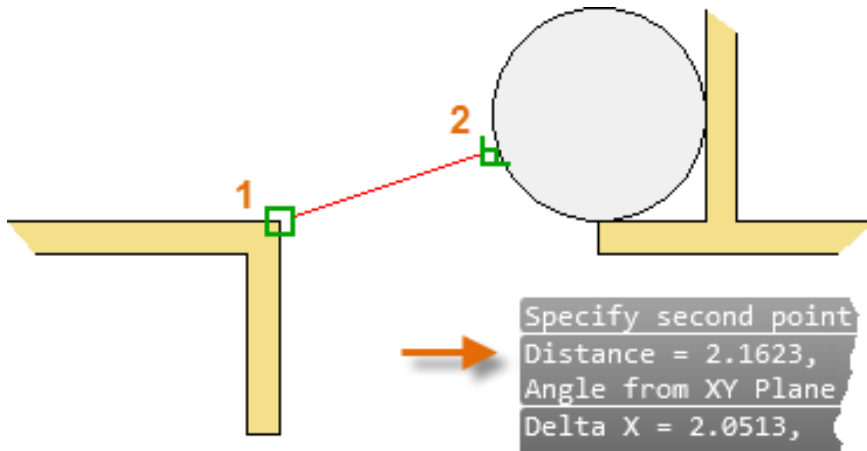
You can now finish creating the line, circle, or other object that you were creating from that location.

## Verify Your Work

Recheck your geometry to catch mistakes early. Enter the **DIST** command (or just **DI**) to measure the distance between any two points in your model.

For example, you might need to find the clearance between two points shown, which might represent the corner of a wall and a small table, or perhaps a 2D section of a plastic part and a wire.

After you enter **DIST**, click the endpoint on the corner (1). Next, hold down Shift as you right-click, and then choose Perpendicular from the object snap menu. Finally, click the circle (2).



## Handy Function Key Reference

All keyboard function keys have assignments in AutoCAD. The ones that are most commonly turned on and off are indicated with a key.

| Key | Feature              | Description  |
|-----|----------------------|--|
|     | Help                 | Displays Help for the active tooltip, command palette, or dialog box.    |
| F2  | Expanded History     | Displays expanded command history in the Command Window.                 |
| F3  | Object Snap          | Turns object snap on and off.  |
| F4  | 3D Object Snap       | Turns on additional object snaps for 3D elements.                        |
| F5  | Isoplane             | Cycles through 2-1/2D isoplane settings.                                 |
| F6  | Dynamic UCS          | Turns on UCS alignment with planar surfaces.                             |
| F7  | Grid Display         | Turns the grid display on and off.                                       |
|     | Ortho                | Locks cursor movement to horizontal or vertical.                         |
| F9  | Grid Snap            | Restricts cursor movement to specified grid intervals.                   |
|     | Polar Tracking       | Locks cursor movement to specified angles.                               |
| F11 | Object Snap Tracking | Tracks the cursor horizontally or vertically from object snap locations. |

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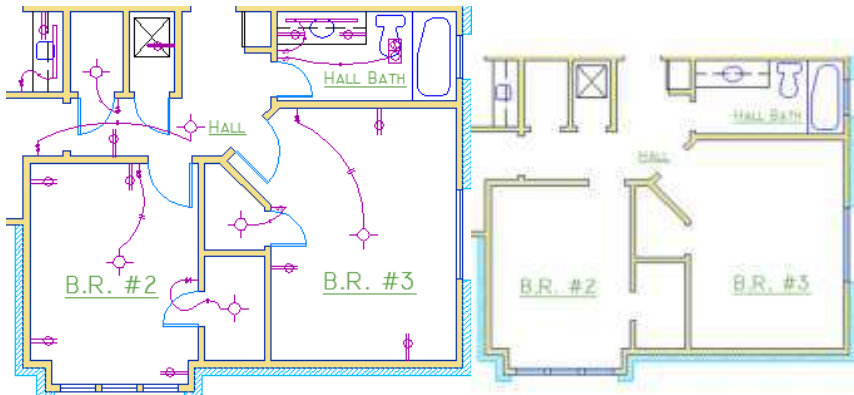
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## Layers

Organize your drawing by assigning objects to layers.

When a drawing becomes visually complex, you can hide objects that you currently do not need to see.

In the drawing below, the doors and electrical wiring were temporarily hidden by hiding their layers.



## Layers

You gain this level of control by organizing the objects in your drawing on layers that are associated with a specific function or purpose. It might be helpful to think of layers as clear plastic sheets:

With layers, you can:

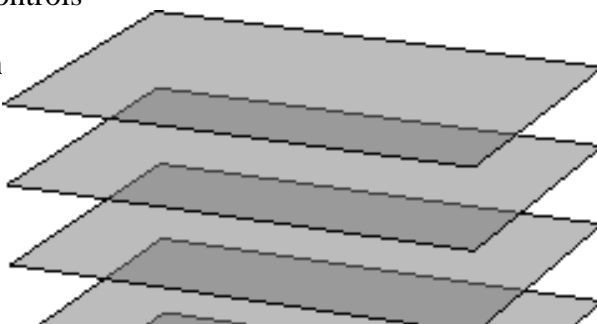
Associate objects by their function or location

Display or hide all objects related to a single operation

Enforce linetype, color, and other property standards for each layer

## Layer Controls

To see h  
You can



**Cabinets** the Layer Properties Manager.  
click the Layer Properties tool

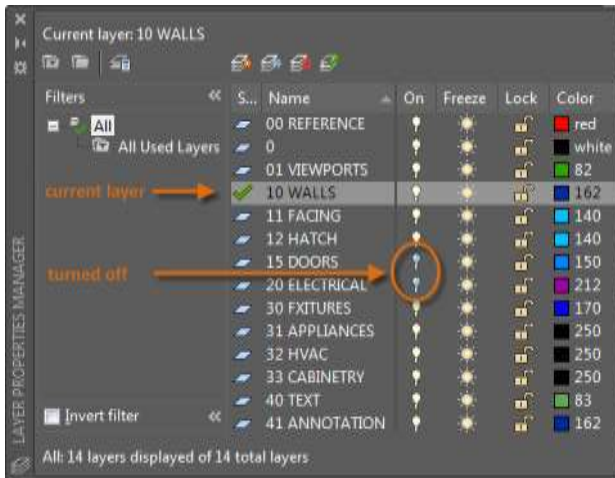
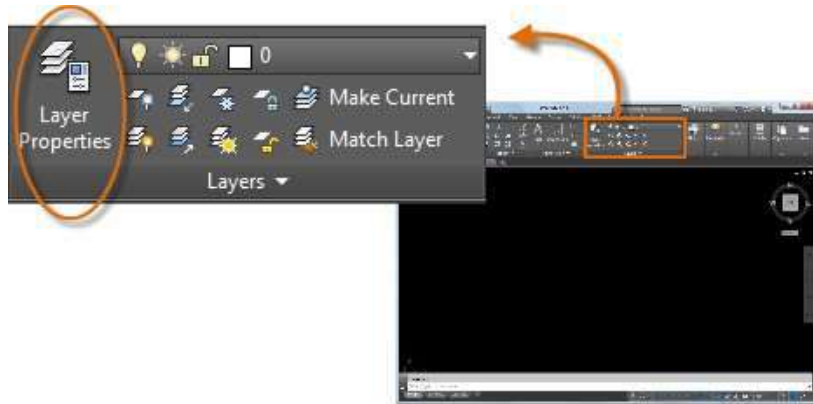
**Fixtures**

**Electrical**

**Doors**

on the ribbon.

Here's what the Layer Properties Manager displays for this drawing.



As indicated, layer 10 WALLS is the *current layer*. All new objects are automatically placed on that layer. In the list of layers, the green check next to layer 10 WALLS indicates that it is the current layer.

In the column labeled On, notice that the light bulb icons for two layers are dark. This indicates that these layers were turned off to hide the doors and electrical wiring in the floor plan.

Notice that each layer name starts with a two-digit number. This convention makes it easy to control the order of the layers because their order does not depend on the alphabet.

Here's a Tip:

For complex drawings, you might want to consider a more elaborate layer naming standard. For example, layer names could begin with 3 digits followed by a naming code that accommodates multiple floors in a

building, project numbers, sets of survey and property data, and so on.

### Practical Recommendations

Layer 0 is the default layer that exists in all drawings and has some esoteric properties. Instead of using this layer, it's best to create your own layers with meaningful names.

Any drawing that contains at least one dimension object automatically includes a reserved layer named Defpoints.

Create a layer for behind-the-scenes construction geometry, reference geometry, and notes that you usually do not need to see or print.

Create a layer for layout viewports. Information about layout viewports is covered in the Layouts topic.

Create a layer for all hatches and fills. This lets you to turn them all on or off in one action.

### Layer Settings

The following are the most commonly used layer settings in the Layer Properties Manager. Click the icon to turn the setting on and off.

**Turn off Layers: This will help reduce the visual complexity of your drawing while you work**

**Freeze Layers:** Freeze layers that you do not need to access for a while. Freezing layers is similar to turning them off, but improves performance in very large drawings.

**Lock Layers:** Locking layers prevents accidental changes to the objects on those layers.

## Controls in the Layer Properties Manager

To create a new layer, click the button shown and enter the name of the new layer. To make a different layer the current one, click the layer and then click the indicated button.



## Quick Access to Layer Settings

The Layer Properties Manager takes up a lot of space, and you may not always need to access all the options. For quick access to the most common layer controls, use the controls on the ribbon. When no objects are selected, the Layers panel on the Home tab displays the name of the current layer as shown here.

Occasionally, check to make sure that the objects you create will be on the correct layer. It's easy to forget to do this, but it's also easy to set. Click the drop-down arrow to display a list of layers, and then click a layer on the list to make it the current layer. You can also click on any layer setting icon in the list to



change its setting.

## Maintain Your Standards

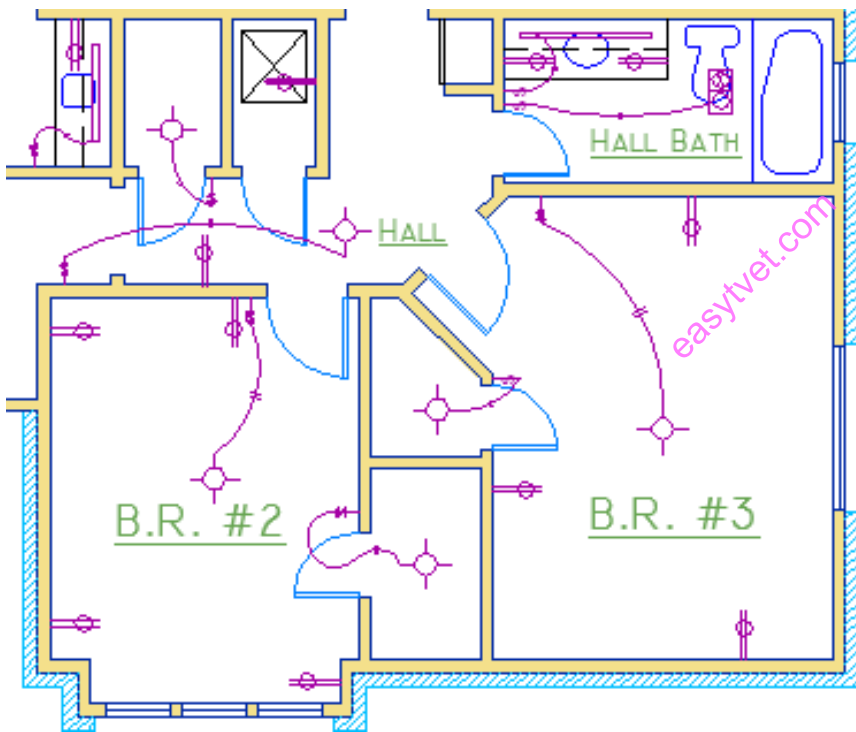
It's important to either establish or conform to a company-wide layer standard. With a layer standard, drawing organization will be more logical, consistent, compatible, and maintainable over time and across departments. Layer standards are essential for team projects.

If you create a standard set of layers and save them in a drawing template file, those layers will be available when you start a new drawing, and you can start working immediately. Additional information about drawing template files is presented in the Basics topic.

### Properties

You can assign properties such as color and linetype to individual objects, or as default properties assigned to layers.

In the following drawing, the walls, exterior stone facing, doors, fixtures, cabinetry, HVAC, electrical, and text were created using different colors to help differentiate them.



### The Properties Palette

The Properties palette is an essential tool. You can open it with the **PROPERTIES** command (enter **PR** in the Command window), you can press Ctrl + 1, or you can click the tiny arrow in the Properties panel on the Home tab whichever you prefer.

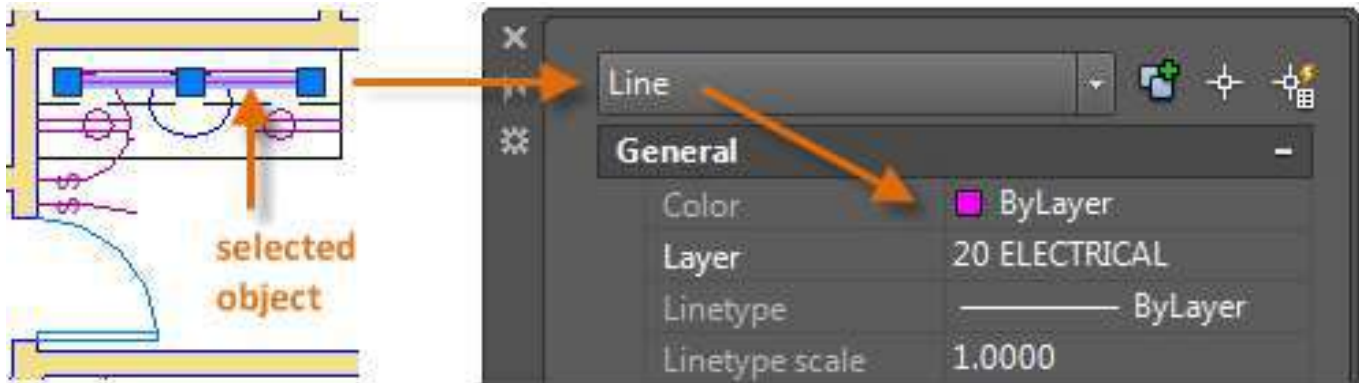


The Properties palette displays a list of all the important property settings. You can click any of the available fields to change the current settings. In the following example, if no objects are selected, the current color will be changed from ByLayer to Red and the UCS icon will be turned off.



## Verify and Change Object Properties

You can use the Properties palette to verify and change property settings for selected objects. If you click an object in your drawing to select it, here is what you might see in the Properties palette.



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**NOTE:** To clear the current selection, press Esc.

Notice that the current properties for the selected object are displayed in the palette. You can change any of these properties by clicking and changing the setting.

A property that is set to “ByLayer” inherits its setting from the layer. In the previous example, the objects that were created on the 20 ELECTRICAL layer are purple because that is the default color of the objects on that layer.

If you select several objects, only their common properties are listed in the Properties palette. If you change one of these properties, all the selected objects will change in one operation. Selecting objects is covered in more detail in the Modifying topic

## Quick Access to Property Settings



The Properties palette can take up a lot of space. For quick access to the most common properties, use the Properties panel. As you can see in this example, the listed properties will all be determined by the current layer.



The Properties panel works the same way as the Properties palette. When you select an object, the current property settings are replaced by the properties assigned to the selected object, and you can use this panel to easily change the properties of one or more selected objects.



Match the Properties of Objects

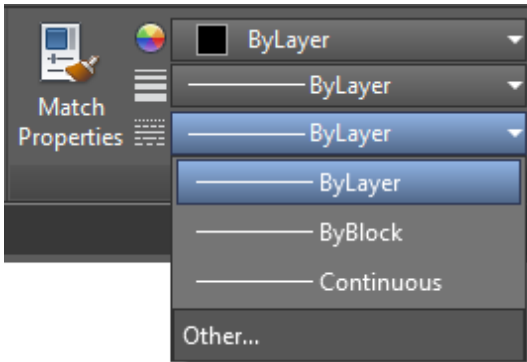
For a fast way to copy the properties of a selected object to other objects, use the Match Properties tool, or enter **MATCHPROP** or **MA** in the Command window.

Select the source object, and then select all of the objects that you want to modify.

### Linetypes

Dashed and other non-continuous linetypes are assigned from the Properties panel. You must first load a linetype before you can assign it.

In the Linetype drop-down list, click Other.



This action displays the Linetype Manager dialog box. Perform the following steps in order:

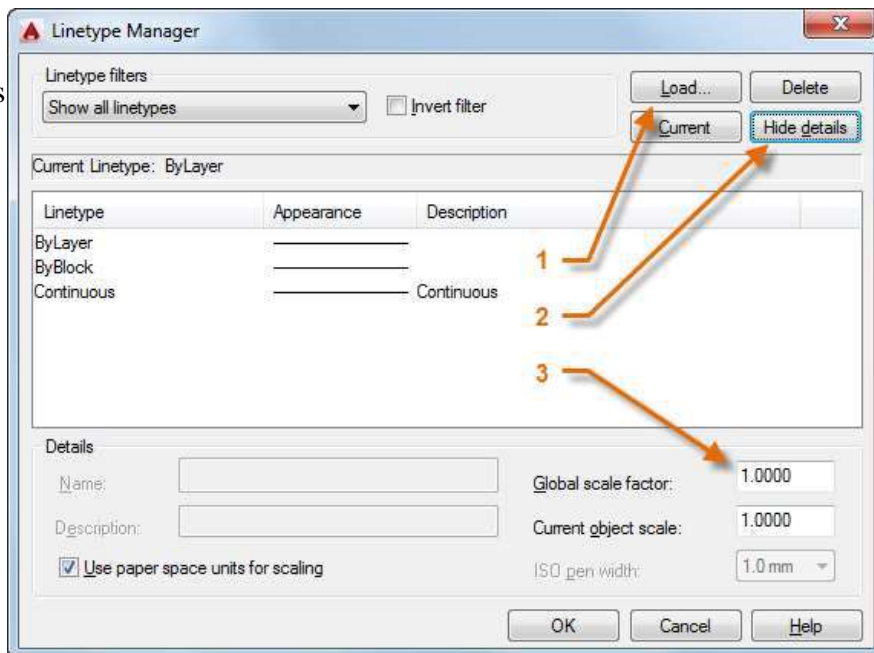
Click Load. Choose one or more linetypes that you want to use. Notice that dashed (non-continuous) linetypes come in several preset sizes.

Click Show/Hide details to display additional settings.

Specify a different “global scale factor” for all linetypes—the larger the value, the longer the dashes and spaces. Click OK.

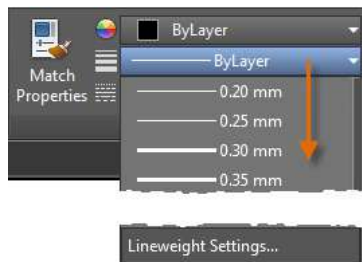
Once you’ve loaded the linetypes that you plan to use, you can select any object and specify a linetype from the Properties panel or the Properties palette. Alternatively, you can specify a default linetype for any layer in the Layer

Properties



## Lineweights

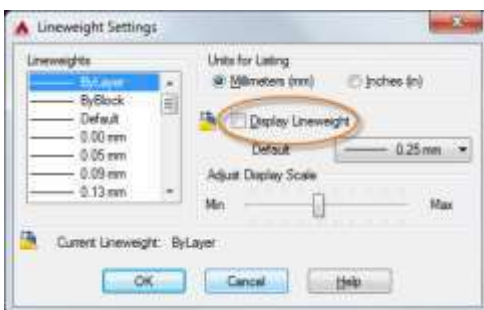
The Lineweight property provides a way to display different thicknesses for selected objects. The thickness of the lines remains constant regardless of the scale of the view. In a layout, lineweights are always displayed and printed in real-world units. Lineweights can also be assigned from the Properties panel.



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You can leave the lineweight set to ByLayer, or you can specify a value that overrides the layer's lineweight. In some cases, the lineweight previews look the same because they are displayed in approximated pixel widths on a monitor. However, they will print at the correct thickness.

To control the display of lineweights, click the Lineweight Settings button at the bottom of the lineweight list. In the Lineweight Settings dialog box, you can choose whether you want to display or hide lineweights.



Regardless of the display setting, lineweights will always be printed at the correct scale.

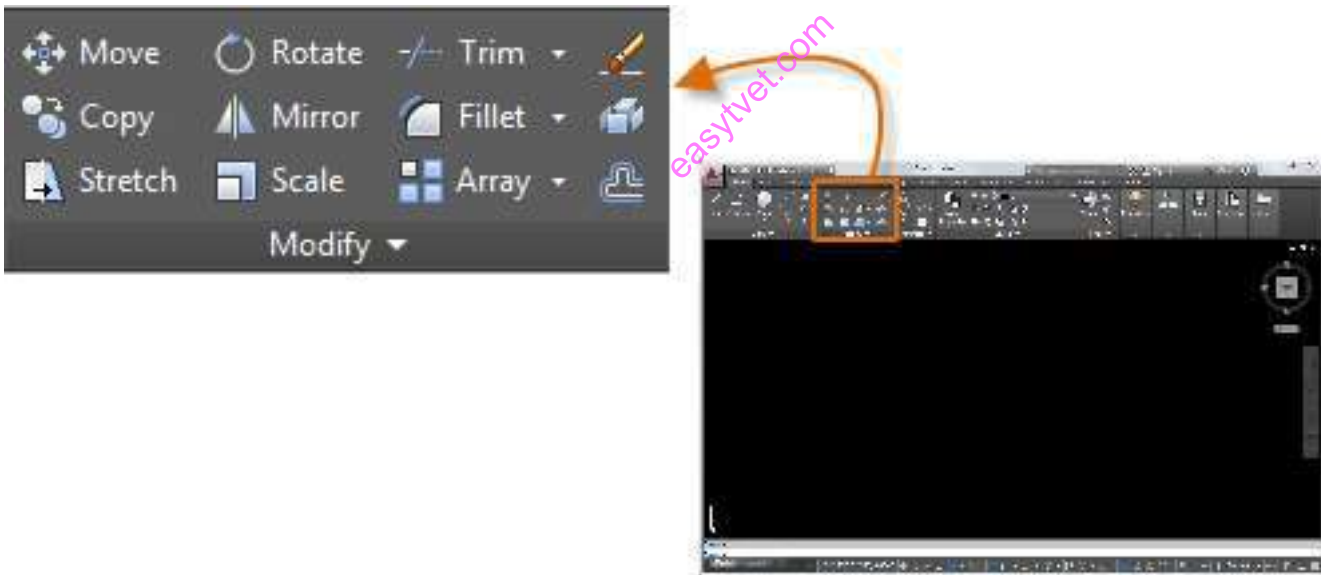
Here's a Tip:

It's usually best to leave lineweights turned off while you work. Heavy lineweights can obscure nearby objects when you use object snaps. You might want to turn

## Modifying

Perform editing operations such as erase, move, and trim on the objects in a drawing.

The most common modifying tools are located on the Modify panel of the Home tab. Take a minute to look through them.

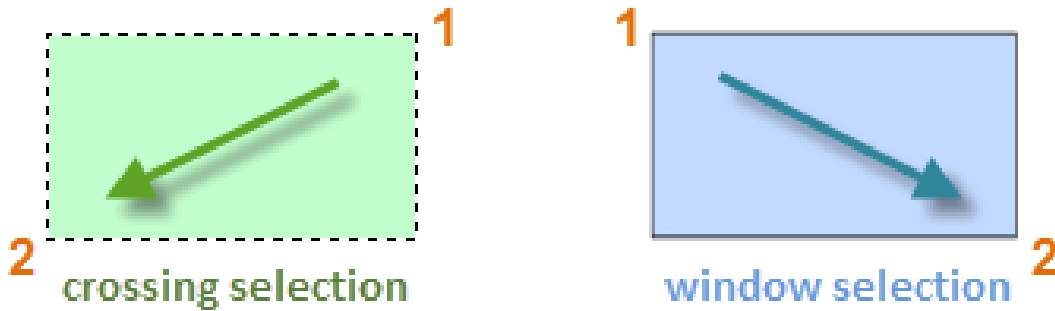


## Erase

To erase an object, use the **ERASE** command. You can enter **E** in the Command window, or click the Erase tool. When you see the cursor change to a square pickbox, click each object that you want to erase, and then press Enter or the Spacebar.

## Select Multiple Objects

Sometimes you may need to select a large number of objects. Instead of selecting each object individually, you can select the objects in an area by clicking an empty location (1), moving your cursor right or left, and then clicking a second time (2).



With a *crossing selection*, any objects within or touching the green area are selected.

With a *window selection*, only the objects completely contained within the blue area are selected.

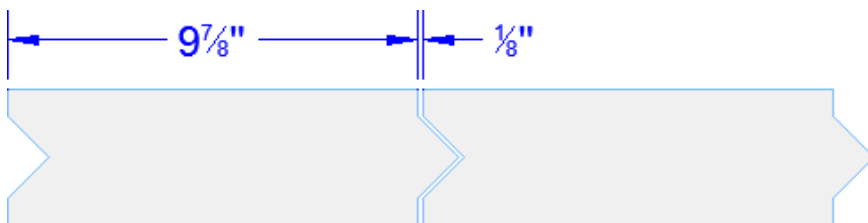
The result is called the *selection set*, which is the set of objects that will be processed by a command.

Here's a Tip:

You can easily remove objects from the selection set. For example, if you select 42 objects, and two of them should not have been

selected, hold down Shift and then select the two that you want to remove. Then, press Enter or the Spacebar, or right click to end the selection process.

### Move and Copy

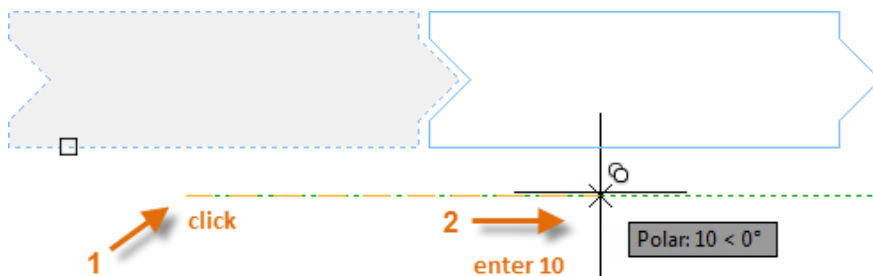


Here's how you would use the **COPY** command to lay out a row of decorative tiles. Starting with a polyline that represents its shape, you need to make copies that are  $\frac{1}{8}$ " apart.

Click the Copy tool or enter **CP** in the Command window to start the command. From here, you can choose between two methods, depending on which is more convenient. You will use these two methods frequently.

### The Distance Method

The second tile needs to be a total of  $9\text{-}7/8'' + 1/8'' = 10''$  to the right of the original tile. Start by selecting the tile, pressing Enter or the Spacebar to end your selection, and clicking anywhere in the drawing area (1). This point does not have to be located on the tile.

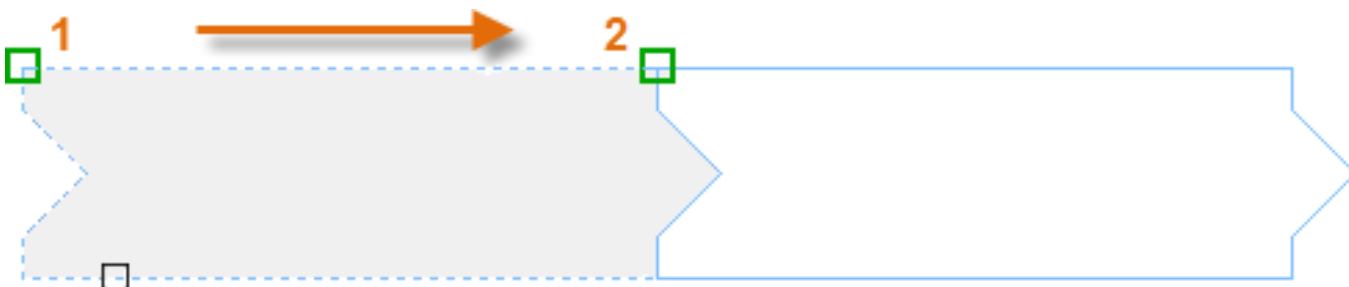


Next, move your cursor to the right, relying on the polar tracking angle to keep the direction horizontal, and then enter 10 for the distance. Press Enter or the Spacebar a second time to end the command.

### Move and Copy (continued)

### The Two Points Method

Another method, one that you will often use when you don't want to add numbers together, requires two steps. Enter the **COPY** command and select the tile as before, but this time click the two endpoints as shown. These two points also define a distance and direction.



Next, to add the 1/8" space between the tiles, click the Move tool or enter **M** in the Command window. The **MOVE** command is similar to the **COPY** command. Select the newly copied tile, and press Enter or the Spacebar. As before, click anywhere in the drawing area and move your cursor to the right. Enter 1/8 or .125 for the distance.

Here's a Tip:

The two points that define the distance and direction don't need to be located on the object that you want to copy. You can use two points specified anywhere in your

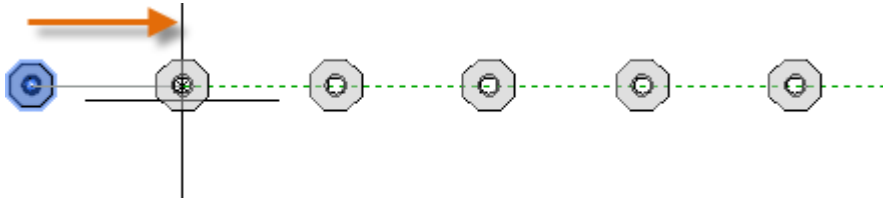
Create Multiple Copies

You can use the two-point method as a repeating sequence. Let's say that you want to make more copies of the circle at the same horizontal distance. Enter the **COPY** command and select the circle as shown.



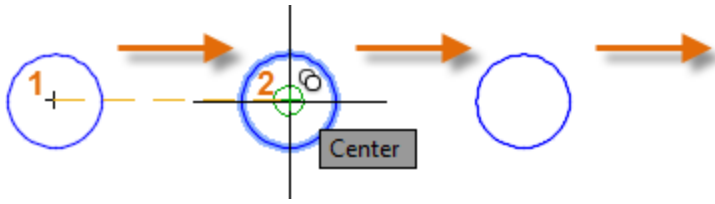
Then, using the Center object snap, click the center of circle 1, followed by the center of circle 2, and so on.

For larger numbers of copies, try experimenting with the Array option of the **COPY** command. For example, here's a linear arrangement of deep foundation piles. From a base point, you specify number of copies and the center-to-center distance.



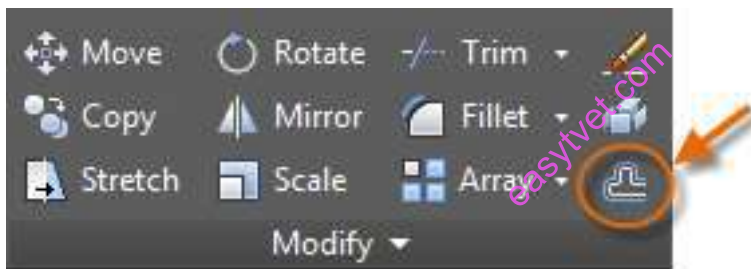
[easytvvet.com](http://easytvvet.com)



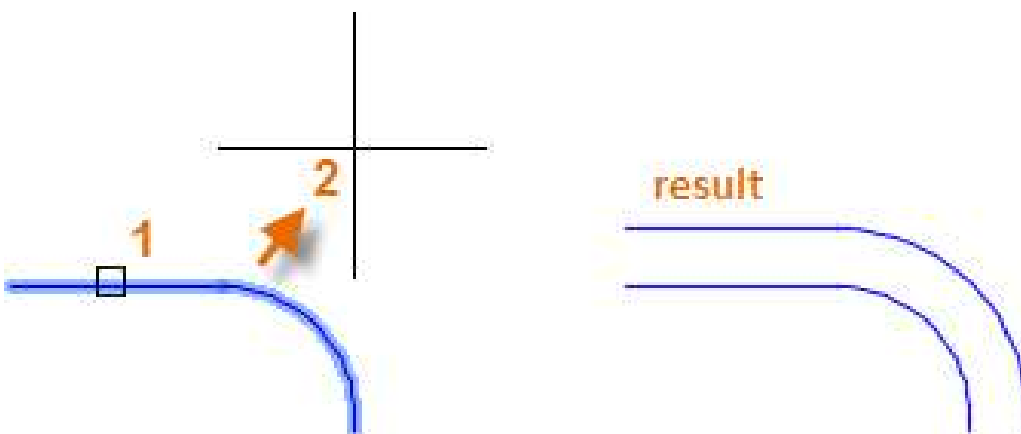


## Offset

Most models include a lot of parallel lines and curves. Creating them is easy and efficient with the **OFFSET** command. Click the **OFFSET** tool or enter **O** in the Command window



Select the object (1), specify the offset distance, and click to indicate on which side of the original that you want the result (2). Here is an example of offsetting a polyline.

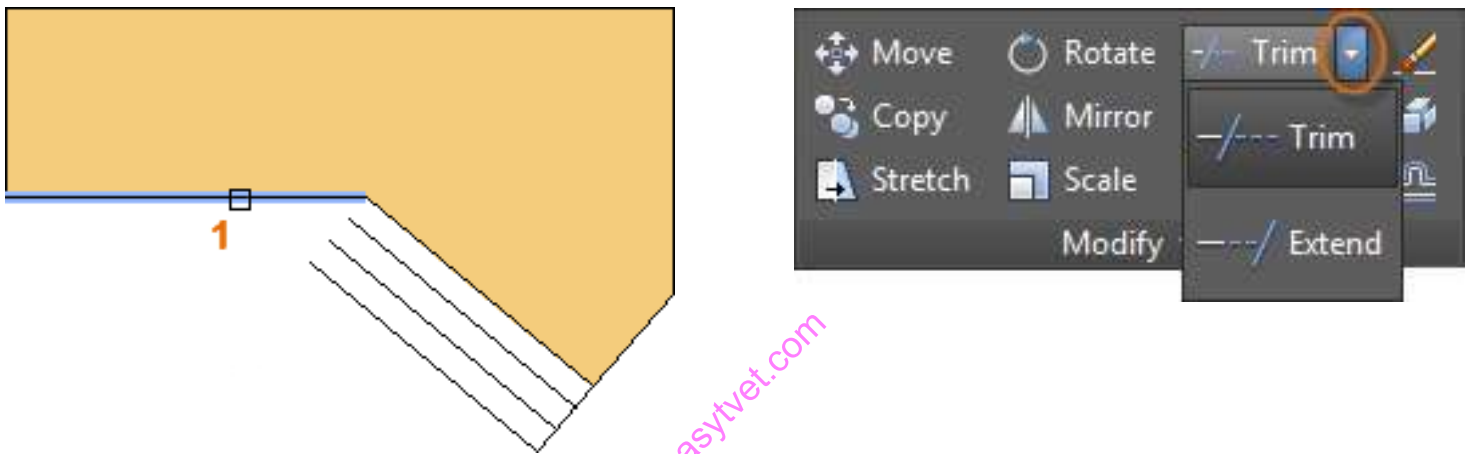


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## Trim and Extend

A popular technique is to use the **OFFSET** command in combination with the **TRIM** and **EXTEND** commands. In the Command window, you can enter **TR** for **TRIM** or **EX** for **EXTEND**. Trimming and extending are some of the most commonly used operations.

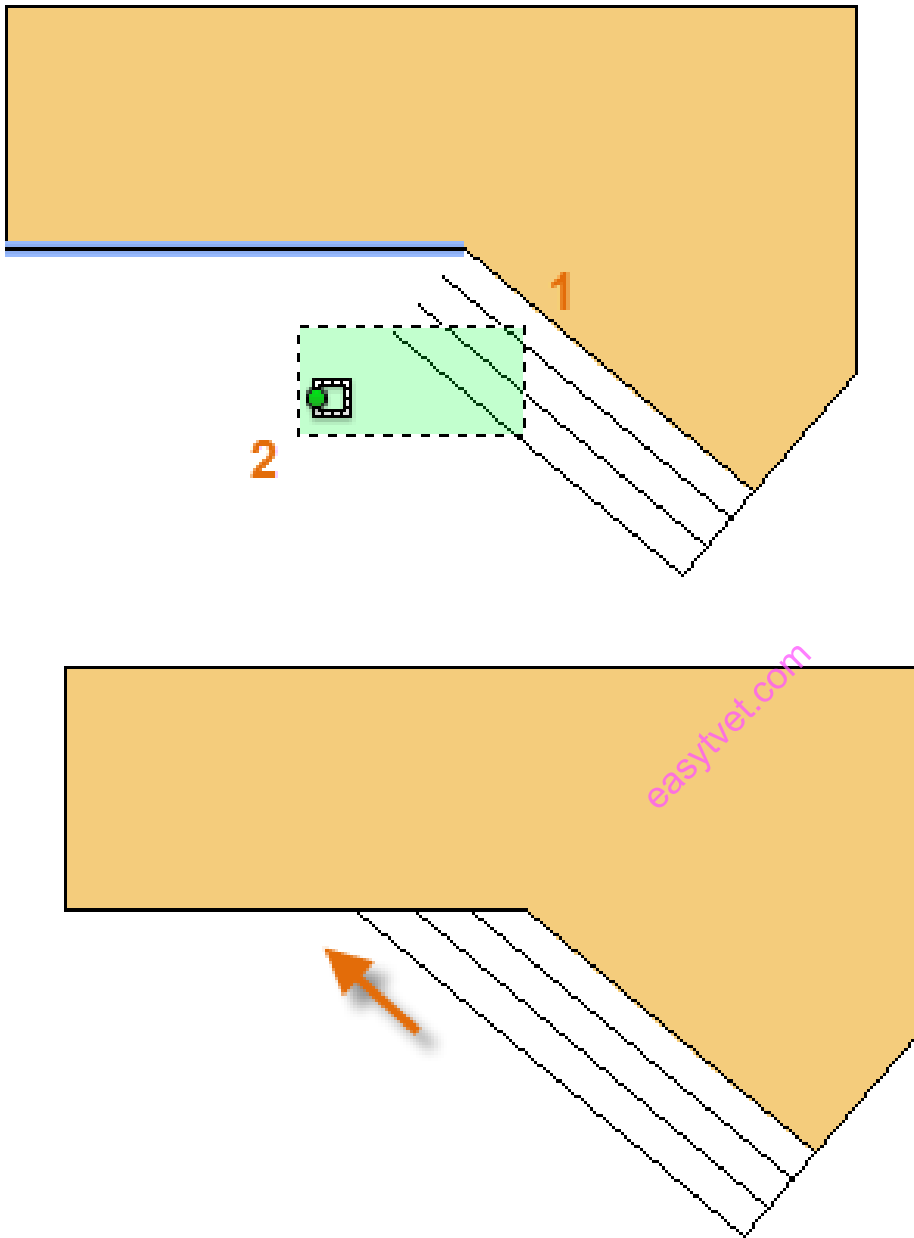
In the following illustration, you want to extend the lines that represent the steps for this deck. Enter the **EXTEND** command, select the boundary, and then press Enter or the Spacebar.



Pressing Enter or the Spacebar indicates that you've finished selecting the boundaries, and that you're now ready to select the objects to be extended. Here's a Tip:

A faster method is to press Enter or the Spacebar right away instead of selecting any boundary objects. The result is that all objects are available as possible boundaries

Next, select the objects to be extended (near the ends to be extended), and then press Enter or the Spacebar to end the command.

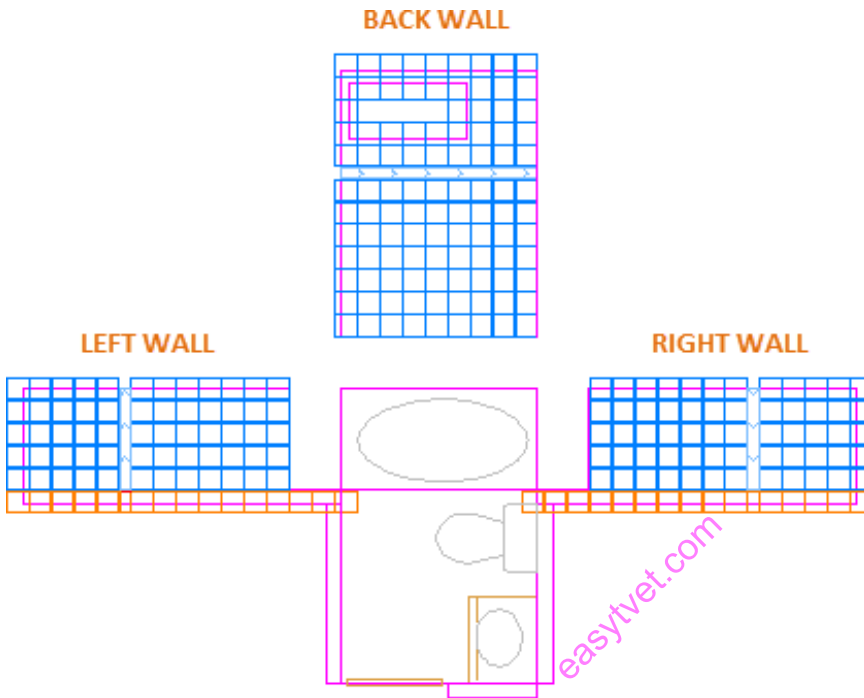


As you can see, the selected lines are extended to the boundary.

The **TRIM** command follows the same steps, except that when you select the objects to trim, you select the portions to trim away.

## Mirror

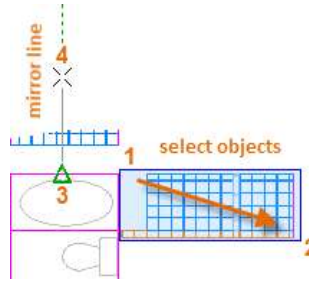
The following illustration comes from a tile project. The walls in this residential bathroom are flattened out to be able to lay out the tile pattern and estimate the number of tiles needed.



You can save a lot of work by taking advantage of the symmetry between the left and right walls. All you need to do is create the tiles on one wall and then mirror the wall across the center of the room. In the example below, begin the **MIRROR** command (or enter

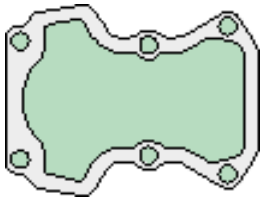
**MI** in the Command window), use window selection (1 and

2) to select the geometry on the right wall, press Enter or the Spacebar, and then specify a mirror line (3 and 4) corresponding to the centerline of the bathroom.

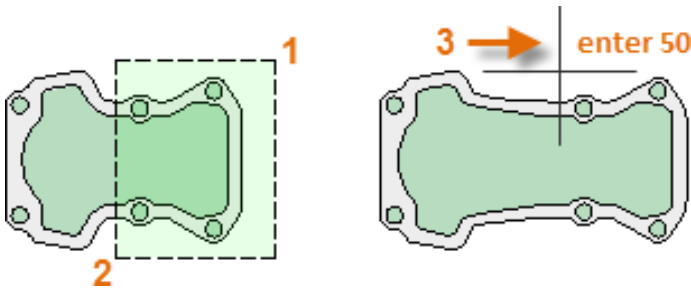


## Finally, Stretch

You can stretch most geometric objects. This lets you lengthen and shorten parts of your model. For example, this model might be a gasket or the design for a public park.



Use the **STRETCH** command (or enter **S** in the Command window) and select the objects with a crossing selection as shown below (1 and 2). The crossing selection is mandatory— only the geometry that is crossed by the crossing selection is stretched. Then click anywhere in the drawing area (3), move the cursor to the right, and enter 50 as the distance. This distance might represent millimeters or feet.

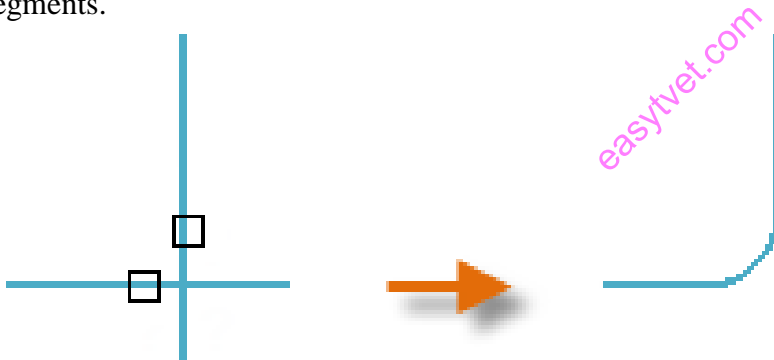


To shorten the model by a specified amount, you'd move your cursor to the left instead.

### Fillet

The **FILLET** command (enter **F** in the Command window) creates a rounded corner by creating an arc that is tangent to two selected objects. Notice that the fillet is created relative to where you select the objects.

You can create a fillet between most types of geometric objects, including lines, arcs, and polyline segments.



### Here's a Tip:

If you specify 0 (zero) as the radius of the fillet (imagine a circle shrinking to a radius of 0), the result trims or extends the selected objects to a sharp corner.

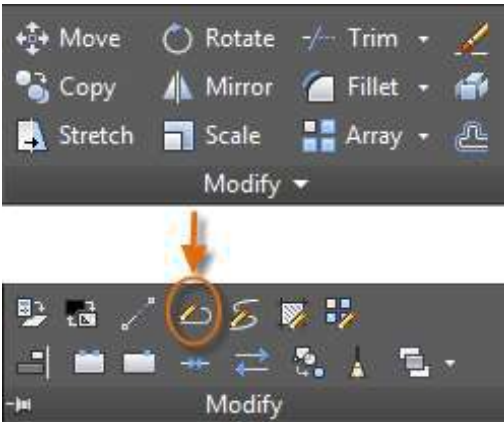
### Explode

The **EXPLODE** command (enter **X** in the Command window) disassociates a compound object into its component parts. You can explode objects such as polylines, hatches, and blocks (symbols).

After you explode a compound object, you can modify each resulting individual object.

## Edit Polylines

You can choose from several useful options when you want to modify a polyline. The **PEDIT** command (enter **PE** in the Command window) is located on the drop-down list of the Modify panel.



With this command, you can:

Join two polylines into a single polyline if they share a common endpoint

Convert lines and arcs into a polyline—simply enter **PEDIT** and select the line or arc

Change the width of a polyline

Here's a Tip:

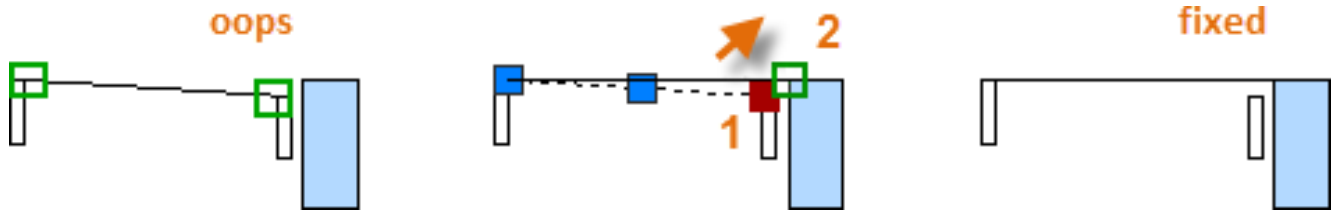
In some cases, the easiest method to modify a polyline is to explode it, make the modifications, and then turn the objects back into a polyline using the Join option of the **PEDIT** command.

## Grips

Grips are displayed when you select an object without starting a command. Grips are often handy for light editing. For example, the line below accidentally snapped to the wrong endpoint. You can



\_\_\_\_\_ select the misaligned line, click on a grip and then click to specify the correct location.

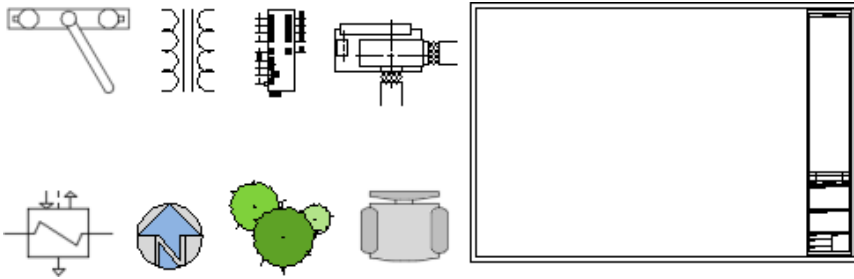


By default, when you click a grip, you automatically start in **\*\*STRETCH\*\*** mode as indicated in the Command window. If you want to explore other ways of editing

## Blocks

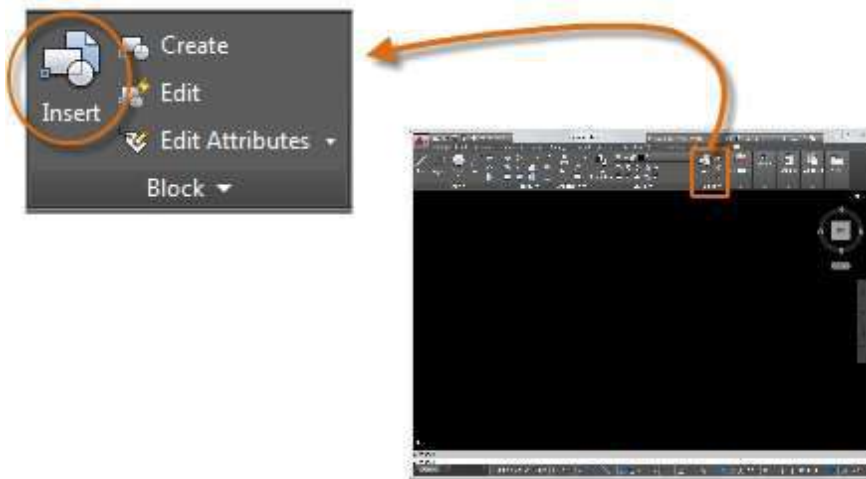
Insert symbols and details into your drawings from commercial online sources or from your own designs.

In AutoCAD, a *block* is a collection of objects that are combined into a single named object. The following are some sample blocks at various scales.



Some of these blocks are realistic representations of objects, some are symbols, and one of them is an architectural title block for a D-size drawing.

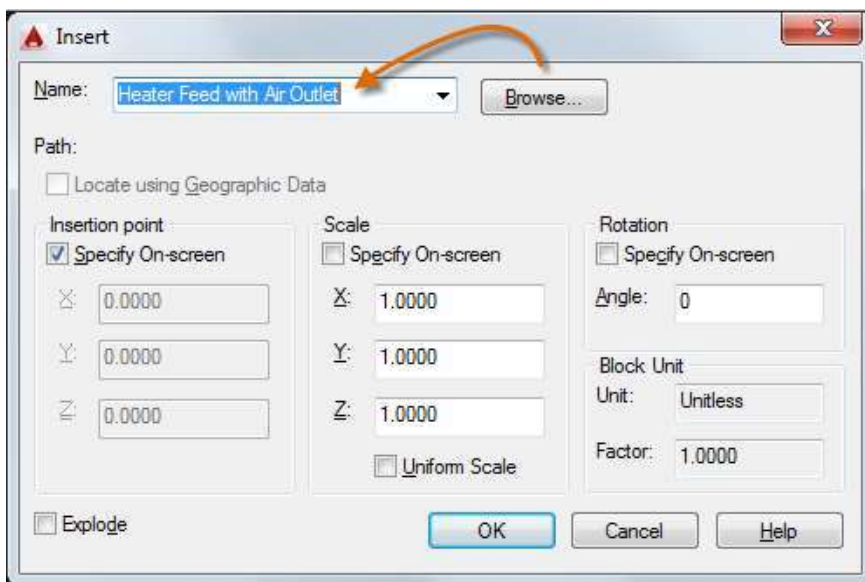
## Insert a Block



Typically, each of these blocks is an individual drawing file, perhaps saved in a folder with similar drawing files. When you need to insert one into your current drawing file, use the **INSERT** command (or enter **I** in the Command window).

### Insert a Block

The first time you insert the drawing as a block, you must click Browse to locate the drawing file. Make sure you organize your blocks into easy-to-find folders.

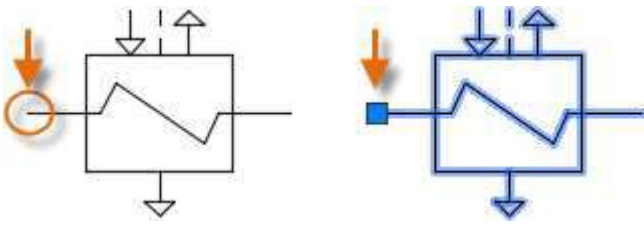


Once inserted, the *block definition* is stored in your current drawing. From then on, you can choose it from the Name drop-down list without needing to click the Browse button.

Here's a Tip:

The default settings in the Insert dialog box are usually acceptable. After you choose the block name, click OK, and then specify its location in your drawing. You can rotate it later, if necessary.

Notice that when you insert a block, it is attached to your cursor at the point indicated. This location is called the insertion point. By default, the insertion point is the origin point (0,0) of the original drawing.



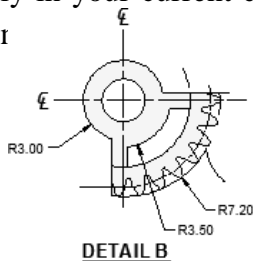
After inserting the block, you can select it and a grip appears. You can easily move and rotate this block using this grip.

In the following example, a drawing file is inserted into the current drawing to provide a standard detail view.

***NOTE:** Inserting a drawing file as a block provides a static reference to the specified drawing. For a reference that automatically updates, you can attach the drawing with the External References palette (**XREF** command) instead.*

### Create a Block Definition

Instead of creating a drawing file to be inserted as a block, you might want to create a block definition directly in your current drawing. Use this method if you do not plan to insert the block into any other drawing the **BLOCK** command to create the block definition.





For example, this is how you could create a module for a cubicle design.

Create the objects for the block.

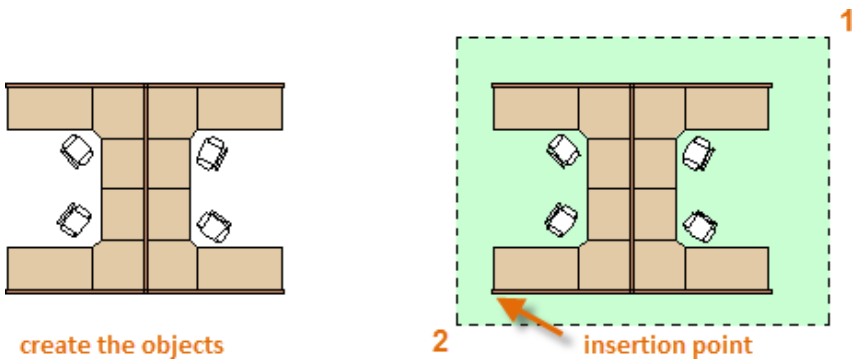
Start the **BLOCK** command.

Enter a name for the block, in this case Quad-Cube.

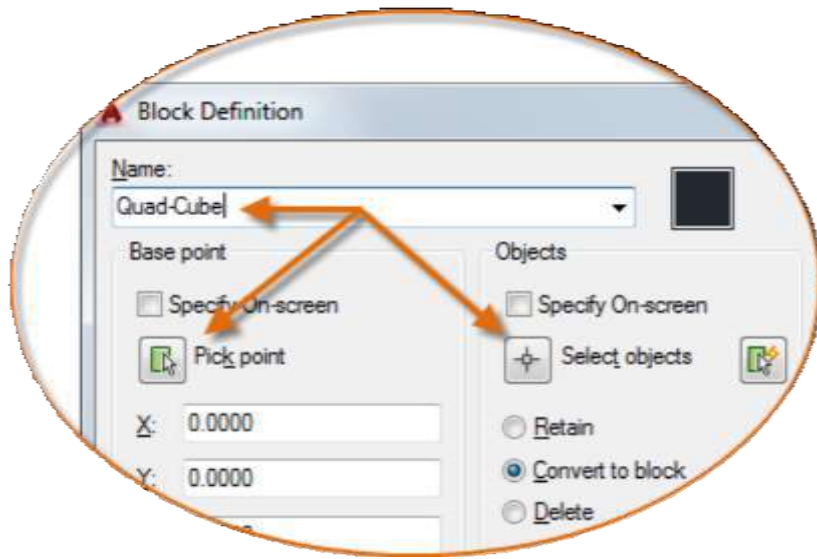
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Select the objects that you created for the block (click 1 and 2).

Specify the block insertion point.

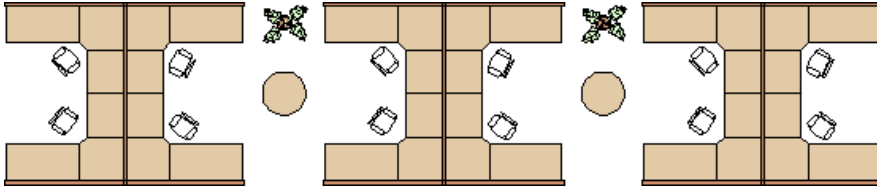


You can enter the information for steps 3, 4, and 5 into the Block Definition dialog box in any order.

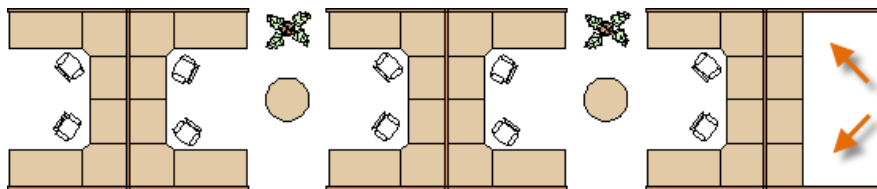


### Create a Block Definition (continued)

After creating the block definition, you can insert, copy, and rotate the block as needed.



Using the **EXPLODE** command, you can explode a block into its component objects if you need to make changes. In the illustration below, the cubicle on the right was exploded and modified.



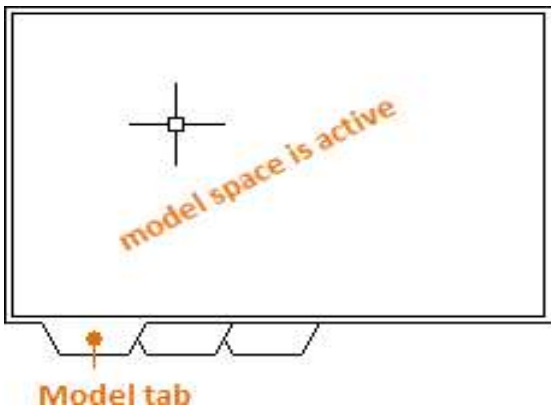
In this example, you would probably create a new block definition from the objects in the exploded block.

### Layouts

Display one or more scaled views of your design on a standard- size drawing sheet called a layout.

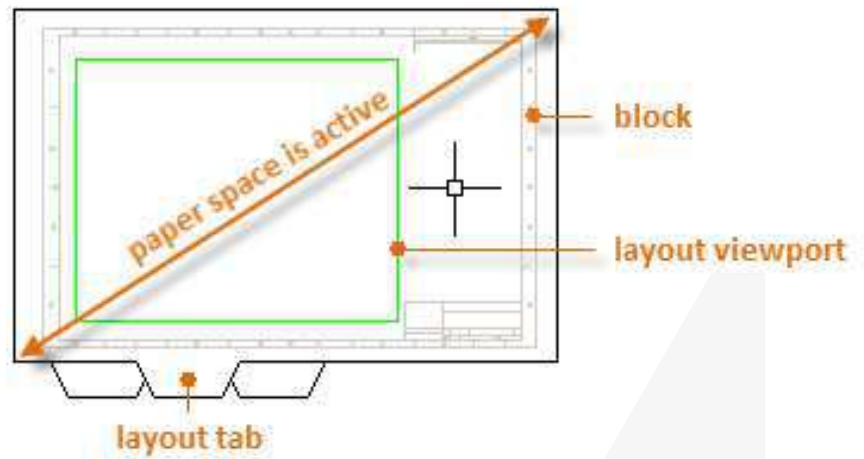
After you finish creating a model at full size, you can switch to a *paper space layout* to create scaled views of the model, and to add notes, labels, and dimensions. You can also specify different linetypes and line widths for display in paper space.

### Model Space and Paper Space



Originally, this was the only space available in AutoCAD. All notes, labels, dimensions, and the drawing border and title block were also created and scaled in the model space.

After *paper space* was introduced, you could click a layout tab to access a space designed specifically for layouts and scaling. In the following illustration, paper space is active. There are currently only two objects in paper space: a drawing border block, and a single *layout viewport*, which displays a view of model space.





## Four Methods for Scaling

There are four different methods in AutoCAD that are used to scale views, notes, labels, and dimensions. Each method has its advantages depending on how the drawing will be used.

Here's a brief summary of each of the methods:

**The Original Method:** You create geometry, annotate, and print from model space.

Dimensions, notes, and labels must all be scaled in reverse. You set the dimension scale to the inverse of the plot scale. With this method, scaling requires a little math. For example, a common scale used in architecture is 1/4" = 1'-0" which is 1:48 scale. If a note is to be printed 1/4" high, then it must be created 48 times as large, or 12" high in model space. The same scale factor also applies to dimensions, and an ARCH D drawing border at that scale is 144 feet long. When the drawing is printed as a D-size sheet, everything scales down to the correct size.

**The Layout Method:** You create geometry and annotate in model space, and print from the layout. Set the dimension scale to 0 and the dimensions will scale automatically.

**The Annotative Method:** You create geometry in model space, create *annotative* dimensions, notes, and labels (using a special annotative style) in model space from the layout, and you print from the layout. Annotative objects display only in layout viewports that share

***NOTE:** Many AutoCAD drawings were created with this method, and many companies still use it. Once everything is set up, the method works well for 2D drawings with single views and inserted details.*

the same scale. The dimension scale is automatically set to 0 and all annotative objects scale automatically.

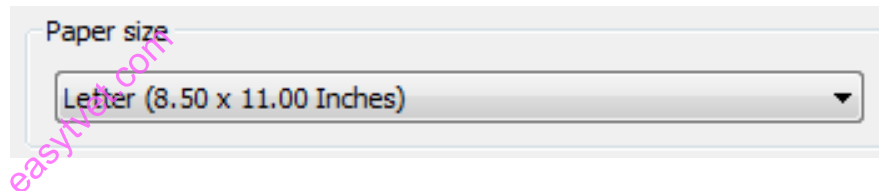
**The Trans-Spatial Method:** You create geometry in model space, create annotations in paper space on a layout with dimension scale set to 1, and you print from the layout. This is arguably the easiest, most direct method, and it is the method of choice for this guide.

Talk to other AutoCAD users in your discipline about these four methods and why they chose the method that they use.

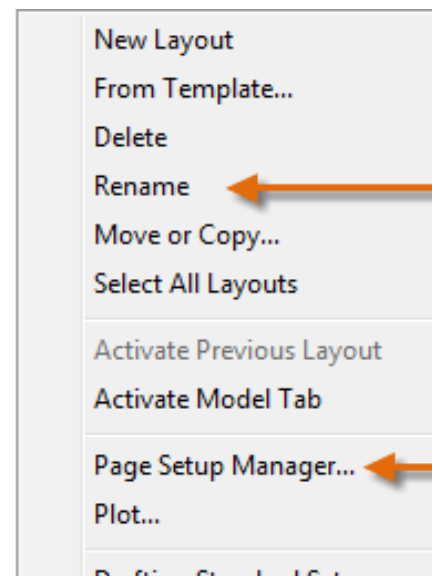
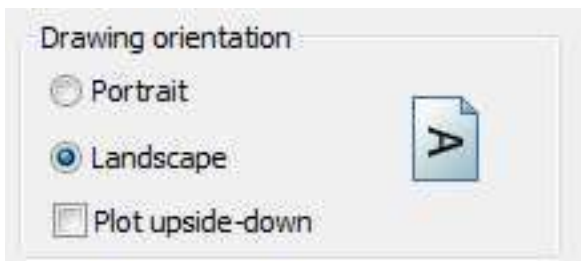
### Specifying the Paper Size of a Layout

The first thing you should do when you access a layout tab (1) is right-click the tab (2) and rename it (3) to something more specific than Layout 1. For a D-size layout, ARCH D or ANSI D might be good choices.

Next, open the Page Setup Manager (4) to change the paper size displayed in the layout tab.

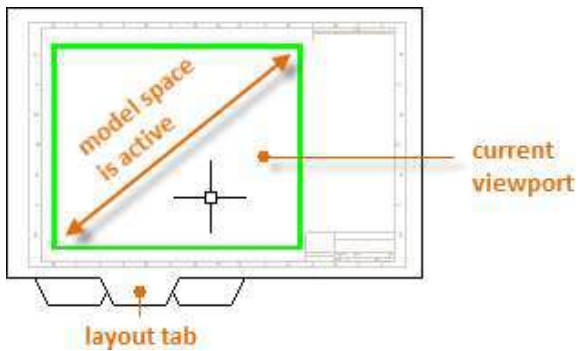


***NOTE:** You might be wondering why there are two entries in the list for every sheet size. This is because some printers and plotters do not recognize the drawing orientation setting.*



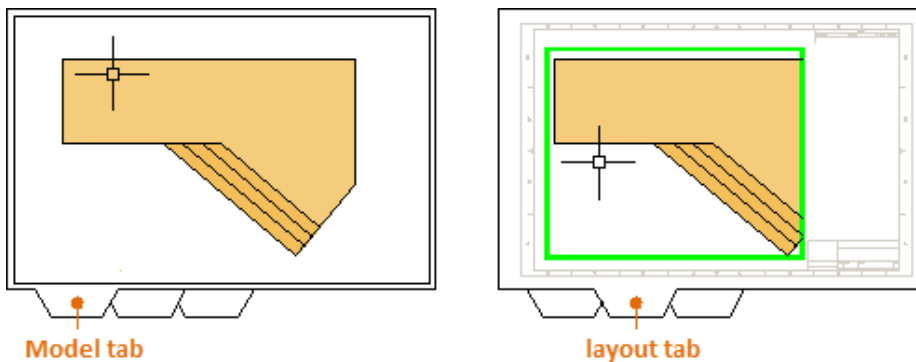
## Layout Viewports

A layout viewport is an object that is created in paper space to display a scaled view of model space. You can think of it as a closed-circuit TV monitor that displays part of model space. In the illustration, model space is active and accessible from within the current layout viewport



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In a layout, when model space is active, you can pan and zoom, and anything else that you could do on the Model tab. For example, let's say that you created a backyard deck design in model space, and now you want to lay out and print your design from a layout tab.



The view in the layout viewport is not yet set to the correct scale.

Important:

You can switch between paper space and model space by double-clicking inside or outside the layout viewport.

**NOTE:** You can use the **MVIEW** (make view) command to create additional layout viewports in paper space. With several layout viewports, you can display several views of model space at the same or at different scales.

Here are the steps to follow if you use the trans-spatial method of annotating your drawing:

Click the layout tab. If you started the drawing with your own custom drawing template file, several tasks might already have been completed: the layout might already be set to

D-size, and the title block might already have been inserted in the layout.

By default, paper space is active, so double-click within the layout viewport to make the model space active. Notice that the edge of the layout viewport becomes thicker as a result of switching to model space.

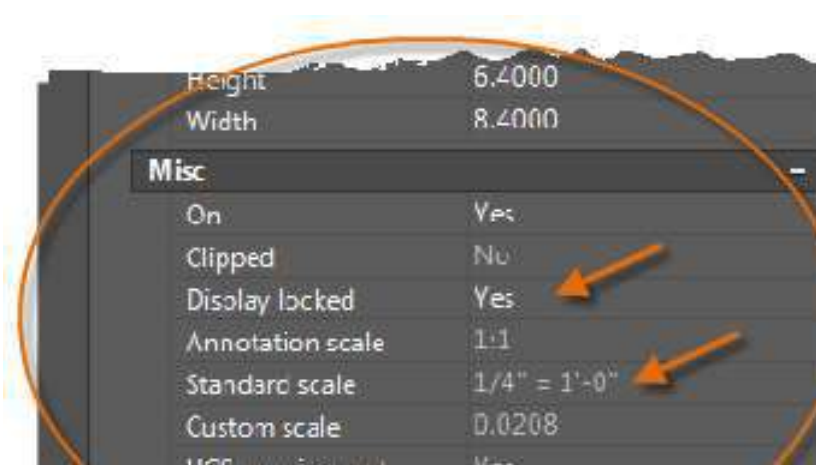
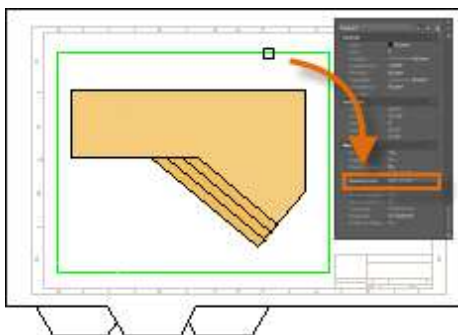
Zoom out and center the model space view by panning. Note that the displayed view will not yet be set to the correct scale.

Double-click outside the layout viewport to make paper space active again.

Open the Properties palette and then click to select the edge of the layout viewport.

In the Properties palette, specify a standard scale of 1/4" =

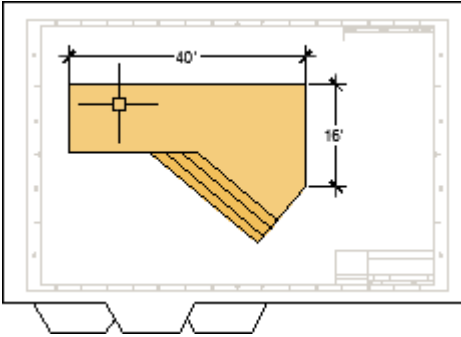
1'-0" from the drop-down list. This action scales your view of model space precisely to the D-size drawing. You should also set the Display Locked property from No to Yes, which will prevent any unintentional display changes to the view.



(continued)

Move the layout viewport as needed, and adjust its edges using grips.

Create notes, labels, and dimensions directly in paper space. They will automatically appear at the correct size.



Turn off the layer on which you created the layout viewport object. This hides the edges of the layout viewport as shown below.

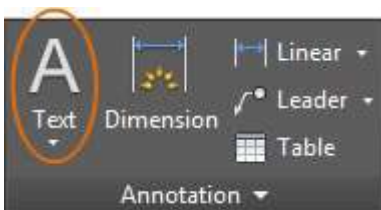
Print the drawing to paper or as a DWF or PDF file.

**NOTE:** After you have finished dimensioning, you can use the *EXPORTLAYOUT* command to merge everything in model and paper space into the model space of a separate drawing file. This operation creates a drawing file that conforms to the original method of creating the model and all annotations in model space.

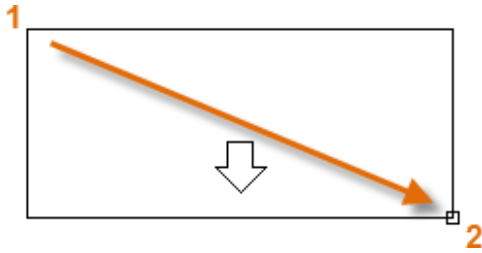
## Notes and Labels

Create notes, labels, bubbles, and callouts. Save and restore style settings by name.

You can create general notes using the **MTEXT** command (or enter **MT** in the Command window), which stands for *multiline text*. The multiline text tool is available on the Annotation panel.



After you start the **MTEXT** command, you are prompted to create a “text box” with two diagonal clicks.



### Create a Text Style

As with several other annotation features, multiline text provides a lot of settings. You can save these settings as a *text style*

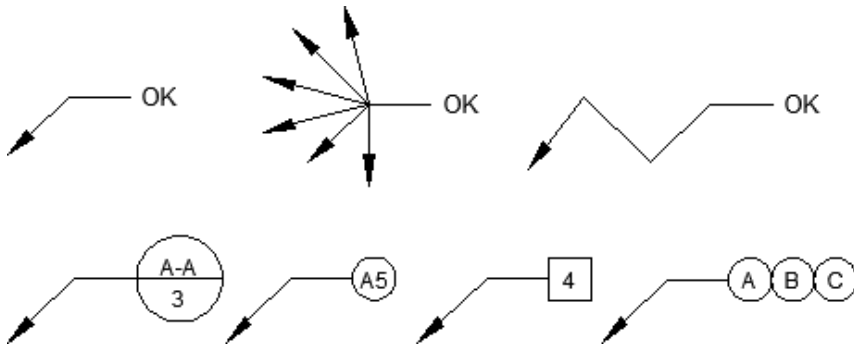
using the **STYLE** command, and then you can access the text styles you’ve saved by clicking the drop-down arrow on the Annotation panel. The current text style is displayed at the top of the drop-down list.

To create a new text style, click the Text Style control as shown.

### Multileaders

*Multileader* objects are used to create text with leader lines such as general labels, reference labels, bubbles, and callouts.

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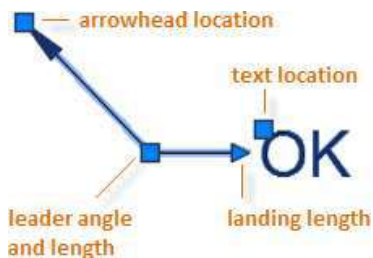
### Create a Multilayer

To create a multilayer, use the **MLEADER** command. Click the Multilayer tool in the Annotation panel or enter **MLD** in the Command window. Follow the prompts and options in the Command window. Feel free to experiment.

After you create a multilayer, select it and then modify it by clicking and moving its grips.

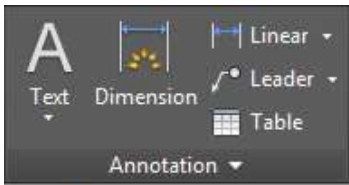
Grip menus appear when you hover over arrowhead and leader grips. From these menus, you can add leader segments or additional leaders.

You can edit the text in a multilayer by double-clicking it.



## Create a Multileader Style

You can create your own multileader styles from the drop-down list in the expanded Annotation panel, or by entering **MLEADERSTYLE** in the Command window.

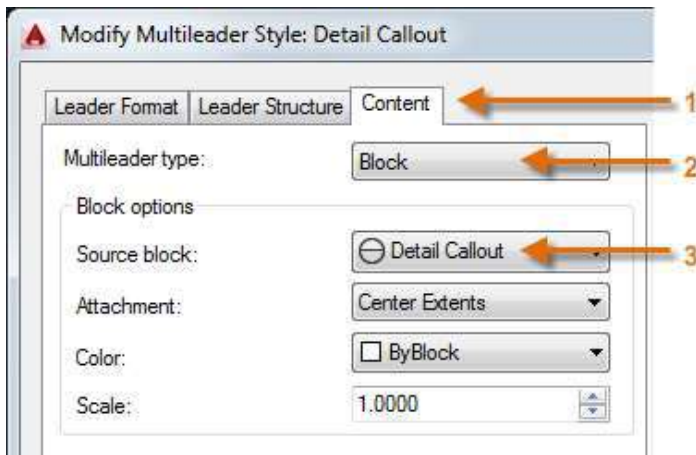


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For example, to create a “detail callout” style, start the **MLEADERSTYLE** command. In the Multileader Styles Manager, click New and choose a descriptive name for the new multileader style. Click the Content



tab, choose Block, and then Detail Callout as shown.

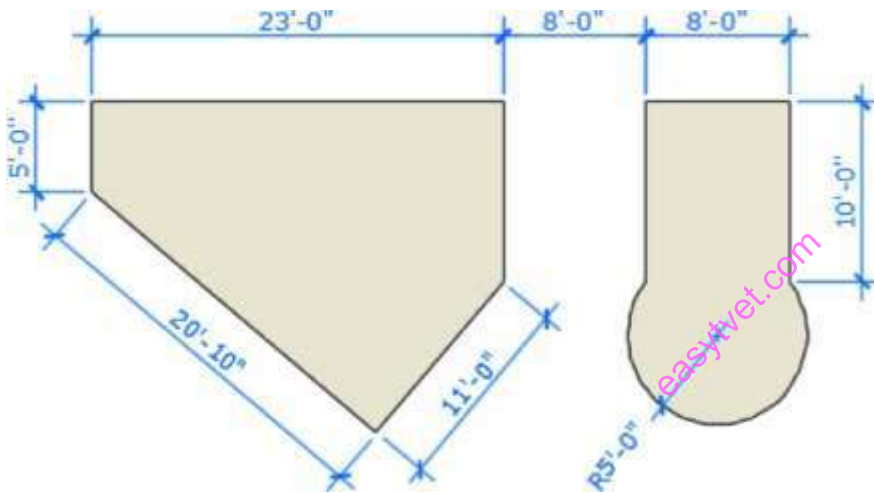


**NOTE:** As with text styles, once you create one or more multileader styles, save them in your drawing template files.

### Dimensions

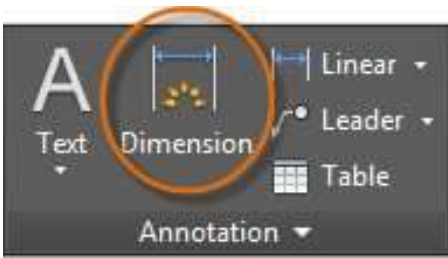
Create several types of dimensions and save dimension settings by name.

Here is an example of several types of dimensions using an architectural dimension style with imperial units.

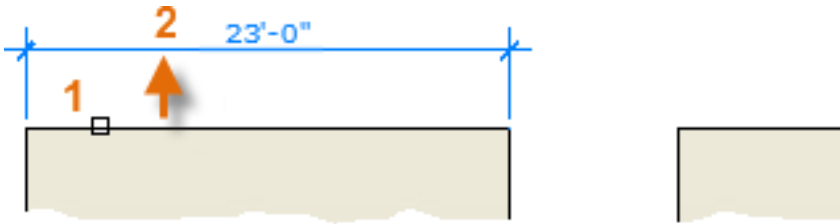


### Linear Dimensions

You can create horizontal, vertical, aligned, and radial dimensions with the **DIM** command. The type of dimension depends on the object that you select and the direction that you drag the dimension line.



The following illustration demonstrates one method for using the **DIM** command. Once you start the command, press Enter or the Spacebar, select the line (1), and then click the location of the dimension line (2).



Linear Dimensions (continued)

For the 8'-0" dimension below, you use another method. You start the DIM command, click two endpoints (1 and 2) and then the location of the dimension line (3). To line up the dimension lines point 3 was snapped to the endpoint of the previously created dimension line.



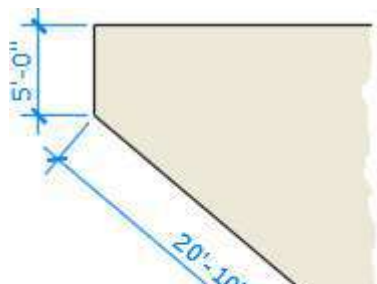
Use the **DIM** command to create dimensions that are parallel to an object by dragging the dimension line at an angle rather than horizontally or vertically.

Here's a Tip:

If points 1 and 2 are not on the same horizontal line, press Shift to force the dimension line to be horizontal. In addition, if the building or part being dimensioned is at an angle, enter **DIMROTATED** for that case.

Another Tip:

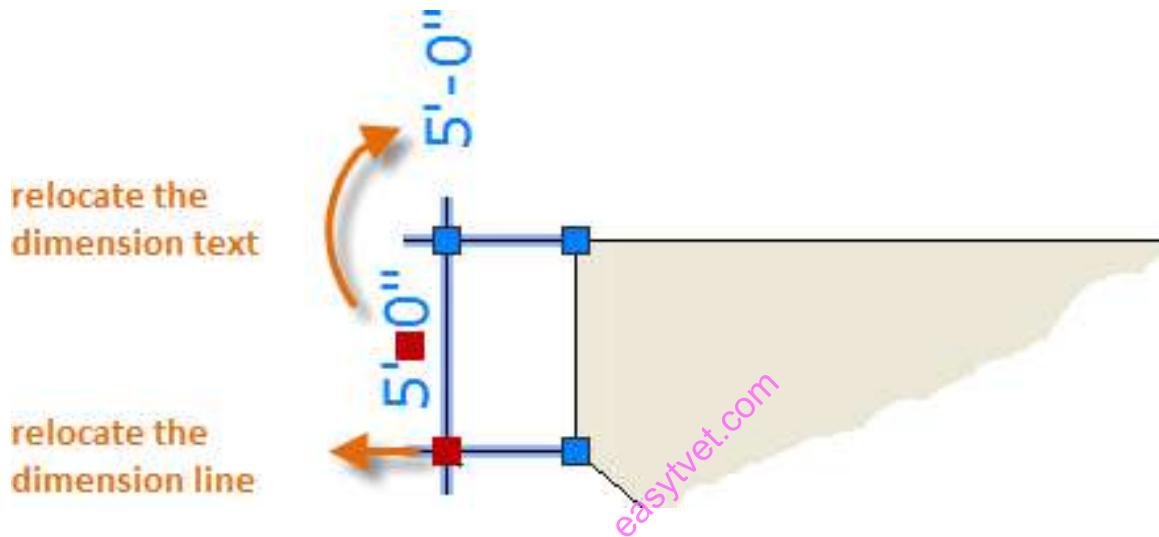
Because it is easy to accidentally snap to the wrong feature or part of a dimension object, be sure to zoom in closely enough to avoid mistakes.



## Modify Dimensions

For simple adjustments to dimensions, nothing is faster than using grips.

In this example, you select the dimension to display its grips. Next, click the grip on the dimension text and drag it to a new location, or click one of the grips at the end of the dimension line and drag the dimension line.



Here's a Tip:

If the changes are more complicated than this, it might be faster simply to delete and then recreate the dimension.

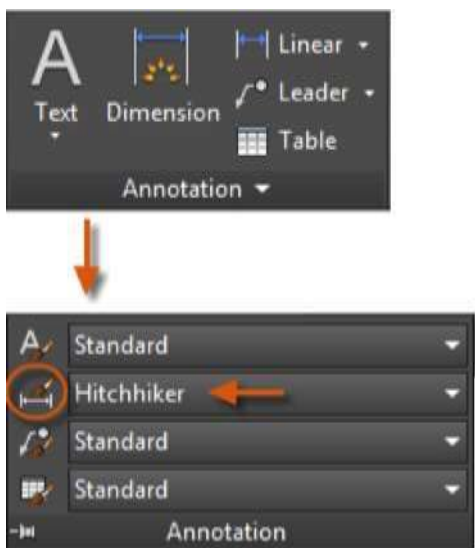
## Dimension Styles

Dimension styles help establish and enforce drafting standards. There are many dimension variables that can be set with the **DIMSTYLE** command to control virtually every nuance of the appearance and behavior of dimensions. All these settings are stored in each dimension style.

The default dimension style is named either Standard (imperial) or ISO-25 (metric). It is assigned to all dimensions until another style is set as the current dimension style.

The current dimension style name, Hitchhiker in this case, is displayed in the drop-down list of the Annotation panel.

To open the Dimension Style Manager, click the indicated button. You can create dimension styles that match nearly any standard, but you will need to invest time into specifying them completely. For this reason, you should save any dimension styles that you create in one or more drawing template files.



## Printing

Output a drawing layout to a printer, a plotter, or a file. Save and restore the printer settings for each layout.

Originally, people *printed* text from printers and *plotted* drawings from plotters. Now, you can perform both with either device, so this guide will use the terms 'print' and 'plot' interchangeably.

The command to output a drawing is **PLOT** and you can access it from the Quick Access toolbar.



To display all of the options in the Plot dialog box, click the More Options button.



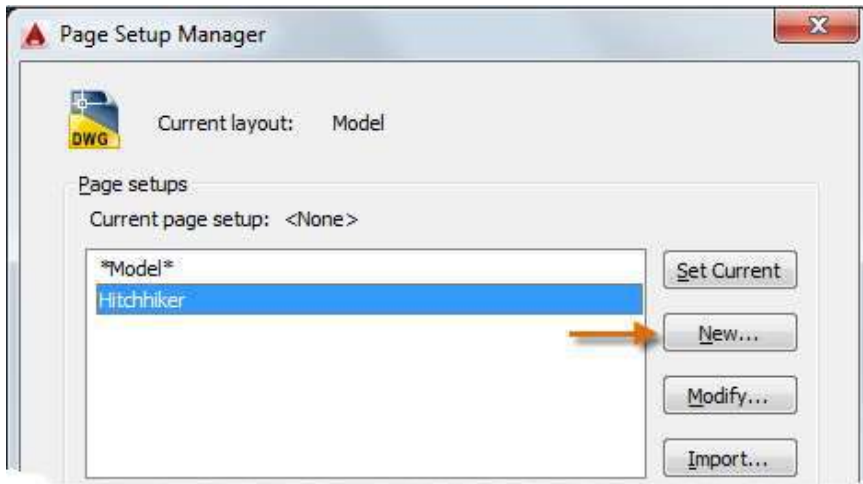
As you can see, there are many settings and options available.

For the sake of convenience, you can save and restore collections of these settings by name. These are called *page setups*. With page setups you can store the

### Create a Page Setup

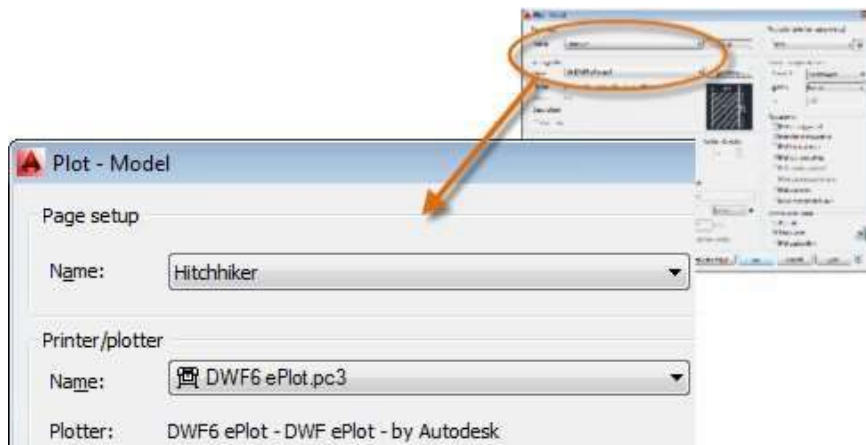
To open the Page Setup Manager, right-click on the Model tab or a layout tab and choose Page Setup Manager. The command is **PAGESETUP**.

Each layout tab in your drawing can have an associated page setup. This is convenient when you use more than one output device or format, or if you have several layouts with different sheet sizes in the same drawing.



To create a new page setup, click New and enter the name of the new page setup. The Page Setup dialog box that displays next looks like the Plot dialog box. Choose all the options and settings that you wish to save.

When you are ready to plot, simply specify the name of the page setup in the Plot dialog box, and all your plot settings will be restored. In the following illustration, the Plot dialog box is set to use the Hitchhiker page setup, which will output a DWF (Design Web Format) file rather than print to a plotter.





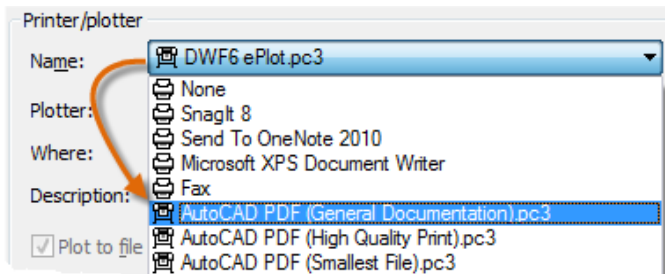
Here's a Tip:

You can

### Output to a PDF File

The following example shows you how to create a page setup for creating PDF files.

From the Printer/plotter drop-down list, choose *AutoCAD PDF (General Documentation).pc3*:



Next, choose the size and scale options that you want to use:

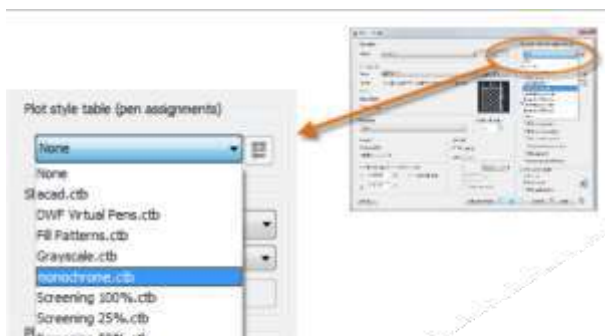
**Paper Size:** The orientation (portrait or landscape) is built into the choices in the drop-down list.

**Plot Area:** You can clip the area to be plotted with these options, but typically everything will be plotted.

**Plot Offset:** This setting changes based on your printer, plotter, or other output. Try centering the plot or adjusting the origin, but remember that printers and plotters have a built-in margin around the edges.

**Plot Scale:** Choose your plot scale from the drop-down list. A scale such as 1/4" = 1'-0" is meant for printing to scale from the Model tab. On a layout tab, you normally print at a 1:1 scale.

The plot style table provides information about processing colors. Colors that look good on your monitor might not be suitable for a PDF file or for printing. For example, you might want to create a drawing in color, but create monochrome output. Here is how you specify monochrome output:



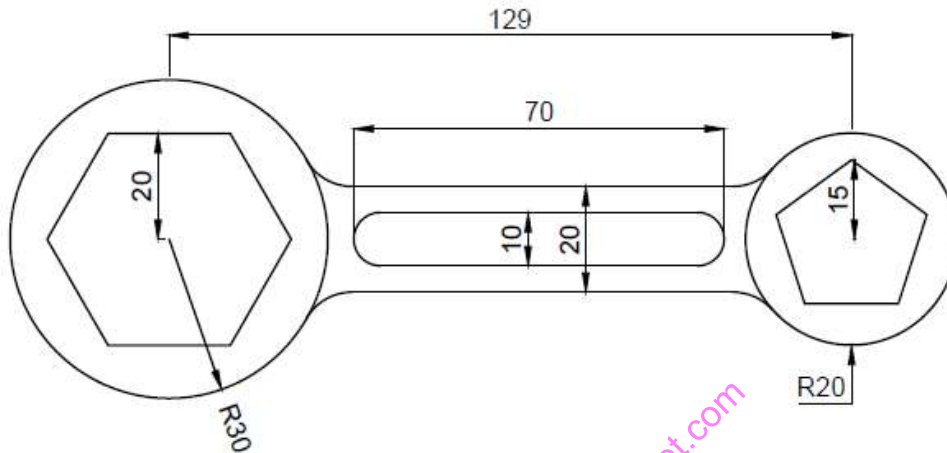
## Learning activities

### Learning activity 1: Apply CAD packages

The following figure is an orthographic view of a lever crank. Redraw the view using AutoCAD.

SET-UP INSTRUCTIONS: Using the UNITS command:

- iv. Set UNITS to Decimal.
- v. Set the accuracy to 2 decimal places.
- vi. Accept the defaults for the remaining prompts.



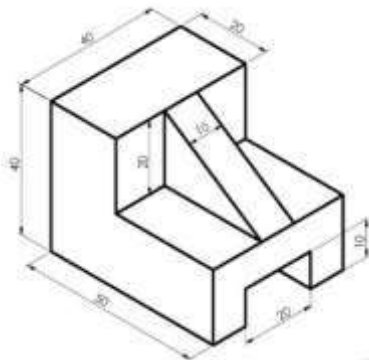
### Learning activity 2: Apply cad packages

The following figure is an ISOMETRIC view. Redraw the view using AutoCAD.

SET-UP INSTRUCTIONS:

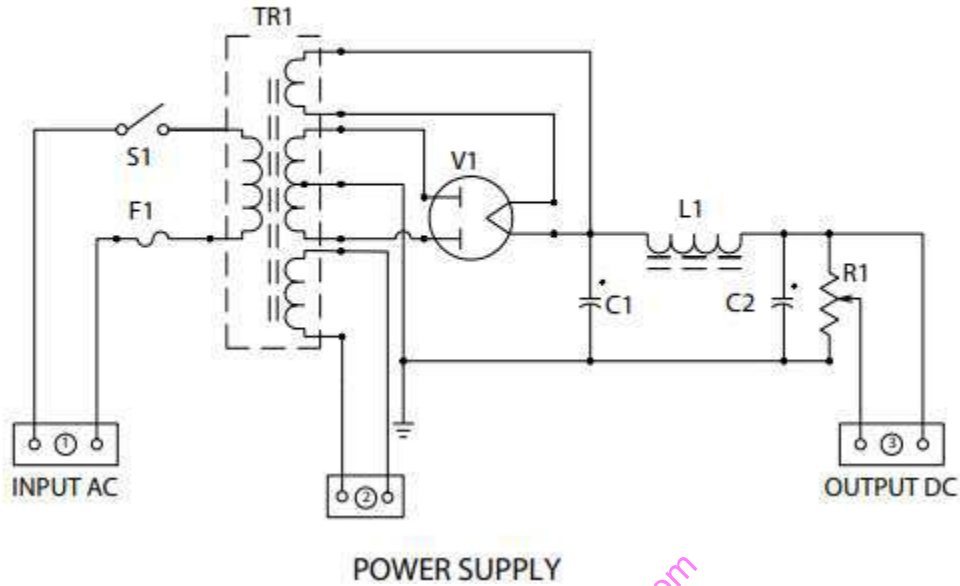
Using the UNITS command:

- iv. Set UNITS to Decimal.
- v. Set the accuracy to 2 decimal places.
- vi. Accept the defaults for the remaining prompts.



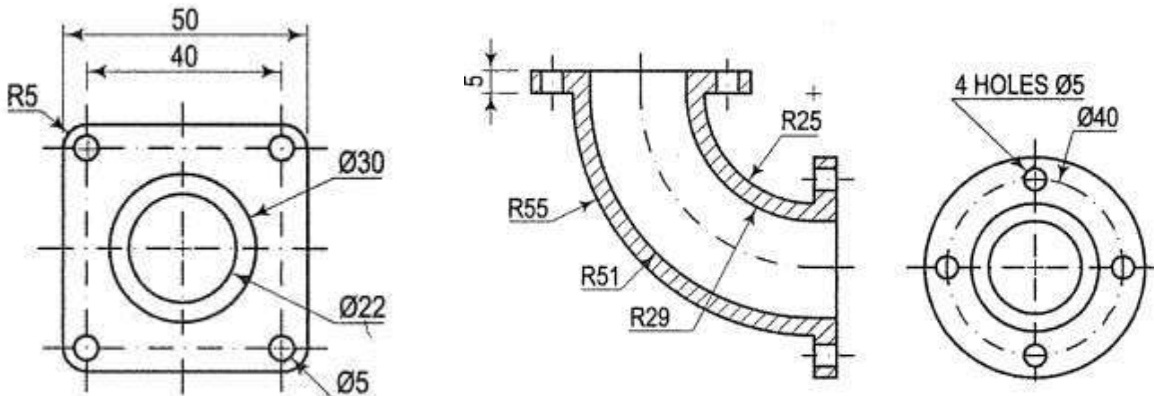
### Learning activity 3: Apply cad packages

Draw this circuit, using the techniques you have learned using AutoCAD.



### Learning activity 4: Apply cad packages

Draw the figure below using line, circle, rectangle, fillet, rectangular array, polar array, dimension, hatch, layer, hidden line, and center line etc., commands.



Self-assessment

36. When creating your own blocks, it is important to avoid drawing any portion of the block in the \_\_\_\_\_ layer.

- E. 0
- F. center line
- G. hatch
- H. hidden line

37. An AutoCAD term that refers to a pre-drawn object which is stored in a drawing file and can be inserted into any other drawing file as needed is a \_\_\_\_\_.

- A. Block
- B. Brick
- C. Balloon
- D. none of the above

38. Before starting an isometric drawing in AutoCAD the drafter needs to \_\_\_\_\_.

- E. set the grid to isometric
- F. set the current layer to Defpoints
- G. turn Object Snap off
- H. turn Ortho off

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39. When lettering a CAD drawing, for clarity you should limit the number of fonts to:

- E. One
- F. Two
- G. Three
- H. Any number

40. The same general concepts and drafting standards apply to CAD as to drawings created by hand.

- C. True
- D. False

**41.** The main difference between a CAD drawing and a freehand sketch is in the appearance of lines.

- C. True
- D. False

42. In a CAD system, you can draw an ellipse by specifying these:

- E. The bounding lines
- F. The midpoint and end points
- G. The center and major and minor axes
- H. The center and radius

43. When creating an isometric drawing in AutoCAD the drafter can utilize the Dynamic Input and Polar Coordinate system to place both vertical and horizontal lines. A line created from one point 3 inches at 180 degrees would be a \_\_\_\_\_ line.
- E. horizontal
  - F. vertical
  - G. inclined
  - H. none of the above
44. AutoCAD refers to isometric ellipses as \_\_\_\_\_.
- E. Ellipses
  - F. Isoellipses
  - G. Isocircles
  - H. circles
45. Drafters should use a \_\_\_\_\_ in a section view of a mechanical part that includes the cylindrical view of a threaded hole.
- E. Center line
  - F. Hatch line
  - G. Poly line
  - H. Dimension line
46. When filling an area with a hatch pattern in AutoCAD the drafter needs to be able to \_\_\_\_\_.
- E. See the entire bounding area to hatch
  - F. set Ortho on
  - G. turn ISO grid off
  - H. set the layer to Defpoints
47. The default position of the UCS icon is positioned at \_\_\_\_\_ on the AutoCAD grid.
- E. 0,0,0
  - F. 10,10,10
  - G. 20,20,20
  - H. None of the above
48. A cylinder can be created by drawing a rectangular shape then the \_\_\_\_\_ tool.
- E. Revolve
  - F. Sweep
  - G. Extrude
  - H. none of the above
49. The MASSPROP shortcut will provide the following information.
- E. mass
  - F. volume
  - G. bounding box

- H. all of the above
50. The 3-D commands on the Modeling toolbar include \_\_\_\_\_.
- E. box
  - F. sphere
  - G. extrude
  - H. all of the above
51. CAD programs which incorporate parametric modeling utilize a system in which the dimensions control the \_\_\_\_\_.
- E. size and shape of the model features
  - F. perspective of the model
  - G. shading used to render the model
  - H. all of the above
52. In order to create one solid model from two or more separate solid shapes the drafter will need to position them and then \_\_\_\_\_.
- E. use Union to join them
  - F. use the Join command
  - G. use the Add Parts tool
  - H. none of the above
53. The Conceptual Visual Style tool is located on the \_\_\_\_\_ toolbar.
- E. Visual Styles
  - F. Modify
  - G. 3-D Modeling
  - H. All of the above
54. Drawings created with commercial software are typically saved as:
- E. Rapid prototypes
  - F. Electronic files
  - G. Draft drawings
  - H. Change orders
55. Newer versions of AutoCAD utilize the \_\_\_\_\_ to make block library management very easy.
- E. File / find
  - F. Design Center
  - G. File / search
  - H. None of the above
56. Inserting blocks into a drawing file usually requires exacting placement. The drafter should insure that \_\_\_\_\_ is turned on.
- E. O Snaps
  - F. Ortho
  - G. Grid
  - H. Dynamic Input

57. The command which identifies the points on drawing entities that are visible on screen is and this option allows the user to pick-up the points very accurately with respect to drawing displayed.
- A. OSNAP
  - B. TABSURF
  - C. SNAP
  - D. GRID
58. The commands Erase, Copy, Mirror, Trim, Extend, Break etc belongs to which tool bar?
- A. Layer tool bar
  - B. Style tool bar
  - C. Modify tool bar
  - D. Draw tool bar
59. The commands Donut, Block, Spline, Polygon, and Arc etc belong to which tool bar?
- A. Layer tool bar
  - B. Style tool bar
  - C. Modify tool bar
  - D. Draw tool bar
60. The command which works on two lines or a single poly line to create a beveled edge is
- A. Chamfer
  - B. Fillet
  - C. Stretch
  - D. Extend
61. The command which is used to create a round corner between two lines is
- A. Chamfer
  - B. Fillet
  - C. Stretch
  - D. Extend
62. The command 'Oops' is used to
- A. create one or more copies of selected objects at another location
  - B. creates mirror image of selected objects about specified line
  - C. retrieves all objects erased by the last erase
  - D. deletes the selected entities
63. The command 'pedit' is used for
- A. erases a portion of line, arc, circle or a 2D poly line between two selected points
  - B. reverses the effects of a series of previously used commands
  - C. breaking a poly line into individual segments
  - D. editing of poly line properties
64. The command 'break' is used for
- e) erases a portion of line, arc, circle or a 2D poly line between two selected points
  - f) reverses the effects of a series of previously used commands
  - g) breaking a poly line into individual segments
  - h) editing of poly line properties
65. The command 'U' is used for

- e) erases a portion of line, arc, circle or a 2D poly line between two selected points
  - f) reverses the effects of a series of previously used commands
  - g) breaking a poly line into individual segments
  - h) editing of poly line properties
66. The command 'Explode' is used for
- e) erases a portion of line, arc, circle or a 2D poly line between two selected points
  - f) reverses the effects of a series of previously used commands
  - g) breaking a poly line into individual segments
  - h) editing of poly line properties
67. The command which is used to set a new coordinate system by shifting the working XY plane to be desired location is?
- e) 3DFACE
  - f) VPOINT
  - g) UCS
  - h) ELEV
68. The command which is used for making planar unmeshed surfaces that have three or four sides is
- e) 3DFACE
  - f) VPOINT
  - g) UCS
  - h) ELEV
69. The command which is used to set the viewpoint in 3D space for viewing the 3D models is
- e) 3DFACE
  - f) VPOINT
  - g) UCS
  - h) ELEV
70. The command which is used to set elevation and thickness properties for 2D wireframe objects such as line, point, circle, polygon, arc is
- e) 3DFACE
  - f) VPOINT
  - g) UCS
  - h) ELEV

#### Tools, Equipment, Supplies and Materials

- 7. Drawing tools
- 8. Drawing set
- 9. Drawing papers
- 10. Erasers
- 11. Series of pencils
- 12. Drawing board



## References

7. *Bhatt, N. D. and Panchal, V. M. 2006. Engineering Drawing : Plane and Solid Geometry. Charotar Publ. House Pvt. Ltd., Anand.*
8. *Bhatt, N. D. and Panchal, V. M. 2004. Machine Drawing. Charotar Publ. House Pvt. Ltd., Anand.*
9. *Narayana, K. L., Kanniah, P. and Reddy, K. V. Machine Drawing. 2011. New Age International Publ., New Delhi.*
10. *Reddy, K. V. 2010. Textbook of Engineering Drawing . B.S. Publ., Hyderabad.*
11. *Textbook of Engineering Drawing Second Edition K. Venkata Reddy Prof. & HOD of Mechanical Engineering Dept. C.R. Engineering College,*
12. *Learn about AutoCAD manual. An Introduction to AutoCAD for Beginners*

## 4.7 MODEL ANSWERS

### Apply and Maintain Drawing Equipment and Materials

9. B
10. A
11. B
12. C
13. A
14. B

15. Why the drawing is called the language of Engineers?

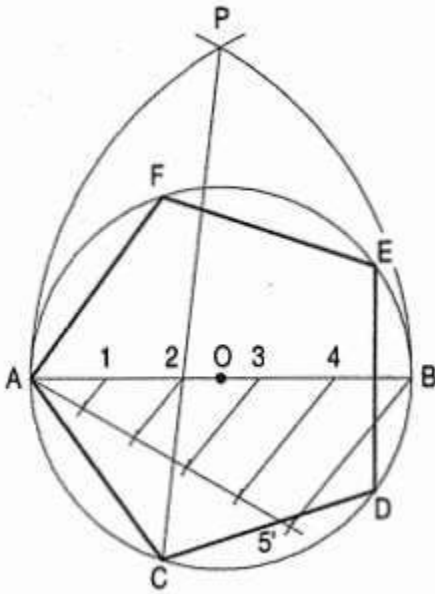
Engineering drawing teaches us to imagine and read the drawing, which is important in industrial or construction engineers to execute the construction with the help of a drawing and execute according to the drawing. Without drawing we can't construct in construction work

16. What is the Necessity of Dimension a Drawing?

## Learning activity 2: Produce plane geometry

### To inscribe a regular polygon of any number of sides, say 5, in a given circle

- xix. With centre  $O$ , draw the given circle.
- xx. Draw a diameter  $AB$  and divide it into five equal parts (same number of parts as the number of sides) and number them as shown.
- xxi. With centres  $A$  and  $B$  and radius  $AB$ , draw arcs intersecting each other at  $P$ .
- xxii. Draw a line  $P2$  and produce it to meet the circle at  $C$ . Then  $AC$  is the length of the side of the pentagon.
- xxiii. Starting from  $C$ , step-off on the circle, divisions  $CD$ ,  $DE$  etc., equal to  $AC$ .
- xxiv. Draw lines  $CO$ ,  $DE$  etc., thus completing the pentagon.



Produce Plane Geometry Drawings

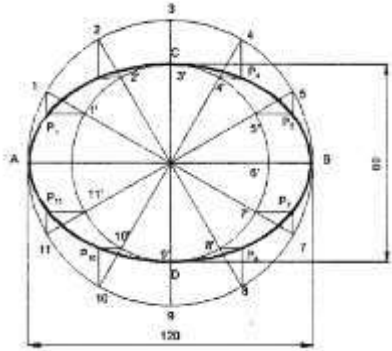
5. D 9

6. D

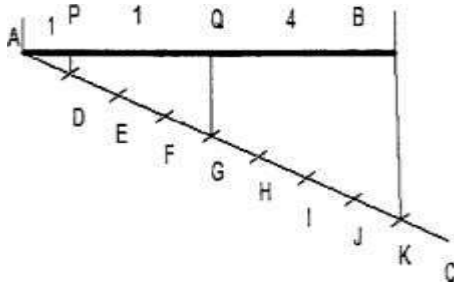
an

inscribed

7. Ellipse

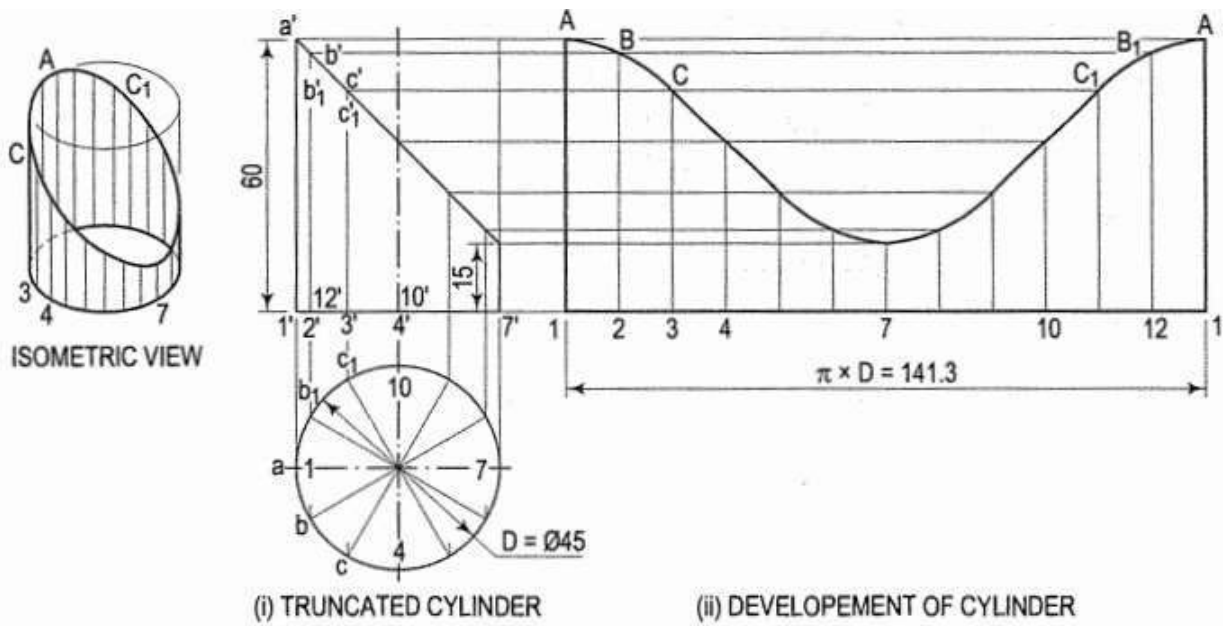


8.

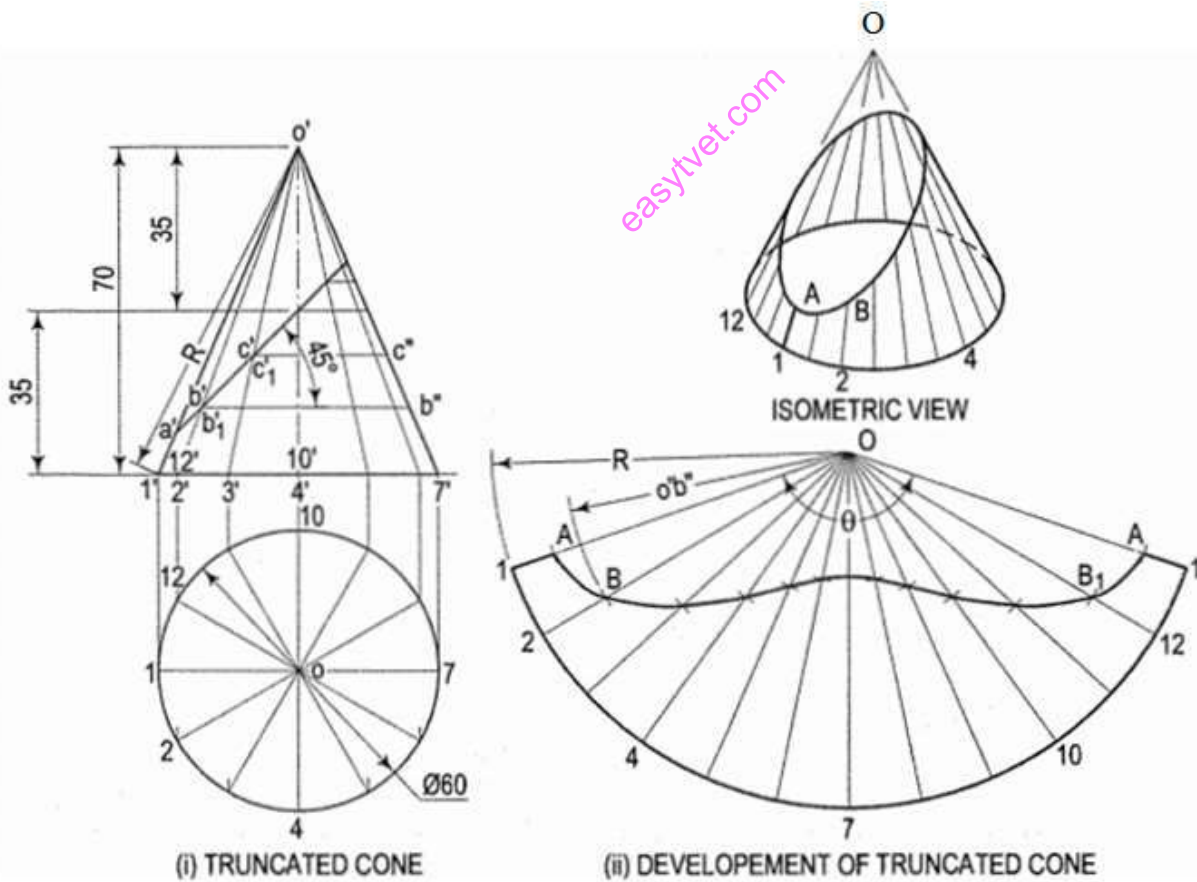


Add the ratios  $1+3+4 = 8$  and divide the line into 8 equal divisions.  
Obtain P and Q to divide the line AB in the ratio 1:3:4.

**Learning activity 1:** Produce solid geometry drawings  
**Develop the lateral surface of the truncated cylinder**



**Learning activity 2: Produce solid geometry drawings**  
**Draw the development of the of the truncated cone**



Produce Solid Geometry Drawings

- 7. A
- 8. C
- 9. B

10. What is the difference between regular and irregular polygons?

**Regular polygon – A regular polygon is a plane figure in which all the sides and angles are equal.**

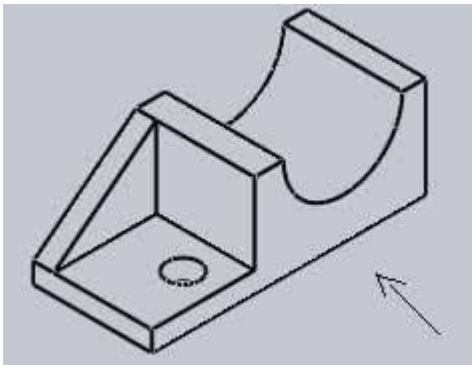
**Irregular polygon – An irregular polygon is a plane figure in which all the sides and angles are not equal.**

11. If an isometric drawing is made use of isometric scale then the drawings are called

Answer: A

Explanation: To avoid confusion, the view drawn with the true scale is called isometric drawing or isometric view, while that drawn with the use of isometric scale is called isometric projection.

12. Identify the front view of the below isometric view.



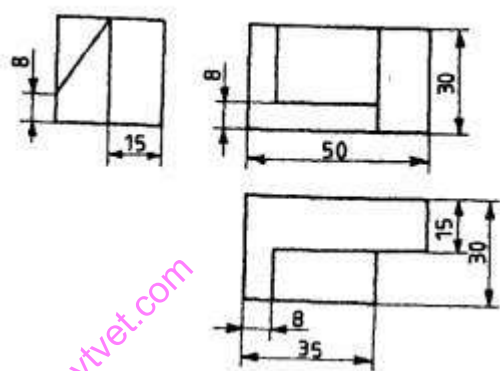
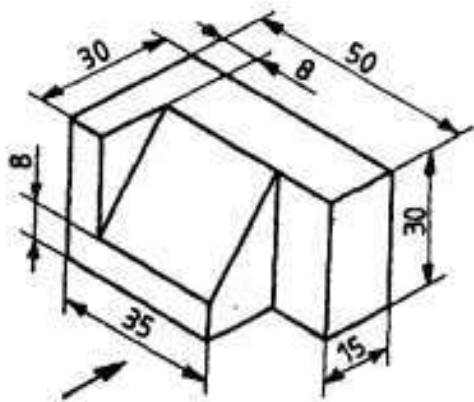
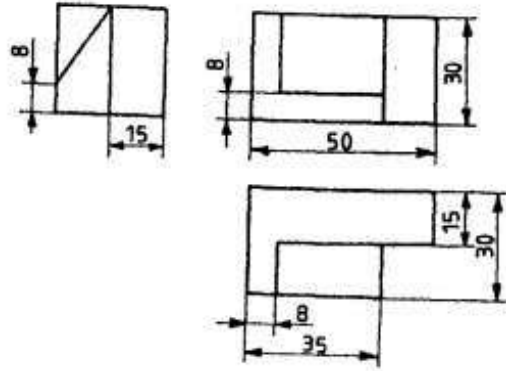
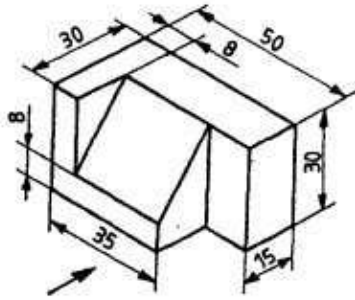
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Answer: a

Explanation: Here the isometric view of some example picture is given. Arrow in question represents the line of sight in case of front view from that we can get other view. Front view is asked which can be watched along the arrow.

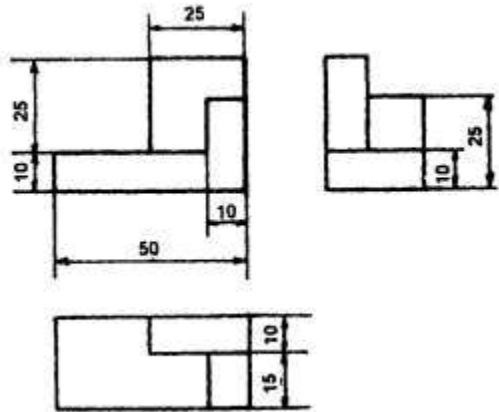
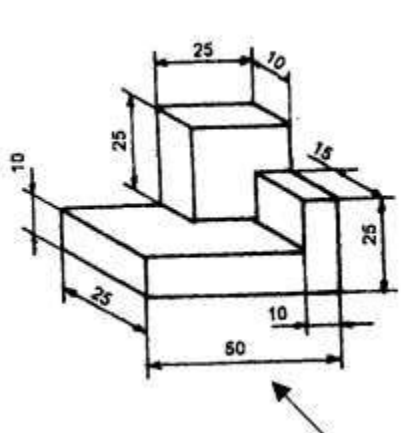
### LEARNING ACTIVITY 1: Produce orthographic and pictorial drawings

- iii. The following figures are in isometric view. Draw the orthographic views in first angle.



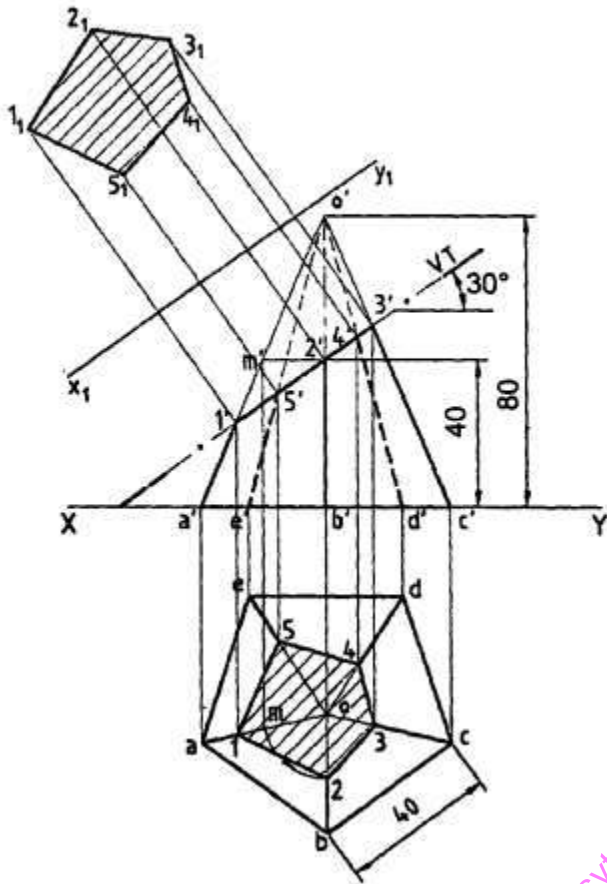
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iv. The following figures are in oblique view. Draw the orthographic views in first angle.



**Learning activity 2: Produce orthographic and pictorial drawings**

A pentagonal pyramid of base side 40 mm and axis length 80mm is resting on HP on its base with one of its base side parallel to VP. It is cut by a plane inclined at 30° to HP and perpendicular to VP and is bisecting the axis. Draw its front view, sectional top view, and the true shape of section.



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Produce Orthographic and Pictorial Drawings

16. D
17. B
18. B
19. A
20. A
21. B
22. A
23. B
24. C
25. A
26. D
27. D
28. C

Explanation: From the front view it is clear that the circle has diameter 20 mm. Hence its radius will be 10mm. The dimension 10mm in the side view is just a repetition of this information. Repetitive dimensions are redundant and they need to be avoided.

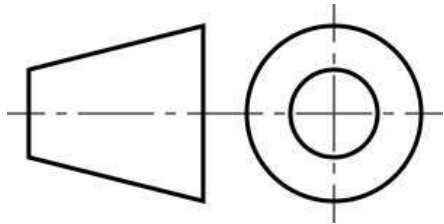
## 29. Views in an Orthographic Drawings

**Front view**

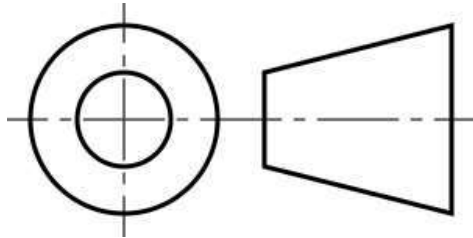
**Side view**

**Plan**

30. First angle projection:-In this projection the object is assumed to be situated in first quadrant, i.e. in front of V.P and above HP the projections obtained on these planes is called first angle projection. The symbol for the first angle projection is



Third angle projection: – In this Projection the object is assumed to be situated in the third quadrant that is below HP and behind VP .The front view comes below the XY line and the top view above it. The symbol for the third angle projection is



easytv.com

### **First angle and third angle symbol in machine drawing**

## Produce Electrical Drawings

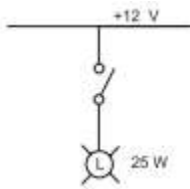
- 5. Definitions;
- iv. Schematic diagram

Schematic diagram: a diagram that uses lines to represent the wires and symbols to represent components. It is used to show how the circuit functions.

- v. Line diagram

Line diagram: a one-line diagram or single-line diagram is a simplified notation for representing an electrical system. The one-line diagram is similar to a block diagram except that electrical elements such as switches, circuit breakers, transformers, and capacitors are shown by standardized schematic symbols.

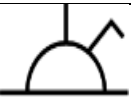
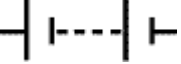
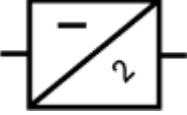







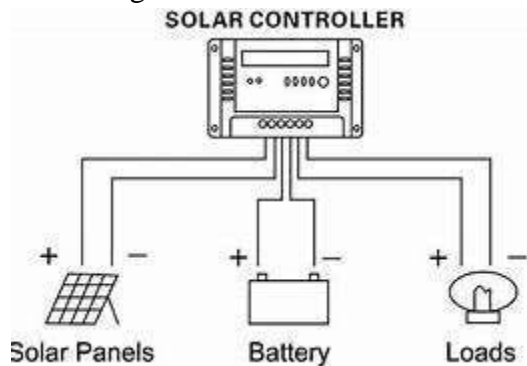
vi. Wiring diagram

A diagram which shows the connections of an installation or its component devices or parts. It may cover internal or external connections, or both, and contains such detail as is needed to make or trace connections that are involved.

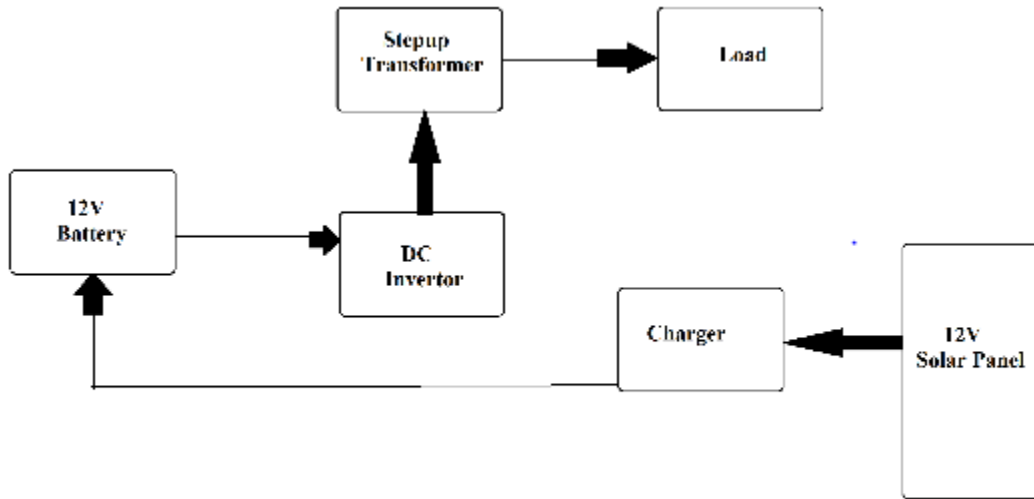
6. Indicate the meaning of the following symbols

| Symbol  | Meaning                               |
|---|---------------------------------------|
|    | 1 gang switched socket-outlet         |
|    | Battery                               |
|   | Inverter                              |
|  | Switch, general symbol                |
|  | Filament lamp                         |
|  | Semi-Conductor Diode - general symbol |

7. A pictorial diagram to show the connection of the solar panel, the battery, and the load to a charge controller.



8. Block diagram of a solar system.



Apply Cad Packages

36. A

37. A

38. A

39. B

40. A

41. A

42. C

43. B

44. C

45. A

46. A

47. A

48. A

49. D

50. D

51. A

52. A

53. A

54. B

55. B

56. A

57. Answer: a

easyvet.com

Explanation: The command which identifies the points on drawing entities that are visible on screen is OSNAP. This option allows the user to pick-up the points very accurately with respect to drawing displayed.

58. Answer: c

Explanation: The commands Erase, Copy, Mirror, Trim, Extend, Break, Join, Scale, Array etc belongs to 'Modify tool bar'. The commands Donut, Block, Spline, Hatch, Rectangle, Ellipse, Polygon, and Arc etc belong to 'Draw tool bar'.

59. Answer: d

Explanation: The commands Erase, Copy, Mirror, Trim, Extend, Break, Join, Scale, Array etc belongs to 'Modify tool bar'. The commands Donut, Block, Spline, Hatch, Rectangle, Ellipse, Polygon, and Arc etc belong to 'Draw tool bar'.

60. Answer: a

Explanation: Chamfer works on two lines or a single poly line to create a beveled edge. Fillet is used to create a round corner between two lines. Stretch command can either lengthen entities or shorten them and thus their shapes.

61. Answer: b

Explanation: Fillet is used to create a round corner between two lines. Chamfer works on two lines or a single poly line to create a beveled edge. Stretch command can either lengthen entities or shorten them and thus their shapes.

62. Answer: c

Explanation: The command 'Oops' is used to retrieves all objects erased by the last erase. Mirror is used to creates mirror image of selected objects about specified line. Command copy creates one or more copies of selected objects at another location. The command 'pedit' is used for

63. Answer: d

Explanation: The command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands. Command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points.

64. Answer: a

Explanation: The command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points. Command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands.

65. Answer: b

Explanation: The command 'U' is used for reverses the effects of a series of previously used commands. Command 'pedit' is used for editing of poly line properties. Command 'break' is used for erases a portion of line, arc, circle or a 2D poly line between two selected points.

66. Answer: c

Explanation: The command 'Explode' is used for breaking a poly line into individual segments. Command 'pedit' is used for editing of poly line properties. Command 'U' is used for reverses the effects of a series of previously used commands.

67. Answer: c

Explanation: UCS is used to set a new coordinate system by shifting the working XY plane to be desired location. 3DFACE is used for making planar unmeshed surfaces that have three or four sides. VPOINT is used to set the viewpoint in 3D space for viewing the 3D models.

68. Answer: a

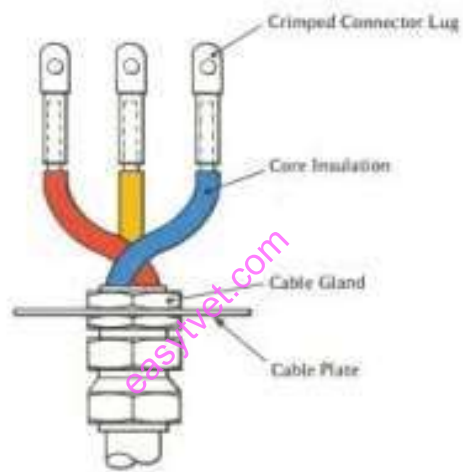
Explanation: 3DFACE is used for making planar unmeshed surfaces that have three or four sides. VPOINT is used to set the viewpoint in 3D space for viewing the 3D models. UCS is used to set a new coordinate system by shifting the working XY plane to be desired location.

69. Answer: b

Explanation: VPOINT is used to set the viewpoint in 3D space for viewing the 3D models. 3DFACE is used for making planar unmeshed surfaces that have three or four sides. UCS is used to set a new coordinate system by shifting the working XY plane to be desired location.

70. Answer: d

Explanation: ELEV is used to set elevation and thickness properties for 2D wireframe objects such as line, point, circle, polygon and arc. 3DFACE is used for making planar unmeshed surfaces that have three or four sides.



Cable termination

The methods used to terminate the cables vary according to;

- Type of cable,
- Type of connector and application.
- Outdoor or indoor use
- Voltage
- Current
- Overhead, or underground
- Type of Connector on the equipment where the cable will be connected.

The common type of terminations

- Crimp connection,
- Soldered connection,
- Compression termination, and wire-wrapping connection,
- Direct connection,

➤ Loop or eye connection.

## Electrical power cable joints

The cable joints are used to connect low, medium or high voltage cables. The type of cable joint sizes, shapes and configurations vary according to the voltage, structure, insulation and the number of cores of the cable to be jointed.

The joints provide electrical insulation as well as mechanical protection and strength. The electrical connection is made in various ways and can crimping, or use of mechanical connectors, soldering, etc.

*Voltage*- The joints are designed for low, medium or high voltages and it is important to match the capacity of the joint to voltage in the cable. Low power cable joint will fail if subjected to high current.

*Structure*- The cable joints are made according to how the cables are to be connected. The simple joints such as the straight through connectors are used to connect two power cables at one point while the other more advanced branch connectors may be used to accommodate a cable branching off the main line or several cables coming into one joint to form one main cable.

*Cores*- The cable joints are required to have the same number of cores to those of the cables to be joined.

*Insulation*- There are different cable insulations depending on the application of the cable and the cable joint must be compatible with the cable insulation. There are a variety of insulation procedures, and can be either heat or cold shrinkable insulation, molded type of insulation, or use of tape.

### Types of electrical power cable joints

There are about four commonly used types of joints; these differ in mechanical arrangement and where they are used. However, some manufacturers may provide custom designs to suit unique customer requirements.

*Straight through joints*- This is the mostly used type of a joint and is used to extend pieces of electrical cables.

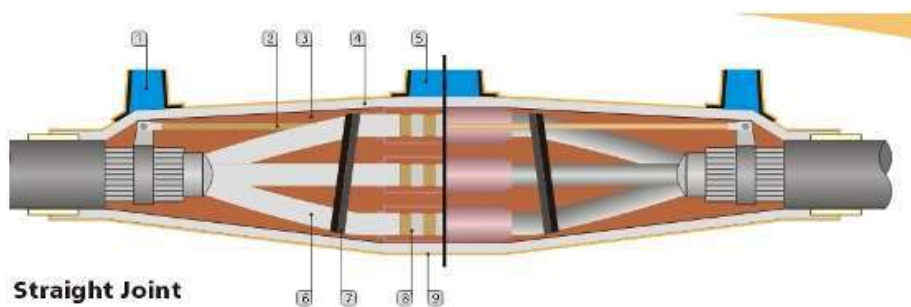


Figure 225:Cable joint:

10. Riser
11. Earth continuity connection
12. C.J compound
13. Plastinet
14. Pouring gate
15. Core Insulation
16. PVC (NA) Tape
17. Ferrule
18. BOPP Tape two layers each half overlapped over plastinet

*Branch which can be a T or Y joint-* This is used to join low voltage, polymeric, non-shielded cables of between 1 and 5 cores. The branch jointing provides a reliable electrical connection, electrical insulation and mechanical protection. The connectors are either the compression or the mechanical type. The branch joints can be used for indoor, outdoor, submerged and underground cable jointing.



T or Y joint

*Pot End Joints-* The pot end joints are used at the live voltage cable ends. In a typical cable, each of the cores is sealed separately using a heat shrink cable end caps. A screen bandage is then applied to provide for earth fault protection and the combination is then covered with a thick wall of heat shrink cable cap. The pot ends joints are suitable for temporary and permanent cable abandonment to provide safe termination of live power cables for indoor, outdoor as well as underground cables

Follow the link below to watch tutorials on cable terminations-

<https://www.youtube.com/watch?v=PgD2D2VnNg0>

- **Importance of termination**

- Provides electrical continuity in the circuit
- Provides mechanical support and physical protection to the cables
- Ensures safety of the circuit, the user and maintenance technician

**Types of cable terminations**

**Soldering-** Flame soldering units can be used to automate the process. In a flame soldering application, the object is placed over a tiny flame, heated for a specified time and a precise amount of solder is applied. Some applications require the terminal to be soldered after it is crimped onto the end of the wire. This method is mainly used in electronics

**Insulation Displacement Connections-** Insulation displacement connectors (IDC) are probably the fastest way to terminate wires. The process can quickly and efficiently terminate the hundreds of wires in large patch panels. There is no need to strip the wires when using IDC. IDC tools are inexpensive and virtually error-proof. There are no chemicals to deal with and no insulation slugs to clean up. IDC applications are usually reserved for small, stranded wire up to 22 AWG.

**Crimping-** Crimping is the most commonly used method of wire termination, and is most efficient for high-volume wire termination. The terminations are fast, clean and mechanically strong. For low volume or fieldwork, loose terminals are applied with a plethora of handheld and benchtop crimping devices.

**Ultrasonic Welding-** Ultrasonic welding is used in various bonding applications, such as joining such dissimilar metals as copper, aluminum, nickel and brass. Ultrasonic welding is widely used in wire harness manufacturing, where welding multiple wires is required. The resulting molecular bonds are strong and can provide lower resistance than soldering or crimping. Ultrasonic welding can also bond wire to terminals. The advantage is the lower resistance. The disadvantage is that this process takes longer than crimping

**Cable lug-** A device attached to a conductor to permit connection to a terminal. It has provisions for attachment of wires or similar electrical conductors in order to establish an electrical connection and could require the use of tools for attachment of wire. A terminal may be attached to a wire by a number of methods including screw-on, press-on or crimp-on

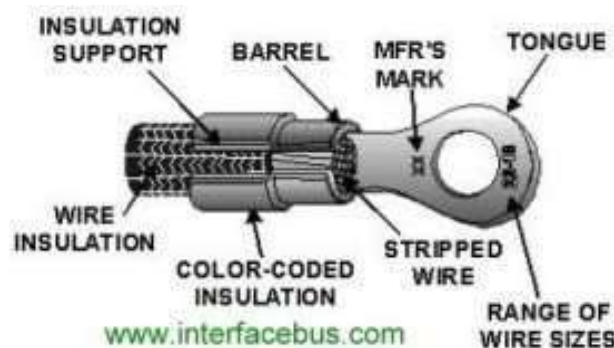


Figure 226: terminal lug (from [www. Interfacebus.com](http://www.Interfacebus.com)):

- **Cable labeling**

Letters, numbers, and wording on wiring labels tell you important information, such as the wire material, the size of the wire, and the type of insulation used on the conducting wires. Labels are found on both individual insulated wires and on insulated cable containing bundles of



wires. Cables carry labels indicating the cable type or construction as well as the number of wires inside the cable.

A ground wire is indicated by "G," "w/G," or "with Ground." The wire material is indicated by "CU" for copper and "AL" for aluminum.

Example

- **14-2G:** Cable contains two insulated wires plus a ground wire; the wires are 14-gauge.
- **14-3G:** Cable contains three insulated wires plus a ground wire; the wires are 14-gauge.
- **12-2 w/G:** Cable contains two insulated wires plus a ground wire; the wires are 12-gauge.
- **12-3 w/G:** Cable contains three insulated wires plus a ground wire; the wires are 12-gauge.
- **600 V:** Cable is rated for a maximum of 600 volts; this is standard for residential NM cable.
- **TYPE NM-B:** Non-metallic type-B cable; this is the current standard for residential installations.

"NM-B" cable is more heat-resistant than older "NM" cable.

### Underground Feeder Cable

Most NM cable is used in "dry," or interior, locations, where the cable is protected inside wall, ceiling, and floor cavities. Underground feeder (UF) cable is a special type of non-metallic cable that is suitable for "wet" locations, or for unprotected locations like direct burial in the ground. UF cable is usually gray (not white, yellow, orange, or black, like standard NM cable); it is labeled "UF-B" and may include "Sunlight Resistant" or similar wording. UF cable uses the same symbols as standard NM cable to indicate the number and gauge of wires.

### Labels on Individual Wires

Individual insulated wires are used in home wiring when an installation calls for conduit—a rigid or flexible protective pipe or tubing through which the wires are run. The important labeling on individual wires relates to the wire insulation—the plastic coating that covers the metal conducting wire. The most common types of wire used in home wiring include:

THHN, THWN, THW and XHHN where;

- **T:** Thermoplastic insulation, a fire-resistant material
- **H:** Heat-resistant; able to withstand temperatures up to 167 F.
- **HH:** Highly heat-resistant; able to withstand temperatures up to 194 F.
- **W:** "Wet," or approved for damp and wet locations; this wire is also suitable for dry locations
- **X:** Insulation made of a synthetic polymer that is flame-retardant
- **N:** Nylon-coated for resistance to oil and gasoline

### Labels on Low-Voltage and Thermostat Wires

Low-voltage wiring used around the home includes small non-metallic cable used for thermostats and other control devices and paired insulated wire used for landscape lighting systems. Wire for landscape lights usually is black and has labeling stamped into the wire insulation. Labels typically include:

- **Wire size:** Indicated by a number (such as 12, for 12-gauge) or a number followed by "AWG," for American Wire Gauge.
- **Number of wires:** Usually indicated by the number 2; landscape wiring typically has two insulated wires stuck together (similar to a lamp cord) and contains no ground wire.
- **Properties:** Wording indicating sunlight-resistance or suitability for underground installation.

Thermostat cable is similar to NM cable but contains four or more small insulated wires and no ground wire. The cable may or may not be labeled. Each wire has its own colour to help you connect to the appropriate terminal at the thermostat and the equipment it controls. Although colour coding is not universal, the lettering on the thermostat terminals is relatively standard:

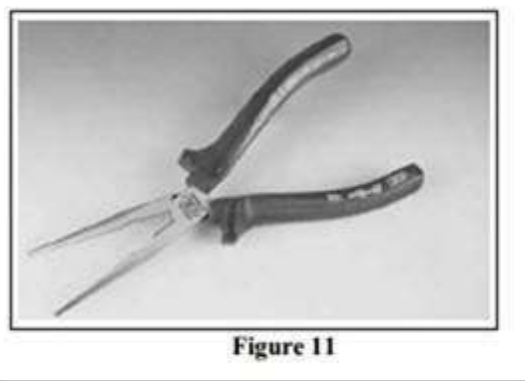
**C:** Common wire; allows for continuous power flow from the R wire; not all thermostats use this terminal

- **R:** 24-volt power supply from the furnace transformer
- **Rc:** Calls for heat or cooling; there may be more than one Rc terminal
- **G:** Fan
- **W:** Heat
- **Y:** Air conditioner

Technicians in their line of work may also find it necessary to label cables especially in industrial installation, cabinets and automated systems for easy troubleshooting and safety.

- **Tools used for cable termination**

- Needle nose crimping pliers-They are applicable as small lug crimpers



Needle nose pliers

- Crimping tool- It is used for fixing a connector to the end of a cable

RJ-11 (6-Pin) and RJ-45 (8-Pin) Crimping Tool



➤ Snips- They are used to cut small cables and conductors, and to trim insulation.



Figure 12

➤ Wire stripper hole for 22- to 24-gauge wire- They are used to strip insulation from conductors. The adjusting screw should be used to prevent the cutting tips doing damage to the conductor. They may also be used to remove the sheath from single core PVC / PVC cable, 1.5mm<sup>2</sup> and 2.5mm<sup>2</sup>, while leaving the insulation intact



Figure 13

➤ Automatic wire stripper- The automatic wire stripper is designed to remove insulation from a range of conductor sizes.



Figure 14

➤ Hack saw- It is used to cut the larger size cables, cut mini trunking and cut out openings in surface boxes for cable entry.



➤ Electrician's knife- Electrician's penknife is mainly used to remove the sheath from the various types of cables and flexible cords.

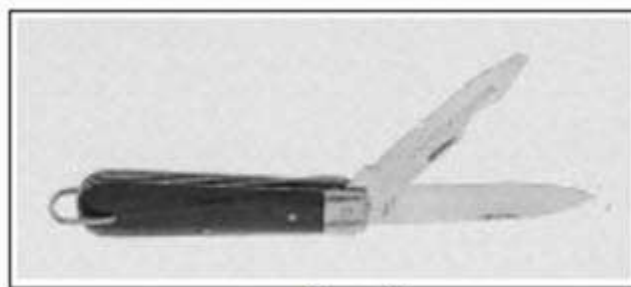


Figure 17

➤ Phase tester -It is a very useful tool when checking if a circuit is “live” or not. This ensures safety of the electrician



Figure 22

### 1.2.6.1 Learning activities

#### Practical activities

##### Field/Visit to an electrical Installation Sites

| Visit Objective/Aim  | Indicators   | Special Instruction   |
|--|--|---|
| To establish how to perform termination on electrical installation | Types of terminations<br>Cable labelling<br>Cable lugging<br>Tools used in termination | <ul style="list-style-type: none"><li>• Observe keenly</li><li>• Take notes</li><li>• Ask questions</li></ul> |

##### Industrial attachment

| Visit Objective/Aim                              | Indicators  | Special Instruction   |
|--|---|---|
| To experience how to terminate electrical cables | <ul style="list-style-type: none"><li>• Demonstrate various methods of cable termination</li><li>• Demonstrate methods of cable jointing</li><li>• Use of various cable termination tools</li></ul> | <ul style="list-style-type: none"><li>• Participate actively</li><li>• Take notes</li><li>• Ask questions</li></ul> |

#### A case study

**Carefully read the case study in the excerpt below and answer that follow**

You are employed by ABC Company limited. The company which deals with electrical installation and consultancy. The company is required to install electrical power in a wheat grinding plant. The plant is powered by 3 phase 415V power to run grinding the machine. The company has

assigned you responsibility to supervise installation process. Installation is complete and now you are required to terminate cables.

6. Explain how you would get 240V power from the 415V for lighting and socket outlets
7. Discuss various termination methods you will apply in the system
8. Give some considerations in selecting cable joints
9. Explain importance of termination in electrical installation
10. Names various tools and how they are applied in cable termination.

#### 1.2.6.2 Tools, Equipment, Supplies and Materials

- Functional workshop
- Tools equipment used in electrical installation e.g.
  - ✓ Pliers
  - ✓ Cable strippers
  - ✓ Crimping tools
  - ✓ Materials e.g.
  - ✓ Cables
  - ✓ Trunking
  - ✓ Conduits
  - ✓ Enclosures

Supplies and consumables e.g.

- ✓ Cable ties
- ✓ Silicon glue
- ✓ Connectors
- ✓ Switches
- ✓ circuit breakers

Computer  
Stationery

Classroom and classroom resources

#### 1.2.6.3 Self-Assessment

8. What are the factors you will consider before selecting the method of termination suitable for various parts of the installation?
9. Give various types of the terminations you will apply for the installation
10. Explain importance of termination
11. What are the factors you will consider when selecting types of cable joints to apply during installation?
12. Give various types of cable joints
13. Explain importance of cable labeling in electrical installation
14. Explain some tools used for performing various types of terminations

#### 1.2.6.4 Reference

Technical Description, electrical installations by World Skills

Measurements on electrical installations Metrel measuring and regulating manufacturer

Electrical wiring components

Measurement and instrumentation principles third edition by Alan S Moris

## **CHAPTER 5: ELECTRICAL INSTALLATION WORK PLANNING**

**Unit of learning code: ENG/CU/EI/CR/01/5/A**

**Related Unit of Competency in Occupational Standard:** Plan electrical installation work

### **5.1 Introduction to the unit of learning**

This unit specifies the competencies required for planning an electrical installation, ranging from surveying the site, determining system size, preparation of materials, tools, and drawings, arranging for logistics, obtaining installation drawings, preparation of work plans, establishing installation team, obtaining necessary work permit and licenses and finally preparation of work site.

### **5.2 Summary of Learning Outcomes**

1. Conduct site survey
2. Perform system sizing
3. Prepare list of tools, equipment and materials
4. Arrange for logistics
5. Obtain installation drawings
6. Prepare installation work plan
7. Establish installation team
8. Obtain necessary permit and licenses
9. Prepare work site

#### **5.2.1 learning Outcome 1: Conduct site survey**

##### **5.2.1.1 Introduction to the learning outcome**

Site survey involves a physical visit and walk through on the proposed site of the electrical installation works by the electrical design and installation team. It is performed so as to mark out the position of the proposed project and to ensure the building is constructed to its correct design, position and height as approved by the relevant certifier e.g. the county planning department.

It is important too for the team to perform the exercise in order to gather information necessary to enable produce detailed working drawings, comprehensive estimates to complete the project, determine a precise location, access as well as location of obstacles if any that may hinder the best orientation of the installation project.

It in the site survey that unforeseen challenges may be realized and tackled which would otherwise lead to the delay on the completion of the electrical installation work e.g distance from the distribution power transformer, presence of underground water pipes or



drainage system which may affect the routing of underground service cables, tall trees or building in the vicinity of the project etc.

### **5.2.1.2 Performance Standard**

- 5.2.1.2.1 The site is surveyed for suitability for the type of installation to be done as per the contract
- 5.2.1.2.2 Conditions of the site are evaluated according to the established procedures
- 5.2.1.2.3 The best location and route for the installation is identified as per the design
- 5.2.1.2.4 Actual measurements are taken
- 5.2.1.2.5 Survey report is generated and shared with relevant parties according to the established procedures

### **5.2.1.3 Information Sheet**

Electrical installations may be categorized as domestic, commercial or industrial installations each of which calls for slightly different installation conditions. There is therefore the need to put into consideration the type of an installation.

While it is true that each type of installation will require to be performed in a building that is certified by the county authority, it is also true that the site must be safe to work in and besides the right voltage levels must be available at the vicinity of that particular building site e.g. single phase i.e., 240V mostly for domestic consumers and three phase 415V/240V for commercial and industrial consumers however it will be necessary to have the following documents during a site survey irrespective of the type of installation involved.

- **Site plans or layout drawings**

These are scale drawings based upon the architect's site plan of the building and they show the position of the electrical equipment, apparatus and routing of the electrical cables which are to be installed. The electrical equipment and apparatus are identified by graphical and schematic standard symbols eg the BS 3939, graphical symbols for electrical Power, Telecommunications and Electronic Diagrams.

The site plan or layout drawing will be drawn to a scale smaller than the actual size of the building, so to find the actual measurement, one must measure the distance on the drawing and multiply by the scale provided.

- **Power Distribution cable route /drawings**

On commercial and industrial installations there may be more than one position for the electrical supplies. Distribution cables may radiate from the site of the electrical mains

intake position to other sub-mains positions. The site of the sub-mains and the route taken by the distribution cables may be shown on a blank copy of the architect's site plan or on the electrician's 'as-fitted drawings.

- **Location drawings**

Location drawings identify the place where items are located on the ground at the site. It might be the position of the manhole covers giving access to the drains, the position of all water stop taps or the position of the emergency lighting fittings all of which may in one way or another affect the routing of the electric power cables

- **Wiring diagrams**

A wiring diagram or connection diagram shows the detailed electrical connections between equipment or circuit works. The purpose of a wiring diagram is guiding the electricians when carrying out electrical works to minimize the chances of making errors which may cause electrical faults leading to electric shock and fires.

[www.EngineeringBooksLibrary.com](http://www.EngineeringBooksLibrary.com)

### **Domestic installation**

This is a type of installation suited for buildings intended for home living. Installation works in a domestic premise may be new or may be an extension to an already existing work. This will be discovered during a site survey and so the contractor will be able to revise the working drawings accordingly and also re-adjust the estimates where necessary. Upon visiting the project site, rerouting of installation cables and/or complete replacement of part or whole of the installation can be considered.

During a site visit the contractor is able to

- identify the best location for the power intake point based on the location of the power distribution line
- advise the client on the suitable wiring system for the prevailing environmental condition
- advise the client of any extra precautions that he may need to observe such as lightning protection provisions

### **Commercial installations**

These include those that are found in schools, hospitals, hotels, offices etc and they mostly require more electric power than residential or domestic homes. It is during the site survey when the contractor will establish the type of equipment and machinery to be supplied, the number of floors in case of a storey building, approximate tenancy and therefore the type of wiring suitable for the premises.

In this type of an installation where there are a wide range of people usually for long periods of time in a day safety has to be paramount because any electrical accident happening is likely to put hundreds of people at risk.

Details revealed in the site survey report will also most probably provide adequate information on the need for the inclusion of extra equipment may be such as air conditioners for ventilation purposes and lifts and/or escalators in case of mall.

### **Industrial installations**

#### **Utilities availability**

Electrical sites may be selected on the basis of vicinity towards access to main road, electricity, health services a site survey will reveal whether these utilities are there and if they are not the client or owner of a building will have the responsibility of ensuring that

he obtains all the necessary approvals from the relevant county authorities for temporary or permanent connections to existing utilities ie clean water, electricity, telecommunication network providers. The building owner should pay for the required construction permits and inspection pertaining to the work being carried out and a site visit is a great opportunity for the contractor to confirm that these payments have been made and that the routing of the utilities will not interfere with the installation or project work

Provision of fencing, temporary lighting and reinforcement by security personnel is also an assurance of safety of construction and installation equipment that belongs to the contractor that the contractor needs to confirm during the site survey,

Besides the project owner shall be required to provide sanitation sewer for the workers on site

### **Taking measurements on site**

. The site plan or layout drawing will be drawn to a scale smaller than the actual size of the building, so to find the actual measurement, one must measure the distance on the drawing and multiply by the scale. To accurately locate the electrical fittings the contractor needs to measure the actual floor area, average temperature and humidity of the site if found to be higher or lower than the design value of the equipment the fittings will require to be adjusted to meet the required installation conditions. During a site visit is a great opportunity to perform crucial measurements such as

- distance between the building and the distribution transformer
- the height of the building to be able to identify the ideal location for the electric meter in case of mansionetes or to be able to determine the height of the rising mains in case of storey buildings
- the length and width of the building to be able to determine floor area of the building and the length of conduit runs or trunking
- size of rooms to be able to design for ring circuits
- distance between switches and lighting points
- actual voltage on site
- soil resistance at the site to determine on the type of earth electrodes to use

### **Procedure of conducting an electrical site survey**

- walk through the proposed site to gather basic facts by observing and questioning the client and other persons such as the site manager, quantity surveyor regarding power quality concerns. It's necessary to review the information so gathered to establish the course of action that best serves the site needs
- organize and perform site analysis. It's important that an organization or individual contractor invests in diagnostic equipment, attend safety training workshops and apply proper test methods to be able to achieve objectivity of test results

- document the exercise by writing a survey report.in this report there must be provision for each type of measurement taken. This will allow for the future use of the document as a log sheet to help track any electrical expansion of available apparatus and/or electrical equipment such as transformers, distribution panels etc. over an extended period of time
  - evaluate the results and provide cost effective solutions.it is important to brief the client and other relevant persons on the results upon completion of the site survey. This will give one a chance to communicate about potential safety hazards, suspected problem areas and possible recommendations
- Organizing documentation is critical part of the survey and pre planning and is mostly required for building permits, and legal utility interconnection.
- The key components of a system documentation package may include. System design and equipment specification, site layout drawings, operator manuals for equipment, installation, operation and maintenance procedures

#### 5.2.1.4 Learning Activities

| Learning activity   | Special instructions   |
|---|--|
| Explain the importance of carrying out a site survey  |  |
| Explain the requirements of the relevant regulatory bodies that are necessary to consider before embarking on any work on a construction site | Illustrate the various examples of various permits e.g. county government permits.NCA licenses, KEBS authoriyation |
| Explain how to identify the locations and routing of the cables   | Conduct a field trip on a construction site and illustrate while on site the critical area to consider             |
| Explain the necessary measurements to be taken and the equipment to be used   | Illustrate while on site how to operate/use the measuring tools  |
| Discuss the need to write a survey report and what it entails   | Trainees to write a sample site survey report based on the previous site visit or field trip                       |

#### 5.2.1.5 Self-Assessment

#### 5.2.1.6 Tools, Equipment, Supplies and Materials

- Spirit level,
- Tri square,
- Measuring tape.
- Thermometer clamp on ammeters

- Harmonics analyzers
- Power line monitors oscilloscopes with line view
- Earth/ground resistance tester impedance tester
- Safety equipment appropriate PPE safety glasses
- Safety Shoes
- Gloves
- RFI, EMI
- Stationary
- Assorted cables
- Copy of OSHA rules
- Copy of county government by laws

#### **5.2.1.6.1 References**

## 5.2.2 Learning Outcome 2: Perform system sizing

### 5.2.2.1 Introduction to the learning outcome

Electricity is much more than a national asset and besides being of deep social importance it is the main influence for good life. It is essential to our daily life and work. There are rules and regulations which govern electrical installation practice. These rules, codes of practice and standards are essential to ensure that all installations provide adequate safety from two types of electric hazards i.e. electric shock and electric fire. A general requirement of every electrician is that he should be familiar with the regulations that govern the electro technical industry,

### 5.2.2.2 Performance Standard

- 5.2.2.2.1 Load estimation is conducted according to the set standard
- 5.2.2.2.2 Types and sizes of protective devices are determined according to IEE regulations
- 5.2.2.2.3 Cable sizes are calculated for the estimated load according to IEE regulations
- 5.2.2.2.4 System sizes are recorded and shared as per established procedures

### 5.2.2.3 Information Sheet

The Rules and Regulations that guide the electrical installation practice are categorized into two, i.e. statutory and non-statutory regulations.

statutory laws are those that have been passed by parliament and have therefore become laws of the land. Non-compliance to such laws can lead to prosecution by courts and possible imprisonment

statutory laws are issued to ensure a proper and safe supply of electrical energy up to the consumers terminal

IEE REGS/

These are non-statutory regulations designed to supplement statutory laws in order to ensure maximum degree of safety particularly from electric fire and electric shock.

These regulations relate primarily to the design, selection, erection, inspection and testing of electrical installations, whether in permanent or temporary, inside and outside buildings generally and to Domestic houses, Commercial buildings, Industrial premises, agricultural and horticultural premises as well as in construction sites. They apply only to electrical installations operating at a voltage of up to 1000V. The current edition of the IEE regs is the 17<sup>th</sup> edition which became law in 2008, following this several guidance notes have been published to help the electricians understand the regulations

[https://www.google.co.ke/search?tbm=bks&tbm=bks&q=inauthor:%22The+Institute+of+Engineering%22&sa=X&ved=2ahUKEwjA4Nnvu4\\_tAhWxtXEKHe1rCJYQ9AgwAHoECAAOBw](https://www.google.co.ke/search?tbm=bks&tbm=bks&q=inauthor:%22The+Institute+of+Engineering%22&sa=X&ved=2ahUKEwjA4Nnvu4_tAhWxtXEKHe1rCJYQ9AgwAHoECAAOBw)

KEBS

The Kenya Bureau of Statistics KEBS has a role of promoting standardization of goods in industry and commerce. It provides the facilities for examination and testing of commodities and materials manufactured in Kenya as well as test goods brought in for consumption in Kenya for purposes of certification. Electrical cables locally manufactured must have the diamond mark of quality which qualifies them to be used with an assurance of maximum safety

## BS CODES OF PRACTICE

British standards and the codes of practice do not have the force of law but they do represent best practice and they may be referred to in a court of law in the event of an accident or installation failure. It is recommended that everyone involved in an installation project should follow the recommendations as far as is practically possible. These regulations are concerned with all the aspects of installations. They touch on particular aspects relating to the construction of electrical equipment.

The electric power supply company is responsible of distributing and supplying electric power according to electricity supply regulations. The electric sub-contractors must carry out installation works as per the supply authority i.e. KPLC by-laws.

The supply regulations are well embedded in the energy act e.g. the energy act of 2019 [https://kplc.co.ke/img/full/o8wccHsFPaZ3\\_ENERGY%20ACT%202019.pdf](https://kplc.co.ke/img/full/o8wccHsFPaZ3_ENERGY%20ACT%202019.pdf)

The national construction authority NCA is a government organization which regulates, streamlines and builds capacity in the construction industry. It is advisable to consult with the NCA to be sure that the building in which the installation is to be performed is constructed in accordance with the county bye laws and is up to the NCA specifications.

System sizing is determined by the individual sizes of various components such as cables, switchgear.

A cable forms the necessary connections between the generating stations, apparatus and consumers which use electricity. They comprise a very wide range of types. The necessary requirements of a cable are that they should conduct electricity efficiently, cheaply and safely. The cable should not be too small such as to have large internal voltage drop.

Cables may be classified according to the number of conductors or according to its application.

E.g. two core cables

3 core cables

power cables

communication cables

welding cables

equipment cables

The IEE regulation requires that

- Every cable shall be selected and installed as to be suitable for operation and at such suitable temperature,
- All cables in an installation shall be properly supported so that there shall be no appreciable strain on cable termination
- All cables shall be adequately protected against mechanical protection
- Where cables pass through ceiling walls or partitions, the surrounding holes must be made good with cement or other fire resisting materials to prevent spread of fire

The electrical installation designer should ensure that the choice of the cables for particular installations should be such that the maximum permissible voltage drop as recommended in the IEE

regulations is not exceeded. The current rating tables are provided which indicate the volt drop when a current of 1 Ampere flows through a 1 meter length of a particular cable

If for a particular size of cable, the voltage drop exceeds the permitted voltage, the next size of the cable is chosen from the tables until the final voltage drop is less than the permitted.

Factors considered while selecting a suitable cable size are,

- Ambient temperature
- Installation conditions ie whether the cable is bunched with others or not
- Type of circuit protection either by use of semi enclosed fuses or MCB
- Type of thermal insulation material used

The IEE regulations require that the choice of a cable to feed a circuit must have regard of all the above factors and not just the current. It is required that the method used to determine the correct size should be based on the rating of the current devices.

#### **Procedure of determining the right size of a cable**

- Determine the load current of the circuit  $I_L$
- Determine the correction factor for ambient temperature which the cable is to be installed  $C_t$
- Determine the correction factor for grouping if the cable is bunched/run with others ie  $C_g$
- Determine the correction factor if the cable is in contact with or surrounded by a thermal insulation material  $C_i=0.75$  if one side of the cable is in contact with the material or  $C_i=0.5$  if the cable is completely surrounded by the material
- Select rating of overcurrent device protection eg for MCB for close excess current protection  $C_P=1.0$  and for coarse excess current protection afforded by semi enclosed fuses rating  $C_P = 0.725$
- Determine the size of circuit conductor by calculating the desired current
- Check to ensure that the the voltage drop does not exceed maximum permitted

Current rating of conductor = load current

$$C_t \times C_g \times C_i \times C_P$$

From the appropriate tables in the IEE regs select a cable size and determine the voltage drop from

$$\text{Total voltage drop} = \frac{\text{milliVolts} \times \text{length of run} \times \text{load current}}{1000}$$

Confirm whether the voltage drop so calculated is within the allowed. If yes, select the next bigger size and repeat again and again until the calculated voltage drop is below the maximum permitted.

#### **Cable insulation**

Cable insulation has the function of confining the electric current within the conductor. Various types of cable insulations are available such as

- Rubber which is used in vulcanized form and it consists of pure rubber mixed with 5 to 6 % of Sulphur. Rubber is flexible and impervious to water
- Pvc - polyvinyl chloride  
Synthetic substitute for rubber with properties similar to those of copper. Suitable for use in temperatures between 0 and 65



Resists direct sunlight and chemical actions

- Paper  
Used in the impregnated form and for voltages between 600V – 1000V to about 33Kv  
Used mainly in underground cables
- Mineral insulation  
Has high resistance to fire and can withstand severe mechanical damage
- Glass insulation is heat resistant used for high temperatures

### Protective devices

Electric circuits need to be protected against excess current which is likely to flow in conductors and may have a value which may be in excess of the rated resulting to a sudden overload, sustained loads and short circuits between conductors o protect the circuits against this the following protective devices can be used

- Fuse

### Symbol of a fuse

The standard IEEE/ANSI symbols for the fuse is as follows:



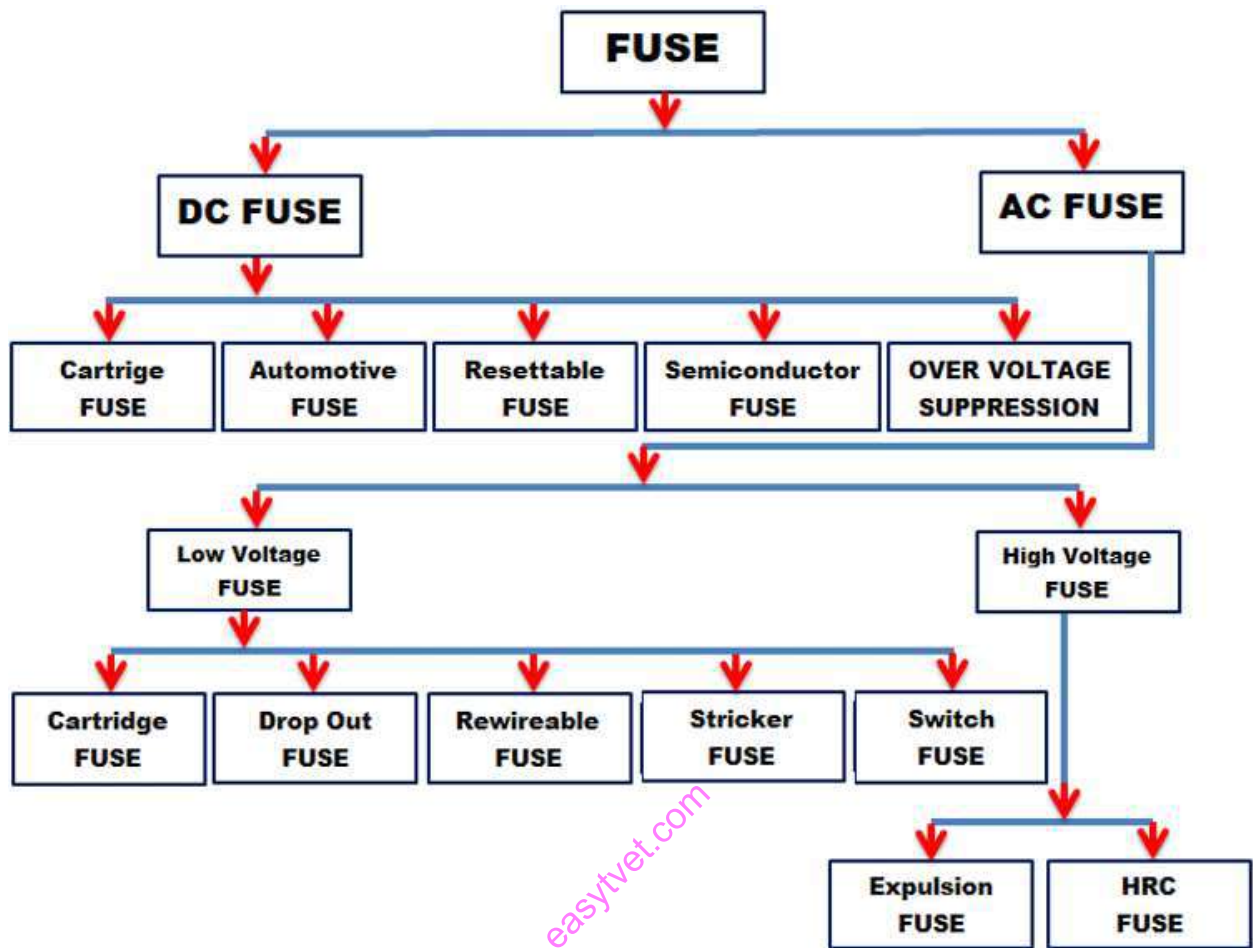
However, the IEC fuse is slightly different:



This is the most common type of fuse. The fuse element is encased in a glass envelope that is terminated by metal caps. The fuse is placed in an appropriate holder. Since the glass envelope is clear, it is easy to visually

determine if the fuse is blown

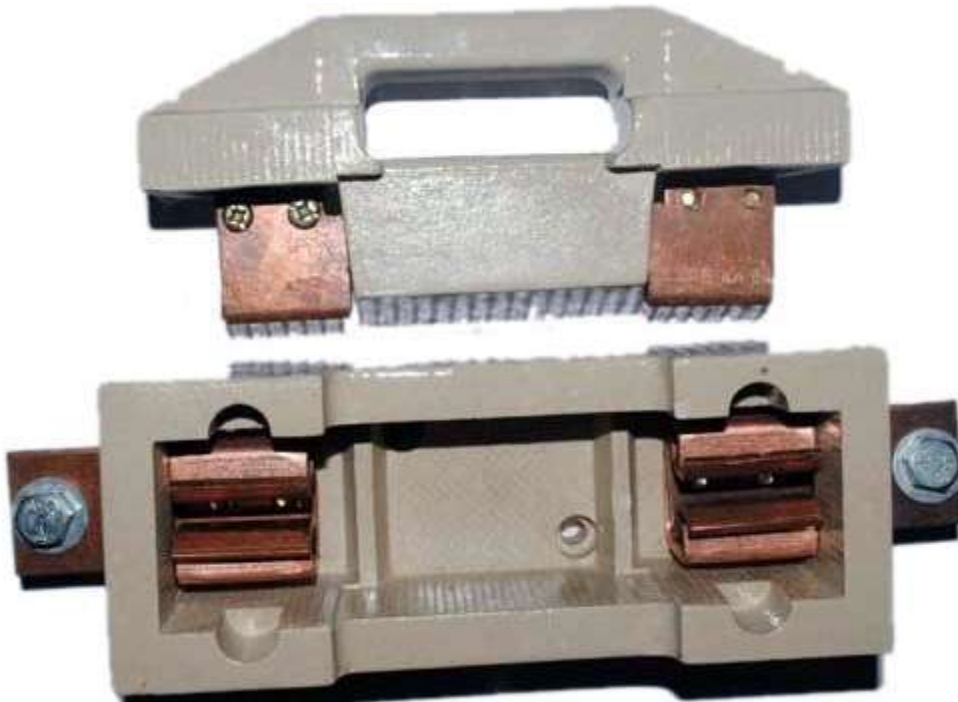
### classification of fuses





### **Cartridge fuse**

This is the most common type of fuse. The fuse element is encased in a glass envelope that is terminated by metal caps. The fuse is placed in an appropriate holder. Since the glass envelope is clear, it is easy to visually determine if the fuse is blown.



**Rewireable fuses:** They are a simple reusable fuse used in homes and offices. They consist of a carrier and a socket. When the fuse is blown, the carrier is taken out, rewired and put back in the socket to resume normal operation. They are somewhat less reliable than HRC fuses.



**Switch fuse:** A handle that is manually operated can connect or disconnect high current fuses.

#### 5.2.2.4 Learning Activities

| <b>Learning activity</b>   | <b>Special instructions</b>  |
|--|--|
| Discuss the procedure of determining the load current for an installation given the system power input, voltage and power factor | Trainees to perform calculations of load current based on the parameters given   |
| Discuss types of protective equipment and their rating fuses and circuit breakers  | Trainees will draw labelled diagrams of the protective devices   |
| Discuss factors that affect the rating and size of cables, illustrate how to interpret data from IEE reg tables                  | Trainees will practice how to determine or calculate the correct cable size for a given load based on available tables |

### **5.2.2.5 Self-Assessment**

- 1) Which four rating factors are necessary to consider while calculating for a cable? size
- 2) Complete the abbreviations MPVD as used in cable size calculation
- 3) A 230V single phase 20Kw load operates at a power factor of 0.7 lagging and is fed from a distribution board located 30m away by a 2 core PVC insulated and armored cable with aluminum conductors. The cable is clipped direct to a cable tray. The ambient temperature is 45<sup>0</sup>C and close excess protection is provided. MPVD is 2.5% using table 25m in the IEE regulations 14<sup>th</sup> edition calculate the correct cable size for the given load.

### **5.2.2.6 Tools, Equipment, Supplies and Materials**

Stationery

IEE regulations 14 th edition

### **5.2.2.7 References**

### **5.2.3 Learning Outcome 3: Prepare list of tools, equipment and materials**

#### **5.2.3.1 Introduction to the learning outcome**

Modern electrical installations using new materials that are lasting for a longer duration than 50 years. Therefore, they must be properly installed. Good design, good workmanship by competent persons and the use of proper materials are essential if the installation is to comply with the relevant regulations, (IEE Regulation 134.1.1) so as to reliably and safely meet the requirements of the customer for over half a century. Electricians are not only in charge of making electrical installation but also have responsibilities of caring, storing and control of their tools, equipment and materials. Proper use, handling and storage of the tools, equipment and materials can protect them against loss, breakage and deterioration. In addition, the electrician has a responsibility of new purchase of tools, equipment and materials. Proper storage and timely maintenance can help the electrician's time in search of the available items in store, save a lot of money spent for maintenance and new purchase for replacement of lost or damaged electrical tools, equipment and materials

#### **5.2.3.2 Performance Standard**

- 5.2.3.2.1 The necessary tools and equipment needed for the work are determined and list prepared as per established procedure
- 5.2.3.2.2 Tools and equipment are checked for correct specifications and functionality and list prepared as per established procedure
- 5.2.3.2.3 Materials needed for the work are determined and list prepared as per established procedure

#### **5.2.3.3 Information Sheet**

The basic tools required by an electrician are those used in the stripping and connecting of conductors. These are pliers, side cutters, a knife and an assortment of screwdrivers. The tools required in addition to these basic implements will depend upon the type of installation work being undertaken. When wiring new houses or rewiring old ones, the additional tools required are those usually associated with a bricklayer and joiner. Tools should be cared for and maintained in good condition if they are to be used efficiently and remain serviceable. Screwdrivers should have a fl at squared off end and wood chisels should be very sharp. Access to a grindstone will help an electrician to maintain his tools in first-class condition. Additionally, wood chisels will require sharpening on an oilstone to give them a very sharp edge.

A list of necessary tools with correct specifications should be prepared for a given task as per the established procedures.

It is required that the tools and materials are stored in a convenient place so as to;

- Minimize the labour required to place the items in the store
- maintain items in good order
- issue items as quickly and orderly
- make easy inventory of the items
- inspect the quality and quantity of items available in store.

Items must be stored safely to prevent loss, breakage, spoilage and deterioration by heat, cold, sunlight, dampness, insects, rats and mice and spontaneous combustion. They must be stored as visible as possible to reduce duplication, prevent wastage, permit quick check and inspection as well as help in maintaining adequate stock (supplies).

**For Storage of tools, equipment and materials**, the electrician, should apply the practice of safe storage of working tools, equipment and materials in a separate kit which may be provided for use for each individual site worker. The type of the kit will vary from one designer to another.



**Tools may be categorized in terms of use such as;**

**Special tools and equipment:** Tools in limited numbers, which may be used by all workers, and are best stored in a centrally located tool crib. This arrangement provides for the proper care and control of these tools. This is particular to high precision instruments.

**Machine accessories:** can be stored in a Central tool room assigned to one particular site worker. Separate facilities convenient to a particular equipment e.g., closet, racks, drawer, boxes may also be used.

Tool cribs and panels may also be used for new or expansion of existing tools storage. while considering the location for the tools panels an electrician should consider the type of tool and each tool should be held in place by hooks against inclined tool board, in cupboard and on wall. The most frequently used tools should be located close to the distribution point.

The place of tools should be marked by:

- Assigning a symbol, letter or number for a particular tool
- Writing the name of a tool painted over or under the position.
- Having a painted outline of the tool in color contrasted with the background, behind the place where it belongs.

Upon Delivery the materials, tools and equipment must be checked to confirm whether the items received

- i. Meet specifications required
- ii. Are of the correct quantities
- iii. Have any Defects
- iv. have Breakages

The accounting procedures must be followed in receiving & checking items delivered ie

- v. Signing a receipt or delivery order
- vi. Posting the quantities received in the inventory sheet

The storekeeper must;

- vii. Open all cases, boxes and inspect all items
- viii. Sort goods accurately
- ix. Place items in proper location

### **Safety precautions (care) in handling electrical tools**

- Handle sharp edge tools with special care
- Never carry unshielded tools in pockets
- Never throw over tools to each other
- Avoid placing your fingers or hands in the path of motion of the cutting tools.
- Never leave tools on top of a step ladder or on any other place above your head.
- Never use tools for the purpose other than the designed.

### **Types and applications of Electrical hand tools**

#### **A. Wire strippers**

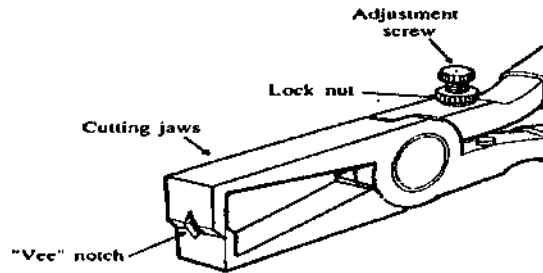
The removal of insulation from wires and cables is one of the tasks which, is a major part of installation work. There are many techniques used within the industry, using tools ranging from the simple hand-operated strippers to automatic, motorized types. Hand-operated strippers fall into two main categories: those which are adjustable and those which are not. Within the non-adjustable types are some which have flexible jaws and will strip a range of wire sizes, while others have a series of cutting holes for each wire size.

#### **B. Adjustable wire strippers**

These have jaws with V-shaped notches to cut the insulation. The adjuster screw acts as a stop to allow for a range of wire diameters. To use the stripper: **i.** Adjust the screw to open or close the jaws so that the V cutting slots cut the insulation cleanly without tearing the insulation or damaging the conductor. **ii.** Use a test piece of wire to adjust the jaws to the correct position to cut the insulation but not the conductor. **iii.** Place the wire in the lower groove; squeeze the handles to cut the insulation, **iv.** Rotate the strippers half a turn and pull off the insulation stub. Check for damage to the conductor. **v.** When the adjustment is found to be correct, tighten the lock nut and test again. If OK, then the strippers are ready for use. **Vi.**



Always check the wire for damage each time you remove insulation with this type of wire stripper.

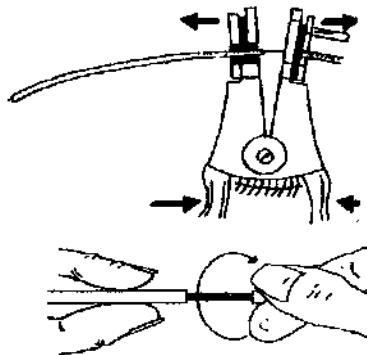


**Fig Adjustable wire stripper**

### **C. Hand-held automatic wire stripper**

These are fully automatic in operation but it is essential that you use the correct size of cutting hole. There are two sets of jaws: one clamps the wire and holds it while the other cuts the insulation. Both jaws separate to pull the insulation stub away from the wire. The cutting blades can be changed to suit different sizes of conductor diameters. A 'length of strip' guide post can also be fitted.

**Hand held automatic wire stripper works as:** Place the wire between the jaws from the clamping jaw side into the correct size of cutting notch. If a 'length of strip' post is fitted, the end of the wire should be positioned so that the end is in line with the end of the post. Squeezing the handles will first cause the wire clamp jaw to close. Next the cutting jaws close; further squeezing will cause both sets of jaws to separate, pulling off the insulation stub. Continue to squeeze the handles and the jaws both open then snap together, releasing the wire. If you are going to twist the strands of flexible wire after stripping it is useful to arrange it so that the insulation stub is not completely removed from the conductor.



**Fig Hand held automatic wire stripper**

### **D. Cutting tools**

The basic tools required by an electrician are those used in the cutting of conductors and other materials like the conduit, trunkings etc, that will be used in a given installation. These are pliers, side cutters, hacksaws, a knife among others. The tools required in addition to these basic implements will depend upon the type of installation work being undertaken. When wiring new houses or rewiring old ones, the additional tools required will be dependent on the

type of the work to be done. All tools must be used safely and sensibly. Cutting tools should be sharpened and screwdrivers ground to a sharp square end on a grindstone.

### E. Pliers

**Pliers** are used for cutting and gripping wires.

- a. **Side cutting plier:** used for cutting and gripping wires; it also pulls on snake wire through pipes.



- b. **Diagonal cutting plier:** used to cut off wires close to connecting points such as switch and outlet terminals which are located close to the fitting so that the side cutting plier may not be able to get close enough.



- c. **Flat nose pliers:** used for bending, twisting and forming conductors and bus bashers.
- d. **Long (sharp) nose pliers:** used for pulling wires and other materials through narrow holes or narrow areas.



- e. **Round nose pliers:** used for looping conductors in order to connect them to the terminals.
- f. **Slip joint pliers**  
The slip joint permits the jaws to be extended to greater width than is possible with a cutting plier of the same size. **The slip joint pliers, are then** used to gripping wires, cutting wires and holding conduits while making up locknuts and bushings.

### F. Electrician knife

**Electrician knives** are used for removing insulation in electrical wiring. The blade should be made of high grade, tempered steel. The knife should be strong, serviceable and, if possible, of the closing type.



### G. Hack saw

It is used for cutting metallic parts such as cable armor and conduit tubes. Hacksaw should be adjusted in the frame to prevent buckling and breaking, but not be tighten enough to break off the pins that support the blade. While installing the blade the teeth should point forward. When using hack saw, pressure is applied on the forward stroke not on the back stroke. **Caution:** If the blade is twisted or too much pressure is applied, the blade may break and cause injury to the hands or arms of the user.



Fig. Hacksaw

### H. Screw drivers (sets)

**Screw drivers** are used to drive screws into and out of wood or some other materials.

- a. **Standard/ Flat/ blade screw driver** is used for general purpose.



- b. **Square blade screw driver:** is a strong screw driver used for turning **stubborn or heavy screws**. It has the possibility of increasing hand pressure and turning moment by means of a plier or a wrench.
- c. **Thin blade screw driver:** is used for installing a screw past an obstacle or a nearby object (Inside a small holes).

#### d. Hammer

**Hammers** are used to drive chisels, straighten metals & pick out nails.

a. **Claw hammers** are of two types: Straight and curved claw hammers.



- b. **Straight claw hammers** are inserted beneath, behind or between boards or timbers to be detached.
- c. **Curved claw hammers** mainly used for picking out nails.
- d. **Ball peen hammer:** provides greater striking power needed in such cases as driving a chisel or a stat drill into brick or concrete walls.
- e. **Peen hammer** used for heavy duties since it provide for greater power.

#### Chisels

**Chisels** are used to cut metals as well as dig holes or grooves in brick or concrete walls. The following chisels are common in doing electrical works.

- a. **Cold chisels** used to cut metals, bricks, concrete or any hard materials forged from alloy steel, hardened and tempered.
- b. **Cape chisels** have sufficient sized striking heads and a narrower cutting edge which enables to penetrate hard surfaces, particularly metal, somewhat better than cold chisels.
- c. **Wood chisel** used for performing soft operation such as grooves on wooden construction.



Cold chisel

Cape chisel



wood chisel



chisel



star/ start

- d. **Star chisel or start drill** used to make a circular hole through brickwork, concrete construction and other stone work

### Steel tape/ draw wire

Direct linear measurements of ordinary or more accurate precision require a steel tape. The most commonly used length is 100 feet, but tapes are also available in 50-, 200-, 300-, and 500-foot lengths. The 500-tape is usually a flat-wire type. Most steel tapes are graduated in feet and decimals of feet, but some are graduated in feet and inches, meters, and chains or other linear units. It is used for passing wire or cable through conduits, pipes or through spaces in the walls and under the floor of a house.

Some tapes, called engineers or direct reading tapes, are graduated in subdivisions of each foot. The tape most commonly used, however, is the so-called chain tape, on which only the first foot at the zero end of the tape is graduated in subdivisions; the main body of the tape is graduated only at every one foot mark. A steel tape is sometimes equipped with a reel on which the tape can be wound, although a tape can be, and often is, detached from the reel for convenience. There are various types of surveying tapes; metallic tape, steel tape on an open reel, steel tape on a closed reel, and special types of low-expansion steel tape, generally called an Invar tape or Lovar tape, used in high-order work.

**Mallet** is a wooden made hammer used to bend (give shape) of wire while working on the machines.



## Equipment

### Drill

**Drills** are of two types: hand drill and electric (hand) drill.

- a. **Hand drill** is used to hold round shank drills during drilling operation to make holes on concrete, wooden and/ or metallic materials.

- b. **Electric hand drill** is portable enough to be carried to places other than the workshop and connected to the power source by means of a long cord to drill holes on concrete, wooden and metallic bodies.



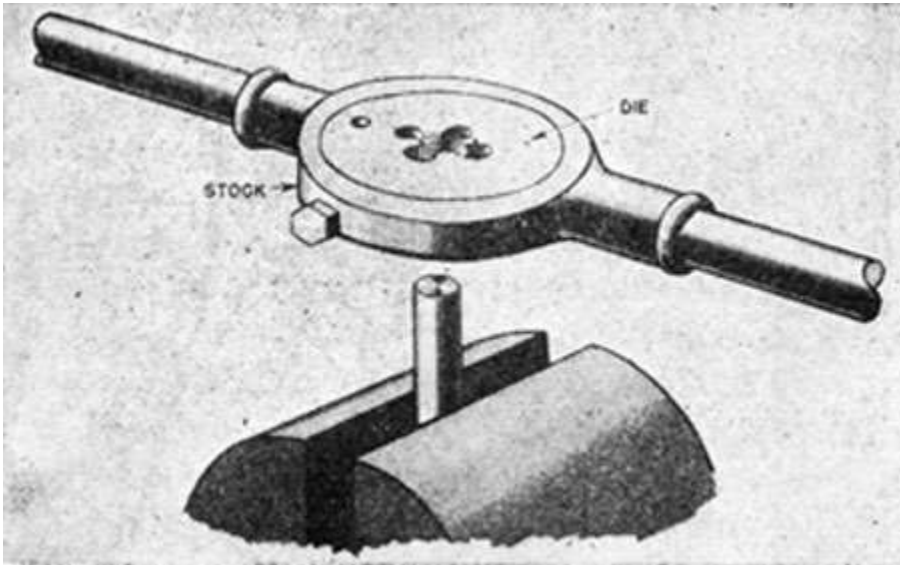
Fig Portable hand drills

### **Stocks and die**

**Dice** are blocks of metal screw spiral cut inside them which are used for making external threads on conduits or pipes.



The most commonly types of vices likely to be used is the “bench” vise which can come with a fixed or swivel base. They are also available with or without pipe holding jaws. Bench vises are usually bolt mounted to a bench but clamp on models are also available for lighter duty. The blacksmith’s vise is useful for work which must be pounded; it is secured to a bench and braced by the long leg attached to a solid base on the floor. Pipe vises are also useful to various trades. The yoke type pipe vise usually has capacity up to about 8 cm. (3 in.). The chain-type vise has a larger diameter capability as well as being useful for irregular shape.



#### **Procedures of Safe uses of vice are:**

- Mount vice securely.
- Keep work close to jaws.
- Keep vice cleaned, oiled.
- Support extra-long work.
- Prop very heavy work in vice with wood blocks to prevent it from falling and causing injury.
- Don't open jaws beyond their capacity; the moveable jaw may fall, causing injury or damage.

#### **Materials**

##### **Cables**

For high voltage distribution services, cables having polymeric insulation, usually cross-linked polyethylene (XLPE), are finding favor over PILC types due mainly to the simplicity with which they may be terminated and jointed. The most usual construction is XLPE/SWA/PVC. For low voltage systems the universal PVC/SWA/PVC is generally satisfactory. Where cables are routed through buildings or in cable tunnels, safety requirements may in some cases dictate the use of low smoke/low fume cable types.

The choice between copper or aluminum conductors and, in the case of aluminium, solid or stranded construction, is influenced by cost and the practicalities of installation. Aluminium cables, where they are known to be such, are much less likely to be the subject of theft while waiting, or during, installation. As in any installation, conductor sizes must be chosen to meet the requirements of both current-carrying capacity and acceptable voltage drop. With regard to current-carrying capacity, decisions should be based on the usual factors and need not be discussed here. The question of cable size in relation to voltage drop is less clear. For low voltage systems the requirements of BS 7671 (IEE 16th edition) are deemed to be satisfied if the voltage drop between the origin of the installation and the fixed current-using equipment does not exceed 4% of the nominal voltage of the supply. This can be interpreted as being applicable to a 'site distribution system' operating at low voltage but there is at present no



equivalent standard for high voltage systems. Where a high voltage system is supplying power to be utilized entirely at low voltage, the voltage drop on the high voltage system may not be as important and can usually be compensated for by tap selection on the transformers at the load center substations. (Overvoltage under light load conditions must not then exceed a value that might be damaging to the connected equipment.) Where loads such as large motors are supplied directly at the high voltage system voltage, cable sizes should be selected to limit the voltage drop to a value acceptable to the manufacturers of the equipment in question.

## **Conduits**

### **Definition of Conduit**

A conduit is a tube, channel or pipe in which insulated conductors are contained. The conduit, in effect, replaces the PVC outer sheath of a cable, providing mechanical protection for the insulated conductors. A conduit installation can be rewired easily or altered at any time, and this flexibility, coupled with mechanical protection, makes conduit installations popular for commercial and industrial applications.

### *Types and applications of conduits*

There are three types of conduit used in electrical installation work. Namely: steel, PVC and flexible.

#### **Steel Conduit**

Steel conduits are made to a specification defined by IEEE standards and are either heavy gauge welded or solid drawn. Heavy gauge is made from a sheet of steel welded along the seam to form a tube and is used for most electrical installation work. Solid drawn conduit is a seamless tube which is much more expensive and only used for special gas-tight, explosion-proof or flameproof installations. Steel conduit is supplied in 3.75 m lengths and typical sizes are 16, 20, 25 and 32 mm. Conduit tubing and fittings are supplied in a black enamel finish for internal use or hot galvanized finish for use on external or damp installations. A wide range of fittings is available and the conduit is fixed using Saddles or pipe hooks.



#### *PVC Conduit*

PVC conduit used on typical electrical installations is heavy gauge standard impact tube manufactured. The conduit size and range of fittings are the same as those available for metal conduit. PVC conduit is most often joined by placing the end of the conduit into the appropriate fitting and fixing with a PVC solvent adhesive.

PVC conduit can be bent by hand using a bending spring of the same diameter as the inside of the conduit. The spring is pushed into the conduit to the point of the intended bend and the conduit then bent over the knee. The spring ensures that the conduit keeps its circular shape. In

cold weather, a little warmth applied to the point of the intended bend often helps to achieve a more successful bend.

The advantages of a PVC conduit system are that it may be installed much more quickly than steel conduit and is non-corrosive, but it does not have the mechanical strength of steel conduit. Since PVC conduit is an insulator it cannot be used as the CPC and a separate earth conductor must be run to every outlet. It is not suitable for installations subjected to temperatures below 25°C or above 60°C. Where luminaires are suspended from PVC conduit boxes, precautions must be taken to ensure that the lamp does not raise the box temperature or that the mass of the luminaire supported by each box does not exceed the maximum recommended by the manufacturer (IEE Regulations. PVC conduit also expands much more than metal conduit and so long runs require an expansion coupling to allow for conduit movement and help to prevent distortion during temperature changes. All conduit installations must be erected first before any wiring is installed. The radius of all bends in conduit must not cause the cables to suffer damage, and therefore the minimum radius of bends as indicated in IEEE regulation. All conduits should terminate in a box or fitting and meet the boxes or fittings at right angles.

When drawing cables into conduit, they must first be run off the cable drum. That is, the drum must be rotated and not allowed to spiral off, which will cause the cable to twist. Cables should be fed into the conduit in a manner which prevents any cable crossing over and becoming twisted inside the conduit. The cable insulation must not be damaged on the metal edges of the draw-in box. Cables can be pulled in on a draw wire if the run is a long one. The draw wire itself may be drawn in on a fish tape, which is a thin spring steel or plastic tape. A limit must be placed on the number of bends between boxes in a conduit run and the number of cables which may be drawn into a conduit to prevent the cables being strained during wiring.

### *Flexible conduit*

Flexible conduit is made of interlinked metal spirals often covered with a PVC sleeving. The tubing must not be relied upon to provide a continuous earth path and, consequently, a separate CPC must be run either inside or outside the flexible tube. Flexible conduit is used for the final connection to motors so that the vibrations of the motor are not transmitted throughout the electrical installation and to allow for modifications to be made to the final motor position and drive belt adjustments.



*Trays/ duct*

Cable tray is a sheet-steel channel with multiple holes. The most common finish is hot-dipped galvanized but PVC-coated tray is also available. It is used extensively on large industrial and commercial installations for supporting Mineral Insulated (MI) and SWA cables which are laid on the cable tray and secured with cable ties through the tray holes. Cable tray should be adequately supported during installation by brackets which are appropriate for the particular installation. The tray should be bolted to the brackets with round-headed bolts and nuts, with the round head inside the tray so that cables drawn along the tray are not damaged. The tray is supplied in standard widths from 50 to 900 mm, and a wide range of bends, tees and reducers is available. The tray can also be bent using a cable tray bending machine to create bends. The installed tray should be securely bolted with round-headed bolts where lengths or accessories are attached, so that there is a continuous earth path which may be bonded to an electrical earth. The whole tray should provide a firm support for the cables and therefore the tray fixings must be capable of supporting the weight of both the tray and cables.

### **Types and application of cable trays**

#### **Metallic cable Tray**

The metallic (often slotted) construction of heavy-duty cable tray makes it appropriate for the support of heavy cables such as SWA mains or large numbers of MICC circuits in an industrial site. Other types and even categories of cables can use the same tray for support when appropriate. Cable ladders are a variation for vertical runs between horizontal trays, and find economic uses in power stations and factories with particularly dense cable populations. The overall technique allows excellent simple mechanical support with accessibility and little of the problem from grouping factors due to bunching of cables. Secondary trays may be installed alongside the main tray to house the final distribution

and/or data cables if segregation is a problem or specific EMC considerations prevail; otherwise the same tray can often house various cables.



Plastic coated cable tray

### **Definition, types and installation of Trunking**

A trunking is an enclosure provided for the protection of cables which is normally square or rectangular in cross-section, having one removable side. Trunking may be thought of as a more accessible conduit system and for industrial and commercial installations it is replacing the larger conduit sizes. A trunking system can have great flexibility when used in conjunction with conduit; the trunking forms the background or framework for the installation, with conduits running from the trunking to the point controlling the current-using apparatus. When an alteration or extension is required it is easy to drill a hole in the side of the trunking and run a conduit to the new point. The new wiring can then be drawn through the new conduit and the existing trunking to the supply point. Trunking is supplied in 3m lengths and various cross-sections measured in millimetres from 50\_50 up to 300\_150. Most trunking is available in either steel or plastic.

### **Types of Trunking**

#### *Metallic Trunking*

Metallic trunking is formed from mild steel sheet, coated with grey or silver enamel paint for internal use or a hot-dipped galvanized coating where damp conditions might be encountered and made to a

specification defined by BS EN 500 85. A wide range of accessories is available, such as 45° bends, 90° bends, tee and four-way junctions, for speedy on-site assembly. Alternatively, bends may be fabricated in lengths of trunking. This may be necessary or more convenient if a bend or set is non-standard, but it does take more time to fabricate bends than merely to bolt on standard accessories. When fabricating bends the trunking should be supported with wooden blocks for sawing and fitting, in order to prevent the sheet-steel vibrating or becoming deformed. Fish plates must be made and riveted or bolted to the trunking to form a solid and secure bend. When manufactured bends are used, the continuity of the earth path must be ensured across the joint by making all fixing screw connections very tight, or fitting a separate copper strap between the trunking and the standard bend. If an earth continuity test on the trunking is found to be unsatisfactory, an insulated CPC must be installed inside the trunking. The size of the protective conductor will be determined by the largest cable contained in the trunking, as described by the IEE Regulations. If the circuit conductors are less than 16 mm<sup>2</sup>, then a 16 mm<sup>2</sup> Circuit Protective Conductor will be required.

#### *Non-metallic Trunking*

Trunking and trunking accessories are also available in high-impact PVC.

The accessories are usually secured to the lengths of trunking with a PVC solvent adhesive. PVC trunking, like PVC conduit, is easy to install and is non-corrosive. A separate CPC will need to be installed and non-metallic trunking may require more frequent fixings because it is less rigid than metallic trunking. All trunking

fixings should use round-headed screws to prevent damage to cables since the thin sheet construction makes it impossible to countersink screw heads.

#### *Mini-Trunking*

Mini-trunking is very small PVC trunking, ideal for surface wiring in domestic and commercial installations such as offices. The trunking has a cross-section of 16 \_ 16 mm, 25 \_ 16 mm, 38 \_ 16mm or 38 \_ 25 mm and is ideal for switch drops or for housing auxiliary circuits such as telephone or audio equipment wiring. The modern square look in switches and sockets is complemented by the mini-trunking which is very easy to install.

#### *Skirting Trunking*

Skirting trunking is a trunking manufactured from PVC or steel and in the shape of a skirting board is frequently used in commercial buildings such as hospitals, laboratories and offices. The trunking is fitted around the walls of a room at either the skirting board level or at the working surface level and contains the wiring for socket outlets and telephone points which are mounted on the cover. Any trunking passes through walls, partitions, ceilings or floors, short lengths of lid should be fitted so that the remainder of the lid may be removed later without difficulty. Any damage to the structure of the buildings must be made good with mortar, plaster or concrete in order to prevent the spread of fire. Fire barriers must be fitted inside the trunking every 5m, or at every floor level or room dividing wall, if this is a shorter distance. Where trunking is installed vertically, the installed conductors must be supported so that the maximum unsupported length of non-sheathed cable does not exceed 5m. PVC insulated cables are usually drawn into an erected conduit installation or laid into an erected trunking installation.



Skirting trunking

### *Fittings*

Fittings are joining materials. Plastic can be joined with an appropriate solvent. Metals may be welded, brazed or soldered, but the most popular method of on-site joining of metals on electrical installations is by nuts and bolts or rivets. A nut and bolt joint may be considered a temporary fastening since the parts can easily be separated if required by unscrewing the nut and removing the bolt. A rivet is a permanent fastening since the parts riveted together cannot be easily separated.

Two pieces of metal joined by a bolt and nut and by a machine screw and nut. The nut is tightened to secure the joint. When joining trunking or cable trays, a round head machine screw should be used with the head inside to reduce the risk of damage to cables being drawn into the trunking or tray.

Thin sheet material such as trunking is often joined using a pop riveter. Special rivets are used with a hand tool. Where possible, the parts to be riveted should be clamped and drilled together with a clearance hole for the rivet.

The stem of the rivet is pushed into the nose bush of the riveter until the alloy sleeve of the rivet is flush with the nose bush

- (a) The rivet is then placed in the hole and the handles squeezed together
- (b) The alloy sleeve is compressed and the rivet stem will break off when the rivet is set and the joint complete
- (c) To release the broken off stem piece, the nose bush is turned upwards and the handles opened sharply. The stem will fall out and is discarded

### Bracket supports

Conduit and trunking may be fixed directly to a surface such as a brick wall or concrete ceiling, but where cable runs are across girders or other steel framework, spring steel clips may be used but support brackets or clips often require manufacturing. The brackets are usually made from flat iron, which is painted after manufacturing to prevent corrosion. They may be made on-site by the electrician or, if many brackets are required, the electrical contractor may make a working sketch with dimensions and have the items manufactured by a blacksmith or metal fabricator. The type of bracket required will be determined by the installation, which may be modified to suit particular circumstances.

### *Fixings*

#### Fixing methods

PVC insulated, and sheathed wiring systems are usually fixed with PVC clips in order to comply with IEEE Regulation 522.8.3 and 4. The clips are supplied in various sizes to hold the cable firmly, and the

fixing nail is a hardened masonry nail. The use of a masonry nail means that fixings to wood, plaster, brick or stone can be made with equal ease in which the screw can be secured.

**a. Plastic plugs**

A plastic plug is made of a hollow plastic tube split up to half its length to allow for expansion. Each size of plastic plug is color coded to match a wood screw size. A hole is drilled into the masonry, using a masonry drill of the same diameter, to the length of the plastic plug. The plastic plug is inserted into the hole and tapped home until it is level with the surface of the masonry. Finally, the fixing screw is driven into the plastic plug until it becomes tight and the fixture is secure.

*Expansion bolts*

The most well-known expansion bolt is made by raw bolt and consists of a split iron shell held together at one end by a steel ferrule and a spring wire clip at the other end. Tightening the bolt draws up an expanding bolt inside the split iron shell, forcing the iron to expand and grip the masonry. Raw bolts are for heavy-duty masonry fixings. A hole is drilled in the masonry to take the iron shell and ferrule. The iron shell is inserted with the spring wire clip end first so that the ferrule is at the outer surface. The bolt is passed through the fixture, located in the expanding nut and tightened until the fixing becomes secure.

*Spring Toggle bolts*

A spring toggle bolt provides one method of fixing to hollow partition walls which are usually faced with plasterboard and a plaster skimming.

Plasterboard and plaster wall or ceiling surfaces are not strong enough to support a load fixed directly into the plasterboard, but the spring toggle spreads the load over a larger area, making the fixing suitable for light loads. A hole is drilled through the plasterboard and into the cavity. The toggle bolt is passed through the fixture and the toggle wings screwed into the bolt. The toggle wings are compressed and passed through the hole in the plasterboard and into the cavity where they spring apart and rest on the cavity side of the plasterboard. The bolt is tightened until the fixing becomes firm. The bolt of the spring toggle cannot be removed after fixing without the loss of the toggle wings. If it becomes necessary to remove and re-fix the fixture a new toggle bolt will have to be used.

## **Measuring tools**

The measuring tools that would be used to measure conductors that is required for a given installation may range from a steel rule to a tape measure.

## **Measuring equipment**

The test instruments and test leads used by the electrician for testing an electrical installation must meet all the requirements of the relevant regulations. The HSE has published guidance note GS 38 for test equipment used by electricians. The IEE Regulations (BS 7671) also specify the test voltage or current required to carry out particular tests satisfactorily. All test equipment must be chosen to comply with the relevant parts of BS EN 61557. All testing must, therefore, be carried out using an 'approved' test instrument if the test results are to be valid. The test instrument must also carry a calibration certificate, otherwise the recorded results may be void. Calibration certificates usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier. This will maintain the accuracy of the instrument to an acceptable level, usually within 2% of the true value. Modern digital test instruments are reasonably robust, but to maintain them in good working order they must be treated with care. An approved test instrument costs as much as a good-quality camera; it should, therefore, receive the same care and consideration.

## Cables and conductors

Most cables can be considered to be constructed in three parts: the conductor, which must be of a suitable cross-section to carry the load current; the insulation, which has a colour or number code for identification; and the outer sheath, which may contain some means of providing protection from mechanical damage. The conductors of a cable are made of either copper or aluminum and may be stranded or solid. Solid conductors are only used in fixed wiring installations and may be shaped in larger cables. Stranded conductors are more flexible and conductor sizes from 4.0 to 25 mm<sup>2</sup> contain seven strands. A 10 mm<sup>2</sup> conductor, for example, has seven 1.35 mm diameter strands which collectively make up the 10 mm<sup>2</sup> cross-sectional area of the cable. Conductors above 25 mm<sup>2</sup> have more than seven strands, depending upon the size of the cable. Flexible cords have multiple strands of very fine wire, as fine as one strand of human hair. This gives the cable its very flexible quality. Rectangular conductors (usually called bus bars) are used in distribution boards or specially constructed bus bar chambers designed to allow many different circuits to be tapped from.

In many existing installations old cables can still be found insulated with rubber although they are no longer manufactured. A modern wiring material for cables is polyvinyl chloride (PVC). PVC insulated single core cables (singles) are used when the installation is to be run in a conduit or trunking. Another type of fixed wiring cable is mineral insulated metal sheathed (MIMS) cable. They are strong and long lasting.

Armored cables are also an extension of the type of cables used in fixed wiring. Here the inner PVC sheath is in turn sheathed in strands of steel wire and an overall sheath fitted on the outer cover.

### Crimping tool

This is a tool that is used to crimp lugs at the end of the conductor. Lug terminations is frequently used for connecting a conductor to the busbars.

accessible conduit system and for industrial and commercial installations it is replacing the larger conduit sizes.

A trunking system can have great flexibility when used in conjunction with conduit; the trunking forms the background or framework for the installation, with conduits running from the trunking to the point controlling the current-using apparatus. When an alteration or extension is required it is easy to drill a hole in the side of the trunking and run a conduit to the new point. The new wiring can then be drawn through the new conduit and the existing trunking to the supply point.

Trunking is supplied in 3 m lengths and various cross-sections measured in millimetres from 50 \_ 50 up to 300 \_ 150. Most trunking is available in either steel or plastic.

### Joining materials

Plastic can be joined with an appropriate solvent. Metal may be welded, brazed or soldered, but the most popular method of on-site joining of metal on electrical installations is by nuts and bolts or rivets. A nut and bolt joint may be considered a temporary fastening since the parts can easily be separated if required by unscrewing the nut and removing the bolt. A rivet is a permanent fastening since the parts riveted together cannot be easily separated. The stem of the rivet is pushed into the nose bush of the riveter until the alloy sleeve of the rivet is flush with the nose bush (a). The rivet is then placed in the hole and the handles squeezed together (b). The alloy sleeve is compressed and the rivet stem will break off when the rivet is set and the joint complete (c). To release the broken-off stem piece, the nose bush is turned upwards and the handles opened sharply.

## 5.2.3.4 Learning Activities

| Learning activity | Special instructions |
|-------------------|----------------------|
|-------------------|----------------------|



|  |   |
|--|---|
| Discuss the necessary types of tools and equipment required according to their purpose for an electrical installation project. | Trainees to identify tools from the tool racks or store and sketch them then list them on a table as guided           |
| Demonstrate how to check on the specifications of tools and equipment required for the project from the manufacturers manual   | Trainees will practice on how to list the equipment and their specifications  |
| Discuss the materials required for a particular installation project   | Identify the materials required at each stage of the installation project and list them according to size and purpose |
|  |   |
|  |   |

### 5.2.3.5 Self-assessment

1. Good housekeeping' at work is about:
  - a. cleaning up and putting waste in the skip
  - b. working safely
  - c. making the tea and collecting everyone's lunch
  - d. putting tools and equipment away after use.
  
2. Which hand tools would you use for terminating conductors in a junction box?
  - a. a pair of side cutters or knife
  - b. a screwdriver
  - c. a wood chisel and saw
  - d. a tenon saw.
  
3. Which hand tools would you use for removing cable insulation?
  - a. a pair of side cutters or knife
  - b. a screwdriver
  - c. a wood chisel and saw.
  - d. a tenon saw.
  
4. Which hand tools would you use to cut across a floorboard before lifting?
  - a. a pair of side cutters or knife
  - b. a screwdriver
  - c. a wood chisel and saw
  - d. a tenon saw.
  
5. Which hand tools would you use to cut and remove a notch in a floor joist?
  - a. a pair of side cutters or knife
  - b. a screwdriver
  - c. a wood chisel and saw
  - d. a tenon saw

### 5.2.3.6 Tools, Equipment, Supplies and Materials

- Screw driver
- Pliers different types
- Cable strippers
- Hammer
- Electrician knife
- Power drill

**Measuring tools**

- Voltage tester
- Clamp on ammeter

**materials**

- Steel conduit
- PVC conduit & Flexible conduit
- Hacksaw Taps & dies
- IEE Regulation and KEBS standards.
- Pieces of conduit with threads and without.
- Running coupler set, conduit boxes, bends
- Different types of cables
- Bolts and nuts
- Flip chart
- Equipment and tools Manufacturer's manuals
- Chalk board

**5.2.3.7 References**

Electrical installation principles and practice by J. Hyde Macmillan text for industrial vocational and technical education. pp 63-85

Basic Electrical installation works by Trevor Linsley, 5<sup>th</sup> edition pp 139- 159

Electrical installation work by Brian Scaddan 7<sup>th</sup> edition pp 253-283

## **5.2.4 Learning Outcome 4: Arrange for logistics**

### **5.2.4.1 Introduction to the learning outcome**

Logistics refers to the process of co ordinating and moving resources ie people, materials, inventory and equipment from one location to the storage at the work site

It is necessary to plan logistics efficiently in order to purchase raw materials transport them, and store them safely and securely until when they shall be used. Coordinating resources will allow for timely delivery and use of tools, materials ensuring a timely completion of electrical installation project work.

### **5.2.4.2 Performance Standard**

5.2.4.2.1 Necessary logistics for the particular work and site is determined

5.2.4.2.2 Determined logistics are reported and arranged with the responsible party according to work schedule

### **5.2.4.3 Information Sheet**

Logisticians should plan on how the acquired resources will be, stored and transported to their final destination. Logistics management will have to identify prospective distributors and suppliers and determine their effectiveness and accessibility.

There are five elements of logistics:

- Storage, warehousing and materials handling
- Packaging and unitization
- Inventory
- Transport
- Information and control

Only two functions are discussed here ie transport and Storage, warehousing and materials handling

### **Transport**

#### *Role of transport*

Transport is the most recognizable role of logistics. This includes all modes of transport including road vehicles, freight trains, cargo shipping and air transport. Without transport, goods as well as human resource would be unable to move from one stage to another. Electrical equipment and material may consist of complex products that may need to be transported from all over the world and so plans must be put in place to ensure the materials arrival is timely. For imported goods, necessary licenses and trade goods certificate must be acquired well in advance to avoid clearance delay at the airport or other points of entry.

### **Storage and warehousing**

This involves safe keeping of the materials, tools and equipment to be used in the project upon arrival on site. The amount of storage capacity required will depend on the type of storage required. The items and quantities to be stored are based on the projects needs within a given contract period. To determine the size of the warehouse required the volume and floor space needed, are considered rather than the weight of the items to be stored. Extra space is needed to load, unload and repack damaged goods, and will also help with ventilation. A good ratio is 30% of the space for access and 70% for storage of materials and equipment. Storage height depends on the type of items and packaging. A two-metre stacking height is appropriate for the majority of items.

### **Storage and warehouse selection**

There are necessary factors to consider while selecting a storage facility for project materials and equipment. Such factors include;

#### *Accessibility:*

Access to warehouse should be easy for cars and trucks in all weathers.

#### *Utilities:*

There should be office space for the storekeeper, preferably with toilet and wash-up facilities, and regular garbage disposal. Lighting in the warehouse and surrounding area. The warehouse should be fenced and should have facilities present for security personnel

#### *Size:*

The warehouse should have sufficient capacity to meet forecast requirements for temporary storage.

*Security:* Area should not be likely to invite intrusion or vandalism.

*Proximity:* There should be good access to transport infrastructure.

*Easy movement:* The warehouse should have sufficient additional floor area to permit easy stock handling and access to all stocks for inspection, and insect and pest control.

*Ventilation:* The construction should be dry and well ventilated. The roof should be leak-proof. There should be no broken windows. Doors should close securely with no gaps. To reduce temperature inside the warehouse, you should paint the roof and walls outside, in white.

*Maintenance:* The floor should be flat and solid, preferably smooth and crack-free concrete. The walls should be as clean and smooth as possible.

### **Storage space management**

Zones for activities and areas for storage must be defined inside the warehouse eg at the;

- arrival zone-during unloading, the storekeeper will inspect the delivery for quality and quantity. If this is correct, the storekeeper will accept and register the goods
- packing zone-for some for those items which need to be moved from the store so as to be delivered elsewhere eg generators used to supply temporary installation on site
- delivery zone-to save time during loading and to avoid disorder, items ready to be delivered are stored per destination
- storage zones-where stock is stored.

### *Human resource involved*

Logistician is the person responsible of planning the entire logistics system and is also responsible of managing the store for a small organization. In case of a big enterprise, a store keeper must be employed to take charge of the store and warehouse

The main responsibilities and tasks of the storekeeper are to:

- ensure a correct physical and administrative stock management
- manage the team of loaders
- check the safety of the warehouse and goods.

The storekeeper is responsible for implementing all necessary measures related to the maintenance of the quality of items. If a problem cannot be solved at the storekeeper's level, the logistician has to be informed. The storekeeper is responsible for the items stored.

### Annex 15.17 Storekeeper job description

#### **loaders**

Loaders are employees working under the responsibility of the storekeeper. They have to load, move and unload goods. They also undertake minor repair and repacking of damaged bags. The number of persons will depend on the volume and on the storage facilities. Loaders can be permanent employees, daily workers or a team paid per ton or unit carried depending on the frequency of activities. For electrical installation work loaders may be hired on a daily basis or for a specific task only

#### **Communication in logistics**

This involves the interaction between all the parties involved in a supply, distribution, storage of materials and equipment. If all people from different points of the logistics process are able give ideas for improvements based on firsthand experience, it will make for a much better managed process. If communication is limited, so is the ability of the timely supply and delivery of goods.

#### **Modes of communication**

Real-Time Communication through mobile phone softwares. this is a secure and safe communication transmission mode

Ways of improving Communications For efficient logistics

- make it a priority to liaise with the suppliers and distributors of material and equipment to ensure that deliveries are on time and in the right quantities at considerable costs
- Regularly meet with stakeholders and suppliers. By getting together with them on a regular basis (weekly for instance) you can highlight and tackle their concerns and worries as they occur. make sure they are regularly updated even if it's just a quick summary email. With suppliers it's also important to regularly asses' relationships from both sides, and offer constructive feedback to the supplier as well as asking for it yourself.
- Always offer options. After negotiations, produce a list of options and relevant cases that back up each. This way, you are giving the stakeholders some influence and aren't taking the decision out of their hands, making them feel they have status.

### Communication

When it comes to the communication method itself, one should assess which method best suits the situation that will deliver the optimum results for supply chain success. There are also some basic principles to consider when it comes to how one communicates with stakeholders and suppliers:

- Be clear. It's necessary to give clear instructions which are understandable to the team of people in the logistics department
- Be personal and pragmatic. Often with stakeholders, it's more beneficial to give them a call or pay a quick visit than to send less direct communication such as emails. A personal and pragmatic approach will get faster and better results when aiming to implement change.

#### 5.2.4.4 Learning Activities

| Learning activity   | Special instructions  |
|---|---|
| Discuss the necessary logistics required for particular work at an electrical installation site | Trainees will list all the necessary tasks to be performed with regard to transport and storage of materials required at site |
| Discuss on how to segregate logistics according to different departments                        | Trainees will role play different departments and prepare their logistics as per specific work schedule for each department   |

#### 5.2.4.5 Self-Assessment

- which two methods of communication may be used by a logistician?

- II. how can a logistician endeavor to improve on his communication with the rest of the departments in an organization?
- III. Which three factors may one need to consider when selecting a storage facility?
- IV. who are the people most likely to be found working in the logistics department?

#### **5.2.4.6 Tools, Equipment, Supplies and Materials**

- Stationary
- Flipcharts
- Whiteboards
- Delivery note books
- Templates of material, tools, equipment checklists

#### **5.2.4.7 References**

Information sources should be quoted and presented as required in the APA format

#### **5.2.4.8 Model answers to self-assessment**

## **5.2.5 Learning Outcome 5: Prepare installation work**

### **5.2.5.1 Introduction to the learning outcome**

Work under this section shall include the supply, installation, testing and delivery in perfect running conditions of the electrical installations for subject project. Preparation of work schedules for the task involved is a major consideration where use of bar graphs, Gantt charts and in some cases critical path analysis. These methods are used to plan how the project will be executed.

### **5.2.5.2 Performance Standard**

- 5.2.5.2.1 Official request is made for installation drawings
- 5.2.5.2.2 Installation drawing is acquired and deposited in a safe place as per established procedure
- 5.2.5.2.3 The scope of installation work is identified
- 5.2.5.2.4 All work is undertaken safely and as per workplace procedures, National/County regulations and legislative requirements
- 5.2.5.2.5 Working drawing is prepared in accordance with the design drawing
- 5.2.5.2.6 Work schedule is prepared based on the scope and the working drawing

### **5.2.5.3 Information Sheet**

#### **Identification of scope of installation work**

These installations comprise, but are not limited to, the following: Main Distribution Boards (MDB) Complete electrical installations for all lighting, sockets, and power outlets lighting fixtures. The supply shall include all the equipment, accessories and other materials not enumerated in these specifications but found necessary for the completion and perfect functioning of the installations. Work shall be executed in a first-class work-manlike manner in accordance with these specifications, the drawings and notes indicated therein, the instructions of the Engineer, the provisions of the Bill of Quantities delivered in place and tested to the full satisfaction of the Engineer

#### **Preparation of work schedules**

##### **Bar chart**

Bar-chart (Gantt chart) Planning Technique. A Gantt chart, commonly used in project management, is one of the most popular and useful ways of showing activities (tasks) displayed against time. On the left of the chart is a list of the activities and along the top is a suitable time scale. Each activity is represented by a bar; the position and length of the bar reflects the start date, duration and end date of the activity. Benefits of Using Bar-chart (Gantt chart) Technique for Project Planning include, Clarity: Gantt chart has the ability to show and clarify multiple tasks and timelines. Communication: It is a visual method to help project team members understand task progress. Motivation: Gantt charts offer project teams the ability to focus work at the front of, or at the tail end of a task timeline. Coordination: project managers use these charts to break down projects into manageable sets of tasks. Creativity: The use of Gantt charts often encourages new partnerships that might not have evolved under traditional task assignment systems. Time Management: Time scheduling is considered as one of the major



benefits of Gantt charts. Flexibility: It offers a view of project which can help team members adjust changes. Manageability: By using Gantt charts, project managers can make more focused, effective decisions about resources and timetables. Efficiency: Visualizing resource usage during projects allows managers to make better use of people, places, and things. Accountability: Using Gantt charts during critical projects allows both project managers and participants to track team progress. Disadvantages of Using Bar-chart (Gantt chart) Technique for Project Planning include: They can become very complex, the length of the bar does not indicate the amount of work, they at all-time need to be updated and Difficult to see on one sheet of paper.

### **Critical path analysis**

Critical path analysis identifies the sequence of crucial and interdependent steps that comprise a work plan from start to finish. The concept of a critical path recognizes that completion of some tasks in a project is dependent on the completion of other tasks. Some activities cannot start until others are finished. The essential technique for using CPM is to construct a model of the project that includes the following:

1. A list of all activities required to complete the project (typically categorized within a work breakdown structure) ,
2. The time (duration) that each activity will take to complete,
3. The dependencies between the activities and,
4. Logical end points such as milestones or deliverable items.

Using these values, CPM calculates the longest path of planned activities to logical end points or to the end of the project, and the earliest and latest that each activity can start and finish without making the project longer. This process determines which activities are "critical" (i.e., on the longest path) and which have "total float" (i.e., can be delayed without making the project longer). In project management, a critical path is the sequence of project network activities which add up to the longest overall duration, regardless if that longest duration has float or not. This determines the shortest time possible to complete the project.

#### **The critical path determination:**

After having computed various time estimates, we are now interested in finding the critical path of the network. A network will consist of a number of paths. A path is a continuous series of activities through the network that leads from the initial event (or node) of the network to its terminal event. For finding the critical path, we list out all possible paths through a network along with their duration. Assuming a network under consideration, has various paths have been listed below with Path Length (in days)

1-2-3-5-6 =36days

1-2-4-5-6 =52days

1-2-3-4-5-6 =50days

Critical path: A path in a project network is called critical if it is the longest path. The activities lying on the critical path are called the critical activities. In the above example, the path 1-2-4-5-6 with the longest duration of 52 days is the critical path and the activities 1-2, 2-4, 4-5 and 5-6 are the critical activities.

#### **Calculation of Floats:**

It may be observed that for every critical activity in a network, the earliest start and latest start time are the same. This is so since the critical activities cannot be scheduled later than their earliest schedule time without delaying the total project duration, they do not have any flexibility in scheduling. However, non-critical activities do have some flexibility i.e. these activities can be delayed for some time without affecting the project duration. This flexibility is termed as slack in case of an event and as float in case of an activity

#### 5.2.5.4 Learning Activities

| Learning activity | Special instructions |
|-------------------|----------------------|
|                   |                      |
|                   |                      |
|                   |                      |
|                   |                      |
|                   |                      |
|                   |                      |

#### 5.2.5.5 Self-Assessment

- 1 what is a critical path
- 2 Draw a critical path network diagram for the following data.

| Task | Immediate Predecessor |
|------|-----------------------|
| A    | —                     |
| B    | —                     |
| C    | B                     |
| D    | B                     |
| E    | B                     |
| F    | E                     |
| G    | A, D, C.              |

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#### 5.2.5.6 Tools, Equipment, Supplies and Materials

- This section should provide for the requirements of the learning outcome in terms of tools, equipment, supplies and materials
- The section should be adequate, relevant and comprehensive for the learning outcome.

#### 5.2.5.7 References

## 5.2.6 Learning Outcome 6 Establish installation team

### 5.2.6.1 Introduction to the learning outcome

Work teams and groups come in a variety of types and sizes, cutting across different contexts, functions, internal processes, and external linkages. However, several features provide a foundation for a basic definition. Work teams and groups: (a) are composed of two or more individuals, (b) who exist to perform organizationally relevant tasks, (c) share one or more common goals, (d) interact socially, (e) exhibit task interdependencies (i.e., workflow, goals, outcomes), (f) maintain and manage boundaries, and (g) are embedded in an organizational context that sets boundaries, constrains the team, and influences exchanges with other units in the broader entity. Teams are embedded in an open yet bounded system composed of multiple levels. This broader system sets top-down constraints on team functioning. Simultaneously, team responses are complex bottom-up phenomena that emerge over time from individual cognition, affect, behavior, and interactions among members within the team context. Based on this perspective, four conceptual issues are critical in efforts to investigate and understand work teams: (1) task or workflow interdependence, (2) contextual creation and constraint, (3) multilevel influences, and (4) temporal dynamics. The centrality of task interdependence is one issue that clearly distinguishes the work teams and small group literatures

### 5.2.6.2 Performance Standard

- 5.2.6.2.1 Team members are identified according to the task
- 5.2.6.2.2 Communication protocol is designed and distributed among the team members
- 5.2.6.2.3 Responsibilities are established and distributed among the team members
- 5.2.6.2.4 Team familiarization is done according to the established procedure

### 5.2.6.3 Information Sheet

**Team building** is a collective term for various types of activities used to enhance social relations and define roles within teams, often involving collaborative tasks. It is distinct from team training, which is designed by a combine of business managers, learning and development/OD (Internal or external) and an HR Business Partner (if the role exists) to improve the efficiency, rather than interpersonal relations.

Many team-building exercises aim to expose and address interpersonal problems within the group

Over time, these activities are intended to improve performance in a team-based environment. Team building is one of the foundations of organizational development that can be applied to groups such as sports teams, school classes, military units or flight crews. The formal definition of team-building includes:

- aligning around goals
- building effective working relationships
- reducing team members' role ambiguity
- finding solutions to team problems

Team building is one of the most widely used group-development activities in organizations. A common strategy is to have a "team-building retreat" or "corporate love-in," where team members try to address underlying concerns and build trust by engaging in activities that are not part of what they ordinarily do as a team.

Of all organizational activities, one study found team-development to have the strongest effect (versus financial measures) for improving organizational performance. A 2008 meta-analysis found that team-development activities, including team building and team training, improve both a team's objective performance and that team's subjective supervisory ratings. Team building can also be achieved by targeted personal self-disclosure activities.

Team building describe four approaches to team building

### **Setting Goals**

This emphasizes the importance of clear objectives and individual and team goals. Team members become involved in action planning to identify ways to define success and failure and achieve goals. This is intended to strengthen motivation and foster a sense of ownership. By identifying specific outcomes and tests of incremental success, teams can measure their progress. Many organizations negotiate a team charter with the team and (union leaders)

### **Role clarification**

This emphasizes improving team members' understanding of their own and others' respective roles and duties. This is intended to reduce ambiguity and foster understanding of the importance of structure by activities aimed at defining and adjusting roles. It emphasizes the members' interdependence and the value of having each member focus on their own role in the team's success.

### **Problem solving**

This emphasizes identifying major problems

### **Interpersonal relations**

This emphasizes increasing teamwork skills such as giving and receiving support, communication and sharing. Teams with fewer interpersonal conflicts generally function more effectively than others. A facilitator guides the conversations to develop mutual trust and open communication between team members.

But sometimes, you get to create your own team. It can happen on special projects when you're pulling people from different departments, or when you are creating a new department. If you're in the situation where you get to create a team from scratch (or have the opportunity to add headcount to an existing group), here's how to create the best team possible.

#### **1. Clearly Identify the Task at Hand**

If your task is nebulous, you will have a tough time knowing what skills you need to find. You're likely tempted to jump right in and hire people with the general skills that fit your overall department. (I need marketing people. I need creative people.)

#### **2. Identify the Skills Needed**

You need to identify the soft skills as well as the hard skills you need. Will the employee need to communicate results and progress to senior management? Are there skills you need that isn't going to be obvious without hard thought? For instance, if you're putting together a team to implement a new software system, you obviously need programmers.

### 3. Identify the People

If you want to build an internal team, you have advantages and disadvantages. The advantages are that you already know the people from whom you are choosing. You know their strengths and their weaknesses. You know who is good at technical work. You know who is creative. You know who is whiny. The disadvantages are that you've got to pull the team from your existing staff, so you can't fix any weaknesses that already exist in your potential team members. You have to deal with the politics of pulling someone from another group's staff. You can't ignore the fact that you can damage relationships if you steal too many of the best people from other departments.

### 4. Hire in the Right Order

Don't hire the administrative assistant first. You may think, "Okay, I'll get this out of the way." But the administration's job is to help the rest of the team and support them. If you hire this person first, you need to find additional people with whom they can work, instead of the other way around. Start with your most senior person, or the person you want leading the team, and work down through the rest of the team members from this hire. You want your most senior person to help you with the additional hiring—either internally or externally.

### 5. Practice Honesty in Your Hiring

Don't just extol the virtues of working on this team. You need to state the challenges honestly to potential employees. For example, you might say: "We'll implement a new software system. You will work hard and put in long hours. We'll experience pushback from senior managers, and I will fight for the team, but it will be difficult." This way, you'll get staff members who know what to expect. Don't lie and say the team's task is a bed of roses unless you really think that is how the team's work will play out. You'll lose your best team members who will feel as if you fooled them.

### 6. Remember to Manage

Once you get your team together, you've got to run it. Great teams seldom run well without a great leader. That's your job. Make sure that you work to make the team cohesive and hard working. Don't ask more of them than you ask of yourself. If you are managing the team leader, the same applies. You need to check in on a pre-planned schedule to ensure that the team stays on track. If it's not, work with the team leader to regroup and move forward.

#### 5.2.6.4 Learning Activities

| Learning activity | Special instructions |
|-------------------|----------------------|
|                   |                      |
|                   |                      |
|                   |                      |

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|--|--|
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**5.2.6.5 Self-Assessment**

1. If you're in the situation where you get to create a team from scratch (or have the opportunity to add headcount to an existing group), outline six steps to create the best team possible?

**5.2.6.6 Tools, Equipment, Supplies and Materials**

- This section should provide for the requirements of the learning outcome in terms of tools, equipment, supplies and materials
- The section should be adequate, relevant and comprehensive for the learning outcome.

**5.2.6.7 References**

Alderfer, C. P. (1977). Group and intergroup relations. In J. R. Hackman & J. L. Suttle (Eds.), *Improving the quality of work life* (pp. 227-296). Palisades, CA: Goodyear.

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**5.2.6.8 Model answers to self-assessment**

## **5.2.7 Learning Outcome 7** Obtain the necessary permit and licences

### **5.2.7.1 Introduction to the learning outcome**

Permit to work (PTW) systems are formal procedures used to control activities that are considered high-risk. Permits only allow authorized personnel to perform those activities at specified times and in a way set out in the permit and referenced documents. A restricted electrical work license (a restricted license) authorizes the holder to perform electrical work only of a particular type stated in the license. An applicant for a restricted license must be able to demonstrate an occupational need to carry out restricted electrical work incidental to a particular trade or calling. For example, a mechanical fitter may be eligible for a restricted license to permit them to disconnect and reconnect an electric motor in order to realign a conveyor system. Similarly, a plumber may be eligible for a restricted license if in the course of their trade they need to disconnect and reconnect hot water systems.

### **5.2.7.2 Performance Standard**

**5.2.7.2.1** Type of permit to work is identified where applicable

**5.2.7.2.2** Permit to work issuing body is identified

**5.2.7.2.3** Permit to work form is filled and submitted to the responsible body

### **5.2.7.3 Information Sheet**

Issuing permits to work can be a complicated and time-consuming process and so adequate notice should be given before a permit to work is required. Permit systems do not in themselves make activities safer, this is only possible through the implementation of the correct procedures. It is important therefore that systems not box-ticking exercises, that they are explained at site inductions and that they are continuously monitored, reviewed and kept up to date. A permit should: Describe the work and its location, Provide information about foreseeable risks, Provide information necessary for working safely, Set out requirements for personal protective equipment, Set out the time when the work can be carried out, Provide information about other permits.

A permit to work system should:

- Only allow permits to be issued by authorised, competent personnel.
- Prevent high-risk work being carried out without a risk assessment having been undertaken.
- Consider whether any other work will impact on, or be impacted by, the permitted work.
- Ensure control measures and supervision are in place.
- Ensure method statements and emergency procedures are prepared.
- Ensure work is checked and returned to a safe state.
- Provide information to other parties that might be affected by the work.
- Include a system for handing back and cancelling permits.

## **Types of permits**

### **General**

A written permit to work system provides formal written procedure and formal actions to ensure that

potentially hazardous activities are carried out as safely as possible. The work permit is a written document which authorizes persons to carry out the work concerned warns of possible dangers and clearly states the precautions to be taken for the job to be carried out safely.

The permit ensures that full consideration is given to the hazards and risks, and that these are properly dealt with, prior to commencement of the work. The permit to work has to be filled by the subcontractors for what concerns its activities and references. Contractor will give the necessary support as required.

The permit to work shall clearly specify the particular equipment and the construction area involved, the extent of work allowed, the conditions to be observed and the duration of the permit. Should any doubt exist as to the requirements for specific types of Permits, YOUR COMPANY NAME's Field HSE Coordinator and/or YOUR COMPANY NAME's Permit Coordinator should be consulted for advice.

### **Activities Requiring a Permit to Work**

A Permit to Work will be required for the following activities:

- Any activity on live electrical equipment.
- Areas electrically classified.
- Closure of site roads to enable excavation and similar activities to be carried out.
- Confined space work (i.e. any work inside a vessel).
- Confined space work.
- Connection to the electrical supply.
- Connection to the water supply.
- Crane Lifts; lifting operations over living lines / equipment.
- Disconnecting or opening of any closed pipeline or vessel containing flammable or other hazardous material.
- Erection of site huts and lay down areas.
- Excavation and trenching.
- Facilities for the storage of cylinder gases, highly flammable liquids, paint or similar hazardous materials.
- Hot work of any type, where heat is used or generated.
- Hot work.
- Installation of pits for the storage of sealed radioactive sources.
- Isolation/lock-out/tag-out.
- Radiography (i.e. any work involving use of radioactive source, including the installation of pits for the storage of sealed radioactive sources).
- Working in hazardous zoned areas.

### **General Work Permit (cold)**

- The general Work Permit shall be utilized for all activities requiring a Permit to Work, other than those capable of generating or using sources of ignition.
- The general Work Permit will facilitate all activities from scaffold erection to those controlling activities such as pressure testing.
- The general Work Permit has the facility to be validated for a period of 28 consecutive days.
- Revalidation of any Permit to Work shall remain at the discretion of YOUR COMPANY NAME's Construction Manager and only if all Permit Signatories are in agreement, that there is no significant change in condition, changes in work schedule or there is no significant changes in personnel.



- Permits to Work shall clearly specify the particular equipment and the construction area involved the extent of work allowed, the conditions to be observed and the duration of the permit.

### Other Permits and Certificates

Should additional and/or other permits be required, they shall be created prior to commencement of work on definable features of work. The following Certificates shall be issued with the Work Permit (both general and hot) and they give details of the existing situation of the area.

### Confined Space Certificate

- The Confined Space Certificate, shall be used in conjunction with the Permit to Work (both general and hot), and is required for any entry into a confined space as defined in this section.
- The Confined Space Certificate, once in place, only controls the entry of persons into a confined space. The actual task shall be controlled by the general Permit to Work. The Permit numbers shall be cross referenced to each other.
- Entry into confined spaces is subject to special requirements being put into place prior to the commencement of work. This will include but not be limited to:
  - Condition monitoring
  - Presence of a Safety Watch Person
  - PPE/RPE
  - Emergency Escape Plan

### Electrical Work Certificate

This Certificate shall be used in conjunction with the Permit to Work (both general and hot), for any activity to be carried out on live electrical equipment or plant.

The Electrical Competent Person should complete this form and demonstrate that all necessary isolations have been made and that the system or plant is safe to be worked on. The electrical work certificate shall be utilized when an energization or de-energization operation should be carried out.

### Lock out-tag out

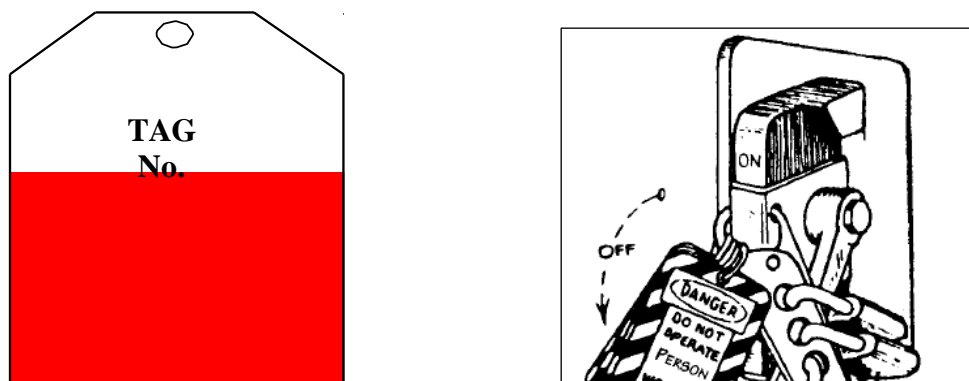
De-energization (Isolation) may be required prior to installation, inspection, repair, cleaning or dismantling. Where a job involves isolation of equipment, there shall be a work permit for the job and a lockout and tag-out procedure shall be followed. A lockout generally involves:

- Stopping all energy flows (for example, by tuning off switches or valves on supply lines).
- Locking switches and valves.
- Securing the machine, device or power transmission line in de-energizer state.

Electrical isolation may be required to immobilize machinery or to protect personnel working in electrical equipment. Situations involving electrical isolation including rotating machinery and machinery with moving parts and entry into vessel which contain stirrers or agitators. Electrical isolation should be performed only by a competent electrical engineer.

An example of a Warning Tag and Tag-out and lock-out are shown in Figure 3.

Figure 3. Example Warning Tag and Tag-out/Lock-out tags.



# DO NOT OPERATE

## CAUTION

DEM  
DAT  
SIG

COMMISSIONING TEAM

If other organizations or individuals working on equipment shall also install their locks and tags at locations have to be fit. In that case multiply lockout clips (Hasps) shall be used if necessary. When all padlocks will be removed energization will be possible. An example of Hasps is shown in Figure 4.

Figure 4. Example HASP



The Competent Electrical Engineer shall report all actions on the substation logbook for record purpose. As a general rule other discipline engineers cannot interfere with any electrical isolation work to be executed inside the substation for safety reasons and nobody (with the only exception of the Competent Electrical Engineer) can take or keep the padlock keys for their scopes.

Field HSE Coordinator should hold spare keys for all Lock Outs. This ensures no keys will go missing, if they are controlled by the Permit to Work Coordinator.

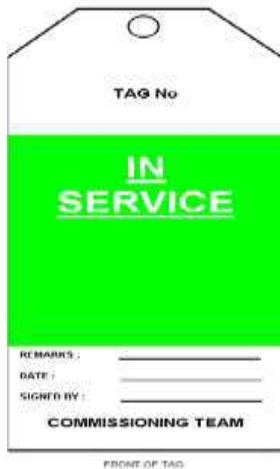
### **Execution of Energization, Removal of Tags, Padlock and Restoration of Power**

After receiving the Electrical Certification in which the ENERGIZATION is required the Competent Electrical Engineer shall proceed to energize the equipment. The following procedure covers the energization for safe execution of the pre-commissioning electrical tests.

- If a padlock and a tag are installed (to show that the switchgear is isolated) the Competent Electrical
  - Engineer shall remove both of them.
- The Competent Electrical Engineer will give power to the equipment.
- As soon as the equipment is energized the Component Electrical Engineer shall hung a tag “IN SERVICE” close to the switchgear, as shown in Figure 5.

The Competent Electrical Engineer shall report all actions on the substation logbook for record purpose.

Figure 5. Example of “In Service” tag.



### **Excavation Work Certificate**

This Certificate shall be used in conjunction with the Permit to Work, for Excavation activities. This Certificate should be submitted with the Permit to Work together with any supporting documentation such as sketches drawings and method statements. In this shall be reported all the underground services present in the area.

### **Accompanying Certification for Permit to Work**

The more information there is to support a permit to work, the more safety factors can be considered or put in place to make the job safer. Therefore it is important to submit supporting documents in the form of site layout drawings, equipment drawings, etc. with the certificate. This is especially important when trying to locate underground services and etc. Failure to provide these documents may result in an application being rejected.

### **Permit issuance and duration**

The Permit to Work will involve the following steps shown below:

1. Conduct a thorough risk assessment and determine who is at risk, what control measures are necessary to eliminate the hazards, and the level of residual risk.
2. Prepare a written system of work identifying the following:
  - The level of competence of all operatives and any specialist skills
  - List Isolation / Pre-work precautions
  - List prohibited activities (communicate to others as necessary)
  - List Plant and Equipment required
  - List Personnel Protective Equipment to be used
  - List sequence of events as planned with identified hazards/residual risks and controls clearly defined
  - Emergency procedures for all foreseeable risks (ensure that procedures are conveyed to competent persons and fully understood)
3. Brief those who will be required to operate under the Permit to Work on the hazards and controls necessary to avoid them being realized (for example during Tool Box Talks).

4. Ensure that those conducting the task know that the safe system must be followed in full and that no other methods or sequence of work are allowed (i.e., work must stop, all persons withdrawn, and the safe system reviewed by the Authorized Person). If the safe system is found to be flawed, then the Permit must be cancelled, the system of work reassessed, a new Permit raised, and those conducting the task re-briefed.
5. Display the Permit at the work site/isolation point to ensure all that those who need to know, do so.
6. Ensure that the work area is clean, tidy, and that all safety devices have been replaced and are functioning correctly, prior to inspection by the Authorized Person. Please note the Authorized Person must not sign the “hand back” section of the form until the area is in fact clean and safe.

The validity of the Permit to Work will be evaluated according to the activity and operative patterns, shall be evaluated at Site by YOUR COMPANY NAME’s Construction Manager (refer to Figure 6).

*Figure 6 Permit Validity Period*

| DOCUME                        | VALIDITY PERIODS          | ENDORSEMENT |
|-------------------------------|---------------------------|-------------|
| Work Permit (cold)            | 28 consecutive (calendar) | 7           |
| Hot Work Permit               | 14 consecutive (calendar) | 12          |
| Confined Space Certificate *  | 28 consecutive (calendar) | 12          |
| Excavation Work Certificate * | 28 consecutive (calendar) | 12          |
| Radiography Work Permit       | Maximum 12 hours          | N/          |
| Electrical Work Certificate * | No validity period        | N/          |

\* Supporting documentation has to be required at the same time of the Work Permit (general and/or hot) for identifying particular hazards introduced by the work, which require further than formal controls.

Where such risks are identified, supporting Certificates are enclosed in the Work Permit.

**Permit closure**

The Permit to Work will be considered to be closed when YOUR COMPANY NAME’s Issuing Authority signs the completion section of the Permit to Work (after receiving the subcontractor confirmation on the Permit to Work that the work is complete). Acceptance of this signature is conditioned to:

- Completion of the work according to the instructions;
- Cleanliness of work area, including the removal of all the work equipment;
- Re-installation of all safety conditions.

**Layout and Color of Permits**

The Permits to Work are in A4 format and for visibility purposes, to aid identification of documents, different colors are used on the border of Permits as per Figure 7.

*Figure 7. Permit and Certificate Identification Color Codes*

| DOCUME | BORDER COLOUR | REFERENCE |
|--------|---------------|-----------|
|--------|---------------|-----------|

|                             |                      |           |
|-----------------------------|----------------------|-----------|
| Work Permit (cold)          | <b>Blac</b>          | Attachmen |
| Hot Work Permit             | <b>Re</b>            | Attachmen |
| Confined Space Certificate  | <b>Dark</b>          | Attachmen |
| Excavation Work Certificate | <b>Brow</b>          | Attachmen |
| Radiography Work Permit     | <b>Bright-Orange</b> | Attachmen |
| Electrical Work Certificate | <b>Blu</b>           | Attachmen |

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| TO BE FILLED BY  | Work Order No.:                                 | WORK PERMIT   | Work Permit No.:       |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
|--|---|---|------------------------|-----------------------------------|--|--|--|------|------|--|------|------------------------------|------|--|--|--|--|--|--|
|  | SUBCONTRACTOR _____                             |   | AREA OF WORK _____     |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
|  | WORK STARTING DATE _____ TIME _____             |   | WORK ENDING DATE _____ |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
|  | DESCRIPTION OF THE WORK _____<br>_____<br>_____ |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| The above signing person is responsible to ensure the work is performed under all the mentioned and required safety precautions. Failure on this will be subject to disciplinary actions.  |   |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| <b>INDIVIDUAL PROTECTION EQUIPMENT (CROSS WITH AN X):</b><br><input type="checkbox"/> Helmet <input type="checkbox"/> Hear Protectors <input type="checkbox"/> Gas Mask <input type="checkbox"/> Dielectric Gloves <input type="checkbox"/> Safety Gloves<br><input type="checkbox"/> Welder's Helmet <input type="checkbox"/> Emergency Respirator <input type="checkbox"/> Safety Shoes <input type="checkbox"/><br><input type="checkbox"/> Rubber Safety Boots <input type="checkbox"/> Safety Glasses<br><input type="checkbox"/> Welder's Apron <input type="checkbox"/> Protective Goggles <input type="checkbox"/> Anti-Dust Overalls<br><input type="checkbox"/> W work Clothes <input type="checkbox"/> Welders Breeches <input type="checkbox"/> H2S Mask<br><input type="checkbox"/> Safety Belts <input type="checkbox"/> Dielectric Boots <input type="checkbox"/> Safety Harness<br><input type="checkbox"/> Dust Mask <input type="checkbox"/> Double Safety Harness <input type="checkbox"/> _____ <input type="checkbox"/> _____ |   |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| <b>COMMON PROTECTION EQUIPMENT</b><br>_____<br>_____   |   |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| <b>OTHER SAFETY MEASURES</b><br>_____<br>_____   |   |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="4" style="text-align: center;">SANCTION AUTHORIZATION SIGNATURES</th> </tr> <tr> <th style="width: 15%;">DATE</th> <th style="width: 15%;">TIME</th> <th style="width: 55%;"></th> <th style="width: 15%;">Date</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">Contractor Issuing Authority</td> <td style="text-align: center;">Time</td> <td style="border: none;"></td> <td style="border: none;"></td> </tr> <tr> <td style="height: 100px;"></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>  |   |   |                        | SANCTION AUTHORIZATION SIGNATURES |  |  |  | DATE | TIME |  | Date | Contractor Issuing Authority | Time |  |  |  |  |  |  |
| SANCTION AUTHORIZATION SIGNATURES  |   |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| DATE   | TIME  |   | Date                   |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| Contractor Issuing Authority   | Time  |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
|  |   |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| Is Electrical PTW required<br>YES ___ NO ___<br>PTW Number ___   |   | Is Confined Space PTW required<br>YES ___ NO ___<br>PTW Number ___                                |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| In case Electrical or Confined Space PTW is required? YES ___ NO ___<br>If yes, attach a Copy.   |   |   |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |
| Site Preparation completed and work can commence.<br>Contractor Operating Authority  |   | I understand the precaution to be taken as described above.<br>Sub-Contractor Operating Authority |                        |                                   |  |  |  |      |      |  |      |                              |      |  |  |  |  |  |  |

|                |  |   |
|----------------|--|---|
| <b>CLOSURE</b> |  |   |
|                | The Work is completed and working area cleared<br>_____<br>Subcontractor<br>performing Authority | The Site has been checked and working Area accepted<br>_____<br>Contractor Operating<br>Authority |

### Electrical licenses

Energy regulatory commission offers licenses to qualified trained technicians and engineers under the following classes.

#### **Class C-2**

This class entitles the holder to carry out electrical installation work for connection to a single phase at low voltage, restricted to up to two storey residential and commercial buildings not used as factories or places of public entertainment.

#### **Requirements:**

Electrical wireman certificate 1 & 2 (copy)

or

Diploma in Electrical engineering (copy)

It can a Technical and Vocational Education and Training certificate, a Technical Education Programme certificate or an electrical engineering certificate from a recognized institution.

Bank deposit slip for kshs 250 (copy)

Identity card (copy)

#### **Class C-1**

The holder of this license is entitled to carry out electrical installation work in class C-2 and for connection to three phase supply at low voltage, restricted to up to four storey buildings not used as factories or places of public entertainment.

#### **Requirements:**

Bachelor of Science in Electrical Engineering certificate (copy)

or

Diploma in Electrical engineering (copy)

or

Electrical technician license- C2 (copy)

Must have held C2 certificate for more than 2 years.

Bank deposit slip for kshs 500 (copy)

Identity card (copy)

#### **Class - B**

Holder of this class can carry out electrical installation works as in C-1 but without limitation as to number of storeys in the buildings whether used as factories or places of public entertainment or for connection to supply metered at voltages not exceeding medium.

**Requirements:**

Bachelor of Science in Electrical Engineering certificate (copy)

or

Diploma in Electrical engineering

or

Electrical technician license - C1 (copy)

Must have held a C1 technician license for more than 2 years.

or

Registration with Kenya Engineering Technology Registration Board (copy)

Bank deposit slip for kshs 750 (copy)

Identity card (copy)

**Class A-1**

The holder of this license is entitled to carry out all kinds of electrical installation works.

**Requirements:**

Bachelor of Science in Electrical Engineering certificate (copy

2

Registration with Engineers Board of Kenya (copy)

or

Electrical technician license - B (copy)

Must have had an electrical technician license class B for more than 2 years.

Bank deposit slip for kshs 1,000 (copy)

Identity card (copy)

**Class A-2**

The holder of this license is entitled to carry out specialized electrical installation work.

**Requirements:**

Bachelor of Science in Electrical Engineering certificate (copy)

or

Diploma in Electrical engineering (copy)

Bank deposit slip for kshs 1,000 (copy)

Identity card (copy)

**5.2.7.5 Learning Activities**

|  |  |
|--|--|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

**5.2.7.4 Self-Assessment**



1. What are the requirements for registering electrical technician license class C-1

#### **5.2.7.5 Tools, Equipment, Supplies and Materials**

#### **5.2.7.6 References**

PN12375 Last updated July 2020 - Electrical licensing eligibility guide

(<https://creativecommons.org/licenses>).

Energy regulatory commission licensing ([www.epra.go.ke](http://www.epra.go.ke))

HSSE 14.20.01 - BPWE JSEA Procedure

HSSE 13.40.01 - BPWE Confined Space Procedure

## **5.2.8 learning outcome 8: Prepare work site**

### **5.2.8.1 Introduction to learning outcome**

The promotion of health and safety measures is a mutual objective for the contractor and his employees at all levels. It is intended that the contractor will conduct his affairs at the work site in a manner which will not cause risk to the health and safety of employees or the general public. The contractor shall exercise his responsibility as an employer and make every effort to meet his legal obligations under the Health and Safety at Work Act to ensure the health and safety of his employees and that of the general public paying particular attention to the provision of the following;

Installation equipment and procedures of work that are safe.

Safe arrangements for the use, handling, storage and transport of tools, materials and equipment.

Sufficient information, instruction, training and supervision to enable all employees to contribute positively to their own safety and health at work and to avoid hazards.

- A safe place of work, and safe access to it.
- A healthy working environment.
- Adequate welfare services.

**Note: Reference should be made to the appropriate safety etc. manuals**

### **5.2.8.2 Performance Standard**

5.2.8.2.1 Special work, hazards and safety requirements are identified

5.2.8.2.2 Identified hazards and safety issues are mitigated according to OSHA

5.2.8.2.3 Work plan is confirmed in accordance with legislative and regulatory requirements and standard operating procedures

5.2.8.2.4 Work site is prepared for accessibility of utilities

### **5.2.8.3 Information Sheet**

Safety hazards exist in every workplace, by identifying hazards at the workplace, one will be better prepared to control or eliminate them and prevent accidents, injuries, property damage, and downtime.

There are a number of factors that are most likely to contribute to potential hazard at the work site;

- Working heights

Bureau of Labor Statistics data shows that falls to a lower level accounted for 14 percent of all fatalities in 2014, and OSHA standards related to scaffolding and ladders are regularly among the most frequently cited violations. Employers need to identify all locations where fall protection is necessary – as well as where the engineered anchor points are – and train employees and regularly audit the fall protection program, she said.

- Poor housekeeping This is where everything is cluttered all over with no clear pathways poor lighting system liquids poured on the floor and Workers shouldn't wait for housekeeping or sanitation crews to take care of these issue rather everyone should take it as a responsibility to maintain good house keeping
- Electrical – Extension cords

Inappropriate use of electrical cords is likely to pose a safety risk. Extension cords lying on the ground for extended periods of time are a trip hazard. They also can be subject to traffic abuse if run over by forklifts or feet, which can wear down insulation and create shock hazards.

Employers should assess whether extension cords are truly being used for temporary measures. At the end of a task the cord should be gathered up at the end and stored. It is recommended to establish a system of periodical inspection of extension cords, as well as train employees safe use of extension cables

- Confined spaces

confined spaces have occurred because a contractor didn't issue a permit or failed to carry out a risk assessment.

The electrical installation shall comply with all regulations on safety aspects issued by the Kenyan Bureau of standards, National Environmental and Management Authority (NEMA) and other relevant authorities.

### Occupational Safety and health act (OSHA)

OSHA focuses on the provision of all safety and protection equipment designed to be worn, or held, to protect against a risk to health and safety. This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high visibility clothing. Under the Health and Safety at Work Act, employers must provide free of charge any safety and protective equipment and employees must make full and proper use of it. Safety signs such as those shown at below are useful reminders of the type of safety and protection equipment to be used in a particular area. The vulnerable parts of the body which may need protection are the head, eyes, ears, lungs, torso, hands and feet and, in addition, protection from falls may need to be considered.

Objects falling from a height present the major hazard against which **head protection** is provided. Other hazards include striking the head against projections and hair and clothing becoming entangled in machinery.

Typical methods of protection include helmets, light duty scalp protectors

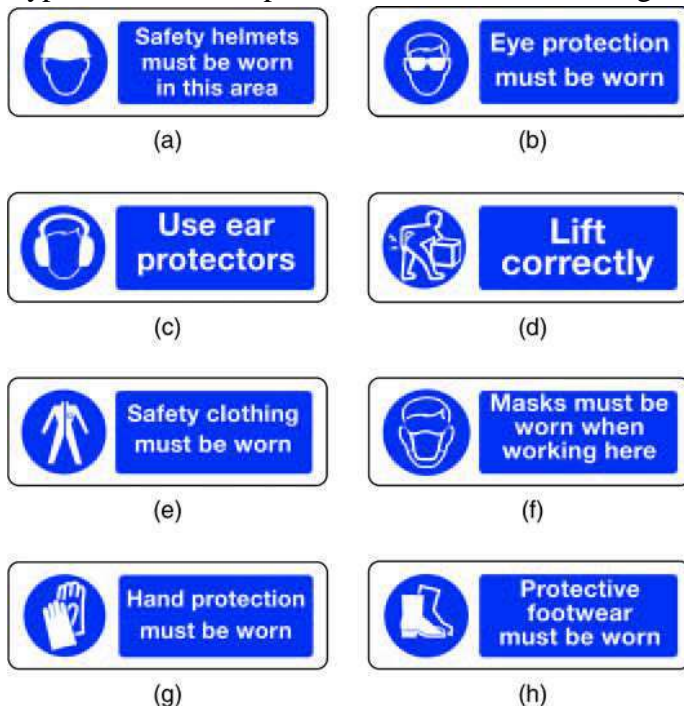


Fig. Safety sign showing protective equipment (Taken from BEIW, 5<sup>th</sup> edition)

To assist electricians in their understanding of the Regulations, the work site manual should contain the safety requirements of doing: *Selection and Erection; Isolation and Switching; Inspection and Testing; Protection against Fire; Protection against Electric Shock; Protection against Overcurrent; Special Locations and Earthing and Bonding*. These safety guide manuals are intended to be read in conjunction with the Regulations.

#### 5.2.8.4 Learning Activities

| Learning activity  | Special instruction  |
|--|--|
| Discuss the possible hazards likely to occur on an electrical installation site  | <a href="https://youtu.be/Yw0eI4oTX3Y">https://youtu.be/Yw0eI4oTX3Y</a><br><a href="https://youtu.be/M8-rYiVrm7g">https://youtu.be/M8-rYiVrm7g</a><br><a href="https://youtu.be/wpiSpt7YyPU">https://youtu.be/wpiSpt7YyPU</a><br><br>trainees to click watch and listen to the videos on |
| Discuss the employers / workers responsibilities with regard to safety at the work site                                    | trainees to practice using a hazard assessment guideline form<br><a href="https://safetylinelneworker.com/downloads/hazard-assessment">https://safetylinelneworker.com/downloads/hazard-assessment</a>   |
| Discuss the steps to be followed in Confirming the legal documents regarding the building to be installed with electricity | Trainees to list the regulatory bodies alongside the certificate that they provide at a construction site  |
| Discuss the accessibility of the site in terms of infrastructure, water and electricity                                    |  |

#### 5.2.8.5 Self-Assessment

- 1) which are two safety responsibilities of an;
  - i) Employer
  - ii) Employee at a work site
- 2) which are the five steps of hazard assessment at a work site
- 3) which three factors are most likely to cause an accident at a site
- 4) what are the recommendations of OSHA regarding safety at a site

#### 5.2.8.6 Tools, Equipment, Supplies and Materials

##### Materials

- Stationary flipchart
- whiteboards
- hazard assessment forms
- personal protective equipment

[easytvvet.com](http://easytvvet.com)

## **CHAPTER 6: PERFORMING ELECTRICAL INSTALLATION**

**Unit of learning code ENG/CU/EI/CR/02/5**

**Related Unit of Competency in Occupational Standard: Perform Electrical Installation**

### **6.1 Introduction to Electrical installation**

This unit specifies the competencies required for performing electrical installation. Competencies required includes; applying health, safety and environmental standards, preparation of working drawings, assembling of tools, equipment, materials and drawing instruments, performing electrical installation, facilitating other service providers and maintain housekeeping.

### **6.2 Summary of Learning Outcomes**

1. Apply health, safety and environmental standards.
2. Prepare working drawings.
3. Assemble tools, equipment, materials and drawing instruments.
4. Perform electrical Installation
5. Facilitate other service providers
6. Maintain housekeeping.

#### **6.2.1 Learning Outcome 1: Apply Health, Safety and Environmental standards**

##### **6.2.1.1 Introduction to the learning outcome**

To apply EHS standards, the learner needs to understand relevant clauses in appropriate acts (OSHA, WIBA and EMCA), relevant regulations on IEE, KPLC by-laws, county by-laws, meaning, purpose, types and correct handling of PPEs, the causes of accidents and their sources, classes of fire and firefighting equipment and first aid procedures

##### **6.2.1.2 Performance Standard**

- 6.2.1.2.1 Apply appropriate safety regulations.
- 6.2.1.2.2 Apply Occupational health and safety standards.
- 6.2.1.2.3 Apply Good housekeeping practices.
- 6.2.1.2.4 Record and report accident, incidents and near misses to the management.
- 6.2.1.2.5 Apply First aid and seek specialised treatment when necessary.

### **6.2.1.3 Information Sheet**

#### **An accident**

It is a sudden happening that causes harm to the body suddenly and unexpectedly.

#### **First Aid**

This is the first help given to a person who is injured before taking them to a health center or hospital or it is the first treatment given to an accident victim before regular medical treatment is obtained.

#### **Personal Protective Equipment (PPE)**

the term 'personal protective equipment' (PPE) refers to a vast group of products (e.g. safety helmets, safety footwear and harnesses, eye protection, gloves, high-visibility clothing, etc.) designed with the aim to protect users against low-, medium- and high-level hazards. This group of products is regulated by the **European Directive (EU) 2016/425**

#### **Safety**

This is the behaviour undertaken to prevent injury to people and damage to machines and equipment.

#### **Electric shock**

This is the passage of electricity in the human body

#### **The Occupational Health and Safety Act (OSHA)**

The act provides for the health, safety and welfare of persons employed, and all persons lawfully present at workplaces and related matters. It is obligatory for an occupier to provide and maintain plant and systems and procedures of work that are safe and without risk to workers' health. Employer must ensure safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances. Provision of such information, instruction, training and supervision of workers as is necessary is very crucial maintain safe and healthy workplace.

Workplace and work environment that is safe, without health risks and adequate as regards facilities and arrangements for the worker's welfare at work should be maintained. Workers should be well informed of any risks and imminent danger related to new technologies and they should participate in the application and review of safety and health measures.

Occupier must also ensure proper cleanliness, ventilation, lighting, drainage of floor, sanitary convenience, avoid overcrowding and control air pollution, noise and vibration at the workplace. Every occupier is required to establish a safety and health committee at the workplace in accordance with regulations prescribed under the law.

Preventive and protective measures should be taken after proper risk assessment (at least once a year) to ensure that all chemicals, machinery, equipment, tools and process are safe and without risk to health and comply with the requirements of safety and health provisions in this Act. An occupier who fails to comply with a duty imposed on him commits an offence and he/she is liable to a fine not exceeding 500,000 shillings or to imprisonment up to six months or to both.

All the above provisions are applicable also to the mine workers, as enunciated under the Mines Act 2016.

### **Free Protection**

In accordance with the Occupational Safety and Health Act 2007, it is the responsibility of employer to provide free protective equipment including clothing and appliances, and where necessary, suitable gloves, footwear, goggles and head coverings to the workers involved in hazardous work. The type of PPE needed varies depending on the nature of work being performed. The right use of PPE reduces risk of accident and illness and helps in creation of safer working environment.

Safety consultant, registered by the Director, assesses the suitability and effectiveness of protective clothes and appliances.

### **Training**

In accordance with the Occupational Safety and Health Act 2007, it is the responsibility of an employer to provide instruction, training and supervision as is necessary to ensure health and safety at work of his workers.

Employment of worker at any machine or in any process that may cause ill health or bodily injury is prohibited unless worker has been fully instructed about the hazards involved and precautions that must be observed. Worker should be properly trained or required to work under supervision of experienced persons.

The training is carried out on recruitment; transfer or change of job; introduction of new work equipment or materials or change in equipment or materials; and introduction of new technology. The training must be arranged regularly at workplace during working hours and adapted accordingly with the new and changed risks.

Employer must ensure that all the persons involved in work must receive appropriate instructions regarding safety and health risks including emergency procedures during their activities at the workplace and actions to be taken in case of an emergency.

If a person fails to comply with these provisions, he/she commits an offence and is liable to a fine up to 200,000 shillings or to imprisonment up to six months or to both.

### **Labour inspection system**

Labour inspection system is present in Kenya. Occupational Safety and Health Act provides for a vibrant Labour inspection system (part IV).

The Occupational Safety, Health and Injury Benefits Authority (OSHIBA) is responsible for the implementation of occupational health and safety, for improving and ensuring health, safety, security and good working conditions at the enterprises, inspecting enterprises and ensuring the law enforcement.

The national legislation provides inspectors the power to enter, inspect and examine the work premises at any time during day or night with or without prior notice; take measurements, photographs, samples and make recordings for the purpose of examination and investigation; ask for registers, documents, certificates and notices to inspect, examine and copy them; interview any one; if the inspector is a



medical practitioner he/she may carry out medical examinations; and may take police officer along with him/her if necessary.

If an occupier or his representatives do not facilitate the inspector and obstruct the execution of his duties, he/she commits an offence and is liable to a fine up to 100,000 shillings or to imprisonment up to six months or to both.

Labour inspectors are authorized to conduct proceedings arising under this Act; to obtain samples of any substance used or intended to be used at workplace; to deal with the cause of imminent danger by seizing it or causing it to be rendered harmless; and issue notices (improvement or prohibition). Inspector must not disclose any information obtained during the course of his/her duty, otherwise he/she is liable (Work Injury Benefits Act, 2007) to a fine up to 100,000 shillings.

### **Work injury benefits act (WIBA)**

Work Injury Benefits Act, 2007 (WIBA, 2007) is subordinate to The Constitution of Kenya, 2010. Enacted in 2007, WIBA, 2007 is still effective by virtue of section 7 of the 6<sup>th</sup> Schedule of the Constitution.

Article 41 of the Constitution gives right to every individual to entitlement of reasonable working conditions.

One of the work conditions is compensation of injuries sustained at work by workers.

WIBA, 2007 provides for compensation of injuries sustained at work.

A number of sections in WIBA, 2007 were however nullified by high court in petition No. 185 of 2008 by LSK and to this date the sections remain unconstitutional. The sections include: -

- 4, 7(1) and (4), 10(4), 16, 23(1), 25(1) and (3), 52(1) and (2), 58(2)

### **Work injury benefits act, 2007**

This Act is applicable to all employees except the armed forces (the army, air force and navy).

For the purpose of the Act, the following persons are not regarded as employees: -

- Casual employee not employed for the employer's trade or business.
- An employee deployed outside Kenya for a continuous period of 12 or more months.
- A dependent – Any person who at the time of the accident is dependent upon the employee for necessities of life.

### **Employer's obligations**

- Register with the Directorate of Occupational Safety and Health Services
- Repair, maintain and replace when necessary appliances for use of victim due to the condition inflicted by the accident
- Furnish the Director with particulars of the business.
- Keep a register for at least 6 years of earning and other employee records and produce it to the Director when required.

- Send notice of occurrence of an accident to the Director
- Convey the accident victim to and from hospital
- Provide first aid to the injured person
- Defray any expenses reasonably incurred by an employee as the result of an accident arising out of and in the course of employment
- Pay compensation to an employee injured while at work.
- Pay reasonable funeral expenses of a deceased employee.

### **Right of compensation**

- An employee who is involved in an accident resulting in disablement or death is subject and entitled to compensation.
- An employee on his/her way to/from place of work by means of transport provided by the employer is entitled to compensation if injured in the process.
- An employee temporarily deployed outside Kenya for a period of 12 or less months and injured during that deployment has right of compensation.
- An employee injured while undertaking training for performance of emergency services

### **Not eligible for compensation**

- Misconduct and if the accident is not serious.

NB. An accident is deemed serious if the degree of disablement is 40% or more.

- An employee who willingly presents false information about the injury is not entitled to compensation
- An employee whose disablement or death was caused or prolonged by deliberate refusal or willful neglect of employee to submit to medical aid.
- If an accident is not reported within 12 months, then the benefits are lost.

### **Reporting of Accidents**

- To the employer by the employee or on behalf of the employee immediately upon occurrence of the accident.
- To the Director by the employer
  - i. Within 24 hours if fatal
  - ii. Within 7 days if non-fatal
- The employee may also report the accident to the Director directly.

### **The director**

- May make inquiry into the occurrence of the accident
- May cause medical examination to be carried out on the claimant
- May require production of medical report by the employer for the purpose of the claim

- May lodge a claim of compensation within 12 months after the date of the accident on behalf of the injured or 12 months after the death of an accident victim if the accident was not reported to the Director.
- May convey the compensation funds to the claimant within 30 days from the date of remittance by employer/insurer.

The injured person just like any other person has a right to fair administrative action pursuant to article 47 of the Constitution.

The Director of Occupational Safety and Health services has a duty of administering WIBA, 2007.

Being a public servant, he is bound by article 232 of the Constitution to uphold values and principles of public service bearing in mind provisions of article 47 in the discharge of duties outlined in WIBA, 2007.

It follows for other public servants e.g. the Director of WIBA, 2007 and implied officers working under the 2 Directors in the Act's spirit.

### **Compensation**

An accident disabling a worker for 3 or more days should be compensated with periodical payment equivalent to employees' earnings but not for a period of exceeding 12 months.

Compensation expires upon termination of disablement or if the employee resumes work of greater earnings

Permanent disablement = Monthly salary x percentage of incapacity x 96 months

Percentage of incapacity may be determined by the doctor attending to the injured.

Earning in respect of temporary incapacity will be equivalent to the periodical earnings while away if the accident victim was not paid while away.

### **Occupational Diseases**

- These are diseases arising from the work conditions where the employee was engaged. On the event of occurrence of an occupational disease, an employee is entitled to compensation whereby the percentage of incapacity is determined by the doctor.

### **Appeals**

- Any person aggrieved by the decision of the Director is to lodge an objection to the Director within 60 days of such decision.
- The Director is to reply within 14 days. If not satisfied by the reply, the objector to appeal to the industrial court.

### **Functions of the Director of WIBA**

- Register employers
- Supervise implementation of WIBA
- Ensure all employers insure their employees
- Receive reports of accidents and carry out investigations
- Ensure compensation of the injured

## **General Penalty**

200,000/= fine or a jail term not exceeding 12 months or both

It is not explicit as to whom delegated prosecutorial powers are vested in WIBA, 2007.

Contravention of provisions of WIBA, 2007 is criminal and their provisions of Criminal Procedure Code Cap. 75 and the Evidence Act Cap.80 come into play during prosecution.

Article 157 of the Constitution establishes the office Director of Public Prosecutions (DPP) in whom powers of prosecution of all criminal cases are vested.

Courts before whom WIBA, 2007 cases are brought have judicial authority as provided for in article 159 The state has a duty to ensure access to justice by any person aggrieved in matters relating to compensation in line the requirement of article 48.

Persons coming within purview of action under the provisions of the WIBA, 2007 have rights as enshrined in articles 49, 50 and 51 of the constitution.

## **In conclusion**

WIBA, 2007 is compliant to the Constitution of Kenya, 2010 by being explicitly in line with the following articles and section of Schedules: - articles 41, 47, 48, 49, 50, 51, 157, 159, 232 and section 7 of the 6<sup>th</sup> Schedule.

## **The IEE wiring regulations BS 7671**

Protection of persons and livestock from shock and burns, etc. and the prevention of damage to property are priorities. In consequence, therefore, thorough inspection and testing of an installation and subsequent remedial work where necessary will significantly reduce the risks. Electric shock is the passage of current through the body of such magnitude as to have significant harmful effects. Figure 1 illustrates the generally accepted effects of current passing through the human body. There are two ways in which we can be at risk:

1. Touching live parts of equipment or systems that are intended to be live.
2. Touching conductive parts which are not meant to be live, but have become live due to a fault.

The conductive parts associated with the second of these can either be metalwork of electrical equipment and accessories (Class I) and that of electrical wiring systems such as metallic conduit and trunking, etc. called exposed conductive parts, or other metalwork such as pipes, radiators, girders, etc. called extraneous conductive parts.

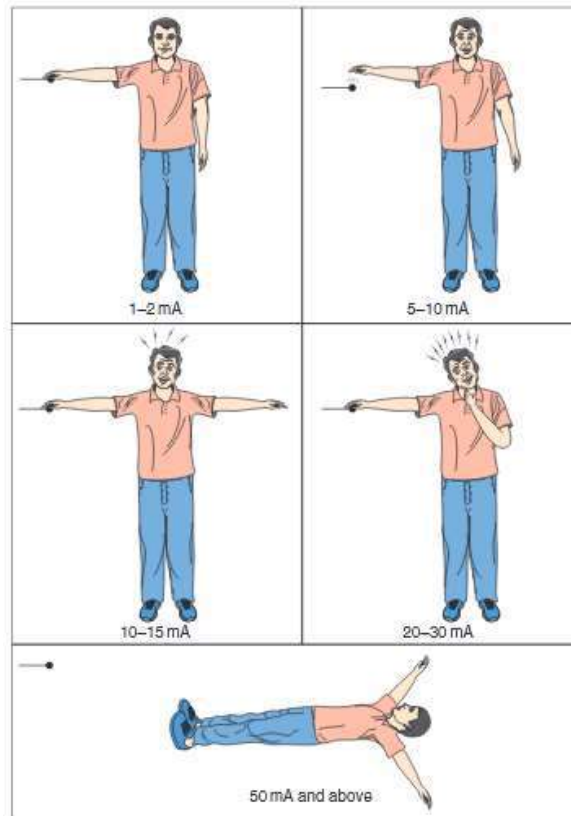


Figure 227 Shock levels

Shock levels.

|                 |  |
|-----------------|--|
| 1 mA – 2 mA     | Barely perceptible, no harmful effects |
| 5 mA – 10 mA    | Throw off, painful sensation           |
| 10 mA – 15 mA   | Muscular contraction, can't let go     |
| 20 mA – 30 mA   | Impaired breathing                     |
| 50 mA and above | Ventricular fibrillation and death     |

### Protection against shock from both types of contact

One method of achieving this is by ensuring that the system voltage does not exceed extra low (50 V ac, 120 V ripple-free dc), and that all associated wiring, etc. is separated from all other circuits of a higher voltage and Earth. Such a system is known as a separated extra low voltage (SELV). If an SELV system exceeds 25 V ac, 60 V ripple-free dc, then extra protection must be provided by barriers, enclosures and insulation.

### Basic protection

Apart from SELV, we can minimize the risk of such contact, and this may be achieved in one or more of the following ways:

1. Insulate any live parts.
2. Ensure that any uninsulated live parts are housed in suitable enclosures and/or are behind barriers.
3. Place obstacles in the way. (This method would only be used in areas where skilled and/or authorized persons were involved.)

4. Placing live parts out of reach. (Once again, only used in special circumstances, e.g. live rail.)

A residual current device (RCD) may be used as additional protection to any of the other measures taken, provided that it is rated at 30 mA or less and has an operating time of not more than 40 ms at a test current of five times its operating current. It should be noted that RCDs are not the panacea for all electrical ills, they can malfunction, but they are a valid and effective back-up to the other methods. They must not be used as the sole means of protection.

### **Fault protection**

Protection against shock from contact with unintentionally live, exposed or extraneous conductive parts whilst touching earth, or from contact between unintentionally live exposed and/or extraneous conductive parts can be achieved by using protective earthing, protective equipotential bonding and automatic disconnection in case of a fault. All extraneous conductive parts are connected with a main protective bonding conductor and connected to the main earthing terminal, and all exposed conductive parts are connected to the main earthing terminal by the circuit protective conductors (CPC). Add to this over-current protection that will operate fast enough when a fault occurs and the risk of severe electric shock is significantly reduced. Other means of fault protection may be used, but are less common and some require very strict supervision

### **Use of class ii equipment**

Often referred to as double-insulated equipment, this is typical of modern appliances where there is no provision for the connection of a CPC. This does not mean that there should be no exposed conductive parts and that the casing of equipment should be of an insulating material; it simply indicates that live parts are so well insulated that faults from live to conductive parts cannot occur.

### **Non-conducting location**

This is basically an area in which the floor, walls and ceiling are all insulated. Within such an area there must be no protective conductors, and socket outlets will have no earthing connections. It must not be possible simultaneously to touch two exposed conductive parts, or an exposed conductive part and an extraneous conductive part. This requirement clearly prevents shock current passing through a person in the event of an earth fault, and the insulated construction prevents shock current passing to earth.

### **Earth-free local equipotential bonding**

This is in essence a Faraday cage, where all metal is bonded together but not to earth. Obviously, great care must be taken when entering such a zone in order to avoid differences in potential between inside and outside. The areas mentioned in this and the previous method are very uncommon. Where they do exist, they should be under constant supervision to ensure that no additions or alterations can lessen the protection intended

### **Electrical separation**

This method relies on a supply from a safety source such as an isolating transformer to BS EN 61558-2-6 which has no earth connection on the secondary side. In the event of a circuit that is supplied from a source

developing a live fault to an exposed conductive part, there would be no path for shock current to flow (see Figure 2). Once again, great care must be taken to maintain the integrity of this type of system, as an inadvertent connection to earth, or interconnection with other circuits, would render the protection useless. Additional protection by RCDs is a useful back-up to other methods of shock protection. The use of enclosures is not limited to protection against shock from contact with live parts, they clearly provide protection against the ingress of foreign bodies and moisture. In order to establish to what degree an enclosure can resist such ingress, reference to the Index of Protection (IP) code (BS EN 60529) should be made. Table 0.1 illustrates part of the IP code. The most commonly quoted IP codes in the 17th edition are IPXXB or IP2X, and IPXXD or IP4X. The X denotes that protection is not specified, not that there is no protection. For example, an enclosure that was to be immersed in water would be classified IPX8, there would be no point using the code IP68.

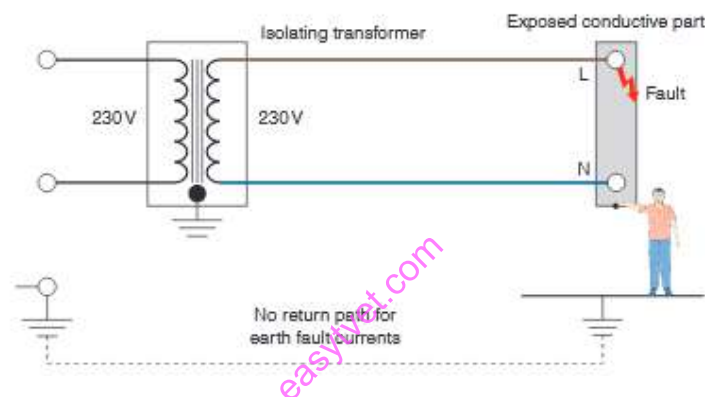


Figure 228 Current flow when not earth

### Environmental management and coordination (amendment) act, 2015

The Environmental Management and Coordination Act, 1999, was amended to comply with the Constitution and integrate emerging environmental issues. The Environmental Management and Coordination (Amendment) Act (EMCA) provides the framework law for environmental conservation, management and coordination. Through EMCA, the government has attempted to harmonize policy regulations for the management of natural resources in Kenya. The EMCA provides for the protection of forests and Environmental Impact Assessment (EIA) of forestry related developments. The institutions formed under EMCA are:

- National Environment Management Authority,
- National Environmental Complaints Committee,
- National Environment Tribunal,
- National Environment Action Plan Committees and;

- County Environment Committees.

The National Environment Management Authority (NEMA) was established as the lead agency of government charged with the implementation of all policies relating to the environment, and to exercise general supervision and coordination over all matters relating to the environment. In consultation with lead agencies, like KFS, NEMA is empowered to develop regulations, prescribe measures and standards and, issue guidelines for the management and conservation of natural resources and the environment.

### **Provisions of the Act relevant to forestry a) Environmental Protection**

The right to a clean and healthy environment was first acknowledged in the EMCA, 1999. This right has now been elevated to constitutional status. The EMCA provides for environmental protection through; Environmental Impact Assessments, Strategic Environmental Assessments, Environmental Audits and monitoring as well as environmental restoration orders, conservation orders, and easements. The Act is based on principles such as: the precautionary principle, the polluter-pays principle, environmental restoration and compensation to victims of pollution. These principles also apply in the Forest Conservation and Management Act (FCMA, 2016). Section 44 provides that the KFS must consider the aforementioned before granting concessions and mining permits within a forest reserve. Section 28 of EMCA also provides that persons engaged in activities that are most likely to have adverse environmental effects must pay deposit bonds equivalent to the cost of environmental restoration. This is the Environmental Protection Bond in the FCMA, 2016. The Amendment Act is also based on principles of sustainable development such as public participation, cultural and social principles, the principle of international co-operation in the case of shared environmental resources and the principle of intra-generational and intergenerational equity.

### **Protection of the rights of forest adjacent communities**

Traditional interests of forest adjacent communities are also protected in the EMCA (Section 43). The Act also promotes community conservation of forests.

### **The roles of County governments in environmental management**

The EMCA has included the role of County governments in forest management through formation of a County Environment Committee (CEC) in Section 29. The committee will be in charge of proper management of the environment within the county for which it is appointed, including forestry functions such as provision of extension services to individuals and communities within their jurisdiction.

### **Functions of NEMA related to forestry**

The NEMA, which is the lead implementing agency of EMCA, is mandated to promote the integration of environmental considerations into national development goals, conduct the valuation of natural resources in the country, review land use guidelines in consultation with other lead agencies and make recommendations to the relevant authorities. It is also mandated to promote environmental education, public awareness and public participation in environmental management, encourage incentives for



voluntary environmental conservation practices and work with other lead agencies to issue guidelines and prescribe measures for the attainment of at least 10% tree cover of the land area of Kenya.

### **Registration of forests**

Section 48 of EMCA outlines the procedure regarding registration of forests. NEMA and the Chief Conservator of Forests, following consultations, may enter into contractual arrangements with private owners for the registration of land as forest land.

### **Climate change mitigation and adaptation**

The EMCA expressly provides for climate change mitigation and adaptation. Section 56 states that the Cabinet Secretary, in consultation with relevant lead agencies will issue guidelines and prescribe measures on climate change. The Act also has provisions for the protection of wetlands in Section 42. The Act restricts introduction of alien species to the environment, which coincides with the provisions of the FCMA, 2016.

### **Dispute resolution mechanisms under the Act**

The EMCA gives power to citizens to apply for redress on environmental issues, whether affected directly or indirectly. Specifically, the establishment of the National Environmental Complaints Committee in Section 31 and the National Environment Tribunal in Article 125 to address environmental grievances. The Land and Environment Court formed under the Environment and Land Act, 2011 will also be charged with handling appeals of environmental grievances as well as forest-based conflicts. These institutions were established to provide the link between environmental management and the judiciary.

### **Forest conservation and management**

Section 124A of the Act provides for the development of legislation by NEMA and lead institutions. In collaboration with KFS, NEMA will develop, issue and implement regulations, procedures, guidelines and measures for the sustainable use of forests, to control harvesting, protect water catchment areas, prevent soil erosion and regulate human settlement. Article 46 of the Act requires that every County Environment Committee (CEC) should identify areas for afforestation and reforestation as well as encourage community members to plant trees. Article 49 (d) of EMCA also provides for the promotion of renewable energy through planting of trees and woodlots by individual, communities and institutions.

### **Conservation of biodiversity**

Sections 50 and 51 of the Act provides for the conservation of biological diversity. The Act requires NEMA to prepare an inventory on biological diversity and specific conservation measures, including *in situ* and *ex situ* conservation, identifying endangered, rare or threatened species, identifying potential threats to biodiversity, prohibiting and controlling the introduction of alien species into natural habitats and protection of indigenous knowledge among others. Section 8 of the FCMA, 2016 has a similar provision. The EMCA also provides for the protection of genetic resources and environmentally significant areas (Section 53 and 54).

## **The IEE Wiring Regulations 17th edition requirements for electrical installations**

The Institution of Electrical Engineers Requirements for Electrical Installations (the IEE Regulations) are non-statutory regulations. They relate principally to the design, selection, erection, inspection and testing of electrical installations, whether permanent or temporary, in and about buildings generally and to agricultural and horticultural premises, construction sites and caravans and their sites. Paragraph 7 of the introduction to the EWR says: ‘the IEE Wiring Regulations is a code of practice which is widely recognized and accepted in Kenya and compliance with them is likely to achieve compliance with all relevant aspects of the Electricity at Work Regulations’. The IEE Wiring Regulations are the National Standard in Kenya and apply to installations. However, they do not apply to electrical installations in mines and quarries, where special regulations apply because of the adverse conditions experienced there.

The current edition of the IEE Wiring Regulations is the 17th edition 2008. The main reason for incorporating the IEE Wiring Regulations into British Standard BS 7671: 2008 was to create harmonization with world Standards.

The IEE Regulations take account of the technical intent of the CENELEC world, which in turn are based on the IEC International Standards.

The purpose in harmonizing Standards is to help develop a single market economy so that there are no trade barriers to electrical goods and services across the world Economic Area.

To assist electricians in their understanding of the Regulations a number of guidance notes have been published. The guidance notes which I will frequently make reference to in this book are those contained in the *On-Site Guide*. Eight other guidance notes booklets are also currently available. These are:

- *Selection and Erection*
- *Isolation and Switching*
- *Inspection and Testing*
- *Protection against Fire*
- *Protection against Electric Shock*
- *Protection against Overcurrent*
- *Special Locations*
- *Earthing and Bonding*

These guidance notes are intended to be read in conjunction with the Regulations.

The IEE Wiring Regulations are the electrician’s bible and provide the authoritative framework of information for anyone working in the electrotechnical industry.

## **Common causes of workplace accidents**

### **1. Lifting**

It is so easy to injure yourself while lifting heavy objects. Eliminate back injuries and muscle strains by ensuring that everyone practices safe lifting procedures. It's always best to recruit a helping hand or to use machinery to move large objects.

### **2. Lighting**

Poor lighting can be a major cause of trips, falls, and other workplace injuries. If you can't see the hazards, they're much more likely to become serious problems. Every area in the workplace should be well lit, including offices, warehouses, parking areas, and outside entryways.

### **3. Violence**

Hundreds of people die each year from workplace violence. Employees in conflict with one another tend to be especially unsafe when working together. OSHA has guidelines for violence prevention if you need help resolving these issues in your workplace.

### **4. Trips/Falls**

Consistently one of the leading causes of workplace injuries, trips and falls continue to be a major problem. Slippery floors, improper footwear, rushing employees, and weather conditions all contribute to trip and fall hazards. Make sure all employees are well trained on the relevant safety information and verify that the physical conditions in the workplace are up to standards to lower the number of injuries in this category.

### **5. Stress**

Physical and mental stress are less commonly recognized workplace hazards, but they can cause serious or even fatal accidents. Employees must be in the right mindset and physically sound for the job. Communicate the importance of mental and physical health to all employees. It's important to take breaks and seek help with managing stressful situations.

### **6. Fatigue**

As mentioned before, it is imperative that employees show up to work physically prepared. A lack of adequate sleep can cause exhaustion, inattention, and accidents. Even a well-rested employee can grow fatigued while on the job, so it's necessary to take breaks at regular intervals or when needed.

### **7. Shortcuts**

Employees should never take shortcuts on the jobs, especially when dealing with dangerous machinery or circumventing safety procedures. The regulations are in place to protect employees and to make sure everything is done correctly.

### **8. Overconfidence**

Employees should be confident about what they're doing, but overconfidence may diminish carefulness or attention. Overconfident employees are likely to ignore safety precautions and forego double checking their work. It's important for them to understand that accidents can occur any time to anyone, no matter how skilled or experienced.

## 9. Poor Housekeeping

A messy workplace is a dangerous workplace. Objects and debris on the floors pose tripping hazards, wet or dirty floors can cause slips, cluttered surfaces can conceal sharp objects, poorly contained chemicals are an obvious hazard... you get the picture. Besides the dangers, good housekeeping sets a good example for other safety precautions as well.

## 10. Lack of Preparation

No one should ever be on the job without the proper knowledge, training, certifications, tools, or PPE. Preparedness on the job is one of the absolute best ways for employees to stay safe.

## 11. Mental Distractions

It's easier said than done, but employees must try to leave personal matters at the door. Being distracted on the job is similar to being fatigued, stressed, or overconfident. Workers simply cannot perform their jobs to their full potential if their mind is elsewhere.

Have you noticed any of these behaviors in your workplace? It may be time to set up some refresher training to reduce the risk of injuries and improve overall performance in your organization. Better safe than sorry, as they say.

## Personal Protective equipment (PPE)

PPE, falling under the scope of the above-mentioned Directive, is intended for use in work and home activities, as well as in leisure and sport events. Such activities can bring harm to the user's body in various ways. To be ensured user's health and safety in any risky situation, a proper type of PPE must be held or worn. In this regard, there are eight types of personal protective equipment critical for the defense of users against hazards.

Many people are injured or killed in electrical accidents due to ignorance or carelessness.

There are various safety/protective wear that needs to be used in a work environment.

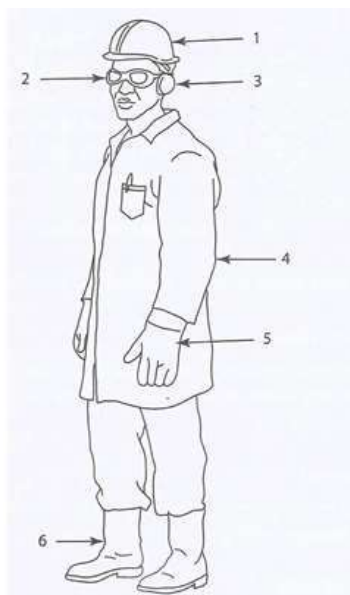


Figure 229 various safety/ protective wears

- Safety helmet-Protects head from falling objects
- Goggles-Protects eyes from flying objects and excessive light
- Ear muffs-Protects ears from excessive sound.
- Dust coat/Overall- Protects personal clothing from dirt
- Hand gloves- Protects hands from injury.
- Safety boots- Protects feet from falling objects.

## **Types of Personal Protective Equipment (PPE)**

### **a. Head protection**

Wearing PPE for head protection will help you avoid any harm that may come to you from falling materials or swinging objects. Moreover, the head protectors are designed to protect you from knocking against stationary objects. Some kinds of head protection equipment (e.g. caps and hair nets) can even protect against entanglement or scalping on machinery.

Examples of head protection equipment:

- Helmets;
- Hard hats;
- Bump Caps;
- Guards;
- Accessories.

Examples of activities where you may need head protection:

- Workplace related: construction or building repair (e.g. renovation, restoration, etc.) and work in tunnels or excavations;
- Leisure/Sport related: driving motorcycles.

### **b. Hand protection**

Arms, hands and fingers are often injured and, therefore, it is vital to wear hand protection equipment when it is required. The hand protection equipment can ensure protection against heat, cold, vibrations, burns, and cuts by sharp objects, bacteriological risks and chemical contamination. Examples of hand protection equipment:

- Work gloves and gauntlets;
- Wrist cuff arm nets.

Activities requiring hand protection equipment:

- construction and outdoor work;
- working with vibrating apparatus;
- working in hot or cold environments;
- working with chemicals and hazardous elements;
- Manual handling of abrasive or sharp objects.

### **c. Eye and face protection**

Numbers are scary! Every day, 600+ workers worldwide suffer from eye injuries. Such injuries can be avoided simply by wearing the proper eye and face protection equipment. As examples of such PPE can be mentioned the following ones:

- Safety glasses and goggles;
- Eye and face shields;
- Eyewear accessories;
- Over specs;
- Visors.

You are encouraged and advised to wear eye and face protection equipment when:

- working with lasers or power-driven tools;
- using gas or vapour under pressure;
- performing welding operations;
- Handling hazardous substances.

### **d. Respiratory protection**

The respiratory protection covers a broad group of PPEs: breathing apparatus, full face or half mask respirators, powered respirators, protective hoods, disposal face masks, detectors, monitors, etc. Adequate training on how users should use the equipment is always required.

This type of PPE must be present when being in contact with large amounts of gases, powders, dust and vapours.

### **e. Hearing protection**

The hearing protection equipment is vital when working in an environment with high-sound levels. The type of hearing protection should not only be suitable for the working environment but also provide a level of hygiene and comfort to the users. A good practice is to provide employees with a range of protectors and then allow them to select the ones which suit them the best.

Examples of hearing protection equipment:

- Earplugs and defenders;
- Noise meters;
- Communications sets;
- Acoustic foam.

### **f. Foot protection**

The foot protection equipment is designed to protect the feet and legs against various hazards, such as extreme temperatures, crushing, piercing, slipping, cutting, chemicals and electricity. It is typically required when users are involved in construction activities, working in very cold or hot environments, working with chemicals and forestry, or when manually handling heavy objects.

As examples of foot protection equipment can be pointed out the following ones:

- Safety boots and shoes;
- Anti-static and conductive footwear.

#### **g. Body protection**

Usually, body protection equipment is required in the following cases:

- For protection against weather conditions when working outdoors;
- Ensuring the high-visibility of users when they work in areas where there is a mixed vehicle (e.g. bikes, motors, cars and busses) and pedestrian traffic;
- For users' protection against extreme temperatures;
- Ensuring protection against entanglement, drowning, chemical contamination, etc.

Examples of body protection equipment:

- Life jackets;
- Clothing for specific weather conditions;
- High-visibility clothing;
- Harnesses, and others.

#### **h. Height and access protection**

This type is highly specialized, and it usually requires users to undergo thorough training before they are allowed to use it. The height and access protection equipment must be inspected periodically by a competent person to ensure it is still fit for use and the health and safety of users is not threatened in any way.

As examples of height and access protection equipment can be mentioned the following ones:

- Fall-arrest systems;
- Body harnesses;
- Lowering harnesses;
- Rescue lifting;
- Energy absorbers, and others

### **Types of Fires**

#### **I. Class A**

Class A fires are fires in ordinary combustibles such as wood, paper, cloth, rubber, and many plastics

#### **II. Class B**

Class B fires are fires in flammable liquids such as gasoline, petroleum greases, tars, oils, oil-based paints, solvents, alcohols. Class B fires also include flammable gases such as propane and butane. Class B fires do not include fires involving cooking oils and grease

#### **III. Class C**

Class C fires are fires involving energized electrical equipment such as computers, servers, motors, transformers, and appliances. Remove the power and the Class C fire becomes one of the other classes of fire.

#### **IV. Class D**

Class D fires are fires in combustible metals such as magnesium, titanium, zirconium, sodium, lithium, and potassium.

#### **V. Class K**

Class K fires are fires in cooking oils and greases such as animal and vegetable fats.

### **Types of Fire Extinguishers**

#### **I. Water and Foam**

Water and Foam fire extinguishers extinguish the fire by taking away the heat element of the fire triangle. Foam agents also separate the oxygen element from the other elements. Water extinguishers are for Class A fires only - they should not be used on Class B or C fires. The discharge stream could spread the flammable liquid in a Class B fire or could create a shock hazard on a Class C fire.

#### **II. Carbon Dioxide**

Carbon Dioxide fire extinguishers extinguish fire by taking away the oxygen element of the fire triangle and also be removing the heat with a very cold discharge. Carbon dioxide can be used on Class B & C fires. They are usually ineffective on Class A fires.

#### **III. Dry Chemical**

Dry Chemical fire extinguishers extinguish the fire primarily by interrupting the chemical reaction of the fire triangle.

Today's most widely used type of fire extinguisher is the multipurpose dry chemical that is effective on Class A, B, and C fires. This agent also works by creating a barrier between the oxygen element and the fuel element on Class A fires. Ordinary dry chemical is for Class B & C fires only. It is important to use the correct extinguisher for the type of fuel! Using the incorrect agent can allow the fire to re-ignite after apparently being extinguished successfully.

#### **IV. Wet Chemical**

Wet Chemical is a new agent that extinguishes the fire by removing the heat of the fire triangle and prevents re-ignition by creating a barrier between the oxygen and fuel elements. Wet chemical of Class K extinguishers was developed for modern, high efficiency deep fat fryers in commercial cooking operations. Some may also be used on Class A fires in commercial kitchens.

#### **V. Clean Agent**

Halogenated or Clean Agent extinguishers include the halon agents as well as the newer and less ozone depleting halocarbon agents. They extinguish the fire by interrupting the chemical reaction and/or removing heat from the fire triangle.

Clean agent extinguishers are effective on Class A, B and C fires. Smaller sized handheld extinguishers are not large enough to obtain a 1A rating and may carry only a Class B and C rating.

#### **VI. Dry Powder**



**Dry Powder** extinguishers are similar to dry chemical except that they extinguish the fire by separating the **fuel** from the **oxygen** element or by removing the **heat** element of the fire triangle. However, dry powder extinguishers are for Class D or combustible metal fires, only. They are ineffective on all other classes of fires.

### VII. Cartridge Operated Dry Chemical

**Cartridge Operated Dry Chemical** fire extinguishers extinguish the fire primarily by interrupting the **chemical reaction** of the fire triangle. Like the stored pressure dry chemical extinguishers, the multipurpose dry chemical is effective on Class A, B, and C fires. This agent also works by creating a barrier between the oxygen element and the fuel element on Class A fires.

Ordinary dry chemical is for Class B & C fires only. It is important to use the correct extinguisher for the type of fuel! Using the incorrect agent can allow the fire to re-ignite after apparently being extinguished successfully.

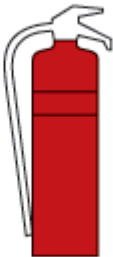


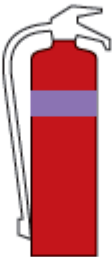
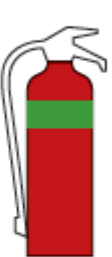
| Type of fire extinguisher       | (i)   | (ii)  | (iii)   | (iv)   | (v)  |
|---------------------------------|---|---|---|--|--|
|                                 | Water   | Foam  | Carbon dioxide gas  | Dry powder   | Vapourizing foam   |
| Type of fire                    | <br>Signal red flash on red | <br>Pale cream flash on red | <br>Black flash on red | <br>French blue flash on red | <br>Emerald green flash on red |
| Class A. Paper, wood and fabric | ✓ Yes   | ✓ Yes   | ✗ No  | ✓ Yes  | ✓ Yes  |
| Class B. Flammable liquids      | ✗ No  | ✓ Yes   | ✓ Yes   | ✓ Yes  | ✓ Yes  |
| Class C. Flammable gases        | ✗ No  | ✗ No  | ✓ Yes   | ✓ Yes  | ✓ Yes  |
| Electrical fires                | ✗ No  | ✗ No  | ✓ Yes   | ✓ Yes  | ✓ Yes  |
| Motor vehicle protection        | ✗ No  | ✓ Yes   | ✗ No  | ✓ Yes  | ✓ Yes  |

Figure 230 Fire extinguishers and their applications (colour codes to BSEN3:1996)

## Rescuing electric shock victim

When a person gets into contact with a live wire and gets an electric shock, the following steps should be followed to save the victim:

1. Switch off the current if possible if not do not waste
2. Secure release from contact. Safeguard yourself when removing the casualty from the contact. Use a dry insulator to remove the victim from electrical contact e.g. rubber, mat gloves, a length of dry rope or a length of dry wood to pull or push the casualty away from the contact
3. Start respiratory resuscitation once the casualty is not breathing. Use the method known best. Continue until casualty is breathing satisfactorily.
4. Send for a doctor and ambulance immediately.

### Methods of resuscitation

#### I. Kiss of life

The procedure for this method of artificial respiration is as follows.

- Place a support below the neck and loosen the clothing.
- Clear all air passages.
- Pinch the nose and breathe into victim's mouth until the chest rises.
- Release the nose and let the air rush out.
- Continue with this process until the victim breathes normally.
- Take the victim to hospital for further medical check-up.

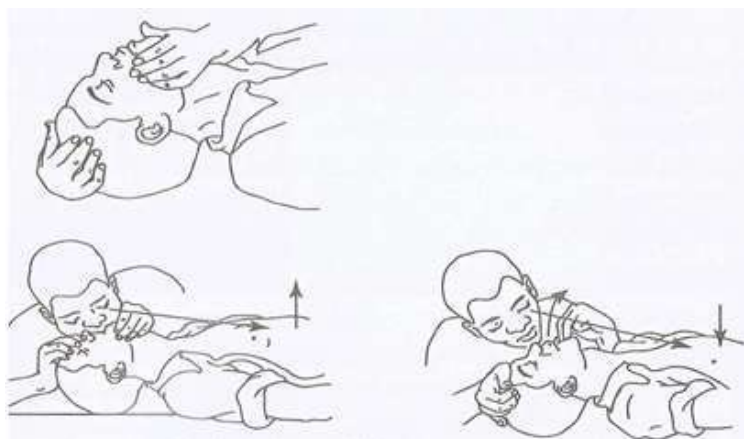


Figure 231 Kiss of life method

#### II. Holger-Nielsen method of artificial respiration

- Lay the casualty in a prone position on a flat surface.
- Place the casualty's hands one over the other under his forehead
- The hand must be turned slightly on one side.
- Nose and mouth must be unobstructed.

- Place one knee with its inner side in line with the casualty's cheek, a few inches from the top of his head.
- Place the other foot with the heel in line with the casualty's elbow.
- Place your hands on the casualty's back on the lower part of the shoulders back, fingers pointing at casualty's feet.
- Keeping the arms straight, rock forward gently until arms are vertical. The movement takes seconds counting ONE, TWO. This pressure causes **expiration**
- Then rock back counting, THREE for one second, and slide your hand past the casualty's shoulder until you can grab his upper arms near the elbows.
- Rise and pull the arms until tension is felt for two seconds counting FOUR, FIVE. Do not raise chest from ground. This movement causes **inspiration**.
- Your hands should remain straight, count SIX for one second.



*Figure 232 Holger- Nielsen method*

### III. Revised Silvester Method

Place the victim on his back. First loosen his clothes around the chest and stomach. Remove false teeth, if any and put a pillow under the shoulders, so that his chest will be rise up and head will titled backward. The tongue should be drawn forward. The rescuer must stand beside the victim in the position shown in fig 7 Grasp the victim just below the elbows. Draw his arm over his head until horizontal, retaining them for two seconds. Next, bring the victim's arms down on each side of his chest and pressing inwards upon it. Leaning upon his arm so as to compress his chest. Remain in his position for two seconds and then again keep repeating the two motions at the same rate. If one more person is present, he should be asked to draw out victims tongue at each action of the victim's lungs inflating and deflating. Be careful in this method to avoid any injury to internal organs resulting from excessive and sudden pressures. Do not give anything to drink to a victim until he is conscious.

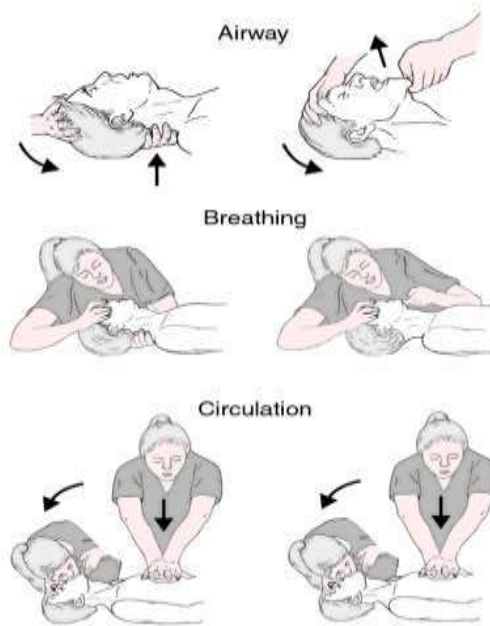


Figure 233 Revised Sylvester method

#### IV. Schafer's Method

The subject is laid in prone position and a small pillow is placed underneath the chest and epigastrium. The head is turned to one side. The operator kneels down by the side of the subject facing towards his head. Two hands are placed on the two sides of the lower part of the chest and then the operator slowly puts his body weight leaning forwards and pressing upon the loins of the subject. Intra-abdominal pressure rises, the diaphragm is pushed up and air is forced out of the lungs.

After this the operator releases the pressure and comes back to his original erect position. The abdominal pressure falls, diaphragm descends and air is drawn in. These movements are repeated about twelve times a minute (roughly the normal rate of respiration).

By this means it is possible to have a total pulmonary ventilation of 6,500 ml per minute, and this amount is sufficient for complete aeration of blood. The advantage of this method is that the patient being in the prone position, mucus or saliva comes out of the mouth and cannot obstruct his airways.



Figure 234 Schafer's method of artificial respiration

### 6.2.1.4 Learning Activities

#### Project/workshop

| Practical activity   | Knowledge   | Special instruction |
|--|---|---------------------|
| 1. Demonstrate the knowledge on safety regulations in the workshop   | <ul style="list-style-type: none"><li>• Relevant safety regulations</li></ul>   |                     |
| 2. Demonstrate knowledge of OSHA standards in the workshop   | <ul style="list-style-type: none"><li>• OSHA, WIBA, EMCA</li></ul>  |                     |
| 3. Demonstrate good housekeeping practices in the workshop.  | <ul style="list-style-type: none"><li>• Housekeeping elements</li></ul>   |                     |
| 4. Demonstrate how to write reports on accidents, incidents and near misses  | <ul style="list-style-type: none"><li>• Causes of accidents</li></ul>   |                     |
| 5. Demonstrate the first aid procedures and methods in the field, identify the various PPEs, identify various firefighting equipment | <ul style="list-style-type: none"><li>• Firefighting equipment</li><li>• Methods of resuscitation</li><li>• PPEs types and applications</li></ul> |                     |

### 6.2.1.5 Self-Assessment

1. What is the meaning of the term PPE
2. What are some of the five pieces of PPE which a trainee could be expected to wear at work and the protection given by each piece?
3. What are some causes of accidents
4. What types of fire extinguishers do you know? And how or when are they applied?
5. Which two methods of artificial resuscitation do you know?

### 6.2.1.6 Tools, Equipment, Supplies and Materials

#### Recommended Resources

|   |  |
|---|--|
| <p><b>Tools and equipment</b></p> <ul style="list-style-type: none"><li>➤ Cable Strippers</li><li>➤ Pliers</li><li>➤ Screw drivers</li><li>➤ Hammers</li><li>➤ Chisels</li><li>➤ Allen keys</li><li>➤ Electrician knives</li><li>➤ Crimping tools</li><li>➤ Bending springs</li><li>➤ Bending machine</li><li>➤ Steel tapes</li><li>➤ Draw wires</li><li>➤ Hack saws</li><li>➤ Drilling tools</li><li>➤ Stock and die</li><li>➤ Bench vice</li><li>➤ Machine vice</li><li>➤ PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li></ul> | <p><b>Materials and supplies</b></p> <ul style="list-style-type: none"><li>• Stationery</li><li>• Cables</li><li>• Light fittings</li><li>• Accessories</li><li>• Conduits and fittings</li><li>• Cable trays</li><li>• Cable ducts</li><li>• Trunkings</li><li>• Computers</li><li>• Drawing instruments</li><li>• Screws</li></ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"><li>• IEE regulations</li><li>• Occupational safety and health act (OSHA)</li><li>• Work injury benefits act (WIBA)</li><li>• Manufacturers’ catalogues</li><li>• British standards</li><li>• KEBS standards</li></ul>  |  |

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<https://www.shaalaa.com>: [https://www.shaalaa.com/question-bank-solutions/i-draw-a-clear-labelled-diagram-of-an-electric-bell-ii-explain-in-brief-its-working-iii-what-material-is-used-for-the-core-of-an-electric-bell-state-the-reason-concept-transformer\\_125412](https://www.shaalaa.com/question-bank-solutions/i-draw-a-clear-labelled-diagram-of-an-electric-bell-ii-explain-in-brief-its-working-iii-what-material-is-used-for-the-core-of-an-electric-bell-state-the-reason-concept-transformer_125412)
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<https://www.ccohs.ca/oshanswers/hsprograms/cklstgen.html>

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### 6.2.1.8 Model Answers to self-assessment

1. What is the meaning of the term PPE

**the term ‘personal protective equipment’ (PPE) refers to a vast group of products (e.g. safety helmets, safety footwear and harnesses, eye protection, gloves, high-visibility clothing, etc.) designed with the aim to protect users against low-, medium- and high-level hazards. This group of products is regulated by the European Directive (EU) 2016/425**

2. What are some of the five pieces of PPE which a trainee could be expected to wear at work and the protection given by each piece?

- **Safety helmet-Protects head from falling objects**
- **Goggles-Protects eyes from flying objects and excessive light**
- **Ear muffles-Protects ears from excessive sound.**
- **Dust coat/Overall- Protects personal clothing from dirt**
- **Hand gloves- Protects hands from injury.**
- **Safety boots- Protects feet from falling objects.**

3. Causes of accidents

- **Trips/fall**



- **Fatigue**
- **Stress**

4. Types of fire extinguishers

- **Carbon dioxide**
- **Dry chemical**
- **Water and foam**

5. Methods of artificial resuscitation

- **Kiss of life**
- **Holger-Nielsen**
- **Silvester method**
- **Schafer's method**

## 6.2.2. Learning Outcome 2: Prepare working drawings

### 6.2.2.1 Introduction to the learning outcome

To prepare working drawings appropriately, the learner need to interpret installation drawings, apply symbols and nomenclature in accordance with British standards (BS 3939), apply appropriate drawing tools, identify components and their ratings, clearly show cable sizes and lengths, show power supply and distribution circuits using single line diagrams, carry out phase balancing of the loads as per the usage, clearly indicate cable routes and prepare working drawings and share any deviation with the relevant bodies

### 6.2.2.2 Performance Standard

- 6.2.2.2.1 Interpret installation drawing
- 6.2.2.2.2 Apply symbols and nomenclatures in accordance with British standards[BS 3939]
- 6.2.2.2.3 Apply appropriate drawing tools
- 6.2.2.2.4 Identify components and their ratings.
- 6.2.2.2.5 Clearly show cable sizes and lengths
- 6.2.2.2.6 Show power supply and distribution circuits using single line diagrams
- 6.2.2.2.7 Carry out phase balancing of loads as per usage.
- 6.2.2.2.8 Clearly indicate cable routes.
- 6.2.2.2.9 Prepare working drawings and share any deviations with relevant bodies.

### 6.2.2.3 Information Sheet

#### *Working drawings*

It is scale drawing of an object to be made or structure to be built intended for direct use by the workman

## Types of electrical drawings

### 1. Site plans or layout drawings

These are scale drawings based upon the architect's site plan of the building and show the position of the electrical equipment which is to be installed. The electrical equipment is identified by a graphical symbol. The standard symbols used by the electrical contracting industry are those recommended by the British Standard EN 60617, *Graphical Symbols for Electrical Power, Telecommunications and Electronic Diagrams*. Some of the more common electrical installation symbols are given in Fig. 9. The site plan or layout drawing will be drawn to a scale, smaller than the actual size of the building, so to find the actual measurement, you must measure the distance on the drawing and multiply by the scale. For example, if the site plan is drawn to a scale of 1:100, then 10 mm on the site plan represents 1 m measured in the building. The layout drawing or site plan of a small domestic extension is shown in Fig. 10.

|  |  |   |  |
|--|--|---|--|
| Main control or intake point                   |  | Single-pole, one-way switch<br>Note: Number of switches at one point may be indicated |  |
| Main or sub-main switch                        |  | Two-pole, one-way switch  |  |
|  |  | Three-pole, one-way switch  |  |
| Socket outlet (mains) general symbol           |  | Cord-operated single-pole one-way switch  |  |
| Switched socket outlet                         |  | Two-way switch  |  |
| Socket outlet with pilot lamp                  |  | Intermediate switch   |  |
| Multiple socket outlet<br>Example: for 3 plugs |  | Lighting point or lamp: general symbol  |  |
|  |  | Example:<br>Three 40 W lamps  |  |
| Push button                                    |  | Lamp or lighting point: wall mounted  |  |
| Luminous push button                           |  | Emergency (safety) lighting point   |  |
| Electric bell: general symbol                  |  | Lighting point with built in switch   |  |
| Electric buzzer: general symbol                |  | Projector or lamp with reflector  |  |
| Time switch                                    |  | Spotlight   |  |
| Automatic fire detector                        |  | Single fluorescent lamp   |  |

Figure 235 Some BS EN 60617 electrical installation symbols

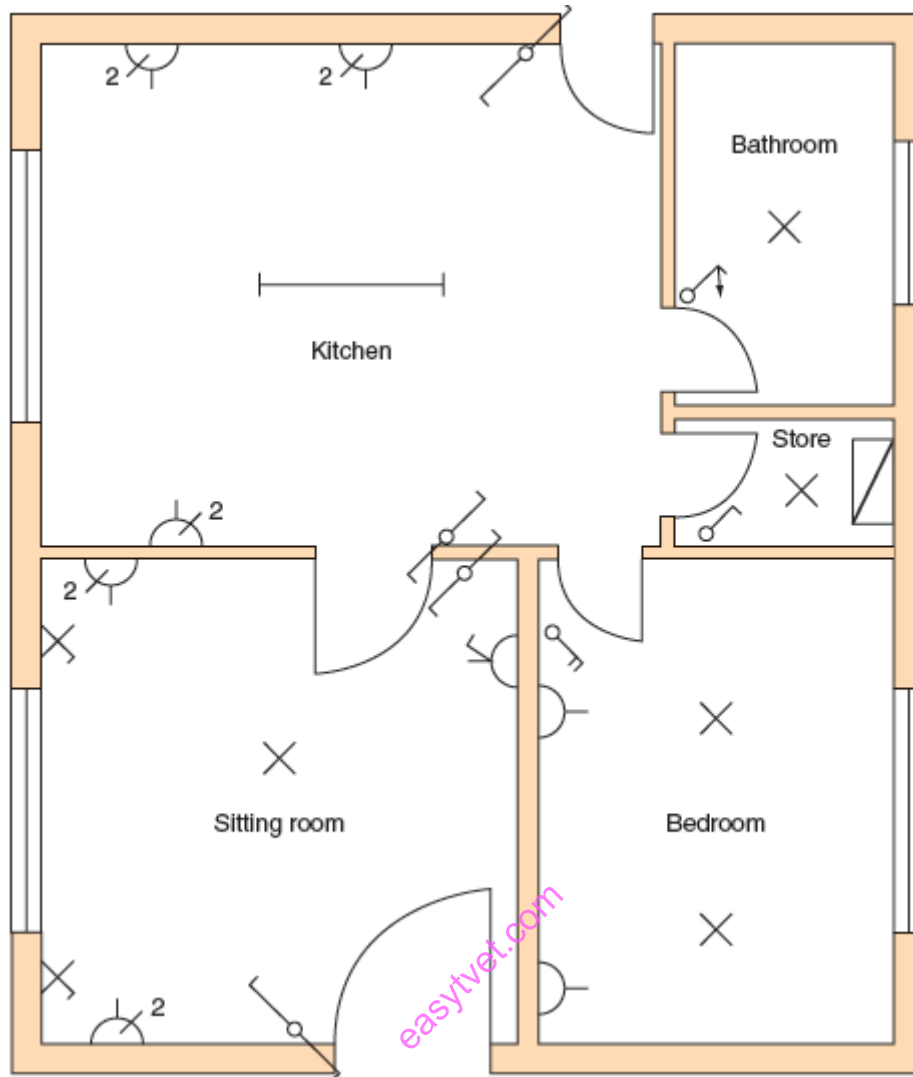


Figure 236 Layout drawing or site plan of a small electrical installation

## 2. As-fitted drawings

When the installation is completed a set of drawings should be produced which indicate the final positions of all the electrical equipment. As the building and electrical installation progresses, it is sometimes necessary to modify the positions of equipment indicated on the layout drawing because, for example, the position of a doorway has been changed. The layout drawings or site plans indicate the original intentions for the position of equipment, while the 'as-fitted' drawing indicates the actual positions of equipment upon completion of the contract.

## 3. Detail drawings and assembly drawings

These are additional drawings produced by the architect to clarify some point of detail. For example, a drawing might be produced to give a fuller description of a suspended ceiling arrangement or the assembly arrangements of the metalwork for the suspended ceiling.

## 4. Location drawings

Location drawings identify the place where something is located. It might be the position of the manhole covers giving access to the drains. It might be the position of all water stop taps or the position of the

emergency lighting fittings. This type of information may be placed on a blank copy of the architect's site plan or on a supplementary drawing.

### 5. Distribution cable route plans

On large installations there may be more than one position for the electrical supplies. Distribution cables may radiate from the site of the electrical mains intake position to other sub-mains positions. The site of the sub-mains and the route taken by the distribution cables may be shown on a blank copy of the architect's site plan or on the electricians 'as-fitted' drawings.

### 6. Block diagrams

A block diagram is a very simple diagram in which the various items or pieces of equipment are represented by a square or rectangular box. The purpose of the block diagram is to show how the components of the circuit relate to each other and, therefore, the individual circuit connections are not shown. Figure 11 shows the block diagram of a space heating control system.

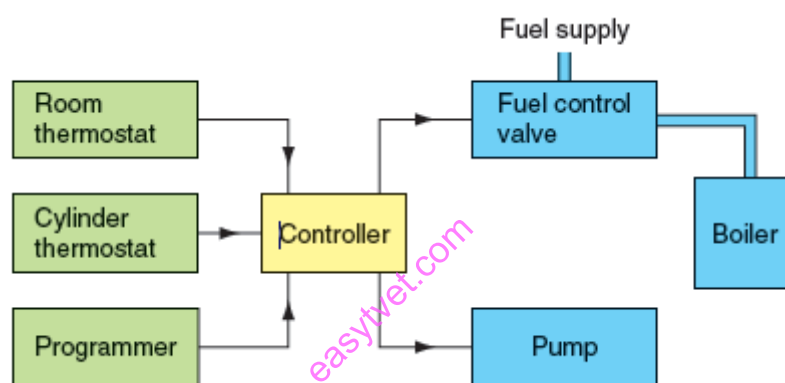


Figure 237 Block diagram of space heating control system

### 7. Wiring diagrams

A wiring diagram or connection diagram shows the detailed connections between components or items of equipment. They do not indicate how a piece of equipment or circuit works. The purpose of a wiring diagram is to help someone with the actual wiring of the circuit. Figure 12 shows the wiring diagram for a space heating control system.

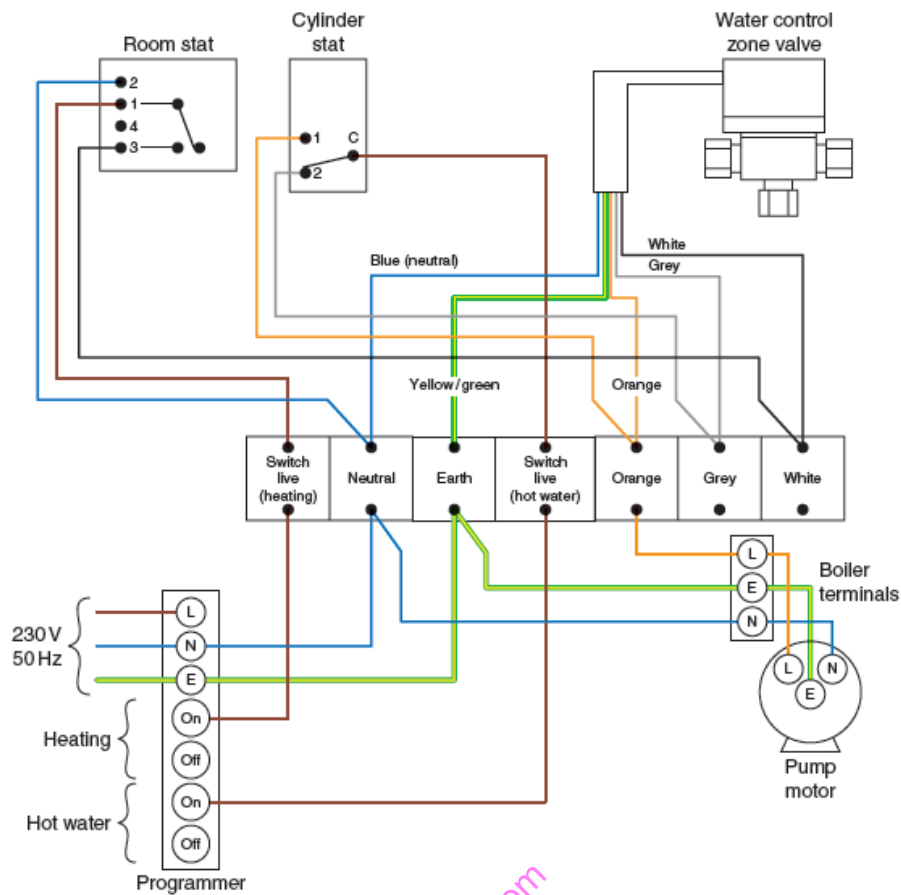


Figure 238 Wiring diagram-space heating control system (Honeywell Y Plan)

## 8. Circuit diagrams

A circuit diagram shows most clearly how a circuit works. All the essential parts and connections are represented by their graphical symbols. The purpose of a circuit diagram is to help our understanding of the circuit. It will be laid out as clearly as possible, without regard to the physical layout of the actual components and, therefore, it may not indicate the most convenient way to wire the circuit. Figure 13 shows the circuit diagram of our same space heating.

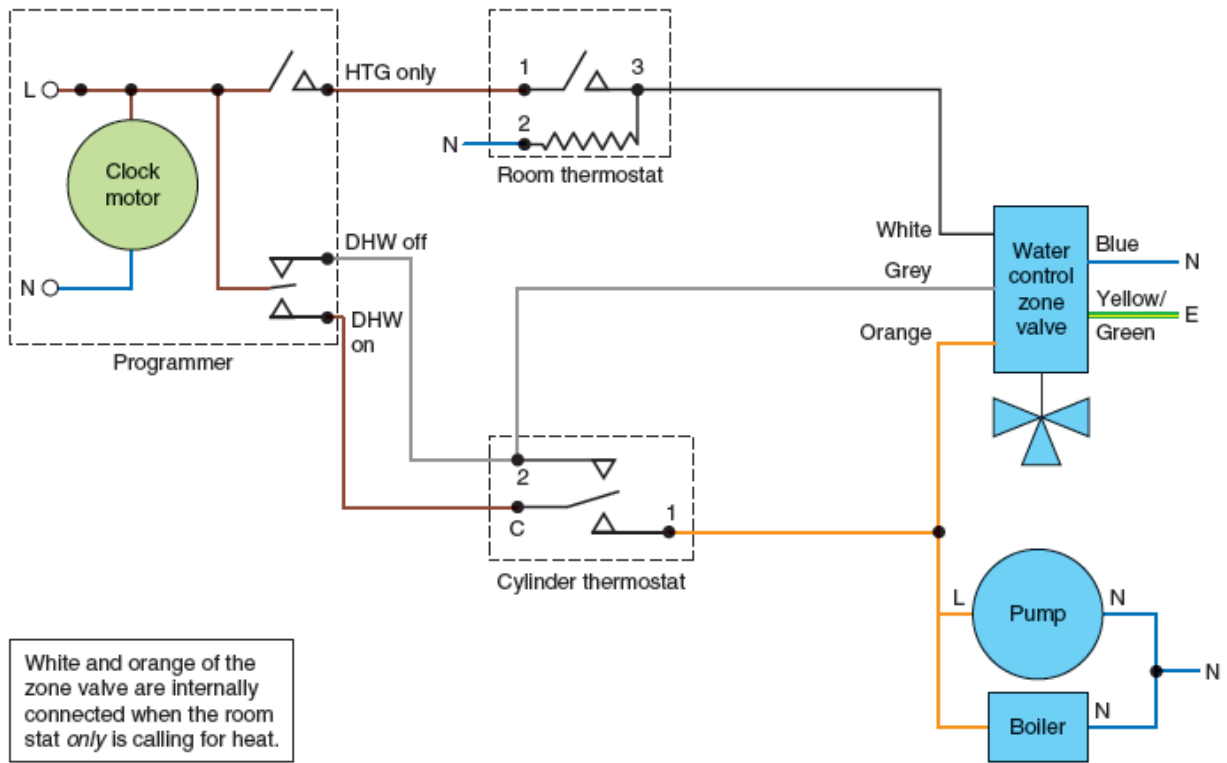


Figure 239 Circuit diagram- space heating control system (Honeywell Y Plan)

## 9. Schematic diagrams

A schematic diagram is a diagram in outline of, for example, a motor starter circuit. It uses graphical symbols to indicate the interrelationship of the electrical elements in a circuit. These help us to understand the working operation of the circuit but are not helpful in showing us how to wire the components. An electrical schematic diagram looks very like a circuit diagram. Figure 14 shows a schematic diagram.

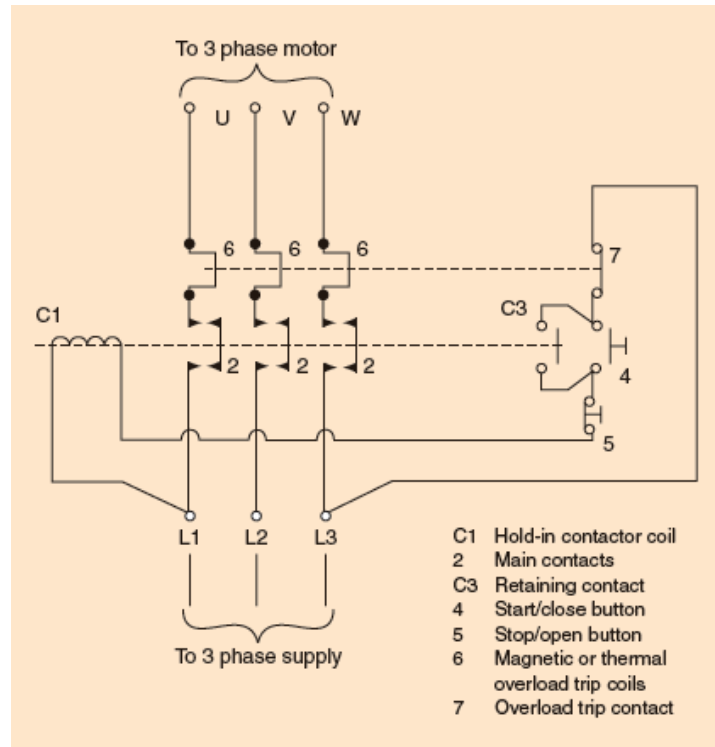


Figure 240 Schematic diagram of a motor starter

## 10. Freehand working diagrams

Freehand working drawings or sketches are another important way in which we communicate our ideas. The drawings are done from freehand sketches. A freehand sketch may be done as an initial draft of an idea before a full working drawing is made. It is often much easier to produce a sketch of your ideas or intentions than to describe them or produce a list of instructions.

To convey the message or information clearly it is better to make your sketch large rather than too small. It should also contain all the dimensions necessary to indicate clearly the size of the finished object depicted by the sketch.

## 11. Line diagram

This is a one-line diagram or single-line diagram is a simplified notation for representing an electrical system. The one-line diagram is similar to a block diagram except that electrical elements such as switches, circuit breakers, transformers, and capacitors are shown by standardized schematic symbols.

## 12. Pictorial diagram

This is a diagram that represents the elements of a system using abstract, graphic drawings or realistic pictures.

## 13. Building plans

These are architectural drawings which the technician uses to design electrical wiring systems. The drawing shows the various elevations of the building.



## Drawing instruments

Drawing instruments are used to prepare neat and accurate drawings. Accuracy of drawings depend on the quality of instruments used to prepare them. The following is the list of drawing instruments and other materials required.

- Drawing board
- T-square or drafter (drafting machine)
- Set squares
- Protractor
- Drawing instrument box
- Drawing sheet
- Drawing pencils
- Drawing pins/clips

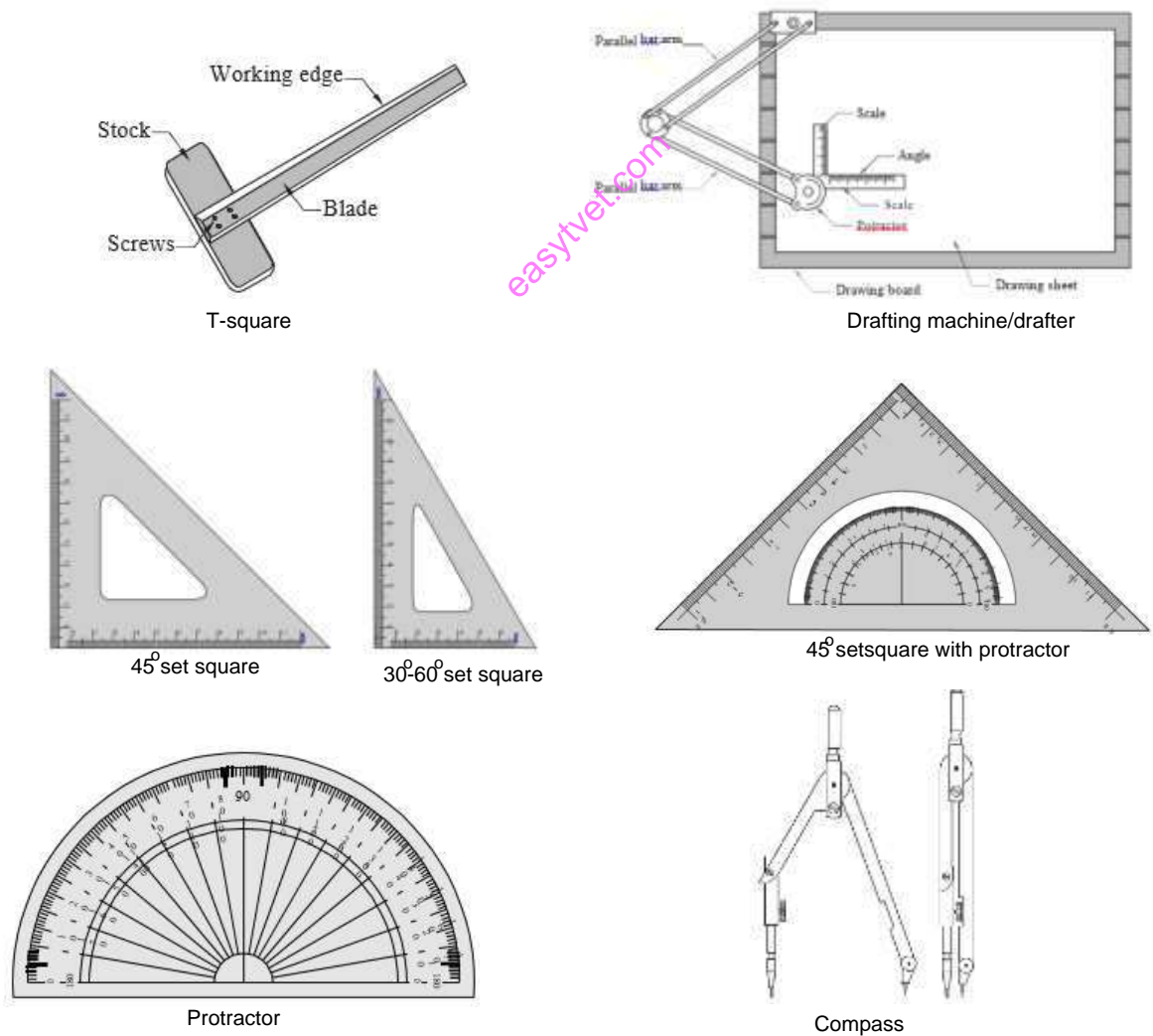


Figure 241 Drawing instruments

### **Drawing Pencils:**

The accuracy and appearance of a drawing depends on the quality of Pencil used to make drawing. The grade of a Pencil lead is marked on the Pencil. HB denotes medium grade. Increase in hardness is shown by value put in front of H such as 2H, 3H etc., Softer pencils are marked as 2B, 3B, and 4B etc. A pencil marked 3B is softer than 2B and Pencil marked 4B is softer than 3B and so on. Beginning of a drawing may be made with H or 2H. For lettering and dimensioning, H and HB Pencils are used.

### **Drawing Pins and clips:**

These are used to fix the Drawing sheet on the Drawing board.

### **Drawing paper sizes**

ISO standard determines the paper dimensions for the A paper series. The most common paper sizes are A0, A1, A2, A3, A4, and A5. The table below shows the dimension of the most common A series paper sizes.

*Table 15 Dimensions for A paper series*

| <b>Paper size</b> | <b>Dimensions (cm)</b> | <b>Paper Area</b>      |
|-------------------|------------------------|------------------------|
| A5                | 14.8 x 21 cm           | 0.03108 m <sup>2</sup> |
| A4                | 21 x 29.7 cm           | 0.0612 m <sup>2</sup>  |
| A3                | 29.7 x 42 cm           | 0.125 m <sup>2</sup>   |
| A2                | 42 x 59.4 cm           | 0.25 m <sup>2</sup>    |
| A1                | 59.4 x 84.1 cm         | 0.50 m <sup>2</sup>    |
| A0                | 84.1 x 118.9 cm        | 1 m <sup>2</sup>       |

Notice that if we split an A1 paper into two equal parts we get two A2 papers. If we split an A2 paper into two equal part we get two A3 papers. If we split an A3 paper into two equal part we get two A4 papers and so on. This is shown visual in the Figure 16.

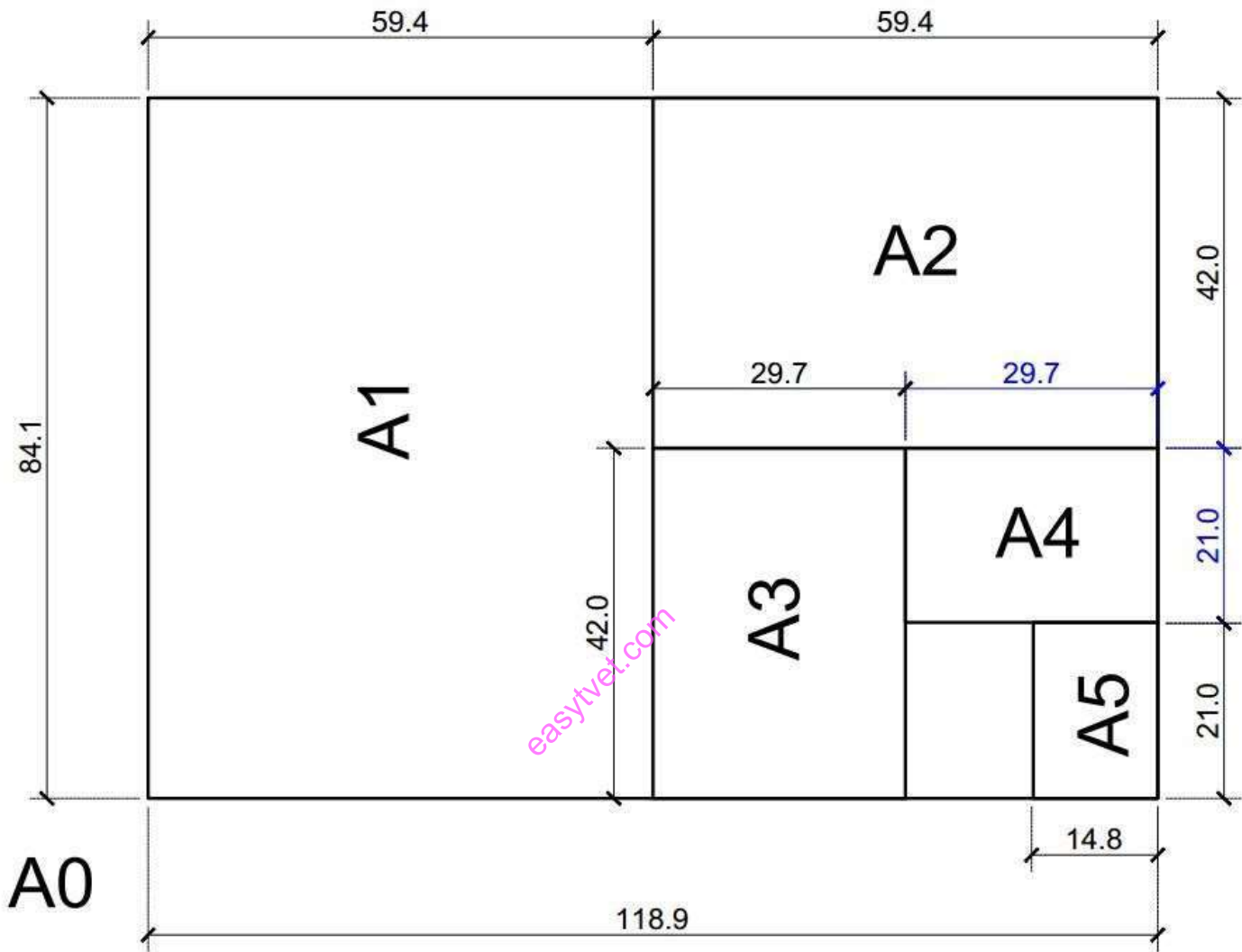


Figure 242 Technical drawing paper sizes

**Lines**

Lines are the continuous association of points. Lines are classified as follows:-

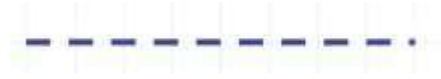
- a) According to Thickness.
- b) According to Shape.
- c) According to Darkness.

**Lines used in Engineering drawings:-**

- a) Outlines- Lines drawn to represent visible edges and surface boundaries. These are also called principal lines.



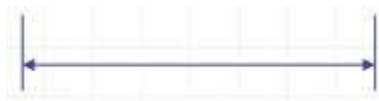
b) Dashed lines- Interior or hidden edges and surfaces are shown by dashed lines. Also called dotted lines. They are of medium thickness. They are short dashed lines of about 3-4mm with 1mm distance between them.



c) Centre lines- These lines indicate axes of cylindrical, conical or spherical objects and the centers of circles. These are medium thick lines consisting of long and short dashes, long dashes of 6-8mm and 1mm distance between them.



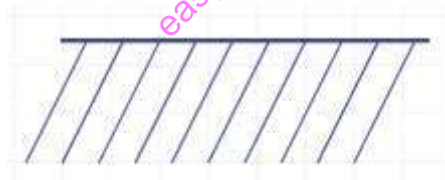
d) Dimension lines- These are continuous thin lines terminated at the outer ends by pointed arrow-heads.



e) Construction lines- These are thin lines drawn during the drawing to help in drawing complex geometrical structures.



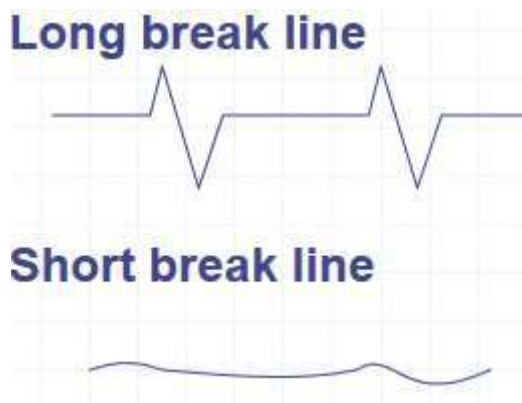
f) Hatching lines- These are thin lines drawn parallel to each other at about 3mm. These lines show the presence of material while object is cut through.



g) Cutting plane lines- These lines show the location of the cutting plane. It is thin & long chain line with two small dashes of about 3-4mm and a long dash of about 6-8mm width



h) Break lines- These lines show imaginary boundaries of the object or to skip up very long part of the object of similar width



## How to draw a title block

The title block of a drawing, usually located on the bottom or lower right hand corner, contains all the information necessary to identify the drawing and to verify its validity. The drawing title and the drawing number are used for identification and filing purposes.

The title block of a drawing is usually located on the bottom or lower right hand corner, contains all the information necessary to identify the drawing and to verify its validity. All engineering drawings should feature a title block. The Figure 17 shows an example of a title block. The title block should include:

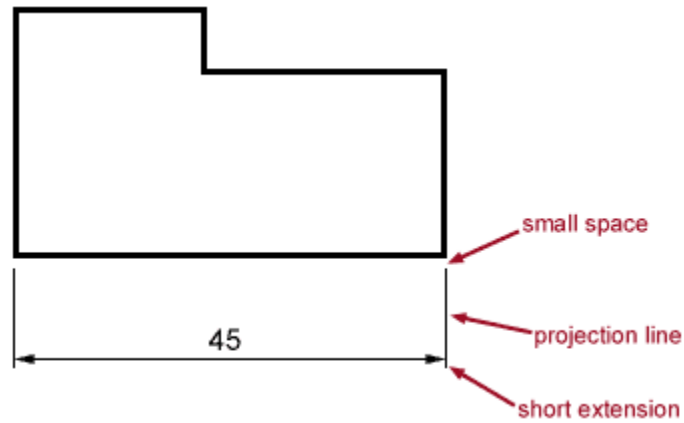
- Title: -title of the drawing
- Name: -name of the person who produced the drawing
- Checked: -before manufacture, drawings are usually checked
- Version: -many drawings are amended, each revision must be noted
- Date: -the date the drawing was produced or last amended
- Notes: -any note relevant to the drawing
- Scale: -the scale of the drawing
- Company name: -name of the company
- Projection: -the projection system used to create the drawing.

|   |                     |               |                   |                   |          |  |
|---|---------------------|---------------|-------------------|-------------------|----------|--|
| SCALE<br>1:1  | NF E 27-494         |               |                   |                   |          |  |
|   | APPLICABLE SPECS.   | NEXT ASSEMBLY |                   | FINAL APPLICATION |          |  |
| Material  | <b>DRAWING NAME</b> |               |                   |                   |          |  |
| Part Number PN-990256   |                     |               |                   |                   |          |  |
| Designer  |                     |               |                   |                   |          |  |
| UNLESS OTHERWISE SPECIFIED:<br>DIM. ARE IN INCHES.<br>DIM. IN PARENTHESIS ARE (MM)<br>DEC: .XX±.01    FRAC: ±1/64<br>.XXX±.005    ANG: ±1°<br>REMOVE ALL BURRS & SHARP CORNERS. | DATE                |               | DRAWING NO.       |                   | ALT.     |  |
|   | CHK.                | AT            | <b>DRAWING NO</b> |                   | <b>A</b> |  |
|   | ENG.                | JF            |                   |                   |          |  |
|   | APP.                | JF            |                   |                   |          |  |

Figure 243 Title block

## Dimensioning of drawings

A dimensioned drawing should provide all the information necessary for a finished product or part to be manufactured. An example dimension is shown below.



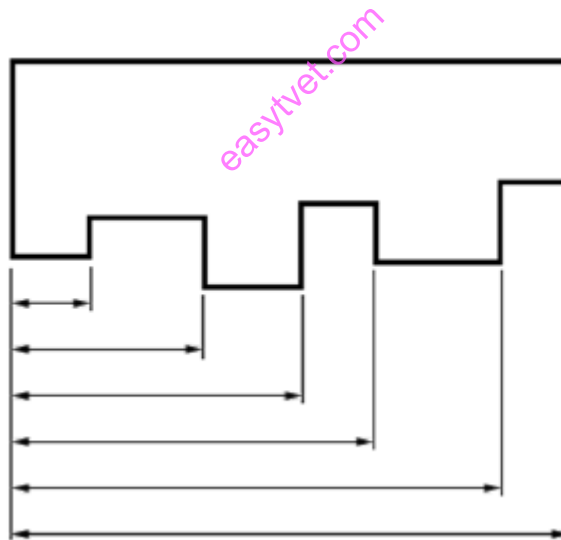
Dimensions are always drawn using continuous thin lines. Two projection lines indicate where the dimension starts and finishes. Projection lines do not touch the object and are drawn perpendicular to the element you are dimensioning.

All dimensions less than 1 should have a leading zero. i.e. .35 should be written as 0.35

### Types of Dimensioning

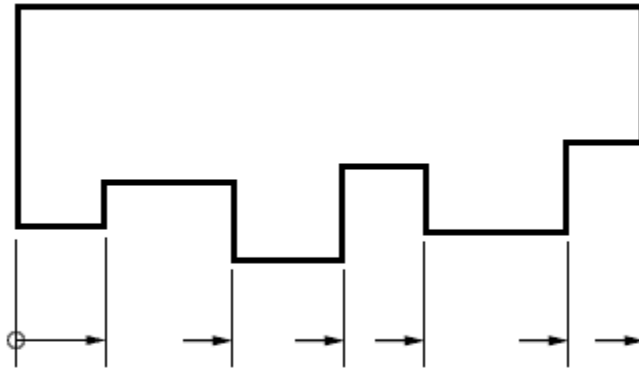
#### I. Parallel Dimensioning

Parallel dimensioning consists of several dimensions originating from one projection line.

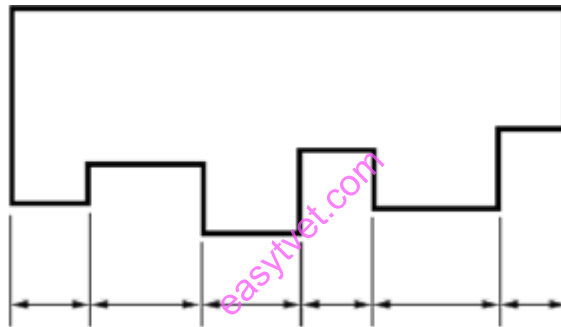


#### II. Superimposed Running Dimensions

Superimposed running dimensioning simplifies parallel dimensions in order to reduce the space used on a drawing. The common origin for the dimension lines is indicated by a small circle at the intersection of the first dimension and the projection line.

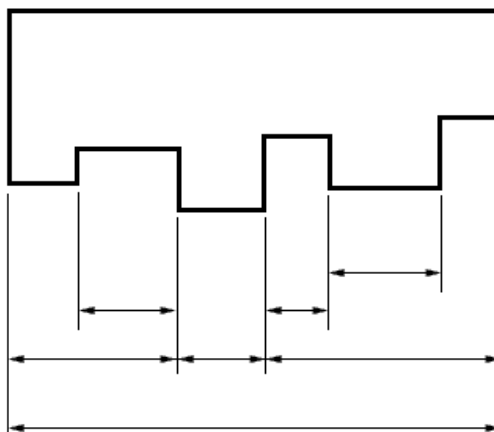


### III. Chain Dimensioning

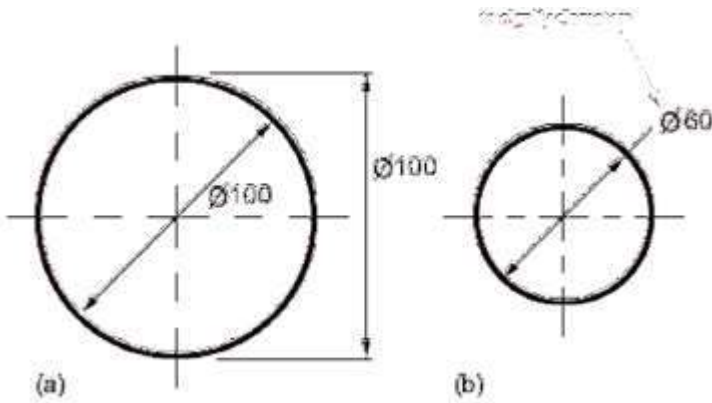


### IV. Combined Dimensions

A combined dimension uses both chain and parallel dimensioning.



## V. Dimensioning of circles



(a) Shows two common methods of dimensioning a circle. One method dimensions the circle between two lines projected from two diametrically opposite points. The second method dimensions the circle internally.

(b) Is used when the circle is too small for the dimension to be easily read if it was placed inside the circle.

## VI. Dimensioning Radii

All radial dimensions are preceded by the capital **R**.



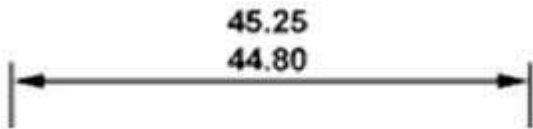
(a) Shows a radius dimensioned with the center of the radius located on the drawing.

(b) Shows how to dimension radii which do not need their centers locating.

## VII. Tolerancing

It is not possible in practice to manufacture products to the exact figures displayed on an engineering drawing. The accuracy depends largely on the manufacturing process. A tolerance value shows the manufacturing department the maximum permissible variation from the dimension. Each dimension on a drawing must include a tolerance value. This can appear either as: a general tolerance value applicable to several dimensions i.e. note specifying that the General Tolerance  $\pm 0.5$  mm. or a tolerance specific to that dimension





## Orthographic Projections

Orthographic Projections are a collection of 2-D drawings that work together to give an accurate overall representation of an object.

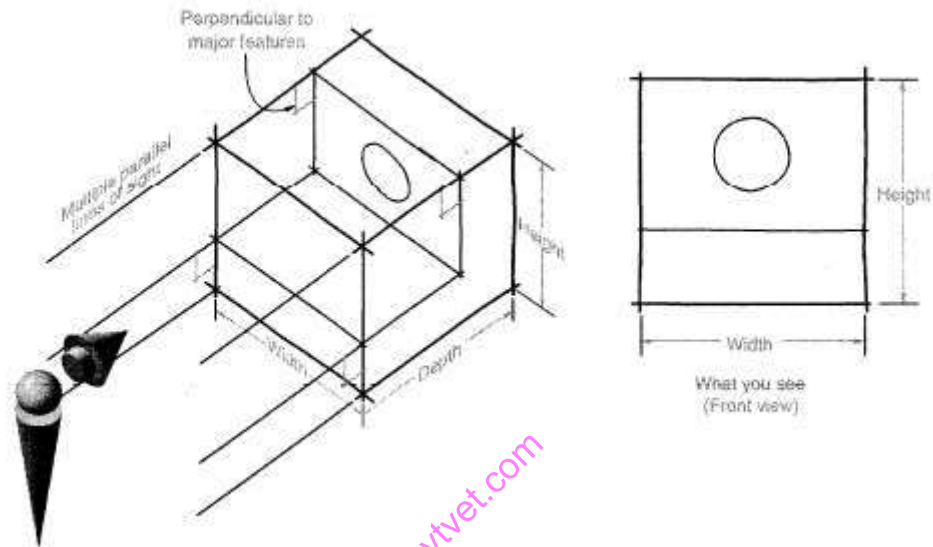


Figure 244 Orthographic projections

## Defining the Six Principal Views or Orthographic Views

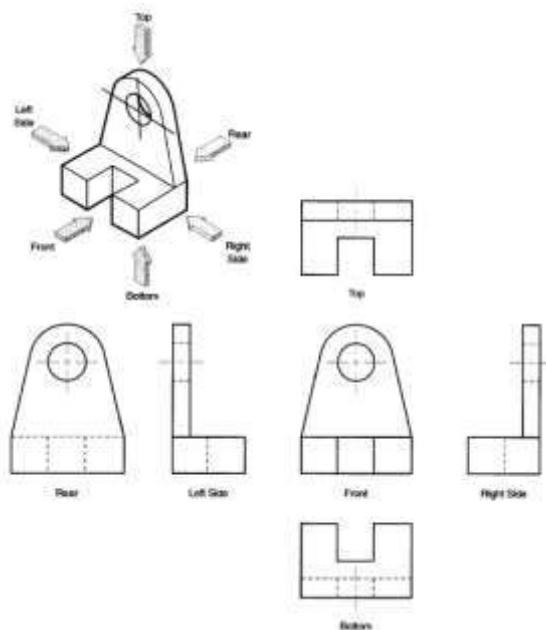


Figure 245 orthographic views

### General Guidelines on which views to present

Pick a Front View that is most descriptive of object. Normally the longest dimension is chosen as the width (or depth). Most common combination of views is to use: Front, Top, and Side View. The figure 20 shows the views to be present.

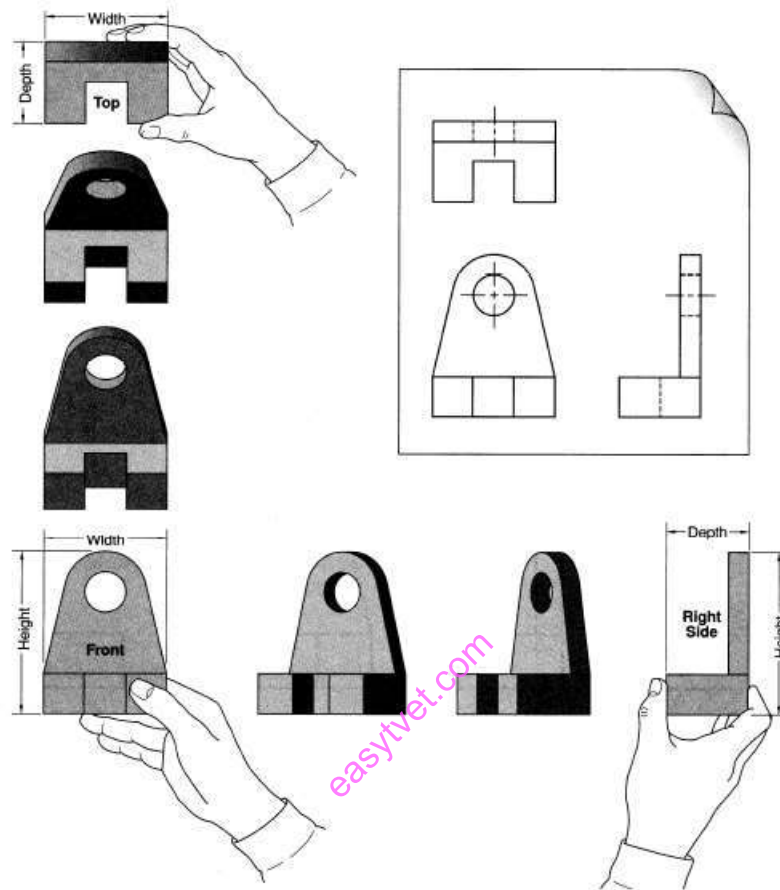
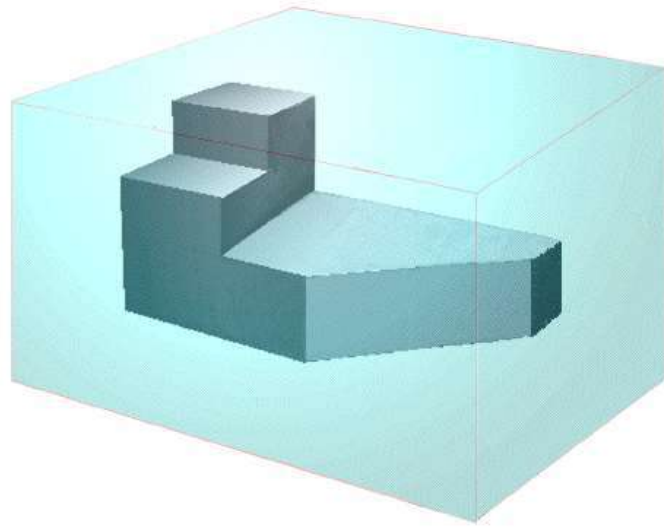


Figure 246 Views to present

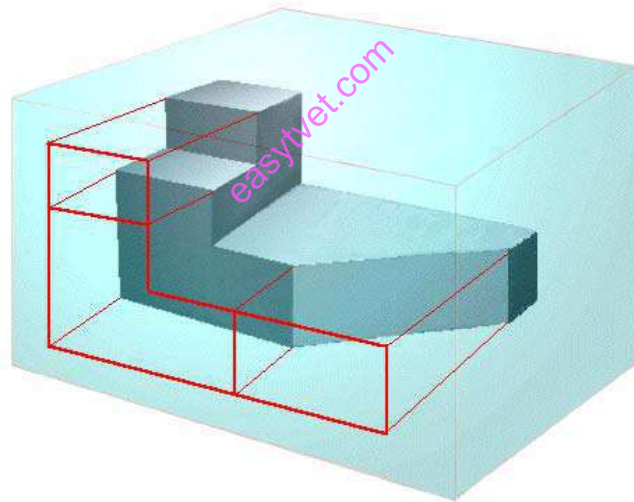
### Glass Box Approach

Place the object in a glass box. Freeze the view from each direction (each of the six sides of the box) and unfold the box

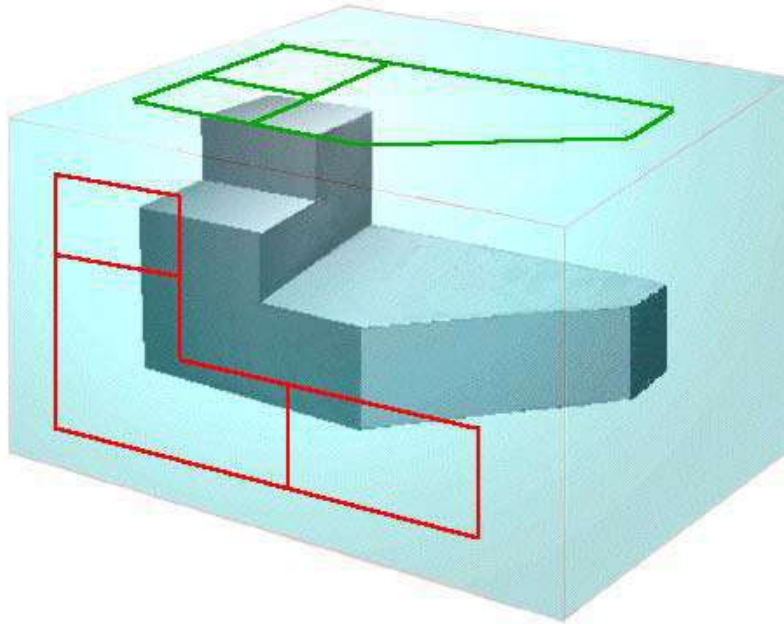
Projection of points to the three views



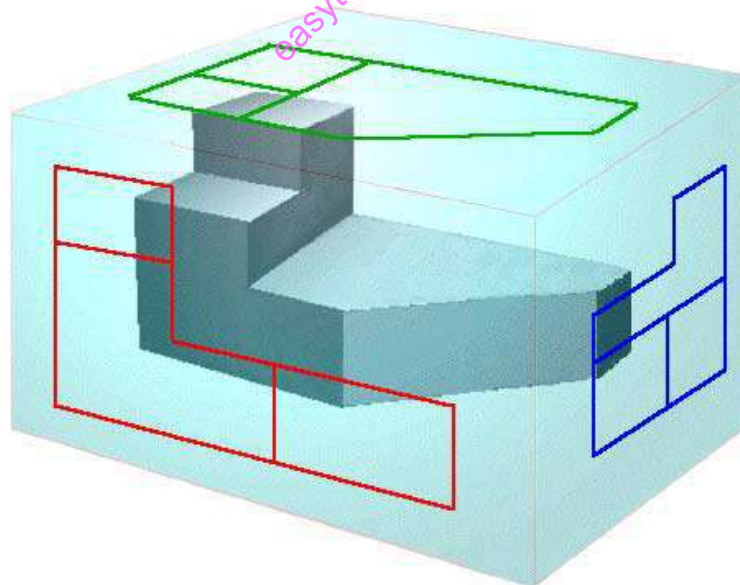
Projection of points to FRONT VIEW



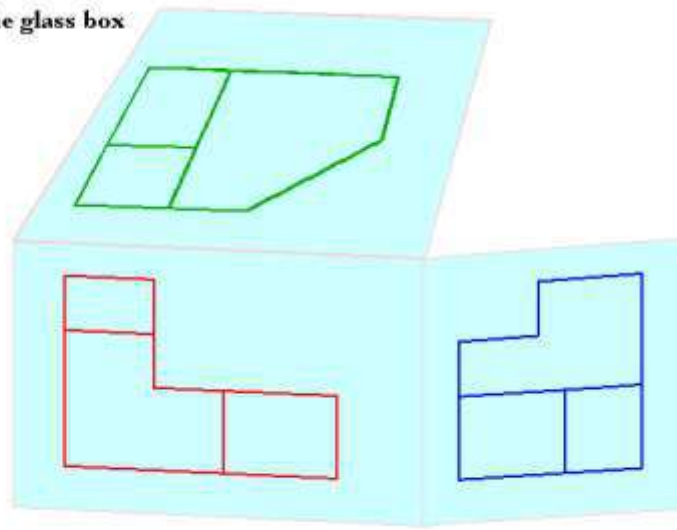
**Projection of points to TOP VIEW**



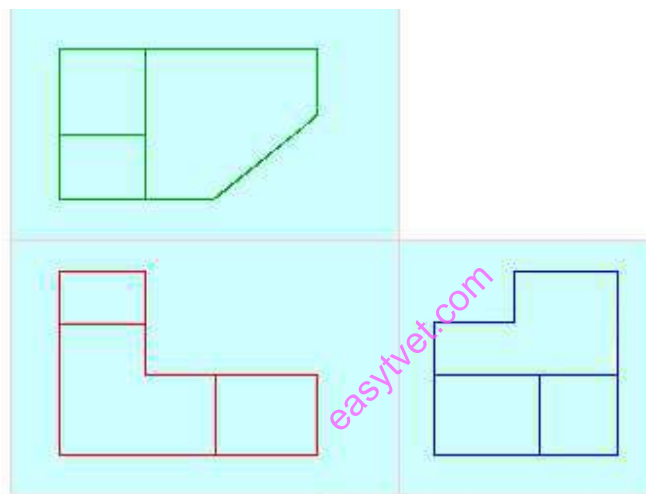
**Projection of points to RIGHT SIDE VIEW**



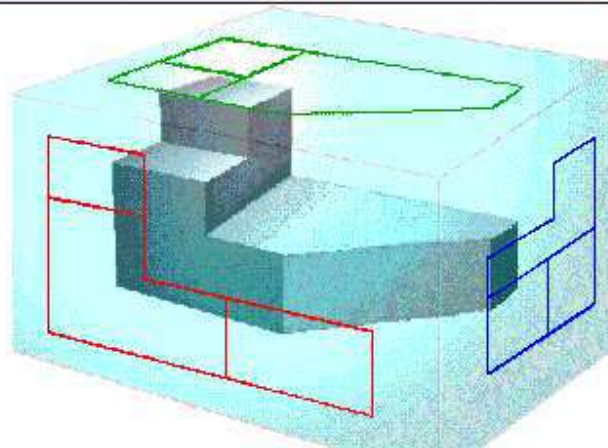
Unfold the glass box



Unfolded  
glass-box



Object in the  
glass-box



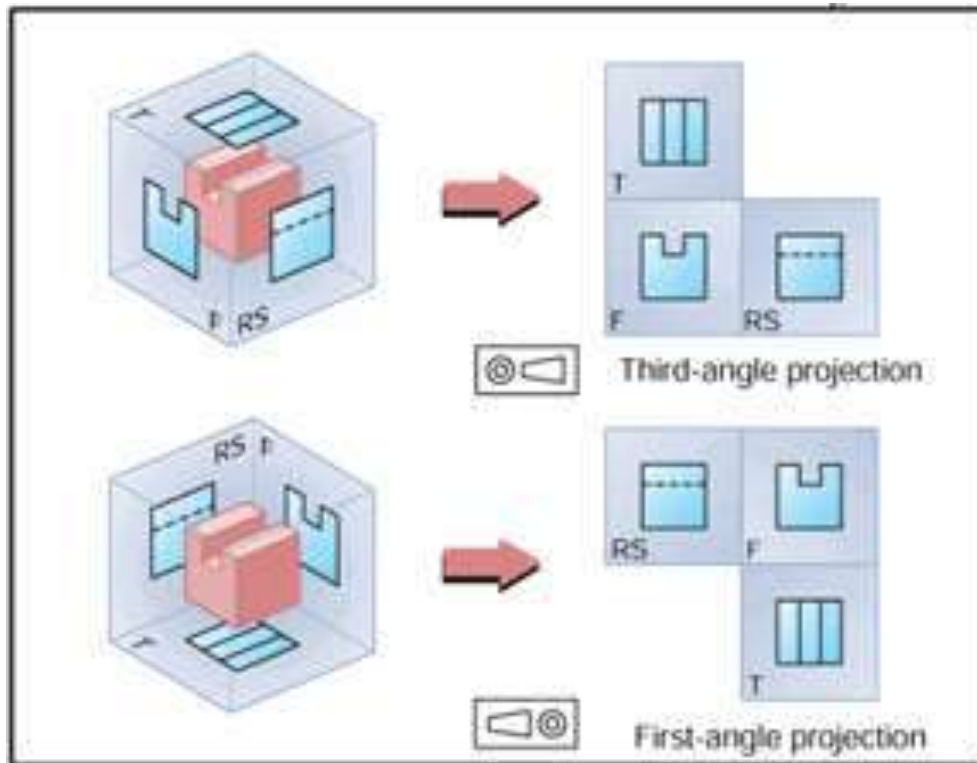


Figure 247 first and third angle projections

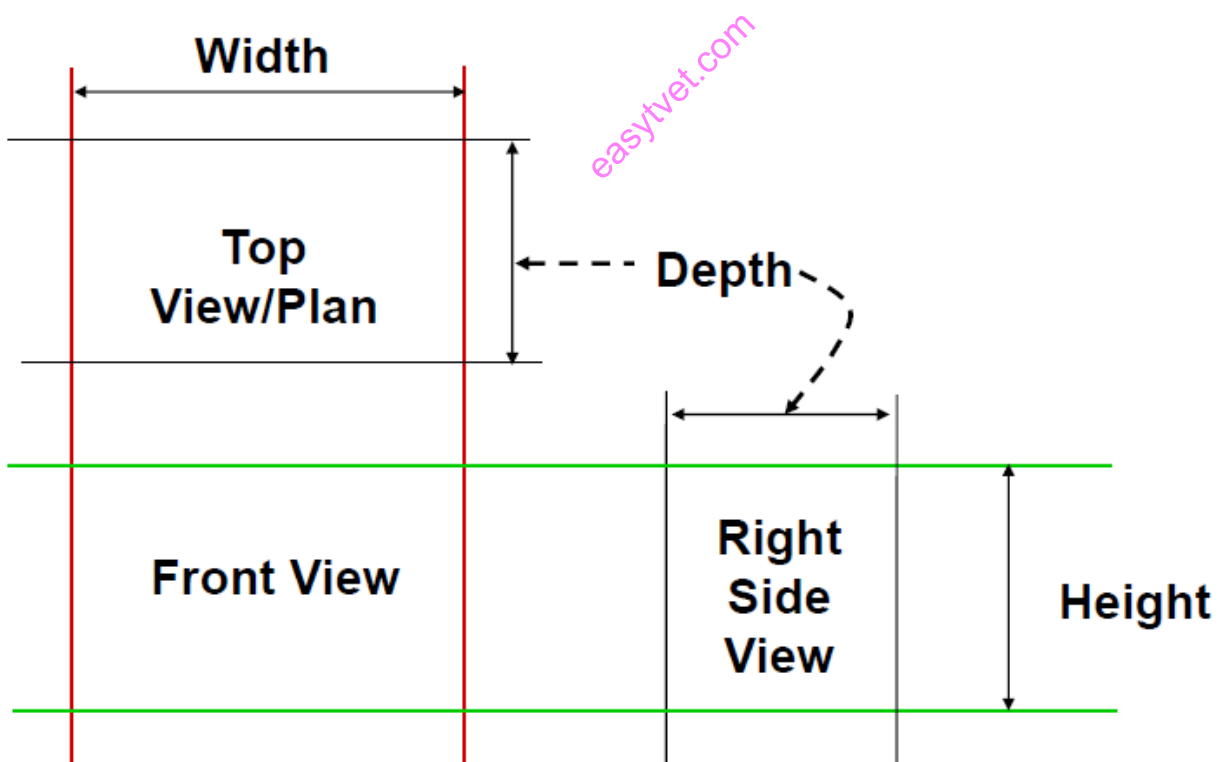


Figure 248 Conventional orthogonal views

### How to read and interpret architectural drawings

The first time you opened a set of architectural plans, you were probably instantly lost and confused. If you are managing your company's real estate project, but don't have any real training in architecture,

reading these plans can be extremely difficult. To save you some time and trouble, we've put together a guide as to how to read architectural plans.

Here are a few additional general guidelines to keep in mind:

- Be organized and diligent when reading plans. Start in upper left corner and work way across page so as not to miss any details.
- Read the plan cover sheet. This contains important project information like the project name, architect, contact information, project information and the date. It might also include a drawing of the finished product.
- There are often reference points that are used between professionals and sets of drawings. These can come in many forms: room numbers, a grid system, structural references, etc.
- Review the plan index which provides a list of all plan sheets.

Start with the Site or Plot plan. This provides an overhead view of the property and details about the boundaries and orientation of the building. There will also be a symbol legend which depicts the symbols used to indicate windows, doors, elevation, etc. Many symbols contain numbers within them which refer to the section and the page number of the plans. Reviewing the symbol legend will help when looking at the actual plans so that you recognize what the symbols are referring to. You may also want to review the list of abbreviations, many of which are standard in the industry, but some may be specific to the architect. This will also help later when you are reading design notes.

Once you move into reading the actual architectural sheets, it's important to know that architectural plans are labeled with an A (A 001 or A1-X, A2-X, etc.). The architectural plans are where you will see where your office is, where the bathrooms are in relation to workstations, etc. They will also provide measurements, elevations, locations of walls, windows, bathrooms, etc. Plans are broken up into many, many parts so it's make sure to look at the plan number (and North arrow) to help orient yourself. Always read the notes on a page! Some design details are easier to communicate via text so notes are included on the drawing or sometimes as additional pages.

There are many additional plans that supplement architectural plans: ceiling, roof framing, finish schedule (paint colors for each wall, flooring type and color, ceiling height, type, and color), door/window schedule, and many more. These plans contain important details, but we will cover those details in a future blog post. For now, hopefully this will help the next time you're trying to figure out how to read architectural plans. The table shows some of the architectural symbols that are always used.

| ARCHITECTURAL SYMBOLS |  |
|-----------------------|--|
|                       | SMOKE BARRIER LINE   |
|                       | BREAK, ROUND (USER DEFINES SIZE)   |
|                       | BREAK, STRAIGHT (SEE SECTION INDICATORS, BUILDING, WITH BREAK STANDARDS) |
|                       | DETAIL INDICATOR   |
|                       | DETAIL INDICATOR   |
|                       | DETAIL INDICATOR FOR SMALL CONDITIONS                                    |
|                       | DIMENSION LINE   |
|                       | DOOR OPENING/BORROWED LIGHT IDENTIFIER                                   |
|                       | DRAWING BLOCK TITLE, TYPICAL   |
|                       | ELEVATION INDICATOR, EXTERIOR  |
|                       | ELEVATION INDICATOR, INTERIOR, MULTIPLE VIEW                             |
|                       | ELEVATION INDICATOR, INTERIOR, SINGLE VIEW                               |
|                       | BUILDING SECTION INDICATOR   |



Department of  
Veterans Affairs

DETAIL TITLE / ARCHITECTURAL SYMBOLS

SCALE : NONE

DATE ISSUED: DECEMBER 2008

CAD DETAIL NO.:

SD000115-25.DWG

## Use of Computer Aided design

CAD stands for Computer Aided Design. CAD is used to design, develop and optimize products. While it is very versatile, CAD is extensively used in the design of tools and equipment required in the manufacturing process as well as in the construction domain. CAD enables design engineers to layout and to develop their work on a computer screen, print and save it for future editing. CAD (Computer Aided Design) is the use of computer software to design and document a product's design process.

Computer-aided design (CAD) involves creating computer models defined by geometrical parameters. These models typically appear on a computer monitor as a three-dimensional representation of a part or a system of parts, which can be readily altered by changing relevant parameters. CAD systems enable designers to view objects under a wide variety of representations and to test these objects by simulating real-world conditions.



When it was introduced first, CAD was not exactly an economic proposition because the machines at those times were very costly. The increasing computer power in the later part of the twentieth century, with the arrival of minicomputer and subsequently the microprocessor, has allowed engineers to use CAD files that are an accurate representation of the dimensions / properties of the object.

CAD is used to accomplish preliminary design and layouts, design details and calculations, creating 3-D models, creating and releasing drawings, as well as interfacing with analysis, marketing, manufacturing, and end-user personnel.

CAD facilitates the manufacturing process by transferring detailed information about a product in an automated form that can be universally interpreted by trained personnel. It can be used to produce either two-dimensional or three-dimensional diagrams. The use of CAD software tools allow the object to be viewed from any angle, even from the inside looking out. One of the main advantages of a CAD drawing is that the editing is a fast process as compared to manual method. Apart from detailed engineering of 2D or 3D models, CAD is widely used from conceptual design and layout of products to definition of manufacturing of components. CAD reduces design time by allowing precise simulation rather than build and test physical prototypes. Integrating CAD with CAM (Computer Aided Manufacturing) streamlines the product development even more.

CAD is currently widely used for industrial products, animated movies and other applications. A special printer or plotter is usually required for printing professional design renderings. CAD programs use either vector-based graphics or raster graphics that show how an object will look.

### **CAD software enables**

- Efficiency in the quality of design
- Increase in the Engineer's productivity
- Improve record keeping through better documentation and communication

Today, the use of CAD has permeated almost all industries. From aerospace, electronics to manufacturing, CAD is used in all industry verticals. Since CAD encourages creativity and speeds up productivity, it is becoming more and more useful as an important tool for visualization before actually implementing a manufacturing process. That is also one of the reasons CAD training is gaining more and more importance.

### 6.2.2.4 Learning Activities

#### Project

| Practical activities  | Knowledge  | Special instruction  |
|---|--|--|
| 1. Interpretation of installation drawing from a typical working drawing                                      | Working drawings   |  |
| 2. Apply and demonstrate knowledge of symbols and nomenclatures in accordance with British standards[BS 3939] | Standard electrical symbols  | Draw and name all electrical symbols   |
| 3. Identify the drawing tools   | Drawing instruments and equipment  | Demonstrate how to use various drawing instruments, identify the paper sizes |
| 4. Identify components and their ratings.   | Electrical components and their ratings  |  |
| 5. Clearly show cable sizes and lengths as provided in the workshop   | Cable sizes  |  |
| 6. Show power supply and draw distribution circuits using single line diagrams                                | <ul style="list-style-type: none"><li>• Line diagrams</li><li>• Distribution circuits</li><li>• Power supply</li></ul> |  |
| 7. Carry out phase balancing of loads as per usage on an existing domestic installation                       | Phase balancing of loads   |  |
| 8. Clearly mark the cable routes.   | Cable routing  |  |
| 9. Prepare working drawings and share any deviations with relevant bodies.                                    | Working drawings   |  |

### 6.2.2.5 Self-Assessment

1. Draw the following types of lines.
  - I. Outline
  - II. Long break line
  - III. Center line
  - IV. Hidden line
  - V. Dimension line
2. Which tools are used by a draftsman when carrying out a task in Technical drawing?
3. Which type of a pencil are used while carrying out drawing assignment?
4. Below is an electrical symbol. Name of the symbol?



One way switch

5. Draw the symbol of the following electrical installation equipment and machines.

| Name                      | Symbol |
|---------------------------|--------|
| i. Motor                  |        |
| ii. Transformer           |        |
| iii. Energy meter         |        |
| iv. Consumer control unit |        |
| v. Fluorescent lamp       |        |

### 6.2.2.6 Tools, Equipment, Supplies and Materials

#### Recommended Resources

|   |  |
|---|--|
| <p><b>Tools and equipment</b></p> <ul style="list-style-type: none"><li>➤ Cable Strippers</li><li>➤ Pliers</li><li>➤ Screw drivers</li><li>➤ Hammers</li><li>➤ Chisels</li><li>➤ Allen keys</li><li>➤ Electrician knives</li><li>➤ Crimping tools</li><li>➤ Bending springs</li><li>➤ Bending machine</li><li>➤ Steel tapes</li><li>➤ Draw wires</li><li>➤ Hack saws</li><li>➤ Drilling tools</li><li>➤ Stock and die</li><li>➤ Bench vice</li><li>➤ Machine vice</li><li>➤ PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li></ul> | <p><b>Materials and supplies</b></p> <ul style="list-style-type: none"><li>• Stationery</li><li>• Cables</li><li>• Light fittings</li><li>• Accessories</li><li>• Conduits and fittings</li><li>• Cable trays</li><li>• Cable ducts</li><li>• Trunkings</li><li>• Computers</li><li>• Drawing instruments</li><li>• Screws</li></ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"><li>• IEE regulations</li><li>• Occupational safety and health act (OSHA)</li><li>• Work injury benefits act (WIBA)</li><li>• Manufacturers’ catalogues</li><li>• British standards</li><li>• KEBS standards</li></ul>  |  |

### 6.2.2.7 References

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### 6.2.2.8 Model answers to self-assessment

1. Draw the following types of lines.

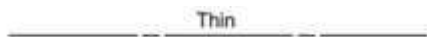
I. Outline



II. Long break line



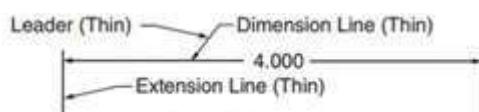
III. Center line



IV. Hidden line



V. Dimension line



2. Which tools are used by a draftsman when carrying out a task in Technical drawing?

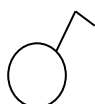
- T squares
- Protractor

- Emery board

3. Which type of a pencil are used while carrying out drawing assignment?

- HB
- 3H
- 2H
- 4H

4. Below is an electrical symbol. Name of the symbol?



One way switch

5. Draw the symbol of the following electrical installation equipment and machines

| Name                      | Symbol |
|---------------------------|--------|
| vi. Motor                 |        |
| vii. Transformer          |        |
| viii. Energy meter        |        |
| ix. Consumer control unit |        |
| x. Fluorescent lamp       |        |

## 6.2.3 Learning Outcome 3: Assemble tools, equipment and materials

### 6.2.3.1 Introduction to the learning outcome

In order to assemble tools, equipment and materials, the learner need check the tools, equipment and materials for proper functionality, assemble and store them as per established procedure.

### 6.2.3.2 Performance Standards

6.2.3.2.1 Check tools, equipment and materials for proper specifications and functionality.

6.2.3.2.2 Assemble and store tools, equipment and materials as per the established procedure

### 6.2.3.3 Information Sheet

**Accessory-** Any device other than a lighting fitting, associated with the wiring and current-using appliances of an installation, e.g. a switch, a fuse, a plug, a socket-outlet, a lamp holder or a ceiling rose.

**Electrical equipment-** means any apparatus, appliance, device, fitting, fixture or material used in distribution, supply or utilization of electric power

### Electrical installation tools, equipment and their use

These are tools used in driving or pounding out nails they are made of hard steel, wood, plastic or rubber.

The following are types of hammers; claw, mallet and Ball peen.

### Hammers



### Wire stripper



A tool used for removing insulation from insulated cables.

### Side cutter





This is a tool used fine medium and big cables

### **Combination pliers**



[easytvvet.com](http://easytvvet.com)

These are made of metal with insulated handles. They are used for cutting, twisted, bending, holding and gripping wires and cables

### **Long nose pliers**



This is used for cutting and holding wires. It made to reach tight space and or small opening where other pliers cannot reach. It is also used in making terminal loops of copper wire

### **Star screw driver**



It has a cross tip and is used to drive screws with cross slot heads.

### **Flat screw driver**



It has a flat tip and is used to drive screws with straight slot heads.

### **Hacksaw**

[easyvet.com](http://easyvet.com)



This is a tool used to cut metal conduit and armoured cable.

### **Fish/Draw tape**



This tool is used to draw cables in the conduit



## Measuring tools



To measure wire length and other items, the Technician finds considerable use of measuring tool

## Soldering equipment



In installing electric wiring, joints made between wires should be soldered, unless you use solder less connectors. Typical equipment available

## Drilling equipment



Drilling equipment is needed to make holes in building structure passages of Conduit and wire

### **How to take care of your tools**

Good tools can be quite an investment, but if you take good care of them, they'll return the favour. Keeping your tools properly stored, cleaned, and maintained will save you time and money and make your DIY endeavors that much more rewarding

In keeping the tools and equipment, you need to work with the space you have. Maybe you hang them on pegboards, maybe you store them in boxes, bags, or chests, or maybe you keep them in drawers or on shelves in your shop. Whatever works for you is best.

Toolboxes also make for great tool storage, offering the primary advantage of portability. While some people opt to store all their tools in toolboxes, for most, the toolbox is a way of carrying around your most-used tools while leaving the bulk safely stored on pegboards, shelves, or drawers.

### **Basic maintenance of electric tools**

To ensure that your **electric tools** work when you need them to, you must take proper care of them. A good regimen of maintenance for your tools is one thing that you can do to make sure that the tool you need is working when you need it.

- a) **Clean out the dust:** To make sure that your electric tools are ready to go when you are, keep them clean and free of dust. The housing intake on your electric tools and the exhaust are especially important areas to keep clean. Take some time to clean out the dust every once in a while, on your tools while they are sitting in storage.
- b) **Check the cords:** Look for wear and tear on the power cords on your electric tools. There can be damage to the insulation and you should keep an eye out for loose wires. This will ensure that your electric tool can get the power that it needs to function without an accident. Wipe the cords down to keep them from becoming damaged from oil and grease. The prongs on the cords should be examined as well. Make sure that the casing is intact and the prongs are not loose.
- c) **Oil some electric tools:** The electric tools in your toolbox that have a cutting surface should be lightly oiled to prevent rust. Examine the cutting surface for rust to make sure that your tools are kept in good condition.
- d) **Storing your tools:** Keep your electric tools stored in their original cases and containers. This will keep them free of dust and dirt while they are not being used.

### **Electrical equipment**

Some of the electrical equipment used are shown in figure 23.

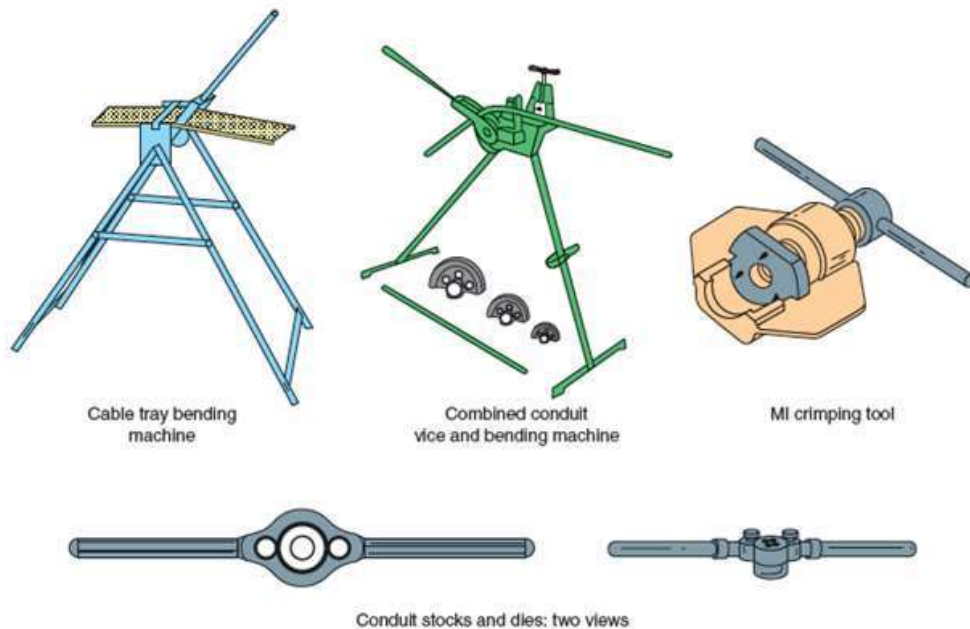


Figure 249 some of the electrical equipment

## Accessories

### Lamp Holders.

These are designed for quick removal and replacement of the lamp, and yet they must hold the lamp in firm metallic contact to prevent overheating.

There are three main sizes of lamp holder, namely;

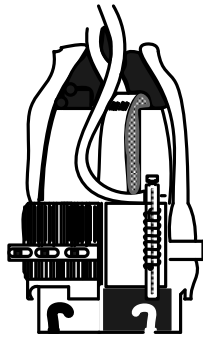
- i. The Bayonet-cap (B.C),
- ii. The medium Edison Screw (E.S) and
- iii. The Goliath Screw (G.E.S).

There are other variations such as the three-slot B.C for the smaller discharge lamps. For ordinary tungsten filament lamps of up to 150W, the lamp caps and thus the lamp holder are B.C, for lamps up to 200 W the caps are E.S, and those above 200W use G.E.S.

In every case where a lamp is to be installed, the appropriate size and type of holder must be fitted. Lamp holder may be either the insulated type of Bakelite or the brass type with porcelain interior.

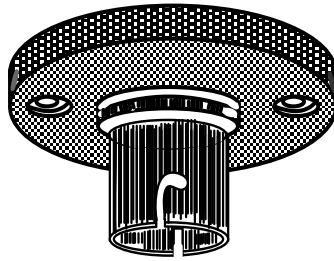
B.C lamp holder should have solid plungers separately sprung by rust-proof steel plunger springs and in the insulated type a metal insert to reinforce the area around the bayonet sockets. An efficient cord grip is also necessary when the lamp is to be suspended from flexible cord.

Figure 24 shows an *insulated* cord-grip lamp holder, the section shows clearly the flexible wire securely fixed to the spring plunger, and also the method of gripping the flexible cord.



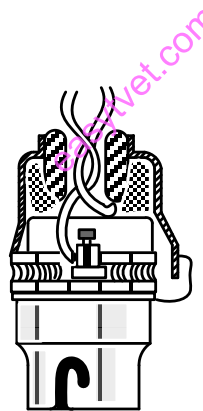
*Figure 250 Insulated cord-grip*

The type shown in figure 25 below is an *insulated* holder suitable for mounting directly on the ceiling.



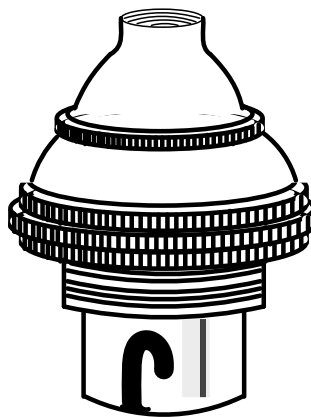
*Figure 251 Insulated holder suitable for direct mounting*

Figure 26 shows a cord grip and the flexible wired to a *brass lamp holder* terminal.



*Figure 252 cord grip and flexible wired to a brass lamp holder terminal*

Figure 27, shows internally threaded to screw to conduit or to a metal lamp bracket or the like.



*Figure 253 internally threaded lamp holder*

Figure 28 is of a batten holder which may be screwed direct to a batten or back board.

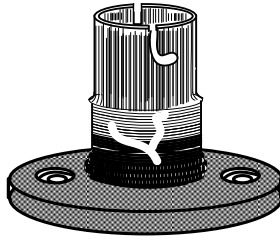


Figure 254 Batten holder

Figure 29 shows a push bar switch lamp holder.

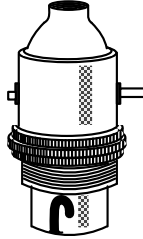


Figure 255 push bar switch lamp holder

A Goliath screw lamp-holder is shown exploded in figure 30. The outer contact is a screwed metal cylinder, and the inner contact is a metal stud. I.E.E. Regulation states that where centre contact bayonet or Edison-type screw lamp holders are connected to a source of supply having an earthed.

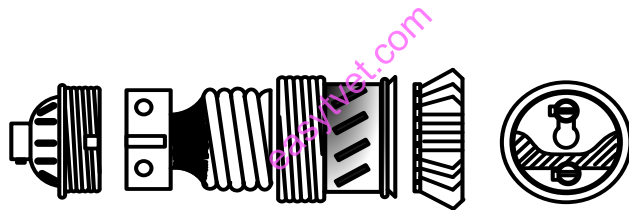


Figure 256 Exploded view of Goliath screw lamp holder

Neutral conductor, the outer or screwed contact shall be connected to that conductor. Where such lamp holders are used in circuits having neither pole connected with earth, or in any damp situation, or in any situation in which they can readily be touched by a person in contact with or standing on earthed metal, they shall be provided with a protective shield of insulating material complying with B.S.98, or shall be so placed or guarded that neither the lamp cap nor the outer or screwed contact of the lamp holder can be touched when the lamp cap is in contact with the lamp holder screw.

Regulations require that, every B.C lamp holder in a damp situation, or in a situation where it can be touched by a person in contact with or standing on earthed metal, shall be constructed of or be shrouded in insulating material, or shall be earthed. Where a lamp holder is likely to attain a working temperature of 135<sup>0</sup> C the lamp holder must be of the special heat-resisting type.

### **Celling roses**

The great majority of ceiling roses already installed contain either two or three connection plates, each plate including a pillar terminal for the circuit wires, and a screw terminal with washer for flexible wire connection.

When wiring ceiling roses with terminal similar to those illustrated above, the flexible wire should be bent under the washer in a clockwise direction, otherwise, it will tend to be squeezed out when the screw is tightened. In some ceiling roses, pillar terminals are provided for both circuit wires and flexible wire.

I.E.E. Regulation requires;

- i. That a ceiling rose shall not be installed in any circuit operating at a voltage normally exceeding low voltage.
- ii. The shrouding of a live terminal in a ceiling rose.
- iii. That not more than one flexible cord shall be attached to a ceiling rose unless the rose be designed for multiple pendants.
- iv. That a ceiling rose shall be provided with an earthing terminal for compliance with I.E.E Regulation

Figure below shows a modern form of moulded ceiling rose which include the earth terminal required by Regulation, and a shrouded terminal for looping- in the live wire as required.



Figure 257 Ceiling rose

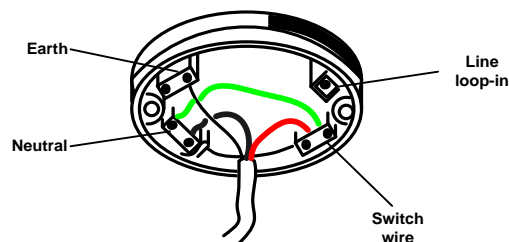


Figure 258 Modern form of moulded ceiling rose

### Lighting circuit switches.



Figure 259 switches showing various plugs

The switches are for switching ON and OFF the lighting points. For direct current circuits, the quick-make- and-break switch is most suitable. The quick break is to prevent the arc formed at the instant of rupture from continuing and burning the contacts



Alternating current can efficiently be interrupted by the opening of a very small gap between silver contacts and most sub-circuit switches are now of this type. All switches should be mechanically robust to withstand the constant operation, and the contacts should be heavy and firm enough to carry the current without overheating.

### Plugs and socket- outlets



*Figure 260 switches showing various plugs*

These are required to enable portable apparatus to be connected to the final sub-circuits. The socket –outlet is the fixed portion connected to the fixed wiring, and comprises two or three contact tubes and terminals. The plug is the movable part connected to the apparatus by flexible wire, and comprises two or three contact pins to fit into the contact tubes. Plugs and socket-outlets are made to British Standard Specifications, the standard sizes being 2 A, 5A, and 30 A. The plug pins are of phosphor- bronze or hard-drawn brass, solid or slotted down the length to form a spring contact in the tubes. The terminals are of substantial construction to clamp the flexible wire firmly. The plug cover, of hardwood or other tough incombustible material, is provided with a clamp to prevent the flexible from pulling out of the plug when in use, this clamp to be inside the cover. The socket-outlet base is of vitreous porcelain or tough insulating material and the contact tubes which must be self- adjusting to the pins are of phosphor-bronze or hard-drawn brass with sound terminals.

The exposed ends of the tubes are below the level of the base to prevent them from being touched accidentally. Figure 36 shows a 3 pin plug with cover

Plugs and sockets may be either of the 2-pin type or of the 3-pin type. Figure 37.shows a 3-pin socket –outlet for flush mounting. For direct current circuits the socket-outlet must be switch-controlled, and this is commonly provided for by a combined switch and socket-outlet.

### Flat pin 13-A fused plug

I.E.E. Regulation allows the use of 13-A fused plugs under certain conditions, figure 1.38 shows a 3-pin fused plug made in accordance with B.S 1363.

The plug is suitable for use with alternating current only. The plug pins are clearly identified by ‘L’ for live ‘N’ for neutral and ‘E’ for earth... A 13 –A cartridge fuse fitted inside the plug.

I.E.E. Regulations require that every plug and socket- outlet shall comply with the following;

- It must not be possible for any one pin of a plug to be in live contact with the socket-outlet while any other pin is exposed.
- No plug should fit any live contact of a socket- outlet, other than that of the socket-outlet for which it is designed

- With exceptions, every plug and socket-outlet must be non-reversible, with provision for earthing
- Every fuse plug is to be non-reversible, with no provision for a fuse in an earthed conductor

### **Fuses.**

A fuse element consists essentially of a piece of copper or tin-lead alloy wire which will melt when carrying a predetermined current. This element with contact carrier, and base is called a fuse. It is placed in series with the circuit or sub-circuit to be protected, and automatically breaks the circuit when overloaded. In general, the regulations regarding fuses require that fuses shall be accessible, and shall be fitted either on the front of a switch board or in a protecting case. In most cases in installation work the fuses are fitted in a distribution board.

The current rating or normal current-carrying capacity of a fuse should not exceed the current rating of the smallest conductor in the circuit protected by the fuse, account being taken of the class of excess-current protection provided by the fuse, coarse or close. For electric motors, a higher fuse rating is allowable. The fusing values of normal duty fuses vary from 160 to 200 percent of the carrying capacity.

### **Rewireable fuses.**

In this type, fuse wire is placed in a removable fuse link. The fuse link may be of porcelain or other suitable insulating materials, it is so constructed that there is no danger to the operator in removing the fuse link. The fuse wire is connected between two terminals and passes through an asbestos tube or is in intimate contact with a sheet of asbestos. The fuse link is push-fitted into the fuse base to make the connection through suitable contacts. Although the material cost of replacing a blown fuse wire in a Rewirable fuse is negligible, nevertheless this fuse had disadvantages, the chief being the deterioration of the fuse wire over a period, and another the possibility of renewal by the wrong size of fuse wire.

### ***Cartridge fuses***

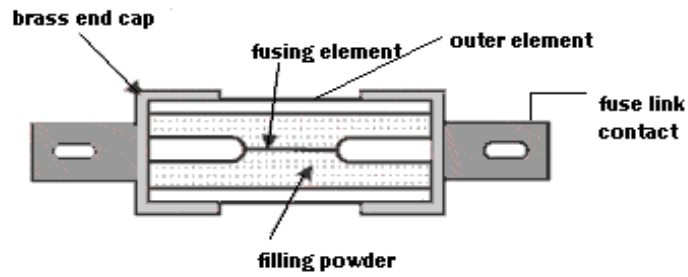
The cartridge fuse consists of a sealed tube with metal end caps. The fuse wire passes through the tube from cap to cap and is welded or soldered to the inside of the cap. There is sometimes a blowout device in the side of the tube to indicate when the fuse is blown. When the fuse is blown the whole cartridge must be replaced. Cartridge fuses only are used in fused plugs, such as the common ring-circuit 13 –A plug.

### **High breaking capacity fuses.**

The H.B.C fuse consists of a ceramic tube with metal end caps and fixing tags. The fuse is a silver strip of special shape with a low melting point rivet in the center. The strip is entirely surrounded by chemically purified silica. When an overload occurs breaking the fuse element, the silica prevents the formation of an arc, thus preventing overheating of the fuse and its surroundings.



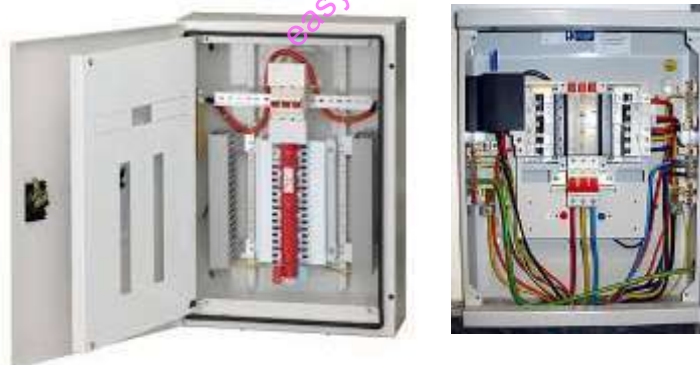
*Figure 261 HRC fuses*



*Figure 262 Construction of HRC fuse*

### **Distribution boards.**

The distribution board is an assemblage of parts, including one or more fuses or circuit-breakers arranged for the distribution of electrical energy to final sub-circuits or to other distribution boards.



*Figure 263 Distribution board*

The boards are usually metal-cased in sheet steel, or hardwood- cased in oak, teak, or mahogany. The doors may be solid or glazed, and the case is fitted with an earthing terminal. Figure 1.38 shows a 1-pole and neutral, 6-way, distribution board with sheet steel body, fitted with Rewirable or H.B.C fuses. There is one fuse bank only, on the live side. One end of each of the six fuses is rigidly connected to a busbar, and the other end is arranged for connection to the circuit wire. The neutral wire of the circuit is connected to the neutral bar.

The regulations require that the neutral conductors for the different sub- circuits shall be connected in the same order as the live conductors to the fuses. Some distribution boards are designed to contain circuit – breakers instead of fuses. These however are more expensive than the equivalent Rewirable or H.B.C fuses.

### ***Miniature circuit- breakers***

These are being increasingly used to provide *close excess - current* protection in single phase, 250 V circuits. The circuit- breaker is essentially a switch which may be:

1. Opened and closed by hand
2. Opened automatically when overloaded

The tripping action may be either magnetic or thermal. In general both these actions are used in this type of circuit-breaker. Protection against sustained over current is given by the bending of a bi-metal strip with its time-lag effect, while high speed protection against a short- circuit is given by magnetic operation.

The circuit-breaker replaces both switch and fuses in the various circuits in which it is used. It can be obtained with plug-in contacts for insertion into a fuse base in a distribution board in place of a plug-in fuse carrier.

### **Main switch and fuses**

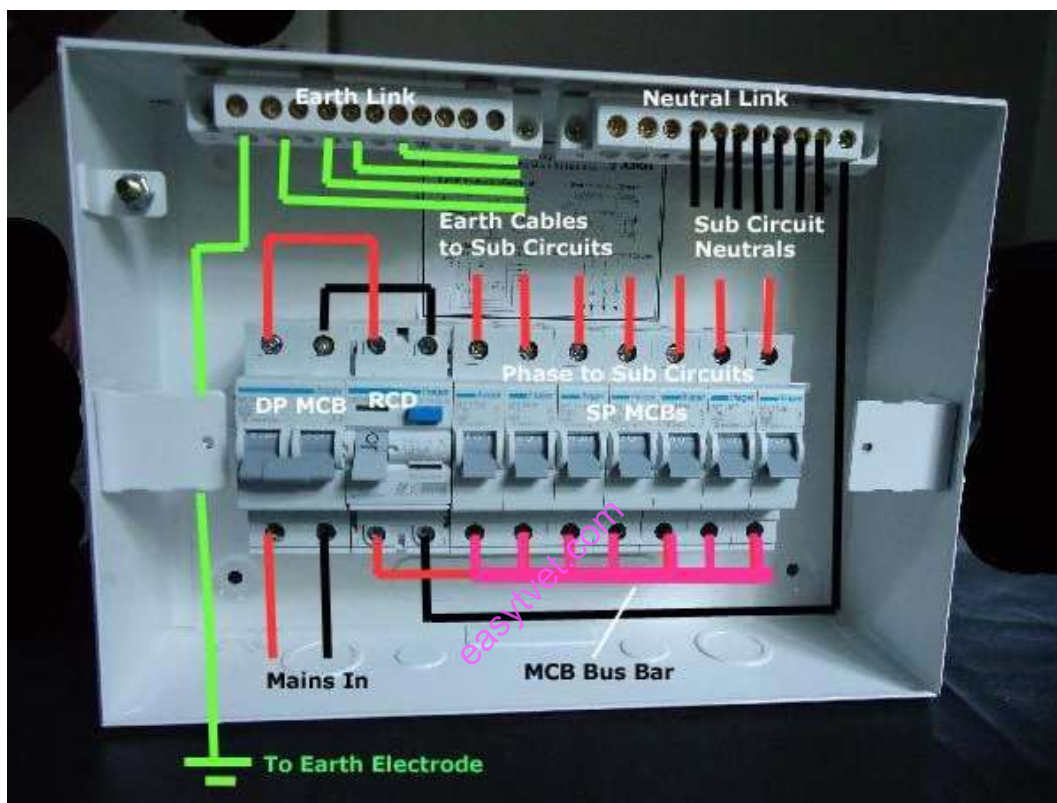
The consumer's main switch and fuses may be combined in one case. With this type of switch and fuse gear, the switch cannot be operated when the case is open, nor can the case be opened while the switch is closed.

### **Consumer's control unit**

In a single-phase installation whose current rating is not greater than 60A, the consumer's main switch and fuse may be combined with the distribution board as one combined unit. The unit comprises a 60A

2-pole main switch and up to 12 single-pole circuit fuses ( 12 way consumer unit). The fuses vary in size, e.g. 5A, 15 A and 30 A.

Obviously the maximum current to be taken from the unit at any one time must not exceed 60 A. either cartridge or Rewirable fuses may be employed. In addition to the fuses a neutral bar and an earthing bar are fitted. The whole is fitted in a suitable sheet steel case, or in a moulded case; figure 39 shows a connection diagram for this unit.



*Figure 264 Consumer control unit*

## **Types of Conductors**

The most common electrical conductors used are copper and aluminum. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. Aluminium wire is also drawn from a solid block

### Characteristics of aluminium and copper as conductors

The table 4 show the summarized characteristics of Aluminium and copper

Table 16 Summary of characteristics of aluminum and copper

| <i>Aluminium</i>  | <i>Copper</i>                                  |
|---|--|
| Smaller weight for similar resistance and current-carrying capacity | Can easily be drawn into wires                 |
| Easier to machine   | Has better electrical and thermal conductivity |
| Greater current density because of larger surface                   | Has greater mechanical strength                |
| High resistivity (2.845 $\mu\Omega$ -cm)                            | Is corrosion resistant                         |
| Light in weight   | Has high scrap value                           |
|   | Easy to joint                                  |
|   | Lower resistivity (1.78 $\mu\Omega$ -cm)       |

The determining factor in the use of one type of metal for conductors is usually that of cost. Aluminium cables are used where weight is a factor like for overhead transmission.

### Stranding of Conductors.

Stranding of conductors is done to make the completed cable more flexible. A set number of strands are used in cables: 1, 3, 7, 19, 37, 61, 91, and 127. Each layer of strands is spiraled on to the cable in opposite direction to the previous layer. This system increases the flexibility of the completed

cable and also minimizes the danger of '**bird caging**', or the opening-up of the strands under a bending or twisting force.

### Size of Stranded Conductors

The size of a stranded conductor is determined by the number of strands and the diameter of the individual strands. For example, a 7/0.85 mm cable consists of seven strands of wire, each strand having a diameter of 0.85 mm.

$$\text{The cross-sectional area will be} = 7 \times \frac{\pi D^2}{4} = 3.142 \times 7 \times \frac{0.85^2}{4} = 4.0 \text{ mm}^2$$



*Figure 265 Stranded conductor*

### Cable

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor (solid or stranded), or of two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall covering for mechanical protection." A cable consists of two basic parts:

- Conductors
- insulators

### Construction of Cables

A cable derives its name from the type of insulation used.

#### **Polyvinyl Chloride (P.V.C.) Cable.**

This is also known as 'thermo-plastic' cable since the insulation is made from a synthetic resin which softens when heated. The process of manufacture is as follows:

#### **Multi-core Cable.**

This is cable which is made up of two or more insulated conductors. Multi-core cable is sheathed in a protective covering— for example, tough rubber for tough rubber-sheathed cables (t.r.s.) and p.v.c. for plastic cables.

#### **Tough-Rubber-Sheathed (t.r.s.) Cable.**

This is made of specially toughened rubber which is resistant to acids and alkalies.

### **Polychloroprene (p.c.p. or neoprene) Cable.**

Uses an insulation somewhat similar to that of t.r.s. but capable of withstanding most weather conditions and particularly direct sunlight.

### **Heat-resisting, Oil-resisting and Flame-retardant (h.o.f.r.) Cables.**

These cables are used in conditions damaging to p.v.c. cables such as high temperature and oil. The resistant qualities are developed by a vulcanizing (or curing) process which forms an elastomer capable of withstanding tough conditions and still retaining its flexibility.

### **Comparison OF T.R.S. AND P.V.C. cable**

The table 5 shows the comparison between T.R.S cable and P.V.C cable

*Table 17 Comparison between T.R.S and P.V.C cable*

| <i>t.r.s. Cable</i>                       | <i>p.v.c. Cable</i>  |
|---|--|
| Affected by oil and water                 | Largely unaffected by oil, water, and corrosive chemicals    |
| More flexible                             | Hardens at low temperatures and softens at high temperatures |
| Must be protected against direct sunlight | Does not support combustion                                  |

The maximum operating temperature for both rubber and p.v.c. insulated cables is 45°C.

### **Flexible cable**

The I.E.E. Regulations define a flexible cable as: "A cable consisting of one or more cores, each containing a group of wires, the diameters of the wires and the construction of the cable being such as to afford flexibility."

### **Flexible cord**

A flexible cord is defined as: "A flexible cable in which the cross-sectional area of each conductor does not exceed 4 mm<sup>2</sup>".



### Twisted Twin Flex Cable

This is made up of a multi-strand tinned-copper conductor with silicon rubber insulation. *Application:* lighting flex.



Figure 266 Twisted twin flex

**Circular Flex.** The rubber-insulated cores are formed into a circular section with cotton worming and contained in a cotton braiding.

*Applications:* connections to household appliances (iron boxes, kettles, etc.)

**Circular Flex, Rubber Sheathed** This flex is also packed with jute or cotton to form a circular cross-section but an outer sheath of rubber replaces the cotton braiding.

*Applications:* vacuum cleaner and portable drill leads (3-core).

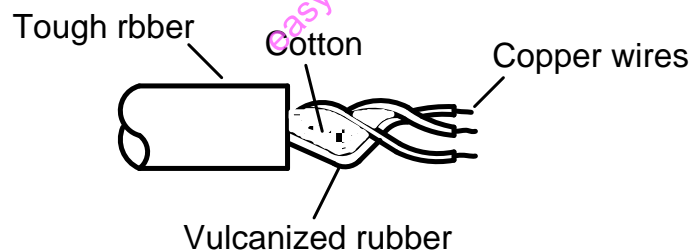


Figure 267 Circular flex, rubber sheathed

### Workshop (or Industrial) Flex

This flex is similar in construction to the above, but has the addition of a compounded braiding. *Application:* connections to industrial lighting.

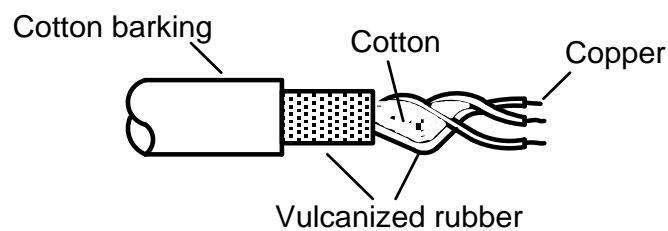


Figure 268 Workshop (or industrial) flex

### **Permissible Voltage Drop in Cable.**

Voltage drop is an essential feature in the calculation of cable size. Low voltage at the consumer's equipment leads to the inefficient operation of lighting, power equipment, and heating appliances. The maximum voltage drop allowed between the consumer's terminals and any point in the installation is 2-5 per cent of the voltage supplied by the Electricity Supply Authority, including motor circuits.

### **Voltage Drop and the I.E.E. Tables.**

The I.E.E. tables state the voltage drop across a section of cable when maximum current is flowing through it. If the current is halved, the voltage drop will also be halved. For example, a 4 mm<sup>2</sup> twin-core cable has a current rating of 24 A and a voltage drop 10 mV per ampere per metre. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per ampere per metre.

The I.E.E. Regulations contain comprehensive information regarding the current-carrying capacity of cables under certain conditions.

These tables supply:

- i. Cross-sectional area, number, and diameter of conductors;
- ii. type of insulation;
- iii. length of run for 1V drop;
- iv. Current rating (a.c. and d.c.), for either single or bunched.

The following terms are used in the I.E.E. tables:

- i. ambient temperature
- ii. Rating factor.

**Ambient Temperature.** This is the temperature of the air surrounding the conductor. The current rating of a cable is decreased as the temperature of the surrounding air increases, and this changed current-carrying capacity can be calculated by using the relevant rating factor.

### **Rating Factor.**

This is a number, without units, which is multiplied with the current to find the new current-carrying capacity as the operating conditions of the cable change. For example, a twin-core 10 mm<sup>2</sup> (7/1.35 mm) p.v.c. cable will carry a maximum current of 40 A at an ambient temperature of 25 °C, but if the ambient temperature is increased to 65 °C the maximum current allowed will now be:

$$40A \times 0.44 \text{ (rating factor)} = 17.6A$$

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carrying capacity will decrease; a rating factor is therefore supplied for the bunching, or grouping, of cables.

### **Current Density and Cable Size.**

The current density of a conductor is the amount of current which the conductor can safely carry without undue heating per unit cross-sectional area. For example, if a copper conductor has a current density of 300 A/cm<sup>2</sup> a copper conductor of cross-sectional 0.5 cm<sup>2</sup> will be capable of carrying one half of 300 A, that is, 150 A.

To calculate the current-carrying capacity of a cable (given cross-sectional area (cm<sup>2</sup>) and current density (A/cm<sup>2</sup>) :

Current-carrying capacity = current density x cross-sectional area

*Example.*

*Calculate the current-carrying capacity of a 0.1 cm<sup>2</sup> conductor if the current density of the conductor is 400 A/cm<sup>2</sup>.*

$$\text{Current-carrying capacity} = 400\text{A/cm}^2 \times 0.1\text{cm}^2 = 40 \text{ A}$$

### **Fittings**

Power is relevant to electricians because it says that reasonable provision shall be made to provide lighting systems with energy-efficient lamps and sufficient controls so that electrical energy can be used efficiently.

The two methods of compliance with these Regulations for both internal and external lighting. It says:

- A reasonable number of internal lighting points should be wired that will only take energy-efficient lamps such as fluorescent tubes and compact fluorescent lamps, CFLs.
- External lighting fixed to the building, including lighting in porches but not lighting in garages or carports, should provide reasonable provision for energy-efficient lamps such as fluorescent tubes and CFLs.

These lamps should automatically extinguish in daylight and when not required at night, by being controlled by Passive infra-red (PIR) detectors. The traditional light bulb, called a GLS (general lighting service) lamp is hopelessly bad in energy efficiency terms, producing only 14 lumens of light output for every electrical watt input. Fluorescent tubes and CFLs produce more than 40 lumens of light output for every watt input.

### **Different types of lamp.**

### a) GLS lamps

GLS lamps produce light as a result of the heating effect of an electrical current. Most of the electricity goes to producing heat and a little to producing light. A fine tungsten wire is first coiled and coiled again to form the incandescent filament of the GLS lamp. The coiled coil arrangement reduces filament cooling and increases the light output by allowing the filament to operate at a higher temperature. The light output covers the visible spectrum, giving a warm white to yellow light with a colour rendering quality classified as fairly good. The efficacy of the GLS lamp is 14 lumens per watt over its intended lifespan of 1000 h. The filament lamp in its simplest form is a purely functional light source which is unchallenged on the domestic market despite the manufacture of more efficient lamps. One factor which may have contributed to its popularity is that lamp designers have been able to modify the glass envelope of the lamp to give a very pleasing decorative appearance, as shown by figure 43.



*Figure 269 some decorative GLS lamp shapes*

### b) Tungsten Halogen Dichroic Reflector Miniature Spot Lamps

Tungsten Halogen Dichroic Reflector Miniature Spot Lamps such as the one shown in Fig. 44 are extremely popular in the lighting schemes of the new millennium. Their small size and bright white illumination makes them very popular in both commercial and domestic installations. They are available as a 12 V bi-pin package in 20, 35 and 50 W and as a 230 V bayonet type cap (called a GU10 or GZ10 cap) in 20, 35 and 50 W. At 20 lumens of light output over its intended lifespan of 2000 h they are more energy efficient than GLS lamps. However, only lamps offering more than 40 lumens of light output are considered energy efficient by the Government's criteria.



*Figure 270 Tungsten Halogen Dichroic Lamp*

### **c) Discharge lamps**

Discharge lamps do not produce light by means of an incandescent filament but by the excitation of a gas or metallic vapour contained within a glass envelope. A voltage applied to two terminals or electrodes sealed into the end of a glass tube containing a gas or metallic vapour will excite the contents and produce light directly. Fluorescent tubes and CFLs operate on this principle.

### **d) Fluorescent tube**

A fluorescent lamp is a linear arc tube, internally coated with a fluorescent powder, containing a low-pressure mercury vapour discharge. The lamp construction is shown in Fig. 45 and the control circuit in Fig 46.

Fluorescent luminaire is equipment which supports an electric lamp and distributes or filters the light created by the lamp. It is essentially the 'light fitting'. A lamp is a device for converting electrical energy into light energy. There are many types of lamps. General lighting service (GLS) lamps and tungsten halogen lamps use a very hot wire filament to create the light and so they also become very hot in use. Fluorescent tubes operate on the 'dis-charge' principle; that is, the excitation of a gas within a glass tube. They are cooler in operation and very efficient in converting electricity into light. They form the basic principle of most energy efficient lamps. Fluorescent lamps are linear arc tubes, internally coated with a fluorescent powder, containing a little low pressure mercury vapour and argon gas. Passing a current through the electrodes of the tube produces a cloud of electrons that ionize the mercury vapour and the argon in the tube, arc radiates much more UV than visible light: almost all the visible light from a fluorescent tube comes from the phosphors. Glass, internally coated with fluorescent phosphor, cut away to reveal cathode-pin cap. Tube filled with argon and mercury vapour. Cathode coated with electron emitting material and fitted with cathode shield producing invisible ultraviolet light and some blue light. The fluorescent powder on the inside of the glass tube is very sensitive to ultraviolet rays and converts this radiation into visible light. Fluorescent luminaires require a simple electrical circuit to initiate the ionization of the gas in the tube and a device to control the current once the arc is struck and the lamp is illuminated.

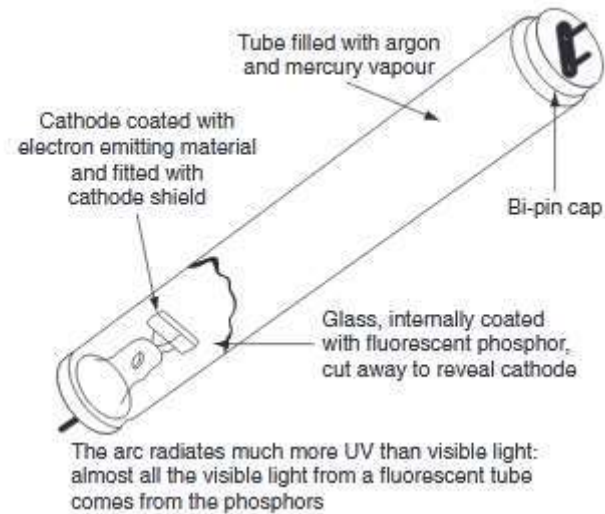


Figure 271 Fluorescent lamp construction

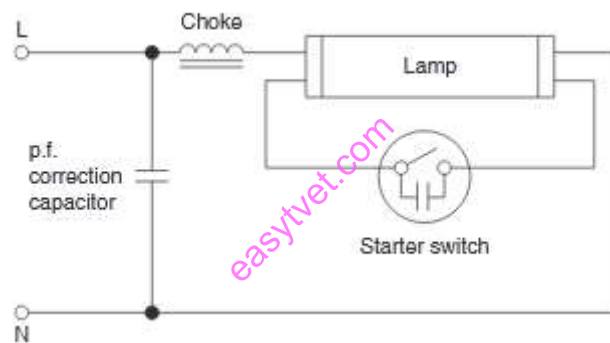


Figure 272 Fluorescent Lamp circuit arrangement

### e) Compact fluorescent lamps CFLs

These are miniature fluorescent lamps designed to replace ordinary GLS lamps. They are available in a variety of shapes and sizes so that they can be fitted into existing light fittings. Figure 46 shows three typical shapes. The 'stick' type gives most of their light output radially while the flat 'double D' type give most of their light output above and below. Energy efficient lamps use electricity much more efficiently than an equivalent GLS lamp. For example, a 20 W energy efficient lamp will give the same light output as a 100 W GLS lamp. An 11 W energy-efficient lamp is equivalent to a 60 W GLS lamp. Energy efficient lamps also have a lifespan of about eight times longer than a GLS lamp and so, they do use energy very efficiently. However, energy efficient lamps are expensive to purchase and they do take a few minutes to attain full brilliance after switching on. They cannot always be controlled by a dimmer switch and are unsuitable for incorporating in an automatic presence detector because they are usually not switched on long enough to be worthwhile, but energy-efficient lamps are excellent for outside security lighting which

is left on for several hours each night. The electrical contractor, in discussion with a customer, must balance the advantages and disadvantages of energy-efficient lamps compared to other sources of illumination for each individual installation



*Figure 273 Energy efficient lamps*

### **Inventory management**

If your business uses a lot of tools and equipment, keeping track of inventory will be no easy task. From small tools like hammers to saws and big equipment like rollers/cement mixers, individual equipment tracking becomes a huge concern for the organization. Deviations from the record can cause a delay in project completion.

Tool data irregularity can cause Shutdowns, Turnarounds, and Outages (STO's) where the cost of project completion becomes 3-4 times the actual cost.

This may lead to inaccurate decision making, inefficient planning, and an inability to stick to the contract. To complete the project on time, most stakeholders just reorder the equipment rather than locating it, which further increases project costs.

The main reasons you cannot find your tools are:

1. **Tools are not there and/or they have arrived in the wrong quantity:** if the tools that are supposed to be shipped haven't reached the designated location or they are shipped to another, you will have a missing tool report.
2. **Tools have been moved:** maybe the tool is still in the warehouse. But someone moved elsewhere without anyone knowing or they have placed it in the wrong location after using it, so it will classify as missing.
3. **Theft/Misplacement:** one of the most common reasons for missing tools is theft. Someone took the tool to work and didn't return it. Or after using it, they misplaced it.

4. **The log is not recorded correctly:** if the log sheet says that someone has issued the tool while it's actually still on the premises, it won't be used if there is a requirement. Conversely, if someone is using the tool but the log sheet says that the tool is available, people will look for it. That will cause confusion, halt work, and waste precious time.

However, there are some tips and tricks you can implement to make sure you keep a good track of your tools and equipment.

### **Track all inventory**

Tracking your inventory is the best thing that you can do.

A good inventory tracking system means it is accurate and up to date. You can do cycle checks instead of daily tracking to reduce the time and effort required for inventory checking.

You may also have a central database where you list everything you own. That will reduce theft, as everyone will know if something's missing.

Inventory checks also make sure you allocate an appropriate budget for the inventory. Most of the time, businesses have much more inventory than they need.

Even if that's not your case, when tracking your inventory, you will be on top of work requirements and order equipment correctly the next time you need it.

### **Categorize Tools and Equipment**

Categorizing tools and equipment can help you identify where similar tools are kept and which ones can be used interchangeably.

While you can categorize your inventory granularly in a program, you can place interchangeable tools in the same location for easier access.

You can divide tools into various categories, in a way that suits your business model best.

For example, you can organize tools by site and divide small and large tools. Other categories can be:

- Type of tool (hand tool, power tool)
- Tool brand
- Use for that tool (indoor, outdoor)

Organize tools as you see fit, but it would be wise to include information on equipment's status, purchase date, and warranty expiration date.

### **Tag individual items**

Tagging items in your inventory will enable you to track, identify and locate each tool you have. You can tag equipment in many ways, barcodes and RFID chips being the most common.

We will explain the benefits of each option later.

### **Track tool usage**



You should know which tool is being used more, how much is it being used, who is using it, and how much does it cost to ship it.

These insights will help you prioritize tools by requirement and transport price so you don't spend an extra dime on tools than you absolutely have to.

If a tool is collecting dust in a warehouse while it's needed somewhere—the business suffers.

Most importantly, if a tool gets stolen, you'll have the record of who was the last person handling it, when they used it, and the last location they used the tool. This is important as over time, the cost of lost tools adds up.

Checking in and checking out tools will help make a strategy for further equipment management.

### **Track Repairs and Warranties**

If you're using one tool daily and another one once a month, the tool you use every day requires more maintenance, and it's more likely to break.

Also, when you have information about the equipment usage, you can plan maintenance for idle tools or machines due for checkups. Being well organized will not affect business processes, and will keep your equipment up and running.

Monitor which tools are under the warranty as you could maintain/fix them free of cost. This will make sure you spend money and time only on that tools/equipment that really need it.

### **What happens if the tool breaks?**

Track which tools are regularly out of commission. If something breaks, try to understand the reason behind it, especially if it happens more often than it should. You can do that by collecting data and conducting trend analysis.

Answer the following questions and you'll have a better understanding of why something breaks:

- Is the equipment not being used properly (handling error)?
- Are they not being used according to correct voltage specifications?
- Does it require a resting period before reuse?

Not only does a broken tool costs time and money to fix it, but your workers would also be idle while it's getting fixed if there's no replacement available.

To save money in the long run, try to buy quality equipment from a trustworthy brand.

### **Determine optimum utilization**

When categorizing tools, you can gather more data for each one.

For instance, you can find out which tools employees like better and which ones are the most effective in getting the job done.

Compare that with the cost and find information on how many companies are making it. Then, try to research which brand has the most durable equipment. Do a cost analysis to figure out which tools drain

you most financially, either by physical issue (breaking too early) or logistical issue (too much requirement?)

With that intelligence, you'll be able to make smarter decisions.

### **Equipment usage accountability**

Making individual workers accountable for the equipment they use is a sure-fire way to reduce thefts and counting errors.

Here's what you can do.

- **Use technology:** use a tool management system instead of a manual record and make sure your employees know how to use it. That way they can self-check-in or check-out the required tools.
- **Bring your employees up to speed** about the tool tracking system you chose and explain how everything functions. You can also put a tool handling and usage chart in the workplace for a better understanding.
- **Create a tool handling agreement** to make sure your workers understand accountability associated with issuing that tool. Tell them about established laws related to the theft of tools and remind them of the consequences.
- **Establish rewards and fines:** for an exceptional tool handling, you can also issue rewards. This will motivate people to handle the tools better. Fines can be given to those who don't follow the rules. Workers who "lose" tools frequently can pay for the equipment out of their paycheck, if this will be your p.

### **Asset management system**

Pen and paper tracking can work for small organizations; however, an asset management system/inventory management system should be used to manage tools in a large organization. It reduces inventory errors and increases safety for tools.

Along with the tagging system, you can formulate a real-time asset tracker for more precise information. You might think, "I can manage my tools with a logbook and RFID tags. Why should I pay for software to do that?"

Well, there are huge advantages to using a dedicated software solution for tool tracking. Pen and paper solutions or spreadsheets are nowhere near good enough then the software method.

Here are some advantages of professional tool and asset management software over paper tracking/spreadsheets:

So now that you know the benefits of a professional tracking solution—how do you choose a tracking solution?

There are many available on the market. Most of them cater to different needs. We'll explore the features you need to be on the lookout for.

There are a few things you should consider before choosing a tool tracking solution.

### Cloud connectivity

Storing your data on a single disk is a big security risk.

Cloud-based solutions allow users to access data from anywhere (flexibility). Also, cloud-native architecture has firewalls and encryption settings that add another layer of security.

### Scanning device

You can use either a smartphone scanner or a dedicated hand-held scanner for equipment scanning.

A handheld scanner is an extra piece of hardware that you have to buy which is why most companies implement smartphone scanners that offer more flexibility for check-in and checkout.

### 6.2.3.4 Learning Activities

#### Workshop Practice

| Practical activities   | Knowledge                               | Special instruction                              |
|--|---|--|
| 6. Check and identify tools, equipment and materials for proper specifications and functionality (in the workshop) | Electrical tools and equipment          | Name and draw the electrical tools and equipment |
| 7. Store and assemble tools equipment and materials as per the established procedure after a project               | Tool's storage and inventory management |  |

### 6.2.3.5 Self-Assessment

1. What are the most commonly used types of conductors?
2. Which electrical accessories are use when carrying out electrical installations
3. Cables consists of three major parts. Name the parts
4. Below are tools and equipment used when preparing steel conduit for installation. What is the function of each?

### 6.2.3.6 Tools, Equipment, Supplies and Materials

#### Recommended Resources

|   |  |
|---|--|
| <p><b>Tools and equipment</b></p> <ul style="list-style-type: none"><li>➤ Cable Strippers</li><li>➤ Pliers</li><li>➤ Screw drivers</li><li>➤ Hammers</li><li>➤ Chisels</li><li>➤ Allen keys</li><li>➤ Electrician knives</li><li>➤ Crimping tools</li><li>➤ Bending springs</li><li>➤ Bending machine</li><li>➤ Steel tapes</li><li>➤ Draw wires</li><li>➤ Hack saws</li><li>➤ Drilling tools</li><li>➤ Stock and die</li><li>➤ Bench vice</li><li>➤ Machine vice</li><li>➤ PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li></ul> | <p><b>Materials and supplies</b></p> <ul style="list-style-type: none"><li>• Stationery</li><li>• Cables</li><li>• Light fittings</li><li>• Accessories</li><li>• Conduits and fittings</li><li>• Cable trays</li><li>• Cable ducts</li><li>• Trunkings</li><li>• Computers</li><li>• Drawing instruments</li><li>• Screws</li></ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"><li>• IEE regulations</li><li>• Occupational safety and health act (OSHA)</li><li>• Work injury benefits act (WIBA)</li><li>• Manufacturers’ catalogues</li><li>• British standards</li><li>• KEBS standards</li></ul>  |  |

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### 6.2.3.8 Model answers to self-assessment

1. What are the most commonly used types of conductors?
  - Copper
  - Aluminium
2. Which electrical accessories are use when carrying out electrical installations
  - Lamp holders
  - Conduits
  - Ceiling roses
  - Patress
3. Cables consists of three major parts. Name the parts
  - Conductor
  - Insulator
  - Mechanical protection or sheath

4. Below are tools and equipment used when preparing steel conduit for installation. What is the function of each?
- b. Stock and die; **threading**
  - c. Hacksaw; **cutting**

## 6.2.4 Learning Outcome 4 Install electrical system

### 6.2.4.1 Introduction to the learning outcome

To install electrical system, one requires to apply appropriate installation procedures and technical standards, implement working drawing, adhere to IEE regulations during installations, adhere to safety procedures for each activity, install cables, conductors, conduits, enclosures and support systems to specifications and label installation for identification.

### 6.2.4.2 Performance Standards

- 6.2.4.2.1 Apply appropriate installation procedures and technical standards
- 6.2.4.2.2 Implement working drawing
- 6.2.4.2.3 Adhere to IEE regulations during installation
- 6.2.4.2.4 Adhere to safety procedures for each activity
- 6.2.4.2.5 Install cables, conductors, conduits, enclosures and support systems to specifications.
- 6.2.4.2.6 Label installation for identification

### 6.2.4.3 Information Sheet

#### Cables

A cable is a length of single conductor having one or several wires stranded together, or two or more such conductors each provided with its own insulation and laid together. The insulated conductors may or may not be further covered with an overall protective sheath to prevent mechanical damage. The insulated conductors are referred to as the cores of the cable.

Sometimes bare or insulated conductors are used for overhead installations, or they are enclosed in a metal casing for rising (vertical) and lateral (horizontal) main supplies in buildings.

Cable consist of three essential parts:

- **Conductor** – to carry the current
- **Insulation (dielectric)** – to provide the means to prevent leakage of current
- **External overall protection** against mechanical damage, chemical attack, fire or other external damaging factors to the cable.

#### Cable layouts and wiring systems

Because of the complexity and hazards involved in the installation of cables in the many types of building and their surroundings, there are quite a number of different types of cables and wiring systems in use. Each is designed to meet and withstand the elements it will encounter and at the same time fit with the overall building construction in terms of convenience and appearance.

It is the responsibility of the contractor, designer or sometimes electrician, himself to study carefully the building specification and decide upon the type of cables and wiring systems most suitable.

### **Wiring system**

A wiring system consist of conductors, insulators, means of mechanical protection and all accessories associated with installation.

### **Factors affecting choice of wiring system**

1. **Type of building construction** – is it permanent or temporary structure, hospital, workshop, office or dwelling house will help to decide the routing, fixing and terminations
2. **Flexibility of the system** –change of location of equipment such as machine shops and temporary buildings i.e. must be flexible to needs of future alterations and modifications.
3. **Installation conditions/special adverse conditions** – protection against mechanical damage requirements and working heights. Also, conditions that are harmful to the wellbeing of a wiring system must be considered e.g. presence of flammable vapours risk of mechanical damage and presence of corrosive environment such as dampness.
4. **Appearance of finished installation (aesthetics)** – can be run on surface or concealed e.g. exposed conduit system cannot be used in an executive office.
5. **Durability** – life of the installation
6. **Economics/ Cost** – Cost of installation and money available. The cost of the wiring system must be compared to get the relative cheap system without compromising on the safety of the wiring.
7. **Type of load to be supplied** –should be made to the level of voltage expected in the circuit e.g. low voltage, medium voltage or extra high voltage.

### **Terminating and Jointing P.V.C. Cables**

#### **Stripping P.V.C. Cables.**

A single-core p.v.c. cable should be stripped by holding the cutting knife at an angle to the cable and cutting away from the hand holding the cable. Multi-core cable is stripped by running the cutting knife along the centre of the cable and then nicking the end of the cable to give two finger grips. This allows the sheathing to be pulled down the cable with the thumb and forefinger of each hand. The sheath is then folded on top of the cable and cut by drawing the knife between the sheathing and the cable.



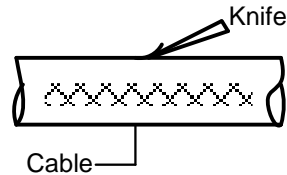


Figure 274 Stripping cable

There are two basic methods of joining electrical conductors: (a) mechanical joints; and (b) soldered joints.

### Mechanical Jointing.

This is done by using connector blocks. These consist of one-way or multi-way brass terminal blocks enshrouded with porcelain or plastic insulation. The connector must be capable of containing all the strands of the conductor.

Another method, usually used with larger cables, is **mechanical crimping**. This is done by placing a sleeve over the conductors to be jointed and crimping (squeezing) the connection with a manual or hydraulically operated crimping jack.

### Soldered Joints.

Materials required: pliers, sharp knife, soldering bit, flux, blowlamp (or butane gas cylinder), solder, p.v.c. tape and black insulating tape.

*Soldering Bit.* Every joint which is made by twisting strands together must be soldered. Where a lot of single-core jointing is being carried out, it is often convenient to use a heavy bit which has a slot filed in it to take cables. The soldering bit should be heated until a green flame appears and must always be kept clean. Always 'tin' the bit with flux and solder before using. *Flux.* The purpose of the flux is to remove the oxide film from the surface of the conductor and prevent it from re-forming.

*Blowlamp.* This should be operated as follows:

1. The lamp should not be more than two-thirds full.
2. Leave the valve open when starting.
3. Start lamp with small rag dipped in methylated spirits.
4. When the lamp is hot, the valve should be closed and the pump operated.
5. The pump forces the paraffin through the heated vaporizing tube and out of the nozzle where it is ignited under pressure.
6. The blowlamp should be played against an asbestos sheet until the flame is fully established.

*Solder.* Two basic types of solder are used in electrical work: fine solder (tinman's solder), which is **60** parts tin and **40** parts lead, and plumber's metal, which is **30** parts tin and **70** parts lead. Fine solder melts more easily, as tin has a lower melting point than lead, and so it is commonly used for electrical

joints. Plumber's metal is used for 'plumbing' joints in armoured cables, as it remains in a plastic state, allowing it to be shaped, longer than fine solder.

### **Methods of Soldering.**

There are three methods used for soldering conductors:

- (a) soldering bit,
- (b) 'stick' method
- (c) (metal) pot and ladle method.

*Soldering Bit.* The conductors to be jointed are first smeared with a resinous flux. The tinned bit is then applied under the joint until the heat penetrates it. The stick of solder is then applied to the joint until the solder flows freely through it.

*'Stick' Method.* In this method, the joint is first heated with a blowlamp, flux being applied. The solder is then applied by pressing the stick of solder against the heated joint until it penetrates the joint. Care should be taken to protect the insulation against the blowlamp flame.

*Pot and Ladle Method.* This method is commonly used by jointers when jointing heavy conductors. A solder pot is heated until the solder is running freely. The solder should not be overheated as this will burn the tin and a dross will form on the surface of the solder. When the solder has reached working temperature it is taken from the pot with a ladle. The solder is then poured over the prepared joint and is caught by another ladle placed under the joint. This action is repeated until the solder penetrates the joint.

### **Soldering Aluminium.**

The following special points should be noted when soldering aluminium:

- All surfaces must be scrupulously clean.
- When making a joint between stranded conductors 'step' the strands to increase the surface area.
- The surface must be heated *before* the flux is applied as the flux will only take when the temperature is high enough.
- Apply aluminum solder until the complete surface is bright.
- Joints in aluminum should be protected from contact with the atmosphere. This can be done by painting, taping, or compounding.

**Soldering a Socket (or Lug).** The method used is as follows

5. Strip insulation back about 5 cm.
2. Tin the socket.
3. Smear both the socket and the bared conductor with flux.

4. Fit the socket to the conductor. The socket should be a hammer fit.

If the socket is too large, the conductor can be enlarged with a tinned-wire binding or, better still, by pressing a strand of cable into the centres of the conductor.

5. Play the blowlamp in the top of the socket until the heat has penetrated the conductor, and then apply a stick of solder to the lip of the socket. The completed connection should have a rim of solder showing round the lip of the socket; this can be done by applying plumber's metal as the joint is cooling.
6. When the termination is cooled, cut back damaged insulation and apply p.v.c or cambric tape.
7. Tape is used to replace insulation which has been removed prior to jointing.

*Do not attempt to cool a soldered joint by pouring water over it. This can lead to an effect joint known as a dry joint. Never smooth the joint with a file but use a dry cloth before it sets.*

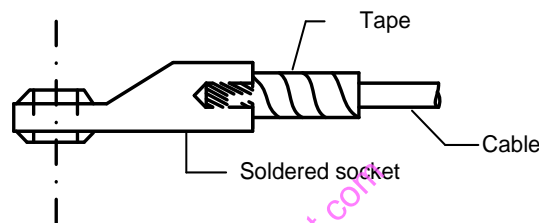


Figure 275 section through soldered socket

### Through joint

This joint is made by using mechanical connectors, compressor ferrules or grip-type (weak back) soldered sleeves.

The completed joint is wrapped with p.v.c. tape. The joint can further be protected by the use of a cold pouring of resin compound to fill the protection box.

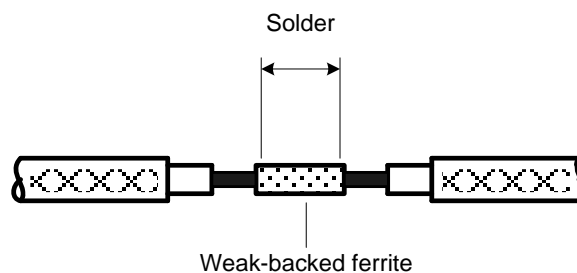


Figure 276 Straight-through joint using weak-backed ferrule

### Straight-through joint using weak-backed ferrule

A weak-backed ferrule is a tubular piece of tinned-copper opened along the top and weakened at the bottom thus allowing it to be closed or opened easily.

*Procedure of making the joint*

1. Strip insulation back from both of the conductors.
2. Clean and tin ferrule
3. Place ferrule on cable. Butt cables together before tightening the ferrule
4. Wind small pieces of cloth at each end of the ferrule to contain the molten metal
5. Solder the connection
6. Remove damaged insulation and apply tape.

### Tee (breeches) Joint

This joint is used to tee-off a service from an armoured cable. The weak-backed ferrule is often used. Mechanical connectors or compression ferrule can also be used

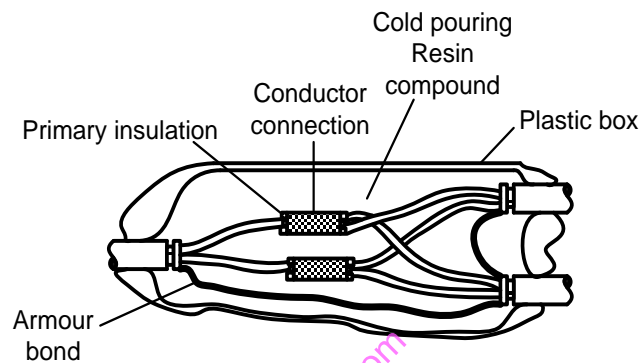


Figure 277 Tee (breeches) joint

### Armoured cable

This cable is used where there is a likelihood of the insulation or conductor being subjected to mechanical damage. This can occur when the cable is run underground.

There are two main types of armoured cables:

- a) Paper insulated lead covered steel wire or steel tape armoured cables, abbreviated as P.I.L.C.S.W.A. and P.I.L.C.S.T.A cables respectively
- b) P.V.C.armoured cable

### P.I.L.C.S.W.A.

The cable has the following parts

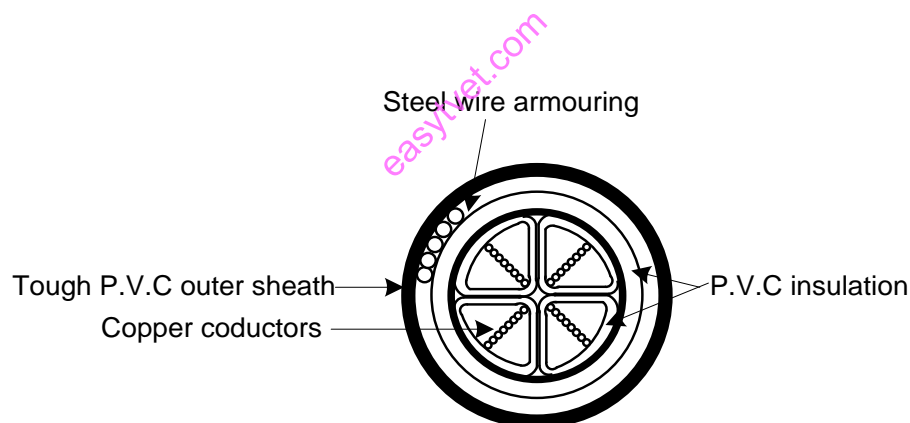
- a) An inner core of jute used to keep the cable circular.
- b) Copper or aluminium conductors insulated with mineral oil-impregnated paper.
- c) A lead sheath which contains the insulation and is also used as an earth continuity conductor
- d) Jute bedding tape impregnated with bitumen that protects the lead from armouring
- e) Galvanized steel wire (one layer) or steel tape (two layers).
- f) Bitumen impregnated jute serving

### Termination of P.I.L.C.S.W.A. cable

1. Place binder 1m from end of cable
2. Remove serving to this point
3. Bend steel wire armouring back until it is clear to lead sheath
4. Remove about 13cm of lead sheath and clean the remainder
5. Place brass gland on cable, leaving approximately 10cm of lead sheath showing. Wedge gland with wood to keep it central on cable
6. Use plumber's metal to plumb the joint
7. Clean galvanized wire paraffin rag and shape the wire over the plumb
8. Clamp wires on the gland and bolt the gland on sealing chamber
9. Cut back paper insulation on conductors and make through-joint to V.R.I conductors, using weak-back ferrule
10. Assemble sealing chamber and pour in hot bitumen to seal oil-impregnated paper against moisture

### **P.V.C. Armoured Cable**

This is made up of p.v.c insulated cores packed with p.v.c. to give a circular cross section. An outer p.v.c. sheath covers the galvanized steel wire.



*Figure 278 P.V.C armoured cable*

### **Termination of P.V.C. armoured cable**

The following must be taken into consideration when terminating

1. P.v.c. must be protected from heat
2. P.v.c. tapes must be used for insulating the conductors
3. Care must be taken when clamping and cleaning the galvanized wire so that it is not broken as it is the sole earth continuity conductor
4. The temperature of the hot pouring compound should not melt the p.v.c. insulation of conductors. Dip a piece of scrap p.v.c. into the compound before pouring to test the temperature.

## Mineral Insulated Metal Sheathed (M.I.M.S.) Cable

This cable consists of three parts. These are:

### *Copper or aluminium conductors*

Each core consists of a single copper conductor. Common core numbers are 1,2,3,4 and 7

### *Insulation*

The insulation between the cores is magnesium oxide. It can withstand high temperatures but is absorbent to moisture

### *Outer sheath*

Is a seamless copper or aluminium tube

Advantages and disadvantages OF M.I.M.S. CABLE (table 6)

Table 18 advantages and disadvantages of M.I.M.S

| Advantages   | Disadvantages   |
|--|---|
| Heat resistant. Can withstand temperatures up to 250°C       | Expensive   |
| The sheath provides an excellent earth continuity conductor  | Termination takes time  |
| Is mechanically strong must be protected against sharp edges | Has greater voltage drop per metre at the same current rating |
| High current density   |   |
| Does not deteriorate with age                                |   |

## Cable Termination

- Termination is the entry of a cable end into an accessory. In case of a stranded conductor, the strands should be twisted tightly together before termination. Great care must be taken not to damage the wires. The I.E.E. Regulation requires that a cable termination of any kind shall securely anchor all the wires of the conductor and shall not impose any mechanical stress on the terminal or socket. If a soldering socket is used, then it must contain all the strands of the conductor.
- A termination under mechanical stress is liable to disconnection. When current is flowing in a cable, certain amount of heat is developed, and the consequent expansion and contraction may force the cable out of the terminal or socket.
- If one or more strands of the cable were to be left out of the terminal or socket, there would be a reduction in the effective cross-sectional area of the conductor at the point. When terminating rubber insulated cable, the technician should avoid exposing the rubber insulation and conductors to the atmosphere. In conditions of heat or moisture, the terminations should be sealed.

- Mineral insulated copper sheathed cables are terminated in *sealed glands*. A common arrangement is the screw-on pot-type seal, in which a small metal pot is screwed on to the copper sheath. Cold plastic compound is then pressed into the pot and a fibre cap and insulating sleeves and threaded over conductors and crimped into position.
- If an insulation test indicates that moisture has entered the mineral insulation, the gland must be undone, the moisture driven out using a blowlamp and the seal re-made.

### ***Types of terminal.***

The most commonly used methods of securing conductors in accessories are:

#### *Pillar terminals,*

A pillar terminal has a hole through its side into which the conductor is inserted and then secured by a set screw. If the conductor is small in relation to the hole, it should be doubled back. When two or more conductors are to go into the same terminal, they should first be tightly twisted together. In the case of flexible cord terminations, the strands must be twisted up (and then bent back if room permits) before being entered into the terminal.

- screw head, and
- Nuts and washers.

When fastening conductors under screw heads or nuts, it is best to form the conductor end into an eye by means of the round-nosed pliers. The eye should be slightly larger than the screw shank, but smaller than the outside diameter of the screw head, nuts or washers. The eye should be placed in such a way that rotation of the screw head or nut tends to close the joint in the eye. If the eye is put the opposite way round, the motion of the screw or nut will tend to untwist the eye, and will probably result in imperfect contact.

The importance of good contact cannot be over-stressed. Poor contact introduces resistances at the termination and leads to over-heating eventually leading to fire.

*Solder less lug connections* are now being used to some extent in the electrical contracting industry, particularly for terminating small sized cables. Lugs of this type are made from solid copper and are tinned. They are fastened to cable ends by crimping. Hand crimping tools usually accommodate several cable sizes in a fixed head.

For the larger sized lugs, there are hydraulic crimping machines with capacities of several tonnes

### **Termination Tools**

- The following tools are required while terminating an electrical cable
- A sharp knife,
- A pair of side-cutters and
- A soldering iron.

- The knife should be sharpened periodically. The cutting edge of pliers and side-cutters should not be used for purposes other than that for which they are intended. The bit of the soldering iron should be kept clean.
- For compliance with the I.E.E. Regulations, joints in cables must be;
  - Made by soldering or by mechanical clamps
  - Mechanically and electrically sound
  - Provided with insulation not less effective than that of the cable cores,
  - Protected against moisture and mechanical damage
  - Accessible for inspection (except in the case of buried cables)

### **Soldering**

- The type of solder to be used for twist-joints is called 'tin man's solder.' It is a soft solder consisting of 60 parts tin to 40 parts leads, with a melting point of 200<sup>0</sup>C (about one-fifth of the melting point of copper). To make the solder flow readily over a surface, a *flux* is required. The function performed by the flux is largely that of cleaning the surface and of reducing any oxide to the metallic state.
- For electrical work, pure amber resin is the safest flux to use, because it does not cause any corrosion of the metal. Soldering fluxes containing acid or other corrosive substances, such as zinc chloride solution (killed spirits) must not be used for this work

### **The Soldering iron**

- When the soldering iron is heated, the surface should be cleaned, a small quantity of resin is applied and then the stick of solder lightly touched. The surface should then have a bright silvery appearance. Powdered resin is applied to the joint which is then laid in a shallow pool of solder. After a short period, the solder will run up into the strands, at which point joint can be removed from the iron and allowed to cool. Sometimes, soldering bits are grooved so that the portion of joint to be soldered can be placed in the groove, thus giving a larger area of surface contact between the two.
- A well-soldered joint should present a smooth, bright appearance. It is important to remember that wiping the joint before it cools destroys this appearance and is liable to roughen the surface and become detrimental to the insulation.
- To avoid damaging the cable insulation near the joint the soldering process should be carried out as quickly as possible. The tendency to burn the insulation is less with a really hot soldering iron than with a cooler one which takes longer to do the job. It is sometimes possible to roll back some of the insulation before soldering and to unroll it afterwards.

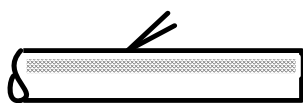


- *The metal pot and ladle.* An iron metal pot about three quarters full of solder, together with the ladle, is heated until the solder is fluid. Any impurities can then be skimmed off the surface. The joint is held over the pot and sprinkled with resin a small amount being allowed to fall into the solder. The ladle should be filled with solder and this should be poured heavily over the joint so as to raise its temperature as rapidly as possible, thereby avoiding damage to the insulation. Pouring is repeated, adding resin as necessary, until the required coating is achieved; at the same time any points that may form are carefully brushed off.
- In the case of a termination, both the lug and the cable end must be heated and ‘tinned’ before any attempt is made to insert cable end in position.
- *The blowlamp.* Before starting to solder, see that the blow lamp is about two- thirds full of paraffin. For pouring, it is best to fit a funnel in the filler cap. A piece of cotton waste is then placed in the annular trough, soaked in methylated spirit, and ignited. It is possible to use paraffin for this purpose, but methylated spirit gives a cleaner flame and starts the lamp quicker. By operating the pump, the pressure inside the reservoir can be increased. This pump reaches nearly to the bottom of the reservoir and is provided with a non- return valve. AS the pressure increases, paraffin will be forced up the tube and becomes vaporized by the heat from the burning waste. Vapour, so formed, will then issue from the orifice (or jet) at high velocity and after mixing with air drawn in through holes at the side of the chamber, will burn at the nozzle.
- To enable the blowlamp to work continuously after it has once started, the tube conveying paraffin from the reservoir to the jet is led near the flame, so that the paraffin is vaporized by the heat of the lamp itself. The pressure inside the reservoir is also maintained by the heat of the lamp. As this pressure is high, the base of the lamp is curved inward to give additional strength.
- To stop the blowlamp working, the valve is opened. The flow of paraffin then stops due to the reduction in pressure. When using the blowlamp to solder a joint, the flame should be directed into the middle of the joint. As the conductor attains the melting temperature of solder, resin and solder, are rubbed into it alternately until it becomes saturated with solder.
- Because of the risk of causing damage, it is advisable to wrap the ends of the insulation with dampened cloth tape before soldering joints with the aid of a blowlamp. Before sweating a cable socket using a blowlamp the interior of the socket must be cleaned. The inside is then tinned by heating and introducing solder and resin. After almost filling the socket with molten solder, the cable end, rubbed with resin, is pushed into it. The solder should run up into the strands of the cable, and should be evenly dispersed round the conductor. The blowlamp jet should always be kept clear by using the pricker as necessary. It is bad practice to operate the pump to clean the jet, if the flame has gone out.

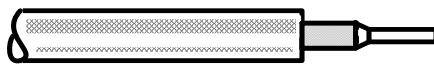
- Blowpipes utilizing propane or butane gases are gradually superseding paraffin blowlamps. Special soldering techniques are used for aluminium.

### EXERCISE 1

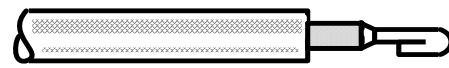
Stripping and preparing 1/1.13mm cable end for entry into an accessory



Correct angle of knife blade



Braid and tape removed



Conductor bent over

#### *Procedure;*

- Remove braid, tape and rubber from the end 25mm of cable
- Remove braid and tape (if any) for a further 15mm
- Bend exposed conductor in two.
- Make a drawing of the cable and its full size, giving actual dimension

### EXERCISE 2

**A Britannia joint between two pieces of 1/1 .78 mm cable**



#### *Producer:*

- Strip and clean one end of each piece for 75mm.
- Strip off braid and tape for a further 15mm on each piece
- Bend the end 6mm of each conductor at right angles
- Clamp the two conductors together so that the ends project outwards.
- Tightly bind both conductors with a tinned copper wire, carrying the binding about 6mm past each end.
- Solder the whole length of the binding.
- Make a drawing of the joint twice its full size, giving actual dimensions.

### EXERCISE 3

**A Bellhangers' joint between two pieces of 1/1.13mm cable.**



#### **Procedure**

- Strip and clean one end of each piece for 90mm.

- Strip off braid and tape (if any) for a further 15mm on each piece.
- Cross the conductors at about 25mm from the insulation, keeping the left-hand conductor in front.
- With the pliers grip the crossed conductors together just to the left of the point of crossing.
- Bend the two conductors at right-angles to the crossing.
- Twist the left-hand conductor tightly round the right-hand one for six turns.
- Twist the right-hand conductor tightly round the left-hand one for six turns.
- Cut off surplus conductors on the bevel with side-cutters and smooth over with pliers.
- Solder the whole length of the joint.
- Make a drawing of the joint twice its full size, giving actual dimensions.

#### EXERCISE 4

##### A Telegraph joint between two pieces of 1/1.38 mm cable

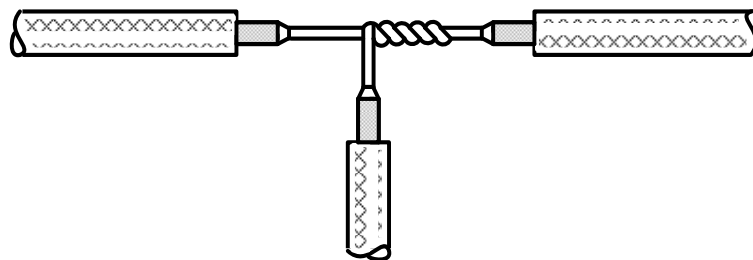


#### Procedure

- Strip and clean one end of each piece for 100mm
- Strip off braid and tape (if any) for a further 25mm on each piece.
- Cross the conductors at about 30mm from the insulation, keeping the left-hand conductor in front.
- With the pliers grip the crossed conductors together just to the left of the point of crossing
- Twist the left-hand end and the right-hand main portion tightly together equally round a common axis at a high pitch (that is, not too sharply) for six turns.
- In a similar way twist the right-hand end and the left-hand main portion tightly together equally round a common axis for six turns.
- Cut off surplus conductors on the level with side-cutters and smooth over with pliers.

#### EXERCISE 5

##### A T-JOINT BETWEEN TWO PIECES OF 1/1.38MM CABLE



#### Procedure

- Strip and clean the through piece for a distance of 37 mm in the center.

- Strip off braids and tape (if any) for 15mm at each side.
- Strip and clean one end of the t-piece for 100mm
- Strip off braids and tape (if any) for a further 15mm.
- Place t-piece at right angles to left-hand side of bared through piece and tightly bind t-piece round through piece.
- Cut off surplus conductor on the level and smooth over with pliers.
- Soldier the right-hand half of the binding.
- I.E.E. regulation to be studied:
- Number b6 and b19
- Question to be answered:
- What should be the minimum voltage rating of every cable in accordance with the appropriate British standard
- What is meant by the expression of the voltage rating of cable as: (a) 600/1000, (b) 600?
- To what type of installation is twist-joining of smaller sized conductors mainly confined?
- State the I.E.E. requirements for the insulation of cables for fixed wiring.
- Make a drawing of the joint twice its full size, giving actual dimensions.

### **EXERCISE 6**

#### **USING A MICROMETER TO MEASURE CONDUCTOR DIAMETERS**

##### *Procedure:*

- Place the wire with its diameter between the anvil of the micrometer and the spindle head.
- Turn the ratchet stud until the ratchet slips to close the head on the wire.
- Note the barrel reading to the nearest 0.5 millimeter under.
- Note the number of thimble divisions and multiply by 0.01
- Obtain the complete measurement by adding the results of operations 3 and 4.
- Repeat operation 1 to 5 for each sample of wire.
- Make a drawing of a micrometer thimble and barrel twice full size to illustrate a reading of 3.18mm

### **EXERCISE 7**

#### **Connecting a flexible pendant**

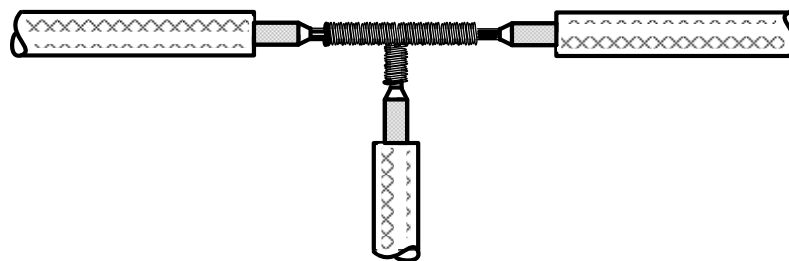
##### *Procedure:*

- Strip the ends of the cable cores and connect the conductors in the appropriate terminals of the ceiling rose.

- Strip both ends of the flexible cord, unscrew the lamp-holder cap, and connect the conductors at one end to the lampholder terminals.
- Thread the flexible cord through the lampholder cap and screw on the cap.
- Unscrew the ceiling rose cover, thread the flexible cord through it, connect the flexible cord conductors to the appropriate terminals of the ceiling rose, and then screw on the cover.
- Make a sectional drawing of the flexible pendant about twice full size (omitting most of the flexible cord), showing connections

## EXERCISE 8

### A T-JOINT BETWEEN TWO PICES OF 7/0.85 MM CABLE.



- *Procedure*
- Strip and clean the through piece for a distance of 37mm in the centre.
- Strip off braids and tape (if any) for 15mm at each side.
- Strip and clean one end of the t-piece for 230mm.
- Strip off braids and tape (if any) for a further 15mm.
- Twist strands of through piece and first 6mm of t-piece
- Untwist remainders of t-piece strands and straighten.
- Placing t-piece at right angles to centre of through piece, tightly bind t-piece strands round through piece against the lay of the cable one at a time; four strands round left-hand half of through piece , and three strands round right hand half.
- Cut off surplus strands on the level and smooth over with pliers.
- Soldier joint ends.
- Make a drawing of the joint twice its full size giving actual dimensions.

## EXERCISE 9

### A married joint between two pieces of 7/0.85mm cable.



- *Procedure:*
- Strip and clean one end of each piece for 230mm.
- Strip off braids and tape (if any) for a further 15mm on each piece.
- Twist strands of each piece for 37 mm from the insulation
- Untwist remainder of strands and straighten
- Cut out centre strands of each conductor.
- Intersperse the strands and butt the twisted portions together.
- Lightly bind the strands on the left-hand side round twisted strands
- Tightly bind the strands on the right-hand side the tightly bind them round twisted strands in the same direction as the left-hand strands.
- Cut off surplus strands on the level and smooth over with pliers.
- Soldier joint at ends.
- Make a drawing of the joint twice its full size giving actual dimensions.

## EXERCISE 10

**Soldering a 30 ampere cable socket on piece of 7/1.04mm cable, using a blowlamp**



### *Procedure*

- Strip and clean one end of cable for about 25mm
- Strip off braids and tape (if any) for a further 15mm
- Twist strands of conductor to tighten
- Cut conductor to length just sufficient to reach bottom of cable socket.
- Roll up rubber insulation for about 15mm.
- Clean inside of cable socket and edge and introduce small quantity of resin and solder. Apply resin to conductor
- Gripping socket firmly in gas pliers hold it in blowlamp flame until solder is molten.
- Push conductor down into molten solder and hold for a short time taking care not to allow flame too near to cable insulation. Apply further resin as necessary until solder runs up into the strands of conductor.
- Remove termination from blowlamp flame, and allow to cool.
- Unroll rubber insulation back into place.
- Apply cord whipping tightly over the edge of braids and tape starting with a loop through which the end can be threaded and pulled.

- Make a drawing of the cable socket termination twice its full size giving actual dimensions.

## EXERCISE 11

### Making off a 7-strands cable at a straining point.



Procedure:

- Strip and clean a piece of 7/1.04m cable for about 180mm at one end.
- Bend all 7 strands tightly round a cylindrical object of suitable diameter (eg 20mm conduits) so as to form a loop.
- Unwind one strands up to the end of the loop then tightly bind round the 13 strands for 6mm
- Unwind each of the other strands in turn up to the binding and bind round the remaining strands for 6mm.
- Cut off the surplus portion of each binding strands at a level
- Tightly press the ends of the strands into the binding so that the finish of one strands butts on to the start of the next then smooth over with pliers.
- Solder the whole of the binding using the blowlamp.
- Make a drawing of the made off cable end twice its full size giving actual dimensions.

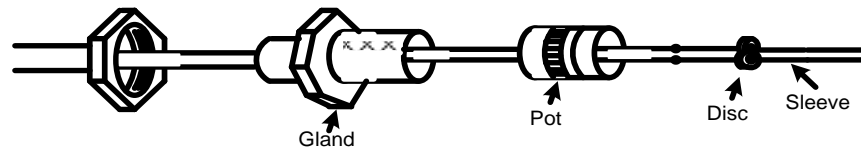
## EXERCISE 12

- Soldering a cable socket on a piece of cable, using a metal pot and a ladle.
- Procedure:
- Strip and clean one end of cable for about 37mm.
- Strip off braids and tape (if any) for a further 15mm.
- Twist strands of conductor to tighten.
- Cut conductor to length just sufficient to touch bottom of cable socket.
- Apply protective tape or string for about 20 mm.
- Clean inside of cable socket and edge and introduce small quantity of resin and solder. Apply resin to conductor.
- Gripping socket firmly in gas pliers, hold it over metal containing molten solder and pour solder from ladle heavily into the socket.
- Tin the conductor by inserting in the socket, applying resin as necessary until solder runs up into the strands of conductor when in position.

- Hold termination firmly in position and allow to cool.
- Remove protective tape or string
- Make a drawing of the cable socket termination twice its full size, giving actual dimension.

### EXERCISE 15

#### Terminating a mineral-insulated copper-sheathed cable by means of a screw on pot type seal



#### Procedure:

- Mark the cable sheath at its terminating position the make a circumferential cut with the ringing tool.
- Start a helical tear in the sheath with either side-cutters or fork-ended stripper and continue in a series of tears holding the tool at about 45 to the cable. Finish with the cutters in line with the cable so as to run out the tear along the cut.
- Remove any burrs in the terminating edge of the sheath, trim back the insulating level with the edge and clean insulation from conductors.
- Pass the pot, internally-threaded are first over the conductors until the thread engages the sheath. Screw on the pot squarely until sheath is level with shoulder of pot.
- Remove any dirt and metal from pot, press in a small quantity of plastic compound then add and compress further compound until pot is filled.
- Select sleeves to suit the conductors pass the through the holes in the sealing cap after anchoring with wedges and thread the assembly over the conductors.
- Use the special tool provided to compress compound and to Crip the rim of the sealing pot. Wipe off surplus compound.
- Test for insulation resistance.
- Make a drawing of a cable termination twice its full size giving actual dimensions.

### Conduit installations

A **conduit** is a tube, channel or pipe in which insulated conductors are contained. The conduit, in effect, replaces the PVC outer sheath of a cable, providing mechanical protection for the insulated conductors. A conduit installation can be rewired easily or altered at any time, and this flexibility, coupled with mechanical protection, makes conduit installations popular for commercial and industrial applications. There are three types of conduit used in electrical installation work: steel, PVC and flexible.

#### i. Steel conduit



Steel conduits are made to a specification and are either heavy gauge welded or solid drawn. Heavy gauge is made from a sheet of steel welded along the seam to form a tube and is used for most electrical installation work. Solid drawn conduit is a seamless tube which is much more expensive and only used for special gas-tight, explosion-proof or flameproof installations. Conduit is supplied in 3.75 m lengths and typical sizes are 16, 20, 25 and 32 mm. Conduit tubing and fittings are supplied in a black enamel finish for internal use or hot galvanized finish for use on external or damp installations.

A wide range of fittings is available and the conduit is fixed using saddles or pipe hooks, as shown in Fig. 48.

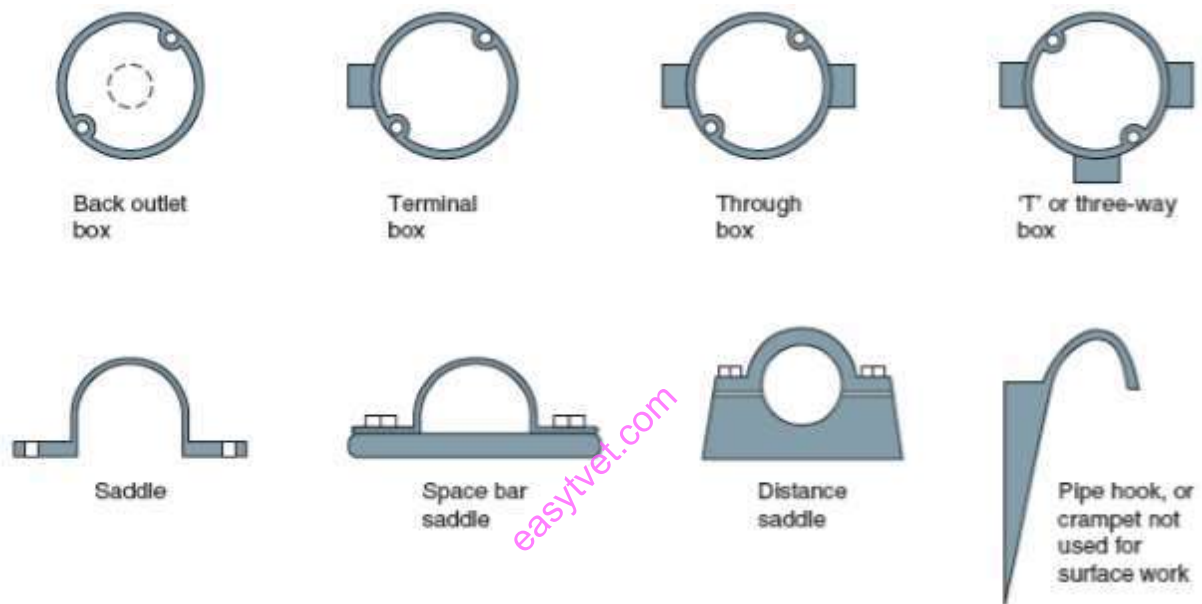


Figure 279 conduit fittings and saddles

Metal conduits are threaded with stocks and dies and bent using special bending machines. The metal conduit is also utilized as the CPC and, therefore, all connections must be screwed up tightly and all burrs removed so that cables will not be damaged as they are drawn into the conduit. Metal conduits containing a.c. circuits must contain phase and neutral conductors in the same conduit to prevent eddy currents flowing, which would result in the metal conduit becoming hot.

## ii. P.V.C. Conduit

PVC conduit used on typical electrical installations is heavy gauge standard impact tube. The conduit size and range of fittings are the same as those available for metal conduit. PVC conduit is most often joined by placing the end of the conduit into the appropriate fitting and fixing with a PVC solvent adhesive. PVC conduit can be bent by hand using a bending spring of the same diameter as the inside of the conduit.

The spring is pushed into the conduit to the point of the intended bend and the conduit then bent over the knee. The spring ensures that the conduit keeps its circular shape. In cold weather, a little warmth applied to the point of the intended bend often helps to achieve a more successful bend.

The advantages of a PVC conduit system are that it may be installed much more quickly than steel conduit and is non-corrosive, but it does not have the mechanical strength of steel conduit. Since PVC conduit is an insulator it cannot be used as the CPC and a separate earth conductor must be run to every outlet. It is not suitable for installations subjected to temperatures below 25°C or above 60°C. Where luminaires are suspended from PVC conduit boxes, precautions must be taken to ensure that the lamp does not raise the box temperature or that the mass of the luminaire supported by each box does not exceed the maximum recommended by the manufacturer. PVC conduit also expands much more than metal conduit and so long runs require an expansion coupling to allow for conduit movement and help to prevent distortion during temperature changes.

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All conduit installations must be erected first before any wiring is installed. The radius of all bends in conduit must not cause the cables to suffer damage, and therefore the minimum radius of bends given. All conduits should terminate in a box or fitting and meet the boxes or fittings at right angles. Any unused conduit-box entries should be blanked off and all boxes covered with a box lid, fitting or accessory to provide complete enclosure of the conduit system. Conduit runs should be separate from other services, unless intentionally bonded, to prevent arcing occurring from a faulty circuit within the conduit, which might cause the pipe of another service to become punctured.

When drawing cables into conduit they must first be run off the cable drum. That is, the drum must be rotated as shown in Fig. 49 and not allowed to spiral off, which will cause the cable to twist.



Figure 280 Cable drum

### iii. Flexible conduit

Flexible conduit is made of interlinked metal spirals often covered with a PVC sleeving. The tubing must not be relied upon to provide a continuous earth path and, consequently, a separate CPC must be run either inside or outside the flexible tube. *Flexible conduit* is made of interlinked metal spirals often covered with a PVC sleeving.

Flexible conduit is used for the final connection to motors so that the vibrations of the motor are not transmitted throughout the electrical installation and to allow for modifications to be made to the final motor.

#### Conduit capacities

Single-PVC insulated conductors are usually drawn into the installed conduit to complete the installation. Having decided upon the type, size and number of cables required for a final circuit, it is then necessary to select the appropriate size of conduit to accommodate those cables.

Table 19 conduit factors adapted from IEE regulations

| Cable factors for runs incorporating bends and long straight runs |                       |     |     |     |          |     |     |     |           |     |     |     |             |     |     |     |
|---|-----------------------|-----|-----|-----|----------|-----|-----|-----|-----------|-----|-----|-----|-------------|-----|-----|-----|
| Length of run (m)   | Conduit diameter (mm) |     |     |     |          |     |     |     |           |     |     |     |             |     |     |     |
|   | 16                    | 20  | 25  | 32  | 16       | 20  | 25  | 32  | 16        | 20  | 25  | 32  | 16          | 20  | 25  | 32  |
|   | Straight              |     |     |     | One bend |     |     |     | Two bends |     |     |     | Three bends |     |     |     |
| 1   | Covered by            |     |     |     | 188      | 303 | 543 | 947 | 177       | 286 | 514 | 900 | 158         | 256 | 463 | 818 |
| 1.5   |                       |     |     |     | 182      | 294 | 528 | 923 | 167       | 270 | 487 | 857 | 143         | 233 | 422 | 750 |
| 2   | Tables                |     |     |     | 177      | 286 | 514 | 900 | 158       | 256 | 463 | 818 | 130         | 213 | 388 | 692 |
| 2.5   |                       |     |     |     | 171      | 278 | 500 | 878 | 150       | 244 | 442 | 783 | 120         | 196 | 358 | 643 |
| 3   | A and B               |     |     |     | 167      | 270 | 487 | 857 | 143       | 233 | 422 | 750 | 111         | 182 | 333 | 600 |
| 3.5   | 179                   | 290 | 521 | 911 | 162      | 263 | 475 | 837 | 136       | 222 | 404 | 720 | 103         | 169 | 311 | 563 |
| 4   | 177                   | 286 | 514 | 900 | 158      | 256 | 463 | 818 | 130       | 213 | 388 | 692 | 97          | 159 | 292 | 529 |
| 4.5   | 174                   | 282 | 507 | 889 | 154      | 250 | 452 | 800 | 125       | 204 | 373 | 667 | 91          | 149 | 275 | 500 |
| 5   | 171                   | 278 | 500 | 878 | 150      | 244 | 442 | 783 | 120       | 196 | 358 | 643 | 86          | 141 | 260 | 474 |
| 6   | 167                   | 270 | 487 | 857 | 143      | 233 | 422 | 750 | 111       | 182 | 333 | 600 |             |     |     |     |
| 7   | 162                   | 263 | 475 | 837 | 136      | 222 | 404 | 720 | 103       | 169 | 311 | 563 |             |     |     |     |
| 8   | 158                   | 256 | 463 | 818 | 130      | 213 | 388 | 692 | 97        | 159 | 292 | 529 |             |     |     |     |
| 9   | 154                   | 250 | 452 | 800 | 125      | 204 | 373 | 667 | 91        | 149 | 275 | 500 |             |     |     |     |
| 10  | 150                   | 244 | 442 | 783 | 120      | 196 | 358 | 643 | 86        | 141 | 260 | 474 |             |     |     |     |

|  |                      |
|--|----------------------|
| Additional factors: For 38 mm diameter use | 1.4 × (32 mm factor) |
| For 50 mm diameter use                     | 2.6 × (32 mm factor) |
| For 63 mm diameter use                     | 4.2 × (32 mm factor) |

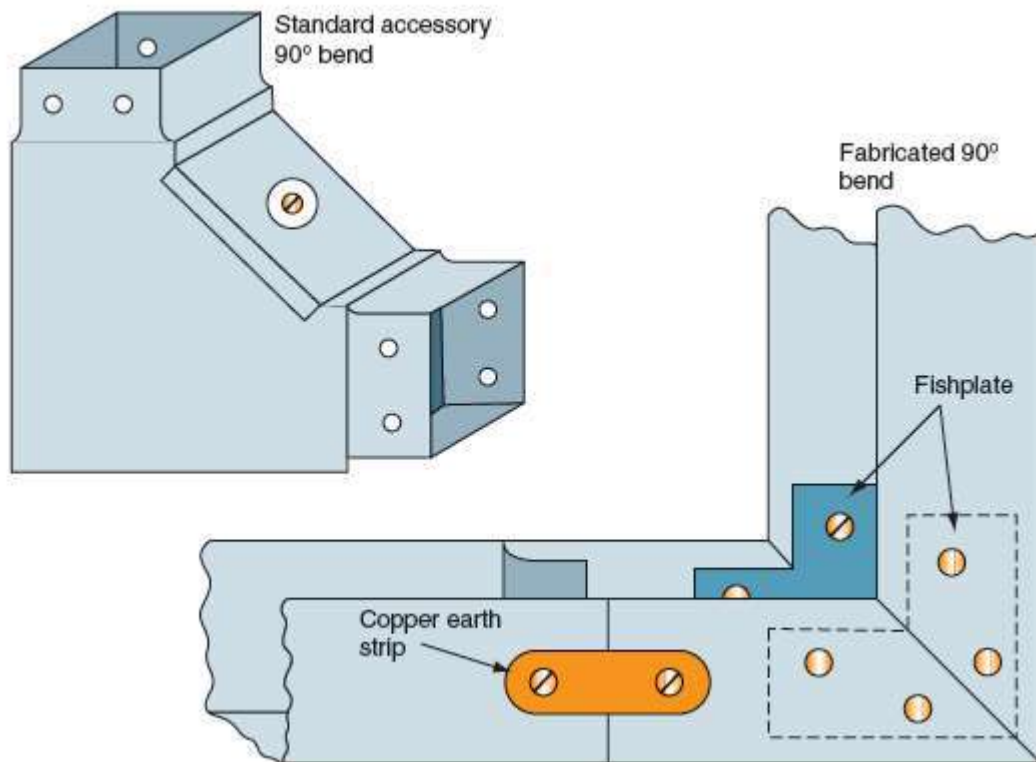
### Trunking installations

A trunking is an enclosure provided for the protection of cables which is normally square or rectangular in cross-section, having one removable side. Trunking may be thought of as a more accessible conduit system and for industrial and commercial installations it is replacing the larger conduit sizes. A trunking system can have great flexibility when used in conjunction with conduit; the trunking forms the background or framework for the installation, with conduits running from the trunking to the point controlling the current-using apparatus. When an alteration or extension is required it is easy to drill a hole in the side of the trunking and run a conduit to the new point. The new wiring can then be drawn through the new conduit and the existing trunking to the supply point.

Trunking is supplied in 3 m lengths and various cross-sections measured in millimetres from 50 \_ 50 up to 300 \_ 150. Most trunking is available in either steel or plastic.

#### i. Metallic trunking

Metallic trunking is formed from mild steel sheet, coated with grey or silver enamel paint for internal use or a hot-dipped galvanized coating where damp conditions might be encountered and made to a specification. A wide range of accessories is available, such as 45° bends, 90° bends, tee and four-way junctions, for speedy on-site assembly. Alternatively, bends may be fabricated in lengths of trunking, as shown in Fig. 55 This may be necessary or more convenient if a bend or set is non-standard, but it does take more time to fabricate bends than merely to bolt on standard accessories.



*Figure 281 Alternative trunking bends*

When fabricating bends the trunking should be supported with wooden blocks for sawing and fitting, in order to prevent the sheet-steel vibrating or becoming deformed. Fish plates must be made and riveted or bolted to the trunking to form a solid and secure bend. When manufactured bends are used, the continuity of the earth path must be ensured across the joint by making all fixing screw connections very tight, or fitting a separate copper strap between the trunking and the standard bend. If an earth continuity test on the trunking is found to be unsatisfactory, an insulated CPC must be installed inside the trunking. The size of the protective conductor will be determined by the largest cable contained in the trunking, if the circuit conductors are less than  $16 \text{ mm}^2$ , then a  $16 \text{ mm}^2$  CPC will be required.

### **Non-metallic trunking**

Trunking and trunking accessories are also available in high-impact PVC. The accessories are usually secured to the lengths of trunking with a PVC solvent adhesive. PVC trunking, like PVC conduit, is easy to install and is non-corrosive. A separate CPC will need to be installed and non-metallic trunking may require more frequent fixings because it is less rigid than metallic trunking. All trunking fixings should use round-headed screws to prevent damage to cables since the thin sheet construction makes it impossible to countersink screw heads.

### **Mini-trunking**

Mini-trunking is very small PVC trunking, ideal for surface wiring in domestic and commercial installations such as offices. The trunking has a cross-section of  $16 \times 16 \text{ mm}$ ,  $25 \times 16 \text{ mm}$ ,  $38 \times 16 \text{ mm}$  or  $38 \times 25 \text{ mm}$  and is ideal for switch drops or for housing auxiliary circuits such as telephone or audio

equipment wiring. The modern square look in switches and sockets is complemented by the mini-trunking which is very easy to install (see Fig. 46).

### Skirting trunking

Skirting trunking is a trunking manufactured from PVC or steel and in the shape of a skirting board is frequently used in commercial buildings such as hospitals, laboratories and offices. The trunking is fitted around the walls of a room at either the skirting board level or at the working surface level and contains the wiring for socket outlets and telephone points which are mounted on the lid, as shown in Fig. 56.

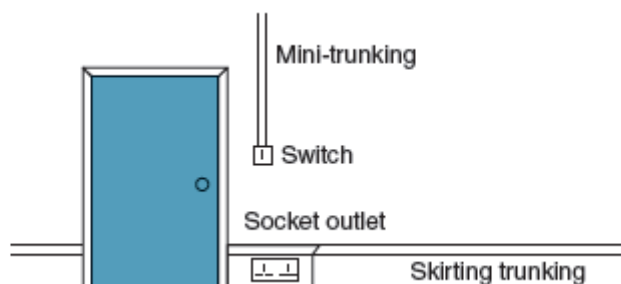


Figure 282 Typical installation of skirting trunking and mini-trunking

Where any trunking passes through walls, partitions, ceilings or floors, short lengths of lid should be fitted so that the remainder of the lid may be removed later without difficulty. Any damage to the structure of the buildings must be made good with mortar, plaster or concrete in order to prevent the spread of fire. Fire barriers must be fitted inside the trunking every 5 m, or at every floor level or room dividing wall, if this is a shorter distance, as shown in Fig. 57 (a). Where trunking is installed vertically, the installed conductors must be supported so that the maximum unsupported length of non-sheathed cable does not exceed 5 m. Figure 57 (b) shows cables woven through insulated pin supports, which is one method of supporting vertical cables. PVC insulated cables are usually drawn into an erected conduit installation or laid into an erected trunking installation.

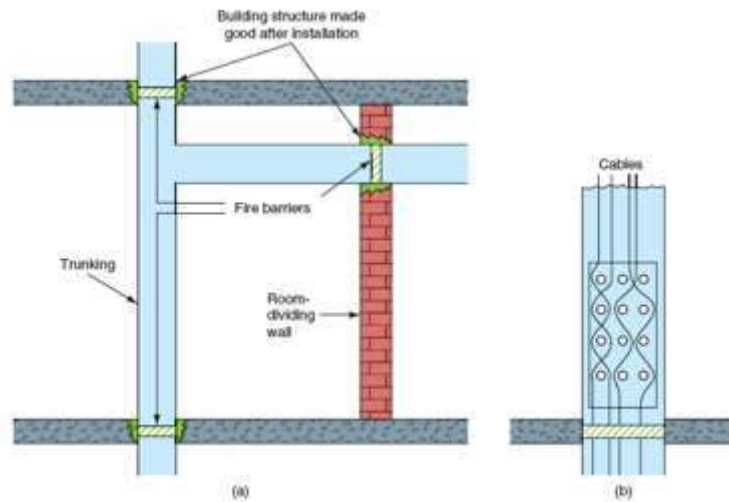


Figure 283 Installation of trunking (a) fire barriers in trunking (b) cable support in vertical trunking

### Trunking capacities

The ratio of the space occupied by all the cables in a conduit or trunking to the whole space enclosed by the conduit or trunking is known as the space factor. Where sizes and types of cable and trunking are not covered by the tables in the *On Site Guide* a space factor of 45% must not be exceeded. This means that the cables must not fill more than 45% of the space enclosed by the trunking. The tables take this factor into account.

To calculate the size of trunking required to enclose a number of cables:

- Identify the cable factor for the particular size of conductor, see Table 8.
- Multiply the cable factor by the number of conductors to give the sum of the cable factors.
- Consider the factors for trunking and shown in Table 9.

The correct size of trunking to accommodate the cables is that trunking which has a factor equal to or greater than the sum of the cable factors.

Table 20 Trunking cable factors adapter from the IEE on site guide by kind permission of the Institution of Electrical Engineers

| Cable factors for trunking |   |                          |                                    |
|----------------------------|---|--------------------------|------------------------------------|
| Type of conductor          | Conductor cross-sectional area (mm <sup>2</sup> ) | PVC BS 6004 Cable factor | Thermosetting BS 7211 Cable factor |
| Solid                      | 1.5   | 8.0                      | 8.6                                |
|                            | 2.5   | 11.9                     | 11.9                               |
| Stranded                   | 1.5   | 8.6                      | 9.6                                |
|                            | 2.5   | 12.6                     | 13.9                               |
|                            | 4   | 16.6                     | 18.1                               |
|                            | 6   | 21.2                     | 22.9                               |
|                            | 10  | 35.3                     | 36.3                               |
|                            | 16  | 47.8                     | 50.3                               |
|                            | 25  | 73.9                     | 75.4                               |

Notes: These factors are for metal trunking and may be optimistic for plastic trunking where the cross-sectional area available may be significantly reduced from the nominal by the thickness of the wall material.  
The provision of spare space is advisable; however, any circuits added at a later date must take into account grouping. Appendix 4, BS 7671.

Table 21 Trunking cable factor. Adapted from the IEE On site Guide by Kind Permission of institution of Electrical Engineers

| Factors for trunking             |        |                                  |        |
|----------------------------------|--------|----------------------------------|--------|
| Dimensions of trunking (mm × mm) | Factor | Dimensions of trunking (mm × mm) | Factor |
| 50 × 38                          | 767    | 200 × 100                        | 8572   |
| 50 × 50                          | 1037   | 200 × 150                        | 13001  |
| 75 × 25                          | 738    | 200 × 200                        | 17429  |
| 75 × 38                          | 1146   | 225 × 38                         | 3474   |
| 75 × 50                          | 1555   | 225 × 50                         | 4671   |
| 75 × 75                          | 2371   | 225 × 75                         | 7167   |
| 100 × 25                         | 993    | 225 × 100                        | 9662   |
| 100 × 38                         | 1542   | 225 × 150                        | 14652  |
| 100 × 50                         | 2091   | 225 × 200                        | 19643  |
| 100 × 75                         | 3189   | 225 × 225                        | 22138  |
| 100 × 100                        | 4252   | 300 × 38                         | 4648   |
| 150 × 38                         | 2999   | 300 × 50                         | 6251   |
| 150 × 50                         | 3091   | 300 × 75                         | 9590   |
| 150 × 75                         | 4743   | 300 × 100                        | 12929  |
| 150 × 100                        | 6394   | 300 × 150                        | 19607  |
| 150 × 150                        | 9697   | 300 × 200                        | 26285  |
| 200 × 38                         | 3082   | 300 × 225                        | 29624  |
| 200 × 50                         | 4145   | 300 × 300                        | 39428  |
| 200 × 75                         | 6359   |                                  |        |

Space factor – 45% with trunking thickness taken into account.



## Cable tray installations

Cable tray is a sheet-steel channel with multiple holes. The most common finish is hot-dipped galvanized but PVC-coated tray is also available. It is used extensively on large industrial and commercial installations for supporting MI and SWA cables which are laid on the cable tray and secured with cable ties through the tray holes. Cable tray should be adequately supported during installation by brackets which are appropriate for the particular installation. The tray should be bolted to the brackets with round-headed bolts and nuts, with the round head inside the tray so that cables drawn along the tray are not damaged. Cable tray should be adequately supported during installation by brackets which are appropriate for the particular installation. The tray should be bolted to the brackets with round-headed bolts and nuts, with the round head inside the tray so that cables drawn along the tray are not damaged.

The tray is supplied in standard widths from 50 to 900 mm, and a wide range of bends, tees and reducers is available. Figure 58 shows associated cable tray installations. The tray can also be bent using a cable tray bending machine to create bends. The installed tray should be securely bolted with round-headed bolts where lengths or accessories are attached, so that there is a continuous earth path which may be bonded to an electrical earth. The whole tray should provide a firm support for the cables and therefore the tray fixings must be capable of supporting the weight of both the tray and cables.

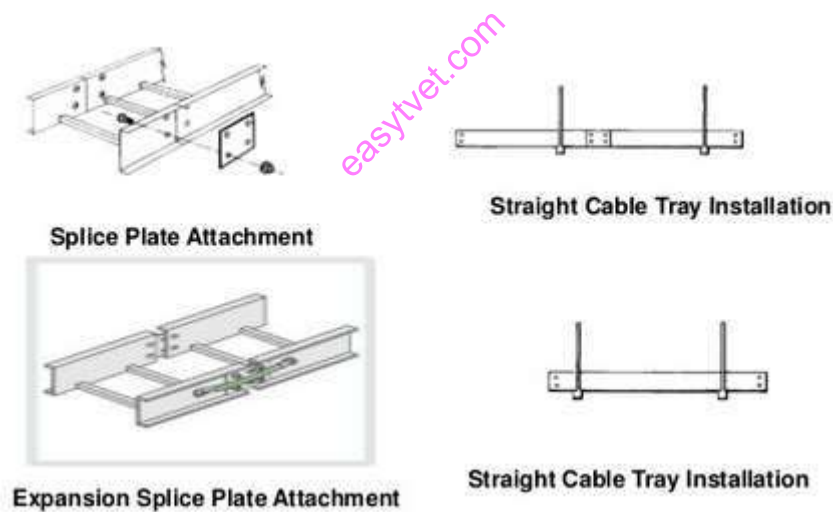


Figure 284 Cable tray installations

## Cable ducts

This is another method of concealing electrical and other services used mainly in large industrial type buildings. The services routes are marked out on plans so that during construction mainly of floor, ducts are precast so that at a later date the services may be installed. The cables which are normally of larger sizes and mainly PILCSWA type are supported by cable cleats fixed either to sides or bottom of the duct. Suitable covers are then placed over the duct so that it hides and protects the services and makes them easily accessible to installers and maintenance staff. Figure 59 shows an image of duct.



*Figure 285 Cable ducts*

## **Installation of final circuits**

### **Definition**

A final sub-circuit is an outgoing circuit connected to a distribution board and intended to supply electrical energy to current-using apparatus, either directly or through socket outlets or fused spur-boxes. Examples of final sub-circuits includes; lighting, socket-outlets, cooker and water heater. A final sub-circuit originates from the consumer control unit (CCU) or distribution board (DB). Each final sub-circuit is protected by an appropriate fuse or circuit breaker mounted in the consumer control unit.

### **IEE Regulations**

- i) Where an installation comprises more than one final sub-circuit, each shall be connected to a separate way in a distribution board.
- ii) The wiring of each final sub-circuit shall be electrically separate from that of every other final sub-circuit to facilitate disconnection of each final sub-circuit for testing.
- iii) Every final sub circuit shall have means of protection against excess current
- iv) The neutral conductor shall never be connected in the same order as that in which the live conductors are connected to the fuses or circuit breakers.
- v) The neutral conductor shall never be connected to fuses, switches or circuit breakers.

### **Terms and Definitions**

*Circuit*- an electric circuit is an arrangement of electrical conductors and associated devices for the purpose of carrying electricity.

*Live conductor*- It is that conductor which carry current towards the appliance from the source.

*Live*- means that under working condition a difference in voltage exists between the conductor and earth.

*Neutral conductor*- The conductor which carries current from the appliances to the source.

*Earth*- This is the conductive mass of the earth whose electric potential at any point is electrically taken to be zero.

*Earth conductor*- The conductor that has the same potential with the earth.

*Phase conductor*-A conductor of an AC system for the transmission of electrical energy other than a neutral.

*Potential*- The level of electric pressure.

*Dead*- At or about earth potential zero and disconnected from any live system.

*Fuse*- A device for opening a circuit by means of a fuse element designed to melt when excess current flows.

*Insulation*- suitable non-conducting material enclosing or surrounding or supporting a conductor.

*Switch*- A mechanical device for making and breaking non automatically a circuit carrying current.

### Need For Switching

- i. Used to put a circuit in use or out of use.
- ii. Emergency switching.
- iii. Isolating a circuit from the supply for maintenance.

### Types of switches

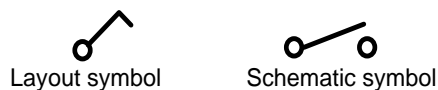
1. Single pole switch
2. Double pole switch
3. Triple pole switch.

I.E.E regulation on switches

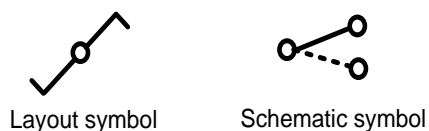
- i) All single pole switches should always be connected in the live (phase) conductor only.
- ii) Fuses shall also be inserted in the live only.

### TYPES OF SINGLE POLE SWITCHES

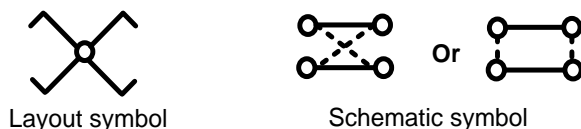
1. One-way switch - This has one path only for current.



2. Two-way switch - This has two alternative paths for current (change over switch).



3. Intermediate switch – This has two double alternative current paths.



### SWITCHING OF LIGHTING POINTS

#### One-way switching.

In the one-way switching, the lamp or set of lamps is switched from one particular point. An example is the switching at the entry of a room with one entry only. The figure 60 shows one-way switch. The ON and OFF control of the lighting point is only at one position.

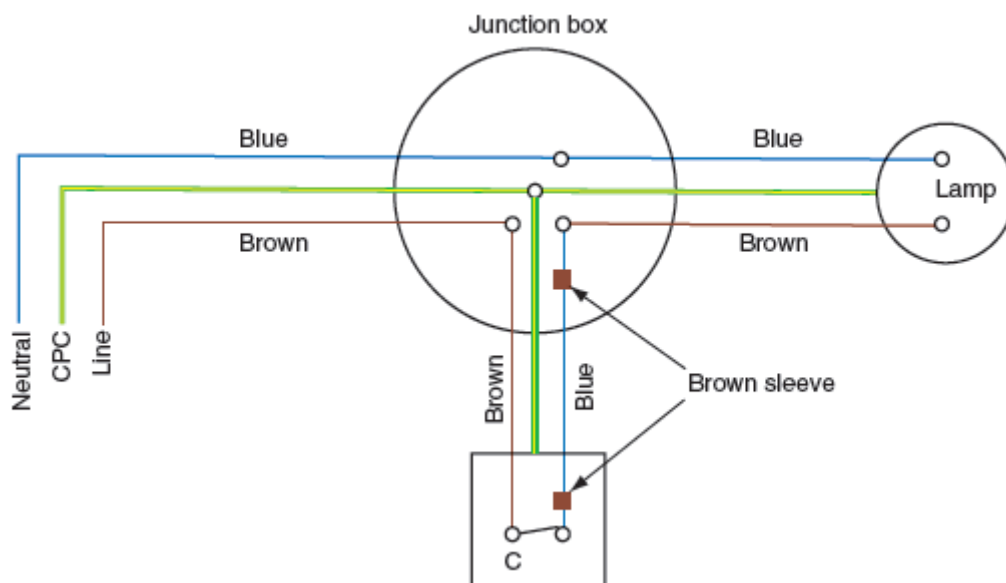


Figure 286 one-way switch

easytv.com

## Two – Way Switching

Where it becomes necessary to have the lamp or set of lamps switched from two separate positions. An example is a long corridor or in a room with two entries. Figure 61 shows a to-way switch. The ON and OFF control of the lighting point is from two positions.

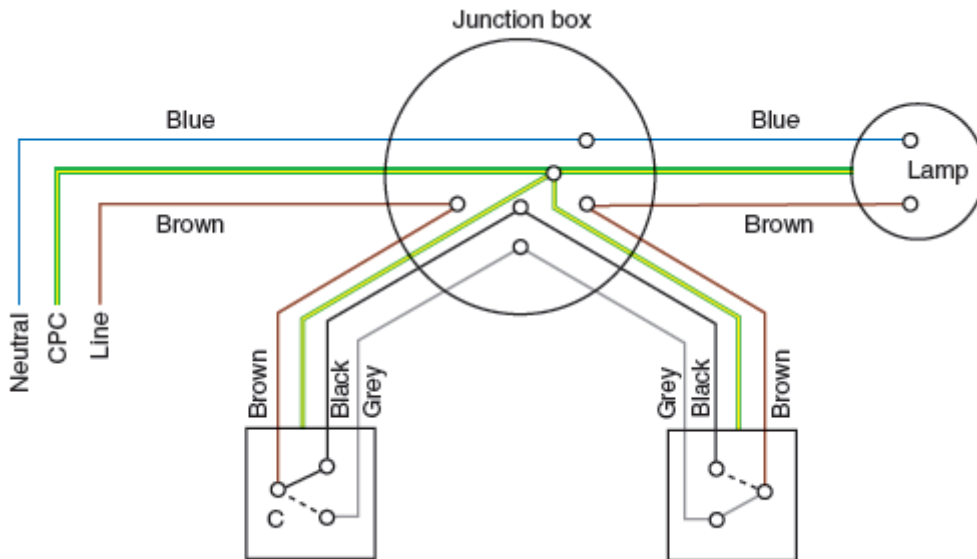


Figure 287 Two-way switches

## Intermediate switching

This is used in conjunction with the *Two-way* switching where the switching of the lamps is from more than two points. All the other points of switching between the two two-way switches will be fitted with intermediate switches. An example of lamp controlled from THREE positions is shown in figure 62

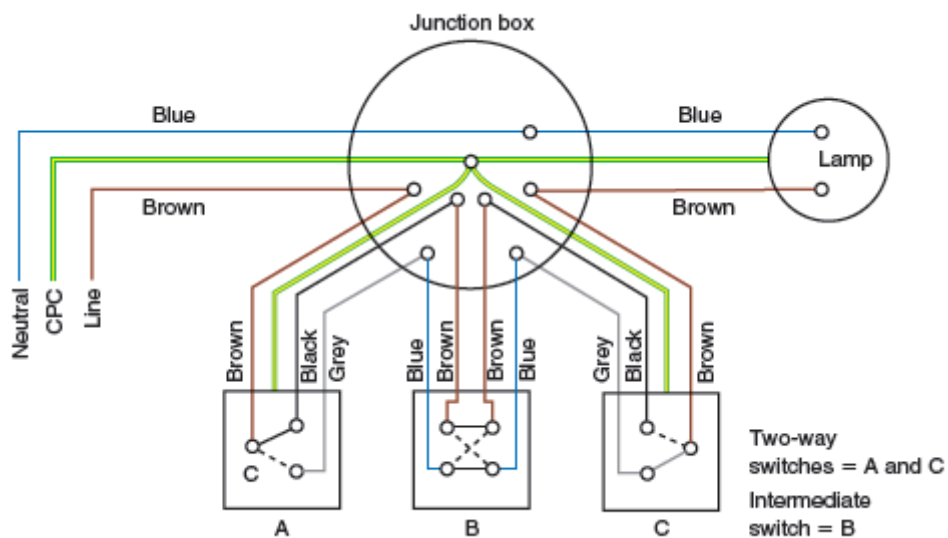


Figure 288 Intermediate switch control

Note

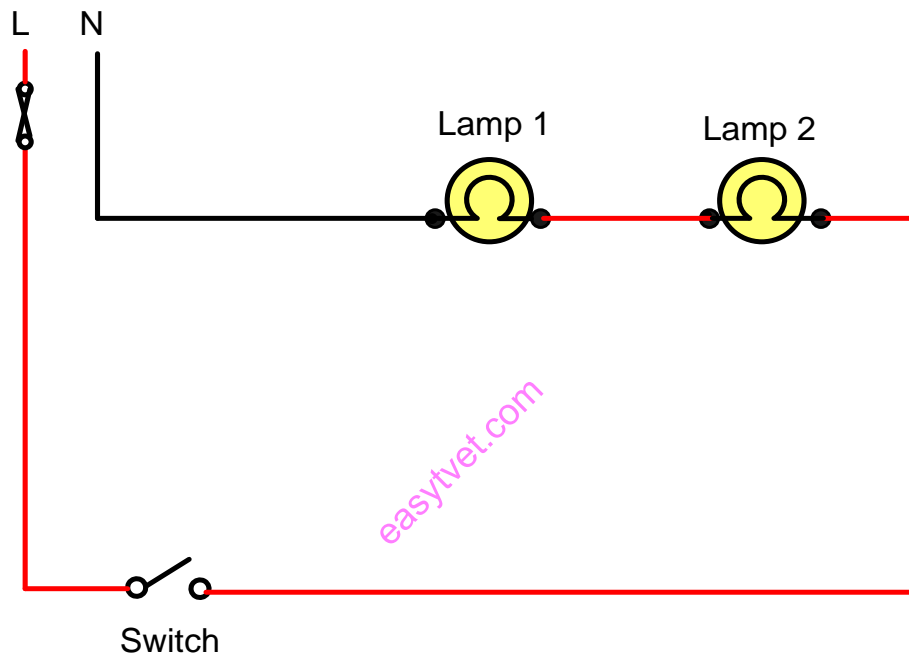
A lamp or set of lamps may be controlled from any number of positions provided we have 2 two-way switches and the rest of the switches been intermediate

**Types of circuit connections**

1. Series connection
2. Parallel connection

**Series Connection**

The current using equipment are connected in series or one after the other. One end of the equipment is connected to the other end (*End to End*) in series connection, the current flowing is the same and the voltage a cross each equipment will depend on the rating and its resistance



*Figure 289 Series connection*

The supply voltage is dropped individually across each lamp and depending on the ratings the voltage across each equipment will vary but the current flowing through all the equipment is the same. That is, if two lamps of equal resistance are connected in series to a 240 V supply, the voltage which will appear across each lamp will be 120 V and the current will be the same in all lamps

**N.B**

The lamps in above example may not produce light or be dim because the light produced is equal to:

$$Power = V^2/R$$

And, V is below rated voltage

For a series connection to work, all lamps have to be good working condition in order to provide continuity of the circuit.

**Disadvantages of series connection**

1. If one lamp blows, all lamps go off.

2. Lamps will be dim (will not produce enough light) or may fail to light
3. Not reliable- Therefore for practical purposes series circuits are not used

### Parallel connection

This is the most common arrangement for lighting circuits.

All lamps are connected across the supply and each lamp receives the supply voltage across it.

Each lamp can be controlled separately. If one lamp blows out, all the other will continue working.

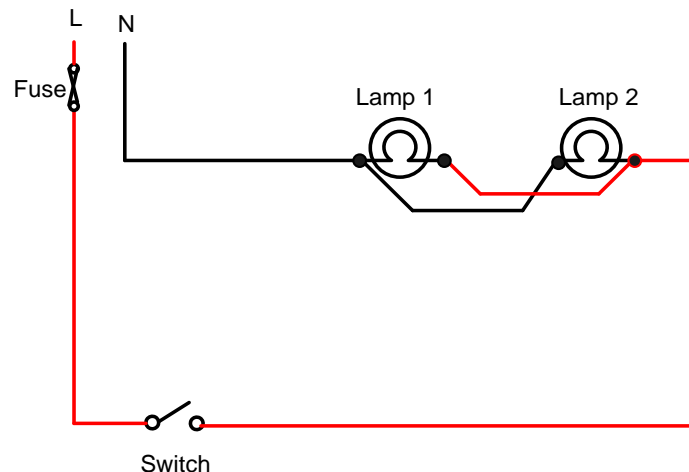


Figure 290 Parallel connection

### Note:

If separately controlled, all switches are to be connected in the live conductor and that No wire goes directly to the lamp by –passing the switch.

### Advantages of parallel

- i) All lamps receive rated voltage
- ii) All lamps are bright
- iii) If one lamp fails, other will not be affected
- iv) Lamps can be controlled individually (separately)

### Looping-In System

Looping-in of wires helps in saving materials and provides a clean piece of work. Looping – in can be done at:

- i) Switches
- ii) Lamp Holders
- iii) Junction Boxes
- iv) Ceiling Roses

If more than one lamp is to be switched from the same switch, it becomes cheaper to loop-in at the lamp holder for the second lamp. Figure 65 shows the theoretical diagram of a final sub-circuit of seven lamps, two controlled separately by 1-way switches, three controlled as a group by a 1-way switch, and

two controlled by a 1-way switch. If the circuit were to be wired exactly as in the diagram, a large number of joints would be necessary. Figure 66 shows the same circuit as wired by the looping-in system. No joints are required except dry twisted joints in the terminals of the two-plate ceiling roses and of the single-pole one-way switches.

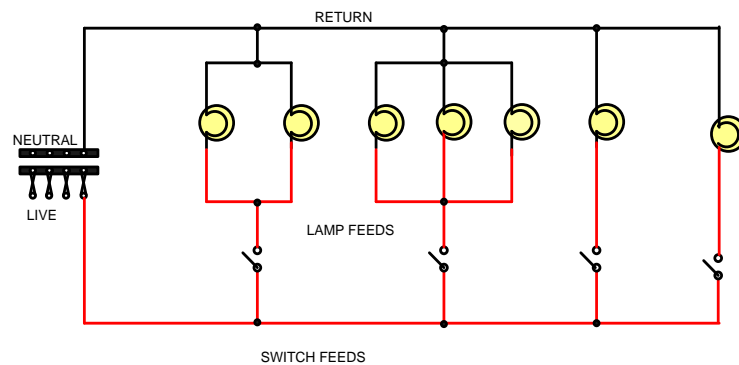


Figure 291 Lighting final circuit

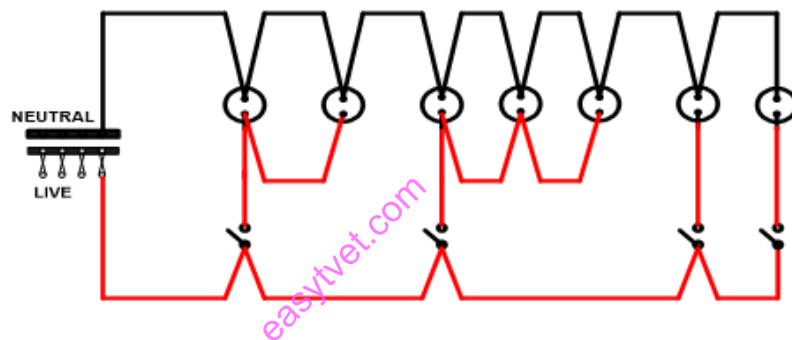
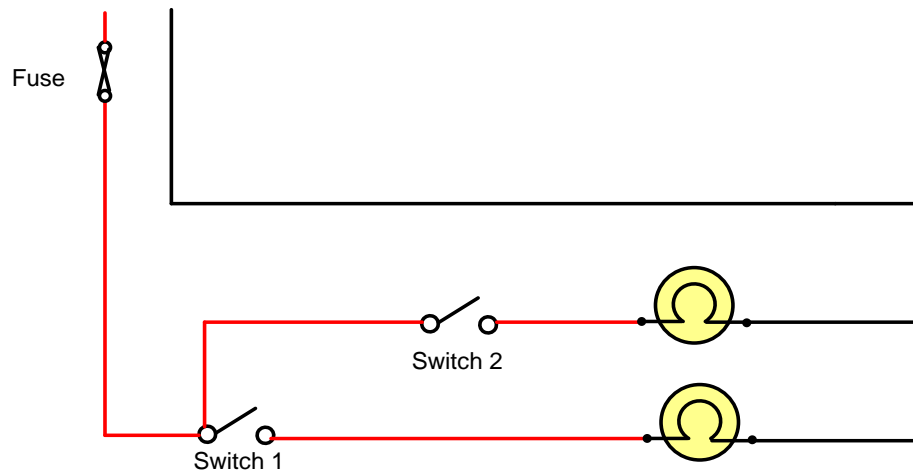


Figure 292 Looping-in method of wiring



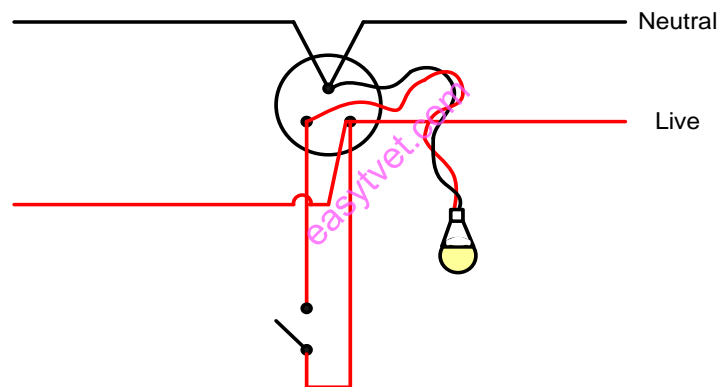
### *Looping in from a switch.*



*Figure 293 Looping-in from a switch*

In this system the Live to switch  $S_2$  is normally looped from  $S_1$ .

### *Looping-in from a three-plate ceiling rose*



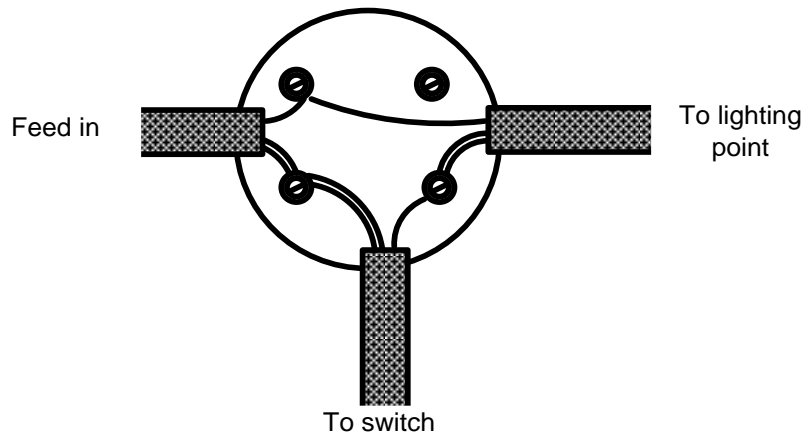
*Figure 294 Looping -in from a three-plate ceiling rose*

A ceiling rose must not be connected in such a manner that one terminal remains alive when the associated switch is OFF, unless that terminal cannot be touched when the ceiling rose is partially dismantled to allow flexible cord replacement.

### *Looping-in At Junction Boxes*

In this method, all the circuit wires are brought to a common Box and distributed to the switches, ceiling roses, lamp holder's etc.

This method of looping in is only used where there are few lamps and more so where there is service wiring using twin core cables.



## COLOUR IDENTIFICATION OF CABLES

### Single phase

|         |   |                        |
|---------|---|------------------------|
| Live    | - | Red                    |
| Neutral | - | Black                  |
| Earth   | - | Green or green /yellow |

### Three Phase

|                |   |        |   |       |
|----------------|---|--------|---|-------|
| L <sub>1</sub> | - | Red    | - | phase |
| L <sub>2</sub> | - | yellow | - | phase |
| L <sub>3</sub> | - | blue   | - | phase |
| Neutral        | - | black  |   |       |

## Size of cables and rating of protective devices

Cables are manufactured in different sizes and compositions and each is designed to carry a maximum amount of current.

The current a cable can carry are given in the I.E.E Regulation tables of current ratings.

For lighting circuits, the cable commonly used is the  $1\text{mm}^2$  or  $1.5\text{mm}^2$  which is rated 18A depending on the type of cable.

The most common cable used is single core and Twin flat and Twin with earth. Most lighting circuits will be rated at either 5A or 10A because most switches are rated 5A or 10A.

The table gives 10 I.E.E Regulations protective ratings of different types of lamps.

Table 22 IEE regulations showing the protective ratings for different types of lamps

| Type of Holder           | Maximum Rating of fuse or Circuit Breaker. |
|--------------------------|--|
| Small Bayonet type       | 5A   |
| Small Edison –type screw | 5A   |
| Bayonet type             | 15A  |
| Bi- pin type             | 15A  |

## **I.E.E Regulations on switches**

1. Every switch or Circuit Breaker the purpose of which is not obvious shall be labelled to indicate the apparatus it controls.
2. All single pole switches shall be always connected to the live conductor.
3. Every switch or other electric control shall be placed so as to be out of reach of a person in contact with bath, shower unit etc.
4. In a two-wire installation connected to a supply having neither pole connected with the earth, switch or circuit breaker shall be of double pole linked type and the fuses shall be installed in both poles.
5. In a two-wire installation connected to a supply having one pole earthed, switches shall be connected in the live conductor only.

## **POWER CIRCUITS**

### **Final power sub-circuits**

A final power sub-circuit is a circuit that allows electrical appliances to access electrical power.

All final sub-circuits must be electrically separate that is there must be no “bunching” of neutral conductors. All neutral conductors must be connected at the distribution board in the same order as the line conductors.

### **Socket Outlet**

*Definition.*

A socket outlet is a device provided with female contacts which is intended to be fitted with the fixed wiring and intended to receive a plug.

A device with protected current carrying contacts intended to be mounted in a fixed position and permanently connected to a fixed wiring of an installation to enable the connection to it of a flexible cord or flexible cable by means of a plug.

Or

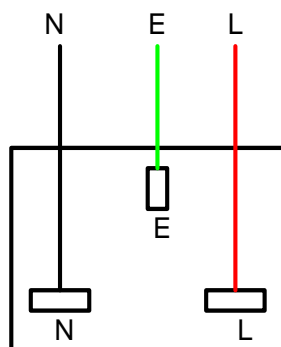
Is an accessory with 3 terminals marked *L*- live, *N*- Neutral and *E* – Earth fitted with the fixed wiring ready to receive a plug.

### **Plug**

*Definition*

A device intended for connection to a fixed cord or flexible cable which can be engaged manually with a socket outlet and which has current carrying contact pins which may be exposed when not engaged.

Socket outlet will be wired such that the terminal marked *L* will receive the live wire, the terminal marked *N* will receive the Neutral and the one marked *E* will receive the earth wire. Socket outlets must be installed in a place to wait for a plug but not the vice-versa. The figure 69 shows a diagram of a plug.



*Figure 295 Plug*

**Note;**

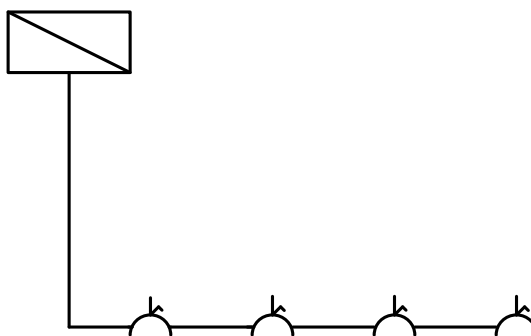
Sometimes the earth terminal is marked with the Earth symbol

There are two ways in which socket outlets may be wired

1. Radial circuit
2. Ring circuit

**Radial Circuit**

A radial circuit is a circuit in which the live, neutral and earth conductor start from the distribution board to sockets connected in series and terminate at the last socket.



*Figure 296 Layout diagram of a radial circuit*

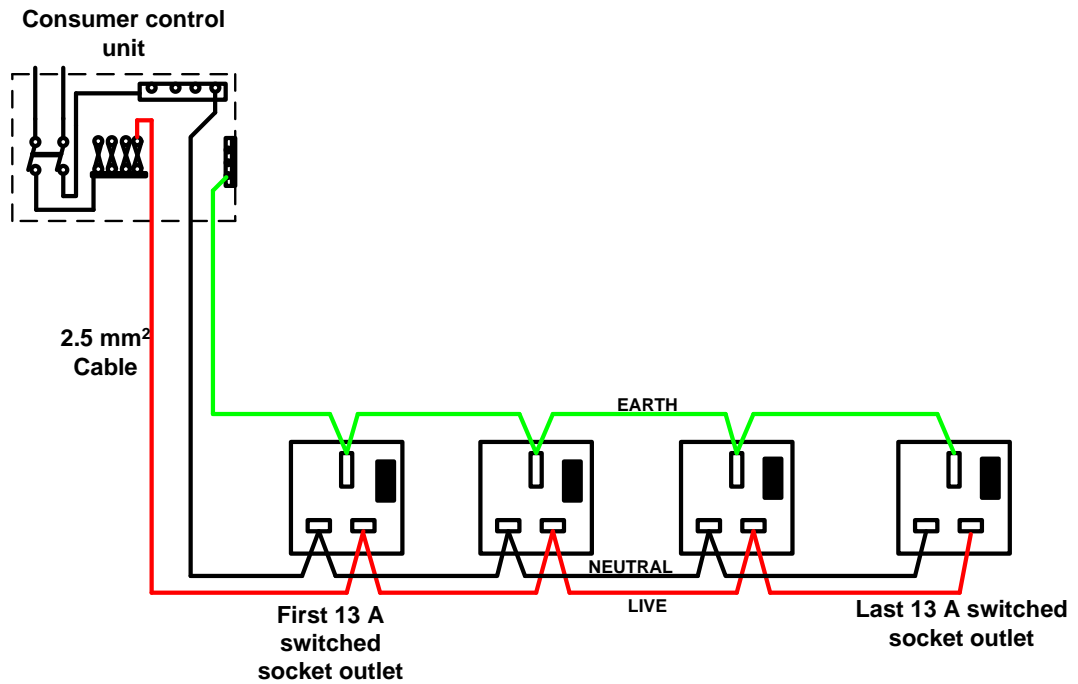


Figure 297 wiring diagram for radial circuit

## Ring Circuits

A ring circuit is defined in the I.E.E. Regulations as “a final sub-circuit in which the current-carrying and the earth-continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution board or its equivalent.

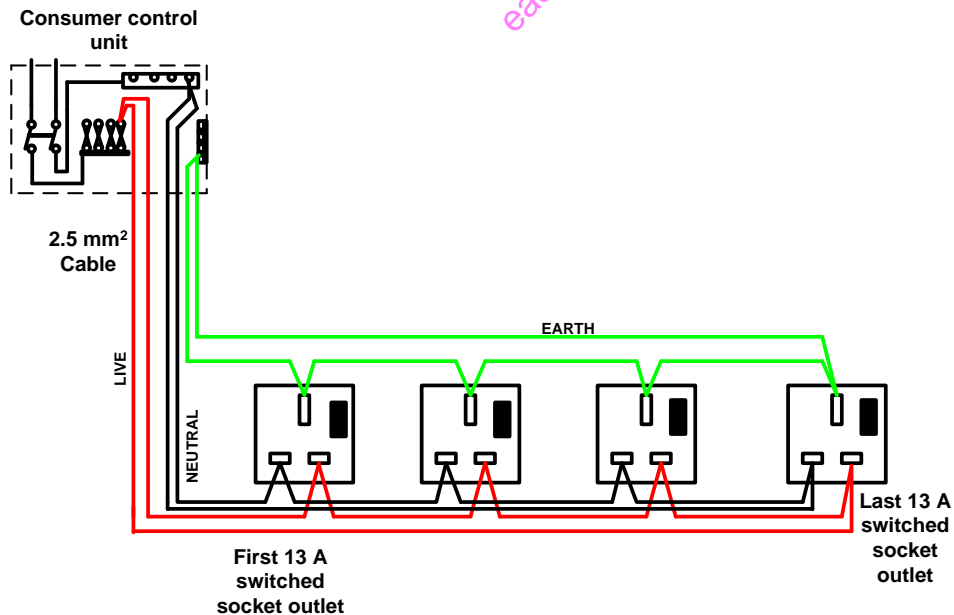


Figure 298 wiring diagram for a ring circuit.

## Spur

A spur is a socket that branches off a ring circuit. The number of spurs fed from a ring circuit must not exceed the number of sockets in the ring. The cables connecting the spur must be of the same size as that of the ring circuit. The minimum cable size for ring and radial circuit is  $2.5\text{mm}^2$ .

#### ***Advantages of a ring circuit over a Radial circuit***

1. There is total safety in ring circuit than in Radial for the circuit is in form of a ring
2. An open circuit point in the Ring circuit will not affect any other socket in the system  
This is because there are two paths of current and if one path is open the current will flow through the other
3. Smaller sizes of cables may be used in Ring than in a Radial. This is because the Ring has two parallel current paths
4. More loads may be fed or connected to a Ring circuit than a Radial circuit of the same capacity

#### ***Disadvantages of Ring over Radial***

1. More cables lengths require in a Ring than in Radial therefore becomes more expensive
2. It consumes more time to install a Ring circuit than Radial because more cables have to be installed.

#### ***I.E.E Regulations on Ring and Radial circuit***

1. A Ring circuit it may serve an unlimited number of points but shall not serve an area of more than  $100\text{m}^2$
2. For a Ring final sub-circuit, the total number of spurs shall not exceed the total number of socket outlets and stationary appliances connected directly in the ring circuit.
3. Where two or more ring final sub circuit are installed, the socket outlet to be served shall reasonably be distributed among the separate ring circuit
4. For a Radial or Ring final sub circuit the Rating of the fuse or circuit breaker at the circuit breaker shall not exceed 30A
5. Each circuit conductor of a ring final sub circuit shall be run in the form of a Ring commencing and returning to the same way in the circuit breaker.
6. Except where Ring is run throughout in metallic conduct, Ducts or Trunking, Earth continuity conductor shall run in form of a ring originating and returning to same point in the circuit breaker.
7. For a Radial circuit the current rating of the circuit conductors shall not be less than Rating of the fuse or circuit breaker protecting the final sub- circuit

#### **Water heating circuits**

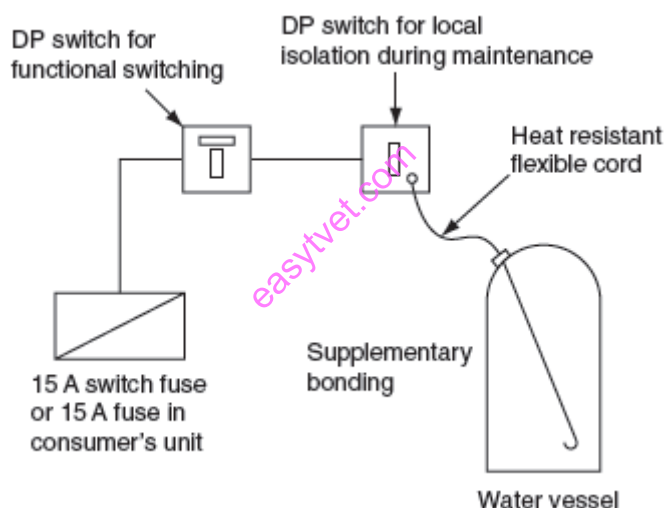
A small, single-point over-sink type water heater may be considered as a permanently connected appliance and so may be connected to a ring circuit through a fused connection unit. A water heater of

the immersion type is usually rated at a maximum of 3 kW, and could be considered as a permanently connected appliance, fed from a fused connection unit.

However, many immersion heating systems are connected into storage vessels of about 150 litres in domestic installations, and the *On-Site Guide* states that immersion heaters fitted to vessels in excess of 15 litres should be supplied by their own circuit. Therefore, immersion heaters must be wired on a separate radial circuit when they are connected to water vessels which hold more than 15 litres. Figure 73 shows the wiring arrangements for an immersion heater.

Every switch must be a double-pole (DP) switch and out of reach of anyone using a fixed bath or shower when the immersion heater is fitted to a vessel in a bathroom. Supplementary equipotential bonding to pipework *will only be required* as an addition to fault protection if the immersion heater vessel is in a bathroom that *does not have*:

- a. all circuits protected by a 30 mA RCD
- b. Protective equipotential bonding,



*Figure 299 Immersion water wiring*

## Cooker circuit

A cooker with a rating above 3 kW must be supplied on its own circuit but since it is unlikely that in normal use every heating element will be switched on at the same time, a diversity factor may be applied in calculating the cable size, as detailed in the *On Site Guide*.

Consider, as an example, a cooker with the following elements fed from a cooker control unit incorporating a 13 A socket:

$$\begin{aligned}4 \times 2 \text{ kW fast boiling rings} &= 8000 \text{ W} \\1 \times 2 \text{ kW grill} &= 2000 \text{ W} \\1 \times 2 \text{ kW oven} &= 2000 \text{ W} \\ \text{Total loading} &= 12\,000 \text{ W}\end{aligned}$$

When connected to 230 V

$$\text{Current rating} = \frac{12\,000}{230} = 52.17 \text{ A}$$

Applying the diversity factor of Table 1A

$$\begin{aligned}\text{Total current rating} &= 52.17 \text{ A} \\ \text{First 10 amperes} &= 10 \text{ A} \\ 30\% \text{ of } 42.17 \text{ A} &= 12.65 \text{ A} \\ \text{Socket outlet} &= 5 \text{ A} \\ \text{Assessed current demand} &= 10 + 12.65 + 5 = 27.65 \text{ A}\end{aligned}$$

Therefore, a cable capable of carrying 27.65 A may be used safely.

A cooking appliance must be controlled by a switch separate from the cooker but in a readily accessible position. Where two cooking appliances are installed in one room, such as split-level cookers, one switch may be used to control both appliances provided that neither appliance is more than 2 m from the switch.

## Conductor size calculations

The size of a cable to be used for an installation depends upon:

- the current rating of the cable under defined installation conditions and
- the maximum permitted drop in voltage

The factors which influence the current rating are:

1. *Design current*: cable must carry the full load current.
2. *Type of cable*: PVC, MICC, copper conductors or Aluminium conductors.
3. *Installed conditions*: clipped to a surface or installed with other cables in a trunking.
4. *Surrounding temperature*: cable resistance increases as temperature increases and insulation may melt if the temperature is too high.
5. *Type of protection*: for how long will the cable have to carry a fault current?



Regulation states that the drop in voltage from the supply terminals to the fixed current-using equipment must not exceed 3% for lighting circuits and 5% for other uses of the mains voltage. That is a maximum of 6.9 V for lighting and 11.5 V for other uses on a 230 V installation.

### Fire alarm circuits

Through one or more of the various statutory Acts, all public buildings are required to provide an effective means of giving a warning of fire so that life and property may be protected. An effective system is one which gives a warning of fire while sufficient time remains for the fire to be put out and any occupants to leave the building.

Fire alarm circuits are wired as either normally open or normally closed. In a normally open circuit, the alarm call points are connected in parallel with each other so that when any alarm point is initiated the circuit is completed and the sounder gives a warning of fire. The arrangement is shown in Fig.74. It is essential for some parts of the wiring system to continue operating even when attacked by fire. For this reason, the master control and sounders should be wired in MI or FP200 cable. The alarm call points of a normally open system must also be wired in MI or FP200 cable, unless a monitored system is used. In its simplest form this system requires a high-value resistor to be connected across the call-point contacts, which permits a small current to circulate and operate an indicator, declaring the circuit healthy. With a monitored system, PVC insulated cables may be used to wire the alarm call points.

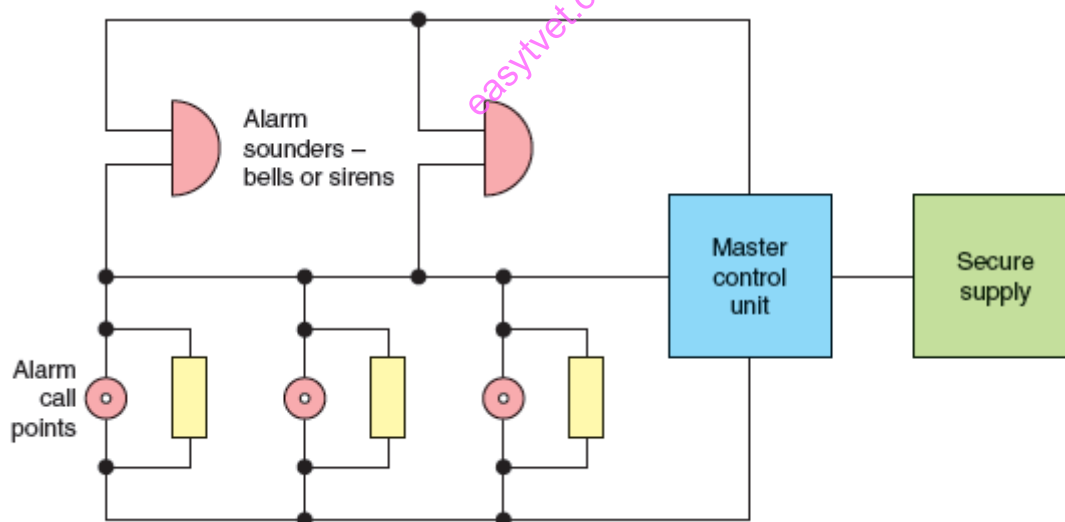
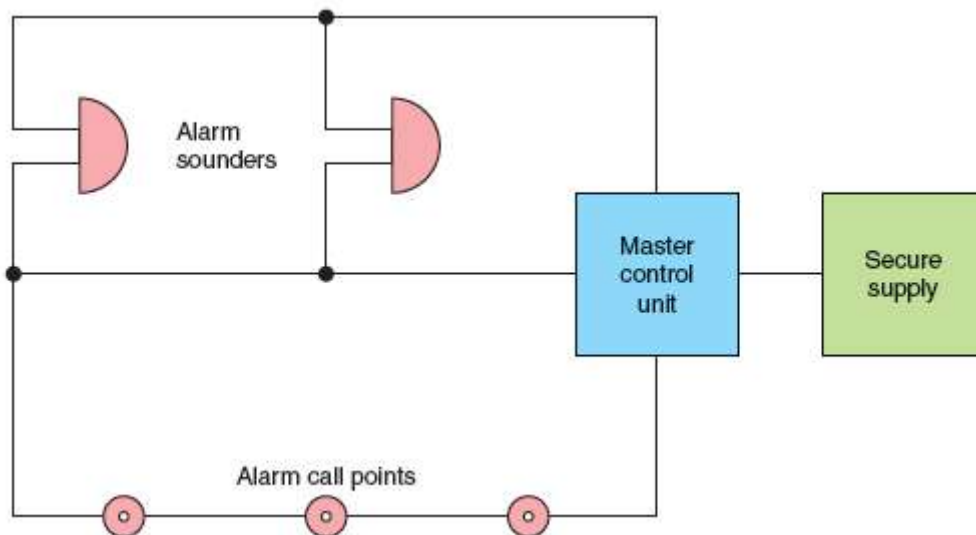


Figure 300 A simple normally open fire alarm

In a normally closed circuit, the alarm call points are connected in series to normally closed contacts as shown in Fig. 75. When the alarm is initiated, or if a break occurs in the wiring, the alarm is activated. The sounders and master control unit must be wired in MI or FP200 cable, but the call points may be wired in PVC insulated cable since this circuit will always ‘fail safe’



*Figure 301 A simple normally closed fire alarm circuit*

### **Alarm call points**

Manually operated alarm call points should be provided in all parts of a building where people may be present, and should be located so that no one need walk for more than 30 m from any position within the premises in order to give an alarm. A breakglass manual call point is shown in Fig. 76. They should be located on exit routes and, in particular, on the floor landings of staircases and exits to the street. They should be fixed at a height of 1.4 m above the floor at easily accessible, well illuminated and conspicuous positions.



*Figure 302 Break glass manual call point*

### **Sounders**

The positions and numbers of sounders should be such that the alarm can be distinctly heard above the background noise in every part of the premises. The sounders should produce a minimum of 65 dB, or 5 dB above any ambient sound which might persist, for more than 30 s. If the sounders are to arouse sleeping persons then the minimum sound level should be increased to 75 dB at the bedhead. Bells, hooters or sirens may be used but in any one installation they must all be of the same type. Examples of sounders are shown in Fig. 77. Normal speech is about 5 dB.



Figure 303 Typical fire alarm sounders

### Bell and bell circuits

The electric bell converts the magnetic effect of an electric current into sound it therefore enables audible warnings or signals to be transmitted as current over long distances by running of electric conductor cables figure 78 shows a single stroke bell. For most bell circuits, the use of lower voltages is employed which necessitates the installation of a bell transformer. Bells can be operated from manually-operated push-buttons or automatic switching from alarm devices such as door or window devices for burglar-alarm systems or detection devices for fire outbreaks.

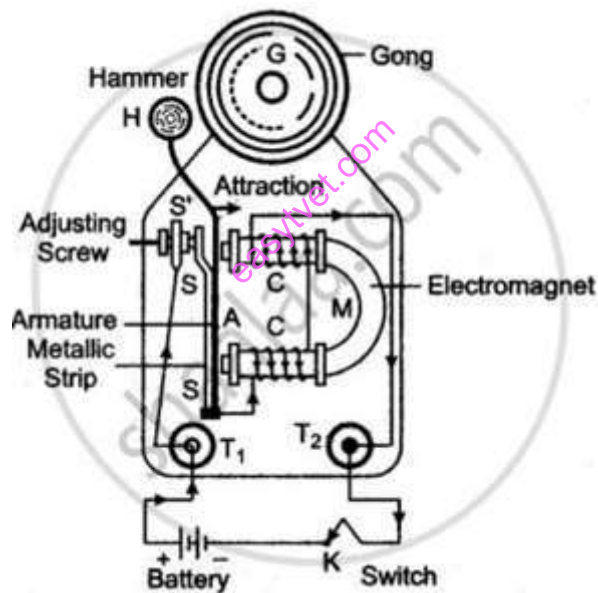


Figure 304 Single stroke bell/trembler bell

## Electrical machines circuits

### Direct on Line (DOL)

A DOL starter connects the three main lines (L1, L2 and L3) directly to the motor terminals when the start button is pressed. The drawing of a DOL starter is generally done in two separate stages. These are called the Power Circuit and the Control Circuit. Power Circuit the power circuit shows all the components or parts of components required to handle the load current of the motor. Remember that the motor in question may be a small 1.5 kW (2 HP) or a large 225 kW (300 HP). As the motor power rating increases so too must the current rating of the contactor, overload relay and supply cables. The control circuit shows all the components or parts of components required to control the motor. These components are basically the same regardless of the power rating of the motor in question. Note that when wiring circuits, the supply should be fed in on the low number terminal and out on the high number terminal. The figure 79 shows a complete schematic diagram of Direct On line (DOL) starter

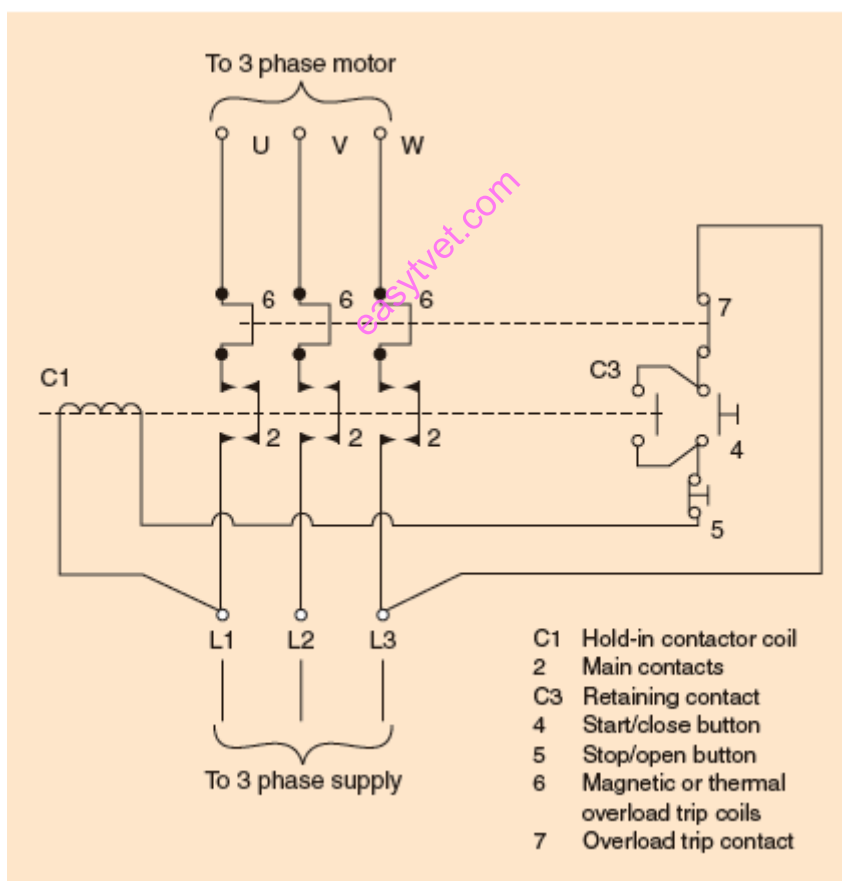


Figure 305 Direct On Line starter



|   |   |  |
|---|---|--|
| 6. Implement electrical installations as per the working drawing                            | 7. Single phase systems<br>8. Wiring systems and accessories<br><br>Electrical installations final circuits |  |
| 9. Adhere to IEE regulations during installation  | IEE regulations   |  |
| 10. Adhere to safety procedures for each activity   | Electrical safety procedures  |  |
| 11. Install cables, conductors, conduits, enclosures and support systems to specifications. | Cables, conduits, enclosures and support systems  |  |
| 12. Label installation for identification   | Cable labelling for identification  |  |

#### 6.2.4.5 Self-Assessment

1. What are the precautions necessary to observe when installing sheathed wiring systems
2. (a). What two advantages do plastic conduit have over metallic conduit.  
(b). what two advantages do metallic conduit have over non- metallic conduit.
3. Mechanical protection of cables in an electrical installation defines the type of wiring system. What factors are to be considered when determining the choice of a wiring system?
4. What are the types of PVC conduits?
5. Conduit installation must meet the IEE regulation; what any two IEE regulation do you think must be observed when installing steel conduits.

**6.2.4.6 Tools, Equipment, Supplies and Materials**  
**Recommended Resources**

|  |  |
|--|--|
| <p><b>Tools and equipment</b></p> <ul style="list-style-type: none"> <li>➤ Cable Strippers</li> <li>➤ Pliers</li> <li>➤ Screw drivers</li> <li>➤ Hammers</li> <li>➤ Chisels</li> <li>➤ Allen keys</li> <li>➤ Electrician knives</li> <li>➤ Crimping tools</li> <li>➤ Bending springs</li> <li>➤ Bending machine</li> <li>➤ Steel tapes</li> <li>➤ Draw wires</li> <li>➤ Hack saws</li> <li>➤ Drilling tools</li> <li>➤ Stock and die</li> <li>➤ Bench vice</li> <li>➤ Machine vice</li> <li>➤ PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul> | <p><b>Materials and supplies</b></p> <ul style="list-style-type: none"> <li>• Stationery</li> <li>• Cables</li> <li>• Light fittings</li> <li>• Accessories</li> <li>• Conduits and fittings</li> <li>• Cable trays</li> <li>• Cable ducts</li> <li>• Trunkings</li> <li>• Computers</li> <li>• Drawing instruments</li> <li>• Screws</li> </ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>• IEE regulations</li> <li>• Occupational safety and health act (OSHA)</li> <li>• Work injury benefits act (WIBA)</li> <li>• Manufacturers’ catalogues</li> <li>• British standards</li> <li>• KEBS standards</li> </ul>  |  |

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#### 6.2.4.8 Model answers to self-assessment

1. What are the precautions necessary to observe when installing sheathed wiring systems
  - i. When concealed in walls, they should further be protected by a channel or tube
  - ii. When run under floors, they should be at a depth sufficient to prevent damage from floor fixings
  - iii. At termination, sheath should enter the terminal housing enclosure
2. (a). What two advantages do plastic conduit have over metallic conduit.
  - i. **cheap**
  - ii. **non corrosive**
  - iii. **easy to install**
  - iv. **provides total insulation to cables**(b). what two advantages do metallic conduit have over non- metallic conduit.
  - i. **Provides better protection against mechanical damage.**
  - ii. **Provides earth return path**
  - iii. **Durability if properly installed**
  - iv. **Low fire risk**
  - v. **Can be easily extended**
3. Mechanical protection of cables in an electrical installation defines the type of wiring system. What factors are to be considered when determining the choice of a wiring system?

- i. **Type of the building**
  - ii. **Durability**
  - iii. **Cost**
  - iv. **Flexibility**
  - v. **Time taken**
4. What are the types of PVC conduits?
- i. **Heavy gauge conduit**
  - ii. **Light gauge conduit**
5. Conduit installation must meet the IEE regulation; what any two IEE regulation do you think must be observed when installing steel conduits.
- i. **Steel conduits must always be earthed.**
  - ii. **Conduits must always be installed before drawing in the cables.**
  - iii. **Radius of the bend should not exceed  $2\frac{1}{2}$  from the diameter of the conduit.**
  - iv. **Space factor of cable in conduit should not exceed 40% or 0.04.**

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## **6.2.5 Learning Outcome 5** Facilitate other service providers

### **6.2.5.1 Introduction to the learning outcome**

To facilitate other service providers, it is important to identify other service providers on site, apply communication protocols and procedures, communicate to other providers during and after the installation as necessary, obtain and agree upon the requirements of other service providers and make provision for other services according to the design.

### **6.2.5.2 Performance Standard**

- 6.2.5.2.1 Identify other service providers on site.
- 6.2.5.2.2 Apply communication protocols and procedures.
- 6.2.5.2.3 Communicate to other providers during and after the installation as necessary.
- 6.2.5.2.4 Obtain and agree upon the requirements of other service providers
- 6.2.5.2.5 Make provision for other services according to the design.

### **6.2.5.3 Information Sheet**

#### **Communication**

When you work in the construction industry you are a member of a team involving many different job roles on site. For a project to run smoothly, there must be effective communication so that everybody does what is required, at the right time, in the right way and with the right materials.

Communications is about transferring information from one person to another both quickly and accurately. We do this by talking to other people, looking at drawings and plans and discussing these with colleagues from the same company and with other professionals who have an interest in the same project. The technical information used within our industry comes from many sources. The IEE Regulations is the 'electrician's bible' and forms the basis of all our electrical design calculations and installation methods. British Standards, European Harmonized Standards and Codes of Practice provide detailed information for every sector of the electrotechnical industry, influencing all design and build considerations. The communication can generally be between:

#### **a) Employers and supervisors**

Many building companies are quite big and you may never actually see or meet the main boss of the company. Communication passes down through the organization to the tradespeople via managers and supervisors.

Larger construction sites may have a project manager who is responsible for the overall running of the project. There will also be a building supervisor or foreperson who liaises with the project manager and directs the daily activities. Alternatively, you may work for a contractor and most of the information and instructions you are given will come directly from your boss.

## **b) Contractors**

Many of the tradespeople you interact with will be contractors; that is, they run their own business and provide their services to the building company. Contractors have to communicate effectively with each other, as they are often working in the same area at the same time. For example, the plumber and the electrician may both be working on the same section of the site, and the bricklayer may need one or both of them to have finished their part of the job before s/he starts. If you're working for or with a contractor, you'll need to be able to share information and negotiate coordination and scheduling issues throughout a construction project.

## **c) Co-workers**

Most of your workplace communication is likely to be with members of your team and other co-workers. Together, you'll be organizing and completing tasks, giving and receiving instructions, helping each other and solving problems.

## **d) Others**

On construction projects there are lots of other people involved at various stages. You may need to communicate with the following people as part of your work responsibilities:

- designers and architects
- safety officers
- union representatives
- clients
- delivery drivers
- Suppliers
- office staff

## **Types of communication**

Communication can be grouped into four main types – verbal, non-verbal, written and Visual

### **a) Verbal communication**

Verbal communication is probably the most used form of communication. It relies on sharing spoken words that the communicator and the receiver both understand.

### **b) Non-verbal communication**

Non-verbal communication is when you communicate with others without using words.

Body language – gestures, facial expressions, posture – can tell other people a lot about what you really mean that might not be communicated by the actual words you use.

Have a look at the body language of the three people below. Which one do you think really does feel happy? What do the other two really think?

Non-verbal communication is often sent unintentionally; that is, you don't deliberately send it as part of your message, but it is still received by the other person. However, sometimes we deliberately use non-verbal communication to create or reinforce a particular meaning in our messages. For example, if you ask, 'What are you doing?' in an angry tone of voice, you're probably expressing displeasure rather than curiosity.

### **c) Written communication**

Written communication means using the written word to send information. This could be on paper, a screen, a billboard or even a T-shirt.

There are many different types of written communication used regularly in the construction industry and some examples are listed in the following table. Each type is more suited to some situations, audiences or purposes than others.

### **d) Visual communication**

Visual communication covers all types of communication we see rather than read or hear. It is usually pictorial, although there could be a few words present as well, such as on a sign or poster. Workers in the construction industry use a lot of visual communication, for example, plans and diagrams, safety signs, warning lights and hand signals.

### **e) Formal and informal communication**

The way we speak to different people depends on who they are, how well we know them and the situation we are in. We don't use the same words and tone of voice to speak to a teacher or boss as we do when we're chatting to our mates.

We are likely to speak quite formally to people in authority like teachers or police officers but we can be far more relaxed and spontaneous with family and friends. In the workplace we usually use formal communication with our employers and supervisors, and informal communication with our workmates. Formal and informal communication can also relate to the way we write. An email to a workmate would probably be quite casual but a job application would definitely be written more formally

### **Sources of technical information**

Equipment and accessories available to use in a specific situation can often be found in the very comprehensive manufacturer's catalogues and the catalogues of the major wholesalers that service the electrotechnical industries.

All of this technical information may be distributed and retrieved by using:

- conventional drawings and diagrams which we will look at in more detail below

- sketch drawing to illustrate an idea or the shape of say a bracket to hold a piece of electrical equipment
- the Internet can be used to download British Standards and Codes of Practice
- The Internet can also be used to download health and safety information from the health and safety.
- CDs, DVDs, USB memory sticks and email can be used to communicate and store information electronically
- The facsimile (Fax) machine can be used to communicate with other busy professionals, information say about a project you are working on together.

If you are working at your company office with access to online computers, then technical information is only a fingertip or mouse click away. However, a construction site is a hostile environment for a laptop and so a hard copy of any data is preferable on site.

#### 6.2.5.4 Learning Activities

| Practical activities   | Knowledge   |
|--|---|
| 3. Identify other service providers on site.                                     | Other service providers in the construction site. |
| 4. Apply communication protocols and procedures.                                 | Communication                                     |
| 5. Communicate to other providers during and after the installation as necessary | Communication                                     |
| 6. Obtain and agree upon the requirements of other service providers             | communication                                     |
| 7. Make provision for other services according to the design.                    | Design  |

#### 6.2.5.5 Self-Assessment

1. What are the five ways in which you can make your communication efforts as effective as possible?
2. Communication can be grouped into four main types. What are these groups?
3. What method would you use to let the office know that the materials you were expecting have not yet arrived?
4. In what ways can technical information be retrieved?
5. What are the advantages of written communication?

**6.2.5.6 Tools, Equipment, Supplies and Materials**  
**Recommended Resources**

|  |  |
|--|--|
| <p><b>Tools and equipment</b></p> <ul style="list-style-type: none"> <li>➤ Cable Strippers</li> <li>➤ Pliers</li> <li>➤ Screw drivers</li> <li>➤ Hammers</li> <li>➤ Chisels</li> <li>➤ Allen keys</li> <li>➤ Electrician knives</li> <li>➤ Crimping tools</li> <li>➤ Bending springs</li> <li>➤ Bending machine</li> <li>➤ Steel tapes</li> <li>➤ Draw wires</li> <li>➤ Hack saws</li> <li>➤ Drilling tools</li> <li>➤ Stock and die</li> <li>➤ Bench vice</li> <li>➤ Machine vice</li> <li>➤ PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul> | <p><b>Materials and supplies</b></p> <ul style="list-style-type: none"> <li>• Stationery</li> <li>• Cables</li> <li>• Light fittings</li> <li>• Accessories</li> <li>• Conduits and fittings</li> <li>• Cable trays</li> <li>• Cable ducts</li> <li>• Trunkings</li> <li>• Computers</li> <li>• Drawing instruments</li> <li>• Screws</li> </ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>• IEE regulations</li> <li>• Occupational safety and health act (OSHA)</li> <li>• Work injury benefits act (WIBA)</li> <li>• Manufacturers’ catalogues</li> <li>• British standards</li> <li>• KEBS standards</li> </ul>  |  |

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### 6.2.5.8 Model answers to self-assessment

1. What are the five ways in which you can make your communication efforts as effective as possible?
  - **Being a keen listener: Effective communication depends on listening skills since it would allow both parties to understand each other.**
  - **Paying attention to non-verbal communication: Communication is often accompanied by non-verbal cues. Every party in a conversation has to identify and understand the non-verbal cues and how to use them to ensure that the information delivered is accurate.**
  - **Making a keen choice of language use: The choice of words hugely impacts the information being delivered during communication and the overall perception of the recipient on the information.**
  - **Efficiently expressing oneself: During a communication, an individual has to share their thoughts and feelings on the topic at hand as honestly as possible, while still acknowledging other people's opinions.**

- **Control of emotions: During a conversation, one must prevent emotions from running the conversation**
2. Communication can be grouped into four main types. What are these groups?
- **Verbal**
  - **non-verbal**
  - **written**
  - **Visual**
3. What method would you use to let the office know that the materials you were expecting have not yet arrived?
- **Email**
  - **Telephone call**
4. In what ways can technical information be retrieved?
- **conventional drawings and diagrams which we will look at in more detail below**
  - **sketch drawing to illustrate an idea or the shape of say a bracket to hold a piece of electrical equipment**
  - **the Internet can be used to download British Standards and Codes of Practice**
  - **The Internet can also be used to download health and safety information from the health and safety.**
  - **CDs, DVDs, USB memory sticks and email can be used to communicate and store information electronically**
  - **The facsimile (Fax) machine can be used to communicate with other busy professionals, information say about a project you are working on together.**
5. What are the advantages of written communication?
- **It is suitable for long distance communication and repetitive standing orders.**
  - **It creates permanent record of evidence.**
  - **It gives the receiver sufficient time to think, act and react.**
  - **It can be used as legal document.**
  - **It can be sent to many persons at a time**

## 6.2.6 Learning Outcome 6

### 6.2.6.1 Introduction to the learning outcome

To maintain housekeeping, prepare safety checklist for electrical equipment and machines, carry out regular follow up according to the prepared checklist, and follow up workplace procedures to deal with any accidents and damage of equipment occurring during the cleaning process and record and report activities as per the established procedures.

### 6.2.6.2 Performance Standard

- 6.2.6.2.1 Prepare safety checklist for electrical equipment and machines
- 6.2.6.2.2 Carry out regular follow up according to the prepared checklist
- 6.2.6.2.3 Follow up workplace procedures to deal with any accidents and damage of equipment occurring during the cleaning process
- 6.2.6.2.4 Record and report activities as per the established procedures.

### 6.2.6.3 Information Sheet

#### Housekeeping

Electrical workshops must be kept clean and dry. If spills or leaks occur, they must be cleaned up promptly to avoid the risk of electrocution. Additionally, walking and working surfaces should be as free from debris as possible to minimize slips, trips and falls. Slipping, tripping and falling into electrical equipment in a workshop can cause severe injuries. The elements of an effective housekeeping program are:

#### a) Maintenance

The maintenance of buildings and equipment may be the most important element of good housekeeping. Maintenance involves keeping buildings, equipment and machinery in safe, efficient working order and in good repair. It includes maintaining sanitary facilities and regularly painting and cleaning walls. Broken windows, damaged doors, defective plumbing and broken floor surfaces can make a workplace look neglected; these conditions can cause incidents and affect work practices. So it is important to replace or fix broken or damaged items as quickly as possible. A good maintenance program provides for the inspection, maintenance, upkeep and repair of tools, equipment, machines and processes.

#### b) Dust and dirt removal

Enclosures and exhaust ventilation systems may fail to collect dust, dirt and chips adequately. Vacuum cleaners are suitable for removing light dust and dirt that is not otherwise hazardous. Industrial models have special fittings for cleaning walls, ceilings, ledges, machinery, and other hard-to-reach places where dust and dirt may accumulate.

Special-purpose vacuums are useful for removing hazardous products. For example, vacuum cleaners fitted with HEPA (high efficiency particulate air) filters may be used to capture fine particles of asbestos or fibreglass.

Dampening (wetting) floors or using sweeping compounds before sweeping reduces the amount of airborne dust. The dust and grime that collect in places like shelves, piping, conduits, light fixtures, reflectors, windows, cupboards and lockers may require manual cleaning.

Compressed air should not be used for removing dust, dirt or chips from equipment or work surfaces.

### **c) Employee facilities**

Employee facilities need to be adequate, clean and well maintained. Lockers may be necessary for storing employees' personal belongings. Washroom facilities require cleaning once or more each shift. They also need to have a good supply of soap, towels plus disinfectants, if needed.

If workers are using hazardous products, employee facilities should provide special precautions as needed such as showers, washing facilities and change rooms. Some facilities may require two locker rooms with showers between. Using such double locker rooms allows workers to shower off workplace contaminants and reduces the chance of contaminating their "street clothes" by keeping their work clothes separated from the clothing that they wear home.

Smoking, eating or drinking in the work area should be prohibited where hazardous products are handled. The eating area should be separate from the work area and should be cleaned properly each shift.

### **d) Surfaces**

Floors: Poor floor conditions are a leading cause of incidents so cleaning up spilled oil and other liquids at once is important. Allowing chips, shavings and dust to accumulate can also cause incidents. Trapping chips, shavings and dust before they reach the floor or cleaning them up regularly can prevent their accumulation. Areas that cannot be cleaned continuously, such as entrance ways, should have anti-slip flooring. Keeping floors in good order also means replacing any worn, ripped, or damaged flooring that poses a tripping hazard.

Walls: Light-coloured walls reflect light while dirty or dark-coloured walls absorb light. Contrasting colours warn of physical hazards and mark obstructions such as pillars. Paint can highlight railings, guards and other safety equipment, but should never be used as a substitute for guarding. The program should outline the regulations and standards for colours.

### **e) Maintain Light Fixtures**

Dirty light fixtures reduce essential light levels. Clean light fixtures can improve lighting efficiency significantly.

#### **f) Aisles and Stairways**

Aisles should be wide enough to accommodate people and vehicles comfortably and safely. Aisle space allows for the movement of people, products and materials. Warning signs and mirrors can improve sight-lines in blind corners. Arranging aisles properly encourages people to use them so that they do not take shortcuts through hazardous areas.

Keeping aisles and stairways clear is important. They should not be used for temporary "overflow" or "bottleneck" storage. Stairways and aisles also require adequate lighting.

#### **g) Spill Control**

The best way to control spills is to stop them before they happen. Regularly cleaning and maintaining machines and equipment is one way. Another is to use drip pans and guards where possible spills might occur. When spills do occur, it is important to clean them up immediately. Absorbent materials are useful for wiping up greasy, oily or other liquid spills. Used absorbents must be disposed of properly and safely.

#### **h) Tools and Equipment**

Tool housekeeping is very important, whether in the tool room, on the rack, in the yard, or on the bench. Tools require suitable fixtures with marked locations to provide an orderly arrangement. Returning tools promptly after use reduces the chance of it being misplaced or lost. Workers should regularly inspect, clean and repair all tools and take any damaged or worn tools out of service.

#### **i) Waste Disposal**

The regular collection, grading and sorting of scrap contribute to good housekeeping practices. It also makes it possible to separate materials that can be recycled from those going to waste disposal facilities. Allowing material to build up on the floor wastes time and energy since additional time is required for cleaning it up. Placing scrap containers near where the waste is produced encourages orderly waste disposal and makes collection easier. All waste receptacles should be clearly labelled (e.g., recyclable glass, plastic, scrap metal, etc.).

#### **j) Storage**

Good organization of stored materials is essential for overcoming material storage problems whether on a temporary or permanent basis. There will also be fewer strain injuries if the amount of handling is reduced, especially if less manual material handling is required. The location of the stockpiles should not interfere with work but they should still be readily available when required. Stored materials should allow at least one metre (or about three feet) of clear space under sprinkler heads.

Stacking cartons and drums on a firm foundation and cross tying them, where necessary, reduces the chance of their movement. Stored materials should not obstruct aisles, stairs, exits, fire equipment, emergency eyewash fountains, emergency showers, or first aid stations. All storage areas should be clearly marked.

Flammable, combustible, toxic and other hazardous materials should be stored in approved containers in designated areas that are appropriate for the different hazards that they pose. Storage of materials should meet all requirements specified in the fire codes and the regulations of environmental and occupational health and safety agencies in your jurisdiction.

Use the following checklist as a general workplace guide.

### **Floors and Other Areas**

- Are floors clean and clear of waste?
- Are signs posted to warn of wet floors?
- Are floors in good condition?
- Are there holes, worn or loose planks or carpet sticking up?
- Is anti-slip flooring used where spills, moisture or grease are likely?
- Are there protruding objects such as nails, sharp corners, open cabinet drawers, trailing electrical wires?
- Are personal items, such as clothing and lunch boxes, in assigned lockers or storage areas?
- Is the work area congested?
- Are floors well-drained?

### **Aisles and Stairways**

- Are aisles unobstructed and clearly marked?
- Are mirrors installed at blind corners?
- Are aisles wide enough to accommodate workers and equipment comfortably?
- Are safe loading practices used with hand and power trucks, skids, or pallets?
- Is the workplace lighting adequate? Are stairs well lit?
- Are stairs covered with an anti-slip tread? Are faulty stair treads repaired?

### **Spill Control**

- Are all spills wiped up quickly?
- Are procedures followed as indicated on the material safety data sheet?
- Are spill absorbents used for greasy, oily, flammable or toxic materials?
- Are used rags and absorbents disposed of promptly and safely?
- Is a spill area surrounded by a barrier to prevent a spill from spreading?

### **Equipment and Machinery Maintenance**

- Is equipment in good working order, with all necessary guards or safety features operational or in place?
- Is equipment damaged or outdated?
- Are tools and machinery inspected regularly for wear or leaks?

- Is equipment repaired promptly?
- Are drip pans or absorbent materials used if leaks cannot be stopped at the source?
- Is a machine that splashes oil fitted with a screen or splash guard?
- Are machines and tools cleaned regularly?

### Waste Disposal

- Are there adequate number of containers?
- Are there separate and approved containers for toxic and flammable waste?
- Are waste containers located where the waste is produced?
- Are waste containers emptied regularly?
- Are toxic and flammable waste chemicals handled properly?

### Storage

- Are storage areas safe and accessible?
- Is material stacked securely, blocked or interlocked if possible?
- Are materials stored in areas that do not obstruct stairs, fire escapes, exits or firefighting equipment?
- Are materials stored in areas that do not interfere with workers or the flow of materials?
- Are bins or racks provided where material cannot be piled?
- Are all storage areas clearly marked?
- Do workers understand material storage and handling procedures?

### Fire Prevention

- Are combustible and flammable materials present only in the quantities needed for the job at hand?
- Are combustible and flammable materials kept in safety cans during use?
- Are hazardous materials stored in approved containers and away from ignition sources?
- Are sprinkler heads clear of stored material?
- Are fire extinguishers inspected and located along commonly travelled routes, and close to possible ignition sources?

Are oily or greasy rags placed in metal containers and disposed of regularly?

### 6.2.6.4 Learning Activities

#### Industrial attachment/workshop Practice

| Practical activities | knowledge | Special instruction |
|----------------------|-----------|---------------------|
|----------------------|-----------|---------------------|

|  |  |  |
|--|--|--|
| 5. Prepare safety checklist for electrical equipment and machines  | Safety and electrical tools, materials and equipment |  |
| 6. Carry out regular follow up according to the prepared checklist   |  |  |
| 7. Follow-up workplace procedures to deal with any accidents and damage of equipment occurring during the cleaning process |  |  |
| 8. Record and report activities as per the established procedures.   |  |  |

#### 6.2.6.5 Self-Assessment

1. What does the team housekeeping mean?
2. What are some benefits of good housekeeping practices?
3. What are the elements of an effective housekeeping program?
4. What would you include in your checklist to ensure waste are disposed appropriately?

#### 6.2.6.6 Tools, Equipment, Supplies and Material

##### Recommended Resources

| <b>Tools and equipment</b>  | <b>Materials and supplies</b>   |
|---|---|
| <ul style="list-style-type: none"> <li>➤ Cable Strippers</li> <li>➤ Pliers</li> <li>➤ Screw drivers</li> <li>➤ Hammers</li> <li>➤ Chisels</li> <li>➤ Allen keys</li> <li>➤ Electrician knives</li> <li>➤ Crimping tools</li> <li>➤ Bending springs</li> <li>➤ Bending machine</li> <li>➤ Steel tapes</li> </ul> | <ul style="list-style-type: none"> <li>• Stationery</li> <li>• Cables</li> <li>• Light fittings</li> <li>• Accessories</li> <li>• Conduits and fittings</li> <li>• Cable trays</li> <li>• Cable ducts</li> <li>• Trunkings</li> <li>• Computers</li> <li>• Drawing instruments</li> </ul> |



|   |  |
|---|--|
| <ul style="list-style-type: none"> <li>➤ Draw wires</li> <li>➤ Hack saws</li> <li>➤ Drilling tools</li> <li>➤ Stock and die</li> <li>➤ Bench vice</li> <li>➤ Machine vice</li> <li>➤ PPE – hand gloves, dust coats, dust masks, helmets, ear muffs, industrial boots</li> </ul>                   | <ul style="list-style-type: none"> <li>• Screws</li> </ul> |
| <p><b>Reference materials</b></p> <ul style="list-style-type: none"> <li>• IEE regulations</li> <li>• Occupational safety and health act (OSHA)</li> <li>• Work injury benefits act (WIBA)</li> <li>• Manufacturers’ catalogues</li> <li>• British standards</li> <li>• KEBS standards</li> </ul> |  |

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#### 6.2.6.8 Model answers to self-assessment

1. What does the team housekeeping mean?

Housekeeping is not just cleanliness. It includes keeping work areas neat and orderly, maintaining halls and floors free of slip and trip hazards, and removing of waste materials (e.g., paper, cardboard) and other fire hazards from work areas. Good housekeeping is also a basic part of incident and fire prevention.

2. What are some benefits of good housekeeping practices?

- reduced handling to ease the flow of materials
- fewer tripping and slipping incidents in clutter-free and spill-free work areas
- decreased fire hazards
- lower worker exposures to hazardous products (e.g. dusts, vapours)
- better control of tools and materials, including inventory and supplies
- more efficient equipment cleanup and maintenance
- better hygienic conditions leading to improved health
- more effective use of space
- reduced property damage by improving preventive maintenance
- less janitorial work
- improved morale
- improved productivity (tools and materials will be easy to find)

3. What are the elements of an effective housekeeping program?

- Dust and dirt removal
- Maintenance
- Surfaces
- Light fixtures
- Aisles or stairways
- Spill control
- Tools and equipment
- Waste disposal storage

4. What would you include in your checklist to ensure waste are disposed appropriately?

- Availability of adequate number of containers
- separate and approved containers for toxic and flammable waste
- waste containers location

- emptying of the waste containers
- proper handling of toxic and flammable waste chemicals

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## **CHAPTER 7: TESTING OF ELECTRICAL INSTALLATION**

**Unit of learning code: ENG/OS/EI/CR/03/5**

**Related Unit of Competency in Occupational Standard: Perform testing of electrical installations**

### **7.1 Introduction to the unit of learning**

This unit covers the competencies required to carry out inspection and testing of an electrical installation. The inspection and testing work covers; identification of types of test, preparation of test equipment, verifying installed fittings, conducting performance tests, recording testing results, generation of reports and issuance of certificates.

### **7.2 Summary of Learning Outcomes**

1. Conduct physical inspection
2. Identify the test to be carried out and test equipment
3. Prepare test equipment
4. Perform the test
5. Issue installation test and wiring certificates.

#### **7.2.1 Learning Outcome 1: Conduct physical inspection**

##### **7.2.1.1 Introduction to the learning outcome**

Once the installation is complete, we need to test it against the original specification for the work. This is in order to check that the finished installation matches the requirements laid out by the customer and is fit for use in the environment where it will be used.

##### **7.2.1.2 Performance Standard**

- 7.2.1.2.1 Visual inspection is carried out
- 7.2.1.2.2 Fitting points and equipment are identified
- 7.2.1.2.3 Physical condition of all fittings is verified for safety appropriateness

##### **7.2.1.3 Information Sheet**

- Visual electrical installation inspection

A visual electrical inspection is a survey of your electrical wiring system. It is used to identify defects, damage or deterioration of the electrical installation and to determine whether it complies with the current BS7671 electrical safety standard. This type of

inspection does not involve any circuit testing, therefore, on its own; it cannot be used to show whether the installation is completely safe for continued use.

Visual electrical checks are best used during the interim period between testing regimes to ensure that an installation remains in a 'safe to use' state. They are not to be used as a replacement for the formal periodic inspection tests as advised by the institute of Engineering and Technology.

### Importance of visual electrical installation inspection

- Electrical leads are checked for damage and repairs and also that they are not in a position where they can be damaged
- All electrical appliances are working
- Extension leads are being used correctly.
- Plugs and sockets are intact i.e. not cracked or damaged, with no dis-colouration or burn marks Socket outlets are not overloaded.
- Light sockets and switches are securely fitted with no dis-colouration or burn marks.
- Bathroom electrical outlets are at least three meters from the edge of a bath or shower cubicle and those electric heaters and boilers are permanently wired. They should not be free standing or portable.
- **Visual electrical inspection sheet**

| Checks to be undertaken |   |                |                               |
|-------------------------|---|----------------|-------------------------------|
| <b>1</b>                | <b>Meter equipment</b>  | <b>Confirm</b> | <b>Date for remedial work</b> |
| <b>A</b>                | There are no visual signs of burning, overheating or damage and no burning smell at the electrical intake position (usually where the consumer unit and electricity meter are located). |                |                               |
| <b>b</b>                | The electrical intake position and consumer unit are easily accessible and free from storage materials  |                |                               |
| <b>2</b>                | <b>Consumer unit (fuse box)</b>   |                |                               |

|  |   |  |  |
|--|---|--|--|
| <b>a</b>   | There are no blanks missing from the consumer unit.   |  |  |
| <b>b</b>   | The consumer unit is correctly labelled for identification of circuits.   |  |  |
| <b>c</b>   | There are no noticeable signs of electrical burning near the consumer unit/ electricity meter (by smell or visual evidence).*   |  |  |
| <b>3 Residual Current Device (RCD, RCBO, RCCB)</b> |   |  |  |
| <b>a</b>   | 30mA RCD(s) are present in the consumer unit.<br><br><i>Please state if not applicable due to RCD(s) being present on all sockets (by writing NA in the tick box)</i>   |  |  |
| <b>b</b>   | I have operated the test button(s) on these RCD(s) during the course of this inspection and confirm they are operating properly.  |  |  |
| <b>c</b>   | RCD(s) not present in consumer unit, but sockets are provided with RCD protection and the test button on each has been operated within the last quarter.<br><br><i>Please state if not applicable because RCDs are present in the consumer unit only (by writing NA in the tick box).</i> |  |  |
| <b>d</b>   | After consulting my tenant, to the best of my knowledge the RCD and/or circuit breakers do not trip frequently.   |  |  |

|                                 |  |  |  |
|---------------------------------|--|--|--|
| <b>4. Fixtures and Fittings</b> |  |  |  |
| <b>a</b>                        | All fittings [light fittings/sockets /switches/outlets/showers/storage heaters etc.] on the premises are tightly secured in their back box, with all screws present. |  |  |
| <b>b</b>                        | All sockets on the premises are working (i.e. power a simple appliance such as a lamp).  |  |  |
| <b>c</b>                        | No fittings [light fittings /sockets/switches/outlets/showers/storage heaters etc.] on the premises show signs of burning or damage.                                 |  |  |
| <b>d</b>                        | There are no signs of modification/alteration to the electrical installation from the previous tenant.   |  |  |
| <b>5 Electrical Appliances</b>  |  |  |  |
| <b>a</b>                        | All portable electrical appliances supplied by the landlord have been visually inspected and tested in line with the risk assessment carried out by the tester.      |  |  |
| <b>b</b>                        | The tenant has been made aware of the danger posed by overloading sockets and understands that it is their responsibility to use appliances safely                   |  |  |

*Table 23 Visual electrical inspection sheet*

### **Firmness of electrical joints**

Electrical joints and terminations provide the required electrical connection as well as the mechanical support, and physical protection of the cable. These joins should be tight and firm.

### **Loose electrical connections**



Loose electrical connections cause multiple problems in appliances, heat being the most common one. Electrical connections need to be mechanically tight to ensure that the resistance across that connection is as low as possible, ideally zero ohms. When a connection becomes either loose or corroded, it develops resistance.

### **Damaged accessories and fittings**

Electrical conduits are metal, plastic or fiber pipes designed to protect electrical cables and wires. They're used in just about every residential and commercial establishment, especially for wiring that is either exposed, or fitted outdoors. Since they are essentially a safety feature, you should check and ensure that these accessories are not damaged.

### **Colour coding**

The color code for AC power wiring is as follows

Phase 1 - Red.

Phase 2 - Yellow

Phase 3 - Blue

Neutral - Black

Ground - Green with Yellow Stripe.

- **Identification of fitting points and identification of equipment**

In new installations, inspection should be carried out progressively as the installation is installed and must be done before it is energized.

As far as is reasonably practicable, an initial inspection should be carried out to verify that:

- i.** all equipment and material is of the correct type and complies with applicable British Standards or acceptable equivalents
- ii.** all parts of the fixed installation are correctly selected and erected
- iii.** no part of the fixed installation is visibly damaged or otherwise defective
- iv.** The equipment and materials used are suitable for the installation relative to the environmental conditions.

The following items must be covered in an inspection.

- i. **Connection of conductors:** Every connection between conductors and equipment or other conductors must provide durable electrical continuity and adequate mechanical strength. Requirements for the enclosure and accessibility of connections must be considered.
- ii. **Identification of each conductor:** Table 3 provides a schedule of colour identification of each core of a cable and its conductors.

| Function             | Old conductor    |         | New conductor    |          |
|----------------------|------------------|---------|------------------|----------|
|                      | Colour           | Marking | Marking          | Colour   |
| Line 1 of a.c.       | Red              | L1      | L1               | Brown(1) |
| Line 2 of a.c.       | Yellow           | L2      | L2               | Black(1) |
| Line 3 of a.c.       | Blue             | L3      | L3               | Grey(1)  |
| Neutral of a.c.      | Black            | N       | N                | Blue     |
| Protective conductor | Green-and-yellow |         | Green-and-yellow |          |

Table 24 colour identification of conductors

- iii. **Routing of cables:** Cable routes shall be selected with regard to the cable's suitability for the environment, i.e. ambient temperature, heat, water, foreign bodies, corrosion, impact, vibration, flora, fauna, radiation, building use and structure. Cables should be routed out of harm's way and protected against mechanical damage where necessary. Permitted cable routes are clearly defined in the IEE On-Site Guide; alternatively, cables should be installed in earthed metal conduit or trunking.
- iv. **Current-carrying capacity:** Where practicable, the cable size should be assessed against the protective device based upon information provided by the installation designer.
- v. **Verification of polarity:** It must be checked that no single pole switch or protective device is installed in any neutral conductor. A check must also be made that all protective devices and switches are connected in the line conductor only (unless the switch is a double pole device) and that the centre contact of Edison screw lamp holders are connected to the line conductor. No switches are permitted in the circuit protective conductor (CPC)
- **Accessories and equipment:** it must be checked that the rating of the accessories and equipments are adhered to. Particular attention should be paid to the

requirements for a cable coupler. Lamp holders should be checked for correct temperature rating.

- **Verification of all fittings for safety appropriateness**

The person carrying out electrical work must inspect the installations before they are taken into use. The inspection helps ensure the electrical safety and conformity of the installations.

- i. **Selection and erection to minimize the spread of fire:** A fire barrier or protection against thermal effects should be provided if necessary to meet the requirements of BS 7671. The Regulations require that each ceiling arrangement be inspected to verify that it conforms to the manufacturer's erection instructions. This may be impossible without dismantling the system and it is essential, therefore, that inspection should be carried out at the appropriate stage of the work and that this is recorded at the time for incorporation in the inspection and test documents.
- ii. **Protection against direct contact:** Direct contact as defined in BS 7671 is the contact of persons or livestock with live parts. Live parts are conductors or conductive parts intended to be energized in normal use including a neutral conductor but by convention not a combined Protective Earthed Neutral (PEN) conductor. Protection is provided using the following methods:
  - i) **Insulation.** Is the insulation damaged or has too much been removed? Although protection by insulation is the usual method there are other methods of providing basic protection.
  - ii) **Barriers.** Where live parts are protected by barriers or enclosures, these should be checked for adequacy and security. Have all covers, lids and plates been securely fitted?
  - iii) **Obstacles.** Protection by obstacles provides protection only against an intentional contact. If this method is used, the area shall be accessible only to skilled persons or to instructed persons under supervision. Obstacles can include a fence around a transformer sub-station and barbed wire fencing on power pylons.

**iii) Out of reach.** Placing out of reach protects against direct contact. Increased distance is necessary where bulky conducting objects are likely to be handled in the vicinity.

**iv. Fault protection:**

Fault protection is the contact of persons or livestock with exposed conductive parts which have become live under fault conditions. An exposed conductive part is a conductive part of equipment which can be touched but is not live although it can become live under fault conditions.

Examples of exposed conductive parts could include metal trunking, metal conduit and the metal case of an electrical appliance, e.g. a classroom overhead projector.

Earthing provides protection against this type of fault. We also need to check that extraneous conductive parts have been correctly bonded with protective conductors.

An extraneous conductive part is a conductive part that is liable to introduce a potential, generally earth potential, and not form part of an electrical installation; examples of extraneous conductive parts are metal sink tops and metal water pipes.

The purpose of the bonding is to ensure that all extraneous conductive parts which are simultaneously accessible are at the same potential. Methods of fault protection are given as:

- Earthed equipotential bonding and automatic disconnection of supply (most common) use of class II equipment
- Non conducting location
- Earth-free local equipotential bonding
- Electrical separation

**v. Protective devices:** This is a device used to protect equipment, machinery, components and devices, in electrical and electronic circuit, against short circuit, over current and earth fault

**vi. Checks on documentation:** Diagrams, schedules, charts, instructions and any other information must be available if inspection and testing is to be carried out in a satisfactory manner.

- vii. Checks on warning notices:** These should be fixed to equipment operating in excess of 250 volts where this voltage would not normally be expected.

#### **7.2.1.4 Learning activities**

Your installation trainer takes your class to the nearby construction site. As a level 5 trainee in electrical installation perform the following;

- i) Visual inspection of the electrical installations
- ii) Identify fitting points and identify the equipment
  - Check that joints and connections are properly secured and that there is no sign of overheating.
  - Check switches for satisfactory electrical and mechanical conditions.
  - Check that protective devices are of the correct rating and type; check for accessibility and damage.
  - Check that conductors have suffered no mechanical damage and have no signs of overheating.
  - Check that the condition of enclosures remains satisfactory for the type of protection required.

#### **iii) Verification of all fittings for safety appropriateness**

The verification should include a check on the condition of all electrical equipment and materials, taking into account any available manufacturer's information with regard to the following:

- Safety
- Damage
- Age
- Wear tear
- Excessive loading
- External influences
- Corrosion
- Suitability

#### **7.2.1.5 Self-Assessment**

- i. What is the purpose of initial verification?
- ii. How do you inspect electrical wires?

- iii. What is the difference between initial verification and periodic inspection?
- iv. What does an electrical inspector do?
- v. Why is an inspection required periodically?

#### **7.2.1.6 Tools, Equipment used in installation testing**

- Multimeter/AVO meter
- Wattmeter
- Insulation resistance tester
- Loop impedance tester
- Earth resistance tester
- Clamp meter
- Power quality analyser
- Infrared camera
- Phase sequence meter
- Frequency meter
- Synchroscope
- Tachometer
- Tacho generator
- Laser meter
- Lux meter

#### **7.2.1.7 References**

1. Noel Williams, Jeffrey S. Sargent, 2014, Electrical Inspection Manual, 2014 Edition, Jones & Bartlett Learning, 2014
2. Hari Mohan Johri, 2010, Electrical Installations in Building (Inglés) Tapa blanda, edition 2010, K W Publishers Pvt Ltd
3. John Blaus, Dave Allan, 2008, Electrical installations NVQ and technical certificate book 2, second edition, Pearson education limited.

#### **7.2.1.8 Model Answers to self-assessment**

- i.** Initial verification is intended to confirm that the installation complies with the designer's requirements and has been constructed, inspected and tested in accordance with BS 7671.
- ii.** Begin your inspection by looking outside the home at the wires coming into the electrical panel. Check that the connection is fastened to the house securely and note any trees that are interfering with the wiring. Visible wiring should appear to be in good condition and covered with insulation, with no metal showing.
- iii.** Periodic Inspection and Testing (sometimes referred to as Periodic Electrical Inspection) is a procedure completed by qualified electricians and is carried out to ensure that the installation is safe and has not deteriorated. Unlike an initial verification, the periodic inspection should not be intrusive.
- iv.** Responsible for inspecting the installation of electrical systems and equipment to detect faulty wiring and ensure they comply with electrical codes and standards. Visits construction sites and residences, performs inspection, and makes recommendations for improvement.
- v.** Businesses must have a periodic inspection undertaken each year to ensure that no electrical systems have deteriorated or become dangerous to work around. With age and use, electrical installations should be carefully inspected to verify compliance for further use.

## **7.2.2 Learning Outcome 2: Identify the test to be carried out and test equipment**

### **7.2.2.1 Introduction to the learning outcome**

Testing is the process of evaluating a system or its component(s) with the intent to find whether it satisfies the specified requirements or not. In simple words, testing is executing a system in order to identify any gaps, errors, or missing requirements in contrary to the actual requirements.

### **7.2.2.2 Performance standards**

- 7.2.2.2.1 The installation to be tested is identified
- 7.2.2.2.2 Test points are identified
- 7.2.2.2.3 Relevant standards for testing are applied

### **7.2.2.3 Information sheet**

#### **Identification of installation to be tested**

##### **i) Domestic**

Unless domestic premises are extremely large, it is unlikely that a three-phase supply would be needed, and consequently only single-phase systems will be considered here.

The requirement is that circuits which need to be separately controlled, for example lighting and power, remain energized in the event of the failure of any other circuit of the installation. Hence, an earth fault on, say, a socket-outlet circuit would cause the whole of the installation to be cut off if protected by one 30 mA RCD.

##### **ii) Industrial**

Industrial installation means an installation intended for use in the manufacture or processing of products involving systematic labor or habitual employment and includes installations in which agricultural or other products are habitually or customarily processed or stored for others, either by buying or reselling on.

##### **iii) Commercial**

Commercial installation means an installation intended for commerce but does not include a residential installation.



Commercial buildings are buildings that are used for commercial purposes, and include office buildings, warehouses, and retail buildings (e.g. convenience stores, 'big box' stores, and shopping malls).

#### iv) **Agriculture/ horticulture**

These are adverse installation conditions which are encountered on agricultural and horticultural installations. They are adverse because of the presence of livestock, vermin, dampness, corrosive substances and mechanical damage.

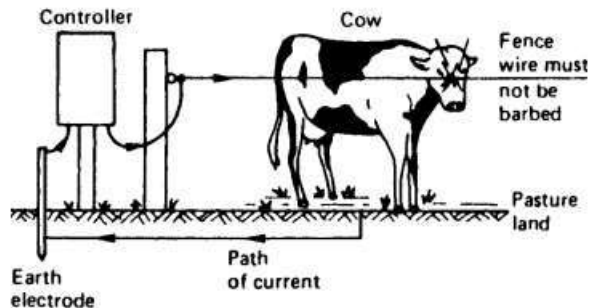


Figure 307: Farm animal control by electric fence.

### **Identification of types of tests**

#### **Polarity tests**

Electrical polarity (positive and negative) is the direction of current flow in an electrical circuit. In the context of electricity installations, a polarity test is used to confirm the correct connection of the line and neutral conductors

#### **Effectiveness of earthing**

Generally, provision of effective earthing system depends on aim and goal involved, and the environment where the earthing or grounding as the case may be, is actually required. For instance, in Power Engineering, providing adequate Earthing in a substation is an important essential safety measure. The aim and goal is to provide under and around the substation, a surface of uniform potential, at near or absolute zero earth potential.

In some cases, earthing or Grounding terminology is commonly used to mean the same thing. However, the two technical terminologies have distinction. Earthing is the connection of non-current carrying parts to ground. Example: All metallic enclosure. This is for human safety.

While, Grounding is the connection of current carrying parts to the ground. Example: Generator or transformer neutral. This is for equipment safety.

Substation Earthing is also crucial and essential for effectiveness of protection and control devices, apparatus and equipment, in its efficient operations and performances. Consequently, a proper and appropriate "Earthing System grid design and design calculation" have to be embarked upon, grid mesh has to be formed, The conductor length required for gradient control has to be determined, numbers of grounding rods have to be determined, Fault Megavolt amperes ( MVA) as to be calculated, soil resistivity has to be measured, grounding fault current has to be calculated etc.; All the needed parameters and data are to be got through the various equations and applied properly, because there is no room for speculation, gambling or/and trial and error approach.

- **Insulation resistance (IR) test**

An insulation resistance (IR) test measures the total resistance between any two points separated by electrical insulation. The test, therefore, determines how effective the dielectric (insulation) is in resisting the flow of electrical current. Such tests are useful for checking the quality of insulation, not only when a product is first manufactured but also over time as the product is used.

Performing such tests at regular time intervals can detect impending insulation failures before they occur and prevent user accidents or costly product repairs.

- **Ring circuit continuity**

The ring final circuit, feeding 13 A sockets, is extremely widely used, both in domestic and in commercial or industrial situations. It is very important that each of the three rings associated with each circuit (phase, neutral and protective conductors) should be continuous and not broken. If this happens, current will not be properly shared by the circuit conductors.

- **Identification of test equipment**

The testing equipment are identified according to their applications.

### **Classification of testing equipment**

Testing Instruments are used to create signals and capture responses from electrical circuits under tests. In this way, the proper operation of the DUT can be proven or faults in the device can be traced. Use of test equipment is essential to any serious work on electrical systems.

The following items are used for basic measurement of voltages, currents, and components in the circuit under test.

- voltmeter (Measures voltage)
- Ohmmeter (Measures resistance)
- Ammeter, e.g. Galvanometer or Milliammeter (Measures current)
- Multimeter e.g., VOM (Volt-Ohm-Milliammeter) or DMM (Digital Multimeter) (Measures all of the above)
- LCR meter - inductance (L), capacitance (C) and resistance (R) meter (measure LCR values)
- **Specification of test equipment**

Manufacturer specifications are an important element of cost and quality control for testing, calibration and other measurement processes. They are used in the selection of measuring and test equipment (MTE) and the establishment of equivalent equipment substitutions for a given measurement application.

#### **7.2.2.4 Learning activities**

As a lead electrician in a construction site carry out the following tests on the electrical installations done by your employees.

1. Polarity test. Under this test make sure that;
  - i. polarity is correct at the intake position and the consumer unit or distribution board
  - ii. single pole switches or control devices are connected in the line conductor only
  - iii. socket outlets and other accessories are connected correctly
  - iv. centre contact bayonet and Edison screw type lamp holders have their outer or screwed contact connected to the neutral conductor
  - v. all multi-pole devices are correctly installed.
2. Carry out Earth-fault loop impedance tests at:
  - i. the origin of each installation and at each distribution board
  - ii. all socket outlets

- iii. At the furthest point of each radial circuit.
- iv. Results obtained should be compared with the values obtained by your employees during previous tests, and where an increase or decrease in values has occurred these must be investigated.

#### **7.2.2.5 Self-assessment**

- iii) Why polarity test is performed?
- iv) What is polarity in electricity testing?
- v) Is polarity a dead Test?
- vi) What is the objective of earthing?
- vii) How do you use insulation tester?

#### **7.2.2.6 Tools, Equipment, used in installation testing**

- Multimeter/AVO meter
- Wattmeter
- Insulation resistance tester
- Loop impedance tester
- Earth resistance tester
- Clamp meter
- Power quality analyser
- Infrared camera
- Phase sequence meter
- Frequency meter
- Synchroscope
- Tachometer
- Tacho generator
- Laser meter
- Lux meter

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### 7.2.2.7 References

Noel Williams, Jeffrey S. Sargent, 2014, Electrical Inspection Manual, 2014 Edition, Jones & Bartlett Learning, 2014

Hari Mohan Johri, 2010, Electrical Installations in Building (Inglés) Tapa blanda, edition 2010, K W Publishers Pvt Ltd

John Blaus, Dave Allan, 2008, Electrical installations NVQ and technical certificate book 2, second edition, Pearson education limited.

### 7.2.2.8 Model Answers to self-assessment

- i. The importance of the polarity test is to make sure that all single-pole devices like switches, circuit breakers, and fuses are allied only in the phase conductor.
- ii. Polarity in electrical terms refers to the positive or negative conductors within a dc circuit, or to the Line and Neutral conductor within an ac circuit. ... In the context of electricity installations, a polarity test is used to confirm the correct connection of the line and neutral conductors.
- iii. There are three checks of polarity during testing – dead and live testing and visual inspection and while they all confirm correct/incorrect polarity they do not necessarily check for the same thing. ... Unless you test for polarity you will never know and neither will the person operating the load.
- iv. Earthing System or Grounding System in an electrical network work as a safety measure to protect human life as well as equipment, the main objective of the Earthing system is to provide an alternative path for dangerous currents to flow so that accidents due to electric shock and damage to the equipment can be avoided.
- v. If you are testing insulation resistance to ground, place the positive probe on the ground wire or the grounded metal junction box and the negative probe on the conductor or terminal. Energize the Megger for 1 minute. Read the value of the resistance at the end of the minute test and note it in your table.

## 7.2.3 Learning Outcome 3: Prepare test equipment

### 7.2.3.1 Introduction to the learning outcome

A Calibration of measuring tools and equipment is necessary to ensure that the tools and equipment used to measure and indicate accurate readings. Preparation of testing equipment involves comparison between a known measurement (the standard) and the measurement using your instrument. Typically, the accuracy of the standard should be ten times the accuracy of the measuring device being tested.

### **7.2.3.2 Performance Standard**

7.2.3.2.1 Appropriate Test equipment are identified

7.2.3.2.2 Test equipment are checked for appropriate specifications and functionality

7.2.3.2.3 Test equipment are prepared and stored for safe and easy access in accordance with established procedure

### **7.2.3.3 Information Sheet**

- **Identification of appropriate test equipment**

Regardless of whether you are performing electrical installation work, equipment maintenance, verifying the absence of voltage for de-energized work, troubleshooting, voltage measurements or similar diagnostic work, collecting accurate and consistent information from these tests is imperative. To comply with electrical industry standards and regulations, there is a need to select and use the right test instruments according to the application.

When conducting voltage verification, for energized and de-energized work, the electrical worker must select the right test instruments and equipment applicable to the work to be performed. As a minimum, these should include the following:

- Voltage indicating instrument suitable for conditions
- Environment
- Correct CAT category I, II, III, or IV
- Continuity test instrument
- Insulation resistance test instrument.

Checking of test equipments for appropriate specifications and functionality

All test instruments include specific manufacturer's operational instructions.

Electrical testing in its most basic form is the act of applying a voltage or current to a circuit and comparing the measured value to an expected result. Electrical test equipment verifies the math behind a circuit and each piece of test equipment is designed for a specific application.

It is the job of a test technician to know which piece of test equipment to use for the task at hand and also understand the limitations of the test equipment they are using.

Electrical test equipment should be considered a source of lethal electrical energy.

Technicians must observe all safety warnings and follow all practical safety precautions to prevent contact with energized parts of the equipment and related circuits, including the use of appropriate Personal Protective Equipment.

➤ **Storage of test equipments for safety and easy access in accordance with established procedure**

One key to ensuring that measuring instruments, maintain a high level of reliability and accuracy is by taking proper care of them. Below is what you should know about the care and maintenance of these special precision tools.

- Lubricate instruments appropriately to prevent corrosion
- Proper lubrication of measuring instruments will prevent damage due to corrosion and oxidation. Precision measuring instruments should be lightly oiled after each use, and any excess oil should be removed from metal surfaces with a clean, dry cloth. A visibly "wet" instrument can attract and hold minute particles that can cause internal wear of precisely fabricated parts, especially those that move against one another.
- **Store instruments in an appropriate environment**

Whenever you place an instrument in its storage location, be sure the location is well-protected from destructive elements. Do not store precision instruments where they can jostle against one another in a drawer; instead, separate instruments from one another using dividers or place them in padded cases. Avoid stacking instruments on top of each other, unless they are well-protected in cases.

- **Know how to properly handle instruments during use**

Once you have a precise measuring instrument in your hand, it becomes that much more important to protect that tool from harm or providing false readings. There are a few things you should do that will help prevent damage or miscalibration during use, including avoiding sudden shocks or rough treatment. Do not drop, throw, or bang measuring instruments against hard surfaces.

- **Obtain professional recalibration assistance**

Some measuring instruments require occasional recalibration to ensure they continue to function as designed, and that is why it is important to have a professional relationship with a precision instrument manufacturer or supplier. They can keep your instruments in top-notch condition so they'll provide years of reliable service.

### **7.2.3.4 Learning activities**

#### **Identification of appropriate test equipment**

A class has been requested by the installation trainer to use different electrical measuring instruments in testing of an electrical installation. As a level five installation student help in

- i. Identification of appropriate test equipment according to the task.
- ii. Checking of test equipments for appropriate specifications and functionality.
- iii. Prepare and stored for safe and easy access.

### **7.2.3.5 Self-assessment**

- i) Can you do a continuity test on a live circuit?
- ii) How do you test electrical continuity?
- iii) What is a bad continuity reading?
- iv) What does a reading of 0 ohms mean?
- v) How do you check continuity on a long wire?

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### **7.2.3.6 Tools, Equipment, used in installation testing**

- Multimeter/AVO meter
- Wattmeter
- Insulation resistance tester
- Loop impedance tester
- Earth resistance tester
- Clamp meter
- Power quality analyser
- Infrared camera
- Phase sequence meter
- Frequency meter
- Synchroscope



- Tachometer
- Tacho generator
- Laser meter
- Lux meter

#### **7.2.3.7 References**

Noel Williams, Jeffrey S. Sargent, 2014, Electrical Inspection Manual, 2014 Edition, Jones & Bartlett Learning, 2014

Hari Mohan Johri, 2010, Electrical Installations in Building (Inglés) Tapa blanda, edition 2010, K W Publishers Pvt Ltd

John Blaus, Dave Allan, 2008, Electrical installations NVQ and technical certificate book 2, second edition, Pearson education limited

#### **7.2.3.8 Model Answer to self-assessment**

- You can measure the voltage and the current of a live circuit and use those figures to calculate the resistance (Ohm's Law), but you can't actually measure the resistance of a live circuit.
- A continuity test is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit is "open".
- If you have a reading higher than 10 ohms, you have poor continuity. The resistance is higher than it should be and you need to replace the wire, fuse, outlet, battery, or device. ... If the reading is higher than 10, then your device, wire, appliance, or fuse will overheat.
- A measurement of Zero, or very close to zero (less than 0.5 ohms) indicates a very low resistance to current flow. Applying voltage to this low level of resistance will result in extremely high current flow.
- To check continuity on a run of wiring, disconnect both ends of the wire. Set your multimeter to check continuity with a tone. Put one meter lead on one end of the wire and the other meter lead on the opposite end of the wire. The meter signals a tone and shows near zero ohms of resistance if the wire has continuity.

## 7.2.4 Learning Outcome 4: Perform the test

### 7.2.4.1 Introduction to the learning outcome

This outcome presents the arguments and the proposal of tests and measurements of electrical installations for buildings. The entire article applies to both large and small electrical installations with uninterruptible power supply(UPS) systems and power generators.

### 7.2.4.2 Performance Standard

- 7.2.4.2.1 Test parameters are identified
- 7.2.4.2.2 Test equipment are assembled
- 7.2.4.2.3 Test sequence procedure is decided based on the test standards
- 7.2.4.2.4 Safety precautions are adhered to
- 7.2.4.2.5 Additional precaution is observed on the installation in hazardous environment as per EHS standard
- 7.2.4.2.6 Tests are carried out in line with the IEE regulations
- 7.2.4.2.7 Functionality of all devices including protective devices is checked as per the set standards
- 7.2.4.2.8 Test results are recorded as per agreed format.

### 7.2.4.3 Information Sheet

#### Reading and interpretation of appropriate manuals

**Manual** - It is a document that shows how equipment, tool or a machine is done, operated, worked, etc., by the hand or hands rather than by an electrical or electronic device.

#### Reasons to read owner's manual

The operator's manual explains safety guidelines when operating specific pieces of equipment. Number two, how to operate the equipment, its safety features and controls. Some manufactures refer to this as “Familiarization Training”.

#### Maintenance Schedule

Maintaining your equipment and tool is important. Educate yourself on what services your equipment and tool needs and when they are recommended. Many manuals include helpful logs to record your service history and repair information.

#### Identification of testing equipment

Continuity tester (ohmmeter)

To measure accurately the resistance of the conductors in an electrical installation we must use an instrument which is capable of producing an open circuit voltage of between 4 and 24V AC or DC, and deliver a short-circuit current of not less than 200 mA.

The functions of continuity testing and insulation resistance testing are usually combined in one test instrument.



Figure 308: Fluke T2 Voltage and Continuity Tester

Insulation resistance tester

Insulation resistance should have a high value and therefore insulation resistance meters must have the ability to measure high resistance readings. The test voltage required for measuring insulation resistance is given in BS 7671 Table 61, as shown in Table 4 below.

| Circuit nominal voltage (volts)                           | Test voltage d.c. (volts) | Minimum insulation resistance (megohms) |
|---|---------------------------|---|
| SELV and PELV   | 250                       | $\geq 0.5$                              |
| Up to and including 500 V with the exception of the above | 500                       | $\geq 1.0$                              |
| Above 500 V   | 1000                      | $\geq 1.0$                              |

*Table 25 Test voltage required for measuring insulation resistance (from BS 7671)*

The figure 3 hows a typical modern insulation and continuity tester that will measure both low values of resistance, for use when carrying out continuity and polarity tests, and also high values of resistance when used for insulation resistance tests.



*Figure 309 Modern insulation and continuity tester*

### **Earth loop impedance tester**

Earth-loop impedance testers of the type shown in the figure 5 below they have the capability to measure both earth-loop impedance and also prospective short-circuit current, depending on which function is selected on the range selection switch. The instrument also has a series of LED warning lights to indicate whether the polarity of the circuit under test is correct. The instrument gives a direct digital read-out of the value of the measurement being taken at an accuracy of plus or minus 2 per cent.



*Figure 310 Earth-loop impedance tester*

## Test lamp

A test light, also known as a test lamp, or voltage tester, or mains tester is a piece of electronic test equipment used to determine the presence of electricity in a piece of equipment under test. A test light is simpler and less costly than a measuring instrument such as a multimeter, and often suffices for checking for the presence of voltage on a conductor. Properly designed test lights include features to protect the user from accidental electric shock. Non-contact test lights can detect voltage on insulated conductors.



*Figure 311 Neon test lamp for line voltage*

## Procedure of conducting identified tests

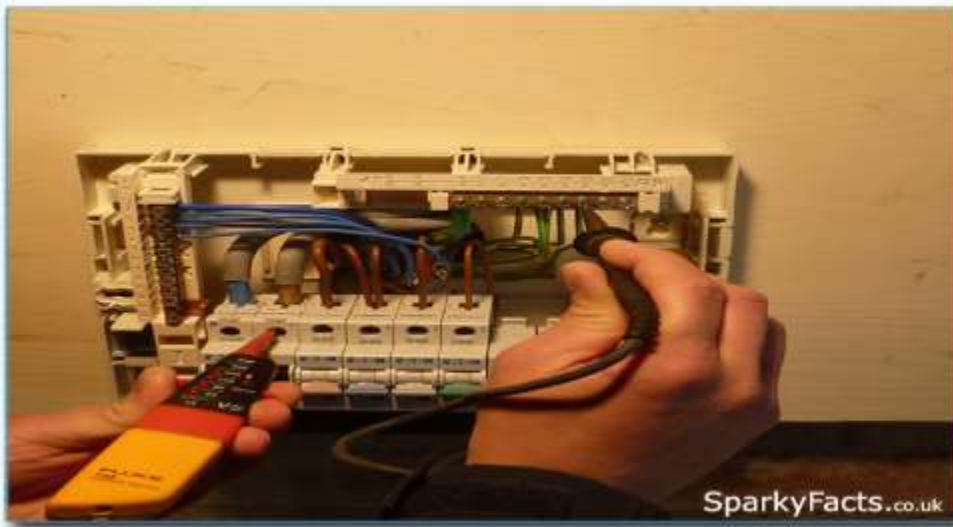
### Polarity test

**Step 1.** Select a GS 38 approved voltage indicator and locate the Main Switch. Test between Line and Neutral terminals.



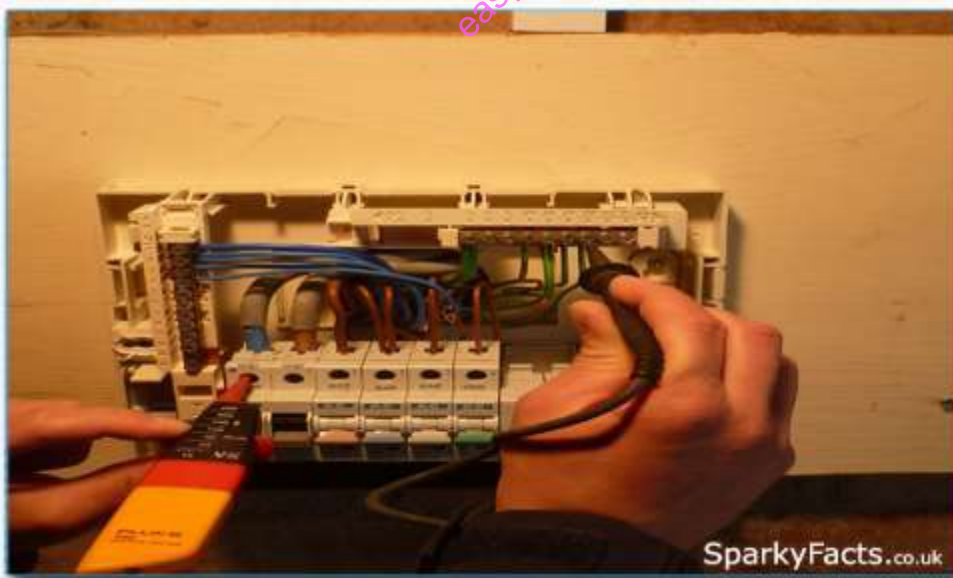
*Figure 312 Test between Line and Neutral terminals*

**Step 2.** Test between Line and Earth terminals.



*Figure 313 Test between Line and Earth terminals*

**Step 3.** Test between Neutral and Earth terminals.



*Figure 314 Test between Neutral and Earth terminals*

The test instrument should indicate full voltage (230V) between Line-Neutral and Line-Earth conductors. No voltage should be detected between Neutral-Earth.

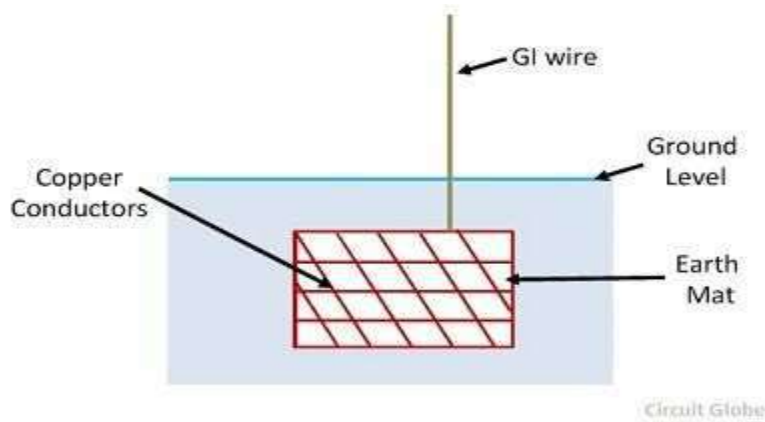
## Methods of Earthing

There are several methods of earthing like wire or strip earthing, rod earthing, pipe earthing, plate earthing or earthing through water mains. Most commonly used methods of earthing are pipe earthing and plate earthing. These methods are explained below in details.

### Earthing Mat

Earthing mat is made by joining the number of rods through copper conductors. It reduced the overall grounding resistance. Such type of system helps in limiting the ground potential. Earthing mat is mostly used in a placed where the large fault current is to be experienced. While designing an earth mat, the following step is taken into consideration.

- i. In a fault condition, the voltage between the ground and the ground surface should not be dangerous to a person who may touch the non current-carrying conducting surface of the electrical system.
- ii. The uninterrupted fault current that may flow into the earthing mat should be large enough to operate the protective relay. The resistance of the ground is low to allow the fault current to flow through it. The resistance of the mat should not be of such a magnitude as to permit the flow of fatal current in the live body.
- iii. The design of grounding mat should be such that the step voltage should be less than the permissible value which would depend on the resistivity of the soil and fault required for isolating the faulty plant from the live system.



*Figure 315 Earthing mat*

## Earthing electrode

In this type of earthing any wire, rod, pipe, plate or a bundle of conductors, inserted in the ground horizontally or vertically. In distributing systems, the earth electrode may consist of a rod, about 1 meter in length and driven vertically into the ground. In generating substations, grounding mat is used rather than individual rods.

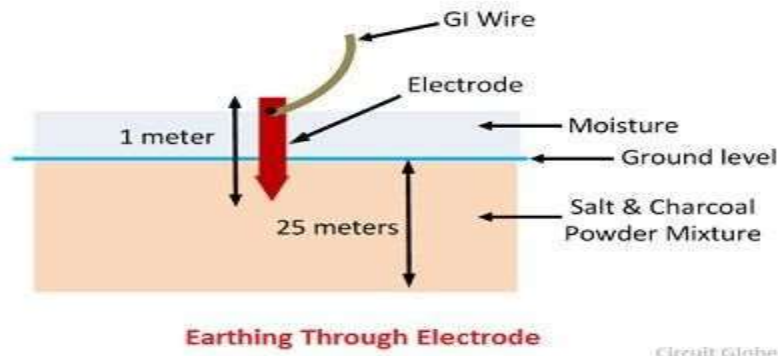


Figure 316 Earthing electrode

## Pipe Earthing

This is the most common and best system of earthing as compared to other systems suitable for the same earth and moisture conditions. In this method the galvanized steel and perforated pipe of approved length and diameter is placed upright in a permanently wet soil, as shown below. The size of the pipe depends upon the current to be carried and type of soil.

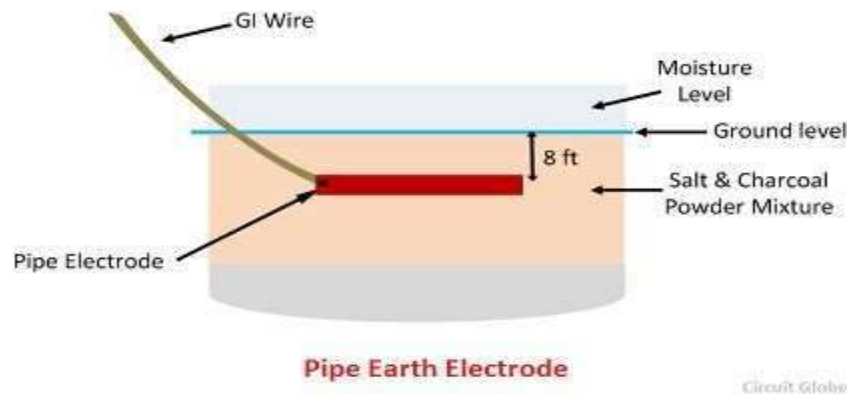


Figure 317 Pipe earthing electrode



Normally, the size of the pipe used for earthing is of diameter 40 mm and 2.5 meters in length for ordinary soil or of greater length in case of dry and rocky soil. The depth at which the pipe must be buried depends on the moisture of the ground.

The pipe is placed at 3.75 meters. The bottom of the pipe is surrounded by small pieces of coke or charcoal at a distance of about 15 cm. Alternate layers of coke and salt are used to increase the effective area of the earth and to decrease the earth resistance respectively.

Another pipe of 19 mm diameter and minimum length 1.25 meters is connected at the top of GI pipe through reducing socket.

During summer the moisture in the soil decreases, which causes an increase in earth resistance. So a cement concrete work is done to keep the water arrangement accessible, and in summer to have an effective earth, 3 or 4 buckets of water are put through the funnel connected to 19 mm diameter pipe, which is further connected to GI pipe.

The earth wire either GI or a strip of GI wire of sufficient cross section to carry faulty current safely is carried in a GI pipe of diameter 12 mm at a depth of about 60cm from the ground.

### Plate Earthing

In Plate Earthing an earthing plate either of copper of dimension 60cm×60cm×3mm or of galvanized iron of dimensions 60 cm×60 cm×6 mm is buried into the ground with its face vertical at a depth of not less than 3 meters from ground level.

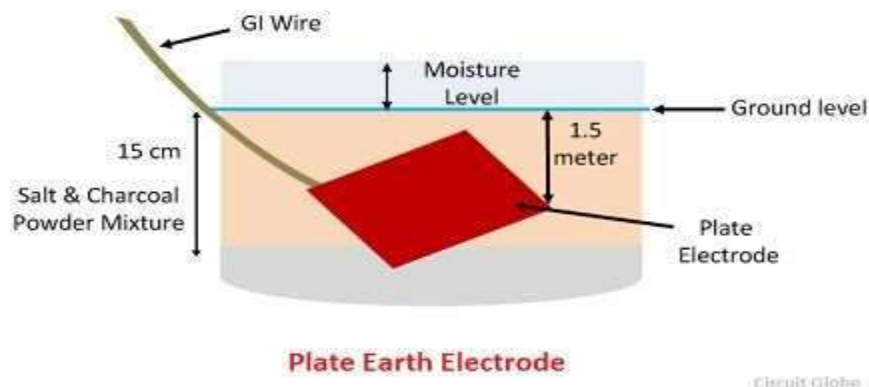


Figure 318 Plate earth electrode

The earth plate is inserted into auxiliary layers of coke and salt for a minimum thickness of 15 cm. The earth wire (GI or copper wire) is tightly bolted to an earth plate with the help of nut or bolt. The copper plate and copper wire are usually not employed for grounding purposes because of their higher cost.

## Earthing Through Water Mains

In this type of earthing the GI or copper wire are connected to the water mains with the help of the steel binding wire which is fixed on copper lead as shown below.

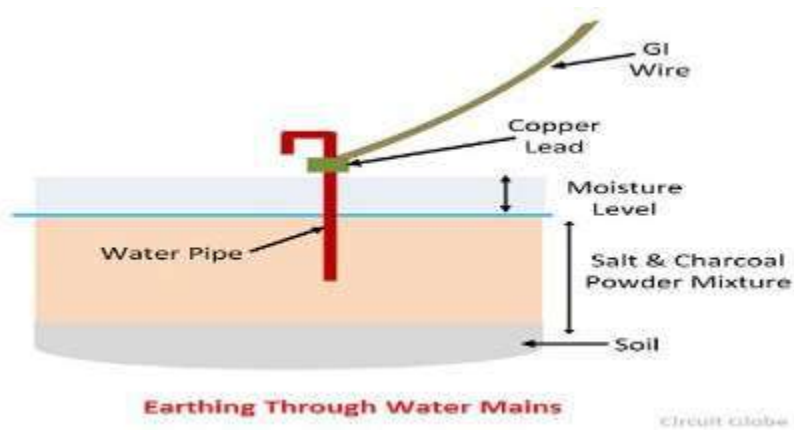


Figure 319 Earthing through water mains

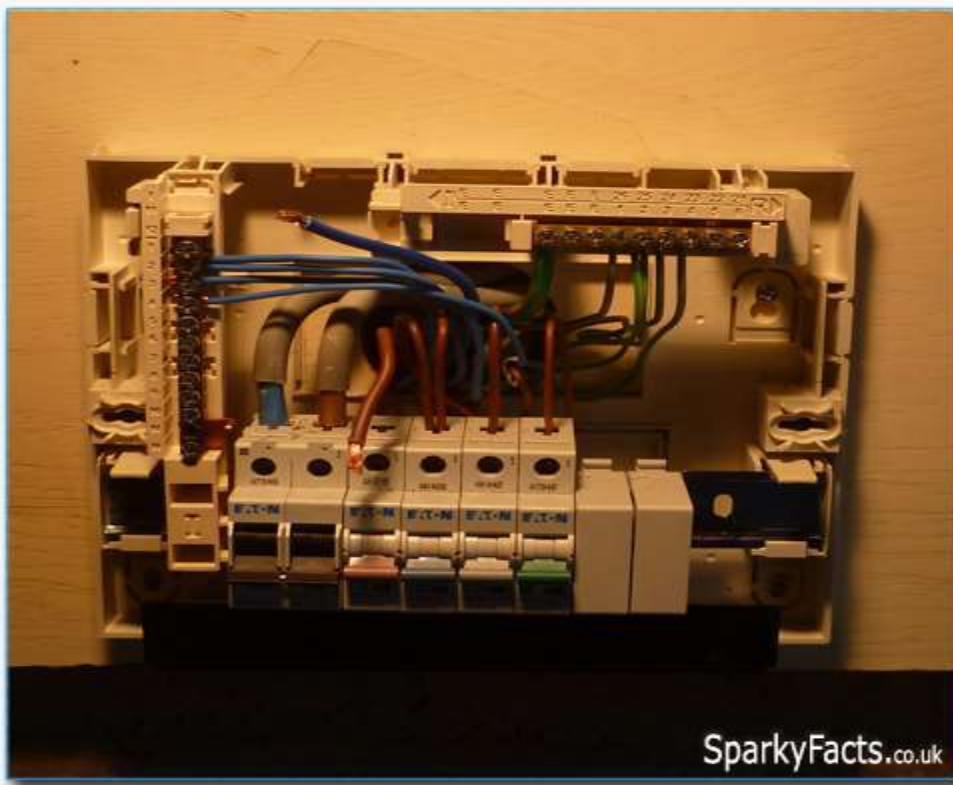
The water pipe is made up of metal, and it is placed below the surface of the ground, i.e. directly connected to earth. The fault current flow through the GI or copper wire is directly get earthed through the water pipe.

### ➤ The Insulation Resistance test sequence

To perform the tests needed, you will need an Insulation Resistance Tester or a multifunctional tester such as the Megger 1553.

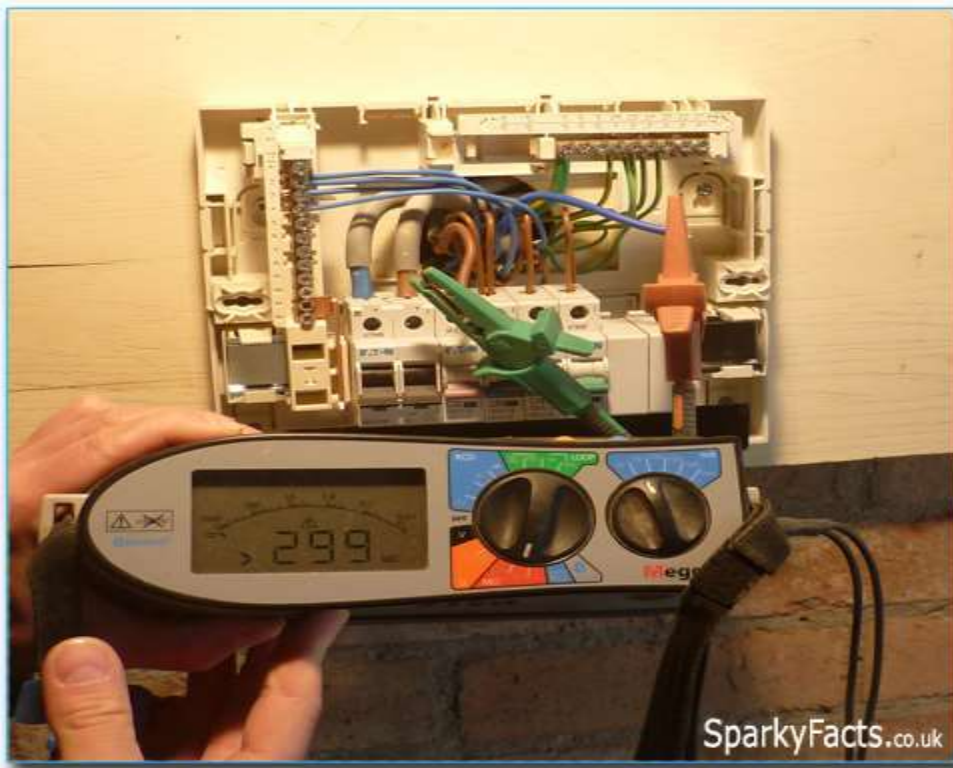
**NB.** Before everything, a safe isolation procedure must be carried out.

**Step 1.** Select the required circuit and disconnect its live conductors from the distribution board (the earth conductor can stay)



*Figure 320 Insulation Resistance test sequence*

**Step 2.** Connect one of the test leads of the Insulation Tester to the Line conductor and the other one to the Neutral conductor. Set the tester to the required voltage and press and hold the TEST button – the tester will display a value in Ohm`s or if it is out of its range than something like this:  $>299 \text{ M}\Omega$



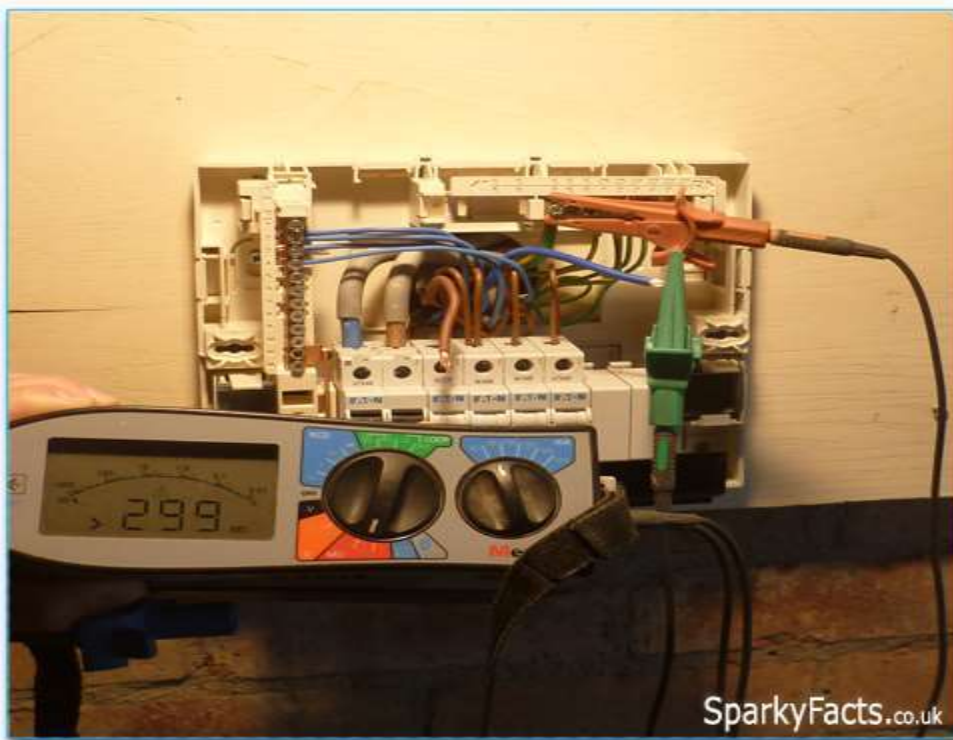
*Figure 321 Insulation Resistance test sequence*

**Step 3.** Repeat the test process with one of the test leads on the Line conductor and the other one on the Earth conductor



*Figure 322 Insulation Resistance test sequence*

**Step 4.** Repeat the test process with one of the test leads on the Neutral conductor and the other one on the Earth conductor.



*Figure 323 Insulation Resistance test sequence*

**Step 5.** That is it - compare all test results to the minimum allowed value in BS7671 (1M $\Omega$  for a 230V a.c. circuit). If any of the values are lower, than further investigation is needed.

Test every circuit within the distribution board one by one, and record the test results on the Schedule of Test Results.

*NB. You can perform this test on a whole range of circuits in a single process. You can test between all of the Line conductors and all of the Earth conductors within the distribution board. After this step, between all of the Neutral conductors and all of the Earth conductors. The only down side is that if there is a low insulation resistance reading then you will have to test the circuits one by one to find out which one has the fault on it. However, most of the time, you can save valuable time by insulation testing the entire board this way.*

### ➤ **Ring circuit continuity**

Provided the test results are recorded methodically the test can be used to confirm:

- The ring is continuous
- There are no interconnections (rings within the ring)
- The value of  $R_1+R_2$

The sockets are correctly connected (provided the readings in steps 2 and 3 below have been made using a test lead with a plug plugged into the socket)

The test will also reveal various types of fault. The test must be carried out at initial verification. IEE Guidance Note 3 suggests that;

It need not always be carried out on a periodic inspection if there are adequate records from previous inspections and the ring has not been modified.

#### **Method**

A low resistance ohmmeter is required.

#### **Step 1**

Measure and record the end to end resistance of each conductor in the ring:

R11 line conductor resistance

Rnn neutral conductor resistance

R22 circuit protective conductor resistance

#### **Step 2**

Connect the neutral conductor of one end of the ring to the line conductor of the other end of the ring. Connect the remaining line conductor to the remaining neutral.

Measure and record the resistance between line and neutral at each socket on the ring (including any spurs). This is most conveniently done with a test lead which connects the ohmmeter directly into the socket with a plug. (Some makers supply such a lead.) This

also has the benefit that successful test results in Step 2 and Step 3 will confirm that the socket has been correctly wired and the polarity is correct.

*NB If testing through the front of the socket with a suitable lead an infinite reading will be obtained unless the switch is on.*

The result expected at each socket should be equal to one quarter of the sum of R11 and Rnn (as measured in Step 1).

The readings at any spurs will be a little higher.

### **Step3**

Connect the circuit protective conductor of one end of the ring to the line conductor of the other end of the ring. Connect the remaining line conductor to the remaining circuit protective conductor.

Measure and record the resistance between line and circuit protective conductor(CPC) at each socket on the ring (including any spurs). As before, this is most conveniently done with a test lead which connects the ohmmeter directly into the socket with a plug.

The result expected at each socket should be equal to one quarter of the sum of R11 and R22 (as measured in Step 1).

As before, the readings at any spurs will be a little higher.

### **Analysis of Ring Continuity Results**

The following end-to-end readings were obtained when a ring was tested:

$$R11 = 0.6\Omega$$

$$Rnn = 0.6\Omega$$

$$R22 = 1.0$$

R11 and Rnn should be the same as the cross sectional areas of neutral and line conductors should be the same in a single phase circuit. So the results look OK.

R22 may be higher than R11 or Rnn as it is common to use a CPC of smaller CSA. In twin and earth cables used in standard ring circuits, line and neutral are 2.5 mm<sup>2</sup> and the CPC is 1.5 mm<sup>2</sup>. Here we should check that the CSA of the CPC is indeed smaller than the CSA of line and neutral.

The reading expected in Step 2 is:

$$(R_{11} + R_{nn}) / 4$$

$$(0.6 + 0.6) / 4$$

$$0.3 \Omega$$

The reading expected in Step 3 is:

$$(R_{11} + R_{22}) / 4$$

$$(0.6 + 1.0) / 4$$

$$0.40 \Omega$$

The actual readings obtained in Steps 2 and 3 were recorded in the table below:

| Socket number | Step 2 reading ( $\Omega$ ) | Step 3 reading ( $\Omega$ ) |
|---------------|-----------------------------|-----------------------------|
| 1             | 0.31                        | 0.41                        |
| 2             | 0.3                         | 0.4                         |
| 3             | 0.32                        | 0.41                        |

*Table 26 actual readings obtained*

The readings above are very close to the expected values so this ring is OK

➤ **Recording and verification of results against appropriate standards**

Using instrument performance specifications plus established in-house, national, and/or international standards for data collection, quality control, and product output, protocols can



be developed to allow for testing an instrument to verify that it meets performance expectations. Calibration of measuring instruments should be done regularly.

➤ **Rectification of any anomalies**

Ways to reduce random errors

- i. Taking repeated measurements to obtain an average value.
- ii. Plotting a graph to establish a pattern and obtaining the line or curve of best fit. In this way, the discrepancies or errors are reduced.

➤ **Safety precautions to be observed**

It's vitally important to take safety precautions when working with electricity. Safety must not be compromised and some ground rules need to be followed first. The basic guidelines regarding the safe handling of electricity documented below will help you while working with electricity.

1. Avoid water at all times when working with electricity. Never touch or try repairing any electrical equipment or circuits with wet hands. It increases the conductivity of the electric current.

2. Never use equipment with frayed cords, damaged insulation or broken plugs.

3. If you are working on any receptacle at your home then always turn off the mains. It is also a good idea to put up a sign on the service panel so that nobody turns the main switch ON by accident.

4. Always use insulated tools while working.

5. Electrical hazards include exposed energized parts and unguarded electrical equipment which may become energized unexpectedly. Such equipment always carries warning signs like "Shock Risk". Always be observant of such signs and follow the safety rules established by the electrical code followed by the country you're in.

6. Always use appropriate insulated rubber gloves and goggles while working on any branch circuit or any other electrical circuit.

7. Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire. Check all the wires, the outer metallic covering of the service panel and any other hanging wires with an electrical tester before proceeding with your work.

8. Never use an aluminum or steel ladder if you are working on any receptacle at height in your home. An electrical surge will ground you and the whole electric current will pass through your body. Use a bamboo, wooden or a fiberglass ladder instead.

9. Know the wire code of your country.

10. Always check all your GFCI's once a month. A GFCI (Ground Fault Circuit Interrupter) is a RCD (Residual Current Device). They have become very common in modern homes, especially damp areas like the bathroom and kitchen, as they help avoid electrical shock hazards. It is designed to disconnect quickly enough to avoid any injury caused by over current or short circuit faults.

#### **7.2.4.4 Learning Activities**

KENM is a fashion industry in Taita Taveta county. An electrical shock occurs in one of its production lines. As the industry lead installation technician lead your team in carrying out the following tests to identify the root cause of the problem

- Continuity test
- Insulation resistance tester
- Earth loop impedance
- Polarity test

#### **7.2.4.5 Self-assessment**

- i) How is continuity test performed?
- ii) How is measurement of earth resistance carried out using earth tester?
- iii) Show how does a Ring circuit work?
- iv) What is a Megger test?
- v) Using an equation explain how do you calculate loop impedance?

#### **7.2.4.6 Tools, Equipment, used in installation testing**

- Multimeter/AVO meter
- Wattmeter
- Insulation resistance tester
- Loop impedance tester
- Earth resistance tester
- Clamp meter
- Power quality analyser
- Infrared camera
- Phase sequence meter
- Frequency meter
- Synchroscope
- Tachometer
- Tacho generator
- Laser meter
- Lux meter

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#### **7.2.4.7 References**

Noel Williams, Jeffrey S. Sargent, 2014, Electrical Inspection Manual, 2014 Edition, Jones & Bartlett Learning, 2014

Hari Mohan Johri, 2010, Electrical Installations in Building (Inglés) Tapa blanda, edition 2010, K W Publishers Pvt Ltd

John Blaus, Dave Allan, 2008, Electrical installations NVQ and technical certificate book 2, second edition, Pearson education limited

#### **7.2.4.8 Answers to the self-assessment**

- i. A continuity test is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit is "open".

- ii. Earth resistivity is usually measured using the Wenner method, which involves the use of four temporary earth spikes. The spikes do not need to be moved as part of the testing procedure however – their location and spacing is determined by the depth at which it is required to determine the earth resistivity.
- iii. The power sockets in a house are connected by means of a ring circuit. In a ring circuit the live, neutral and earth wires form a loop of cable going from the consumer unit to all of the sockets in turn and then back to the consumer unit. The live wire carries current to the house/appliance at a high voltage.
- iv. The Megger test is a method of testing making use of an insulation tester resistance meter that will help to verify the condition of electrical insulation. The IR gives a measure of the enduring power of an insulator to bear the service voltage without any current leakage path.
- v. Therefore, where reliable measured values are available for the external earth loop impedance ( $Z_e$ ) and for the loop resistance of the line and protective conductors ( $R_1 + R_2$ ) of the circuit, it is permissible to derive the loop impedance of a circuit by using the following formula:  $Z_s = Z_e + (R_1 + R_2)$ .

## **7.2.5 Learning Outcome 5: Issue installation test results and wiring completion certificates**

### **7.2.5.1 Introduction to the learning outcome**

An installation certificate is a test certificate produced by an electrician after they have carried out wiring work. It confirms that they have tested the work and it's safe.

The Electrical Installation Certificate is to be used only for the initial certification of a new installation or for an alteration or addition to an existing installation where new circuits have been introduced. It is not to be used for a Periodic Inspection for which a Periodic Inspection Report form should be used.

### **7.2.5.2 Performance Standard**

7.2.5.2.1 Test certificate is issued to the relevant parties

7.2.5.2.2 Wiring certificate is issued to the relevant parties

### **7.2.5.3 Information sheet**

Installation test results certificate

- Meaning terms

“**Electrical Installation Certificate**” (EIC) is the declaration of conformity from the installing contractor that the new electrical work described has been installed in accordance with the wiring regulations in force at the time of installation. It includes circuit charts and records test results taken prior to commissioning. An EIC cannot be issued by anyone other than the installing contractor and will include a date for re-inspection and testing.

Variants of this certificate include:

- “Minor Works Certificate” for installation works not requiring a new circuit from the distribution board.
- “Domestic Installation Certificate” a reduced EIC tailored specifically for dwellings.

An Electrical Installation Certificate will be issued for all Installation work carried out by contractor.

### **Types of electrical safety certificates.**

There are four types of electrical safety certificates.

- Electrical installation certificate

- Periodical test, inspection & report
- Domestic installation certificate
- Minor works certificate

### **Electrical installation certificate / Domestic installation certificate**

This is issued to the customer on the completion of any electrical installation works. It details the type of works undertaken; any deviations from the regulations as listed in BS 7671, who designed, installed and tested the works and when the next inspection is due.

### **Periodical test, inspection & report**

This is used for the testing of existing electrical installations that have come up for their next inspections or for installations that do not have a current installation certificate. It will detail most if not all of the deviations that need to be addressed and will fall into four categories / codes.

- |         |  |
|---------|--|
| Code 1. | Major deviation from the regulations, immediate remedial works are required and the system is unsafe to remain in service in its present condition.  |
| Code 2. | Minor deviation from the regulations, remedial works are required to the electrical installation, this should be carried out soon and in there, present condition does not provide immediate danger to life or property. |
| Code 3. | Requires further investigation.  |
| Code 4. | Does not comply with BS 7671: as amended (2004)  |

*Table 27 Periodical test, inspection & report*

### **Minor works certificate**

This is used for small works like additional sockets or lights that are not in special locations. A minor works certificate cannot be used for the provision of a new circuit.

### **Issuing authority**

The certificate can be issued by accredited, competent persons, such as a registered electrician.

|   |                                    |                                   |                                   |
|---|------------------------------------|-----------------------------------|-----------------------------------|
| <b>Client details :</b> .....   |                                    |                                   |                                   |
| <b>Address of Installation :</b> .....  |                                    |                                   |                                   |
| <b>Postcode :</b> .....   |                                    |                                   |                                   |
| <b>Description and Extent of Installation :</b> .....   |                                    |                                   | <b>New Installation</b>           |
| <b>Description :</b> .....  |                                    |                                   | <b>Addition</b>                   |
| <b>Extent :</b> .....   |                                    |                                   | <b>Alteration</b>                 |
| <b>For design, Construction and Inspection and Testing</b>  |                                    |                                   |                                   |
| I being the person responsible for the Design, Construction and Inspection and Testing of the Electrical Installation (as indicated by my signature below) and particulars of which are described above, having exercised reasonable skill when carrying out the Design, Construction and Inspection & Test, hereby CERTIFY that the said work for which I have been responsible is to the best of my knowledge and belief in accordance with BS 7671, amended to ..... (date) except for the departures, if any, detailed below. |                                    |                                   |                                   |
| Departures from BS 7671 (if any)  |                                    |                                   |                                   |
| .....   |                                    |                                   |                                   |
| The extent of liability of the signatory is limited to the work described above as the subject of this certificate.   |                                    |                                   |                                   |
| Name : .....  |                                    | Position : .....                  |                                   |
| Signature : .....   |                                    | Date : .....                      |                                   |
| For and on behalf of : .....  |                                    |                                   |                                   |
| Address : .....   |                                    | Tel no. : .....                   |                                   |
| <b>Next inspection</b>  |                                    |                                   |                                   |
| I recommend that this installation is further inspected and tested after an interval of not more than : .....   |                                    |                                   |                                   |
| <b>Supply characteristics and earthing arrangements</b>   |                                    |                                   |                                   |
| Earthing arrangements   | Number and Type of live conductors | Nature of supply                  | Protective device characteristics |
| TN-S  | 1 phase – 2 wire                   | Nominal voltage : .....           | Type : .....                      |
| TN-C-S  | 1 phase – 3 wire                   | Frequency : .....                 | Current rating : .....            |
| TT  | 2 phase – 3 wire                   | Prospective fault current : ..... |                                   |
|   | 3 phase – 4 wire                   | External loop impedance : .....   |                                   |

Figure 324 Electrical installation certificate

- Importance of installation test certificate

Electrical certifications provide vital information about the legal compliance and safety of electrical installations in your home. Securing these certificates from a local authority approved inspector, hired electrician, or third party certifier is important because these documents are typically requested as part of legal procedures when putting your property up for sale. Inability to produce such documents may cause much delay in your legal proceedings.

An electrical installation certificate is to be expected, regardless how small or large the job had been. Ask your electrician for an electrical installation certificate, which confirms that the work that had been carried out meets all standards for electrical safety according to British standard (BS 7671). Every electrical work in all dwellings is covered by building regulations. This means that for any notifiable work, you should always be given a certificate that confirms the compliance of the work with regulations that apply.

### **Wiring certificate**

- Meaning

This is a certificate issued by the Energy and Petroleum Regulatory Authority (EPRA) for qualified electricians.

- Types of certificates issued by EPRA

Class A

Class B

Class C





Requirements before commencing application

**Electricians**

Scanned copies of your: certificates, National ID/Passport and bank payment slip

**Contractors**

Scanned copies of: business registration certificate, PIN Certificate, bank payment slip, Local authority business permit, electrician licence, lease agreement/title deed and a copy of list of tools.

**Application Fees Class:** C-2: 250/=      C-1: 500/=      B: 750/=      A-1 & A-2: 1000/=

**Bank:** Kenya Commercial Bank

**Account Name:** Energy Regulatory Commission

**Account Number:** 1107180198

**Branch:** Moi Avenue

**Application Guideline:**

1. Open ERC Website [www.erc.go.ke](http://www.erc.go.ke)
2. Click on the tab "online services"
3. Click "access our online portal"
4. For new users click on the "register" tab. For existing users login using your user name and password
5. Click "apply for a new licence"
6. For electricians select "individual" for contractors select "business/company"
7. Select the class of licence you wish to apply for.
8. Select the tab that corresponds to your academic qualifications
9. Enter your personal details and press save. Ensure that you enter your correct email address. Create a unique username and password.
10. Open your email, you will find a message from ERC. Open our portal through the link given in your inbox and fill in the rest of the details.
11. Fill in your work experience, academic qualifications, knowledge of rules, and other ERC

*Figure 325 EPRA certificate*

**Issuing authority**

*Energy and Petroleum Regulatory Authority (EPRA)*

#### **7.2.5.4 Learning Activities**

##### **Installation certificate**

As a lead and qualified electrician, prepare an installation certificate for your junior who have completed a new electrical installation.

#### **7.2.5.5 Self-Assessment**

- i) What does an electrical certificate cover?
- ii) What makes you a qualified electrician?
- iii) What kind of degree does electrician need?
- iv) How does one apply for ERC certificate in Kenya?

#### **7.2.5.6 Tools and equipment**

- Multimeter/AVO meter
- Wattmeter
- Insulation resistance tester
- Loop impedance tester
- Earth resistance tester
- Clamp meter
- Power quality analyser
- Infrared camera
- Phase sequence meter
- Frequency meter
- Synchroscope
- Tachometer
- Tacho generator
- Laser meter
- Lux meter

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#### **7.2.5.7 References**

- 1, Noel Williams, Jeffrey S. Sargent, 2014, Electrical Inspection Manual, 2014 Edition, Jones & Bartlett Learning, 2014
- 2, Hari Mohan Johri, 2010, Electrical Installations in Building (Inglés) Tapa blanda, edition 2010, K W Publishers Pvt Ltd
- 3, John Blaus, Dave Allan, 2008, Electrical installations NVQ and technical certificate book 2, second edition, Pearson education limited

### 7.2.5.8 Model Answers to self-assessment

- i. When a Certificate of Electrical Compliance is Required  
The certificate guarantees that the work undertaken in your state complies with both the Electricity Safety Act and the Electricity Safety Regulations.
- ii. You'll need to have an industry recognized level 3 qualification for example a level 3 diploma in electro technical services. Most people get into this career via an apprenticeship. It normally takes two to four years to become fully qualified. GCSEs grade D or above, including Math and English, would be an advantage.
- iii. No college education is required to become an electrician, but significant training takes place through an apprenticeship program, which provides in-class and hands-on instruction. They can be employed in a number of electrical jobs or work freelance, both of which mandate licence.
- iv. Procedure
  - a) Open ERC Website ERC Website.
  - b) Click on the tab “online services”
  - c) Click “access our online portal”
  - d) For new users click on the “register” tab.
  - e) Click “apply for a new license”
  - f) For electricians select “individual” for contractors select “business/company”
  - g) Select the class of license you wish to apply for.

## **CHAPTER 8: ELECTRICAL INSTALLATION MAINTENANCE**

**Unit of learning code** ENG/CU/PO/CR/01/6

**Related Unit of Competency in Occupational Standard:** Maintain electrical installation systems

### **8.1 Introduction to the unit of learning**

This unit covers the competencies required to carry out maintenance in electrical installation systems. The maintenance includes scheduling, inspection of electrical system, preparation of list of tools, material and equipment, system maintenance and tests.

### **8.2 Summary of Learning Outcomes**

1. Prepare maintenance schedule
2. Inspect electrical installation
3. Perform installation servicing
4. Conduct installation tests

#### **8.2.1 Learning Outcome 1: Prepare maintenance schedule**

##### **8.2.1.1 Introduction to learning outcome**

This learning outcome entails definition of maintenance, types of maintenance and procedures, Scheduling maintenance based on service manuals as well as Safety precautions to be observed.  
Information sheet

##### **12.2.1.2 Performance standards**

- 12.2.1.2.1 Type of the system to be maintained is identified
- 12.2.1.2.2 The maintenance type and scope are defined
- 12.2.1.2.3 Relevant manual/service instruction is referred to
- 12.2.1.2.4 Maintenance schedule is developed in accordance with the service checklist
- 12.2.1.2.5 Relevant maintenance procedures are referred to where applicable

##### **12.2.1.3 information sheet**

#### **Prepare maintenance schedule**

Maintenance is the keeping of equipment, building and services of the plant in satisfactory repair and operating conditions.

#### **Importance of Maintenance**

- It helps the industry to maintain continuous supply of goods and services.
- Keeps equipment running (operating)
- Keeps the installation efficient

#### **Control of Maintenance Work**

In order that there should be some control over the work of maintenance, four rules should be rigidly enforced.

- All requests for maintenance work must be made preferably in writing) to one central control point (maintenance supervisor). No work should be carried out without the knowledge and approval of the maintenance supervisor. Lack strict adherence to this rule will allow a waste of skilled staff and inability to keany schedule of essential work.
- No maintenance work should be undertaken by productive staff unless the operator is seconded to the maintenance department.
- Maintenance stores must be as carefully controlled as any other of the company's stores, as the absence of a vital, part can lead to an expensive plant shut down.
- Records of work carried out, including a statement of materials required, should be kept as those assist in selling rational maintenance, replacement and depreciation policies

## **Maintenance Policies**

Within the context of maintenance, failure is defined as an inability to produce work in the appropriate manner rather than inability to produce any work. Work carried out before failure is said to be overhaul, or planned maintenance work while that carried out after failure is emergency, breakdown or recovery work.

In order to come up with rational policies there is need to collect and analyze maintenance information and data of the installations to actual times taken and work Involved when carrying out maintenance tasks and also maintenance costs. From here a choice can then be made of one or a combination of several of the following five types of maintenance policies

- Time base ('overhaul every x months')
- Wok based ('overhaul when x volume of work is produced')
- Opportunity based ('maintain when available')
- Condition based ('repair when parameter is at level p')
- Emergency based ('continue to operate until plant fails, then maintain)

The new above policy decisions as an address to the following questions

- Should maintenance consist of service or repair or both?
- What should be the timing of service or preventive work in order to involve minimum effort and cost and yet minimize the probability of breakdown resources?
- How should the repair work be conducted?
- What should be the size of maintenance teams?
- How should information be gathered to enable the above question be answered?

## **Duties of Maintenance**

The duties of maintenance can be classified into five

- Inspection
- Engineering
- Production
- Clerical

- Housekeeping

## **1. Inspection**

Inspection is concerned with the routine scheduled checks of the plant, building and its equipment and their conditions and to check or needed repairs. On intensively used production equipment Inspection is much more frequent and detailed than function of housing, eg production machines, motors and belting may be inspected once every week, boilers, furnaces and compression equipment every month, overhead cranes may be Inspected every 4 to 6 months.

Facilities will normally be inspected at Intervals in order to determine whether services and\or preventive maintenance is required is likely to be required in the rear future. Such work may Involve visual inspection or the measurement certain of the physical characteristics of a facility. It may Involve the whole facility or simply these parts, which are known to be liable to failure.

A report should be made after such inspection showing the condition of plants, probable reasons for their development and suggested repairs and replacement. A succession of these reports often indicates their weaknesses, which may be developing or may call for change in the inspection interval.

## **2. Engineering**

Engineering is concerned with developing changes and improvement in the plant building or the operating equipment. Recurring breakdowns in certain equipment may suggest a need for engineering by the maintenance department to determine what has caused the difficulty. After the study, maintenance would then develop some modification to prevent or at least reduce such future recurrences. In its engineering capacity, for example, maintenance might be deciding to study and develop ways of directing sufficient illumination towards a particular job through stronger fixture brazing arrangement.

## **3. Production**

This puts into operation the ideas developed by the engineering phase. It is also concerned with the performing work suggested by inspection function as well as performing other tasks such as servicing and lubricating of equipment. The implementation aspects of maintenance are the part that will the classified under this heading.

## **4. Clerical Work**

This is largely keeping records of cost, time progress on jobs etc. It is also responsible for maintaining records to the important features of the plant, equipment and other properties. These may include records of property maps, complete building drawing. Complete writing and power line drawings, maps of underground piping of water, steam, air and similar lines, complete layout drawings of whole machinery, showing types, location and date purchased, spares parts required

etc., and records of all inspection, adjustment, repairs, and replacement by department, equipment and date.

## **5. House keeping**

As the name suggest, it means taking care of the detail of the upkeep and cleaning of the buildings, equipment, tools and plant facilities.

These five functions are in essence the total duties of maintenance department.

### **Types of Maintenance**

Fundamentally there are only two types of maintenance,

- a. preventive maintenance carried out before failure
- b. breakdown maintenance carried out after failure.

### **Preventive Maintenance**

This is also called overhaul, schedule or planned maintenance.

It is generally defined orderly routine of inspecting, cleaning, testing, furnishing, adjusting, and lubricating machines. The main objective of this of program is to avoid or reduce the number of avoidable breakdowns. It is a cores mechanical tear and wear.

A good preventive maintenance program provides for plant shut down during periods of inactivity or least usage for purpose of major overhauls. This ensures continuity of operation and lessens the danger of breakdowns at peak loads.

When preparing routine inspection schedule, it must be recognized that too frequent inspection are a waste time and money and that insufficient inspection places equipment in virtual jeopardy. The frequency of inspection should depend on the equipment' contribution to profitable production, its duty cycle, age, overload etc.

In order to carry out a preventive maintenance schedule it is first necessary to produce an inventory of every item, its service, its role and method required for maintenance, the acceptable frequency of maintenance and attention needed. The selection would be based on the consequences in failure in regard to such factors as safety, productivity and the frequency based on analysis of the past records.

This program is a corrective measure carried out on an item before it fails prevent failure. In most cases, the whole factory would be closed due to overhauls. It embraces type 1 and 3 of maintenance policies.

### **Planning a preventive maintenance program**

- A) The most important phase of a preventive maintenance program is the recording and interpretation of data pertinent to each piece of equipment.
- B) Maintenance personnel should be selected on the basis of qualification on the job.
- C) A skilled maintenance force should be kept abreast of the latest techniques and developments in the field. Files of equipment, manufacturer's bulletins and instructions should be available to all maintenance personnel.
- D) Only modern testing equipment, proper tools and latest methods should be used
- (e) A carefully selected assortment of spare parts is essential to a good maintenance program and represents insurance against prolonged shutdowns. Overstocking and understocking should be avoided, since overstocking involves excessive holding of funds as well as losses due to theft and obsolescence of equipment, while under stocking leads to production in jeopardy if a break down occurs.
- F) Safe operation of machines and safety to personnel should be the uppermost when planning any maintenance program.

### **Objectives of Preventive Maintenance**

- (a) To minimize the possibilities of anticipated production interruption by identifying any condition which might lead to it.
- (b) To make plant equipment and machines available and ready for use.
- (c) To reduce the work content of maintenance jobs that would be occasioned by breakdowns
- (d) to ensure safety of employees.

**Advantages (Benefits) of Preventive Maintenance**(a) A good preventive maintenance ensures cost and lessens the chances of breakdown at peak load.

- (b) It enables troubles to be detected in their early stages so that corrective action can be taken before expensive damage is done
- (c) The relatively high cost of down time due to equipment failure is avoided particularly in processing plants, assembly.
- (e) The total cost of down time and emergency and clock repairs, which can be staggering are minimized (f) The probability of law suits that may arise from injury to personnel and failure to meet commitments because of unavoidable break down are eliminated
- (g) Leads to better spare parts control leading to minimum inventory level and reduction in maintenance.

### **Running Maintenance**



This is part of preventive maintenance, which is done more routinely. It involves walking around and inspecting machines through observation while in operation in order to ascertain loose parts like nuts, screws, parts which by their nature require oiling, greasing, etc. and being able to take the necessary action i.e. tightening or replacing loose nuts, rivets, clips, etc., oiling, greasing, adjusting offset parts, etc.

### **Total Preventive maintenance**

This is where you have workers perform preventive maintenance activities. It's based on the machines they operate, rather than use separate personnel for the task. It is a system where employees are given greater responsibility for quality productivity and the general functioning of the system.

### **Predictive Maintenance**

It is an attempt to determine when maintenance activities. It is based on historical records, analysis of technical data to predict when a piece of equipment of a plant is about to fail. The better the predictions of failures are, the more effective preventive maintenance will be. A good preventive maintenance effort relies on complete records for each piece of equipment. Records must include information such as data of installation, operating hours, dates and types of insurance and dates and types of repairs.

### **Break Down Maintenance**

It is also called corrective, emergency or recovery work. It is type 4 and 5 of maintenance policies.

This is a maintenance, which is carried out on an item, which has failed in its service. It is repair work, which is carried out through fault diagnosis, analysis and identification to establish its position. It is done by repairing the faulty part so as to restore its operation. Some of the worn out or broken parts are removed and replaced.

Repair or breakdown maintenance is remedial; taking place after an item has ceased to operate. The need to repair is not necessarily that result of inefficient or insufficient inspection, service or preventive maintenance, since in some cases the cost of repairs will be less than the accumulated cost of preventive work.

### **Causes of Breakdown**

- (a) Failure to identify and replace worn out parts
- (b) Lack of lubrication.
- (c) Inefficient cooling system
- (d) Difference towards minor faults

(e) Use of standard or wrong fluids.

### **Disadvantages of Breakdown Maintenance**

(a) It is expensive since It results in high cost of down time due to outage for during repair work the equipment is scheduled out of service.

(b) It results to disruption of production and losses thereof, excessive delays or reduction in output.

(c) Failure of machines may cause accident leading to losses and strained industrial relations.

### **Reasons why breakdowns should be avoided**

(a) Avoid production disruptions

(b) Prevent addition to production costs

(c) Maintain high quality products,

(d) Avoid missed delivery dates

### **Adverse consequences when breakdown occurs**

(a) Production capacity is reduced and orders are delayed

(b) There is on production but overheads continue increasing the cost per unit.

(c) There are quality issues, product may be damage

(d) There are safety issues, employees or customers may be injured

### **Handling Breakdowns**

The following are some are some major approaches used to deal with breakdown maintenances.

(a) Have standby or back up and that can be quickly pressed into service.

(b) Have inventories, of spare parts that can be installed as needed, thereby avoiding lead times involved in ordering parts and buffer inventories, so that other equipment will be less likely to be affected by short-term downtime of a particular piece of equipment.

(c) Have operators who are able to perform at least minor repairs on the equipment.

(d) Repair people who are well trained and readily available to diagnose and correct problem with equipment.

## 1. Learning Outcome 2: Inspect electrical installation

### 1.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to inspect electrical installation in the electrical installation maintenance. It includes recording of inspection findings, Identification and documentation of maintenance tools, materials and equipment specifications of identified tools, materials and equipment against safety standards Inspection procedure

#### 1.2.1.1 Performance Standard

1. System is inspected according to the established procedure
2. Instances where the maintenance activities cannot be fully met or where there are defects outside the planned schedule are identified and recorded

#### 1.2.1.3 Information Sheet

##### Definition of terms

**Double installation**-insulation comprising both basic (functional) insulation and supplementary (protective) insulation.

**Earth fault loop impedance**- the impedance (total opposition to flow of current) of the earth fault current loop (phase to earth loop) starting and ending at point of earth fault.

**Earthing conductor**- a protective conductor which connects a main earthing terminal of an installation to the earth electrode or to the other means of earthing.

**Electrical installation**-an assembly of associated electrical equipment such as machines, apparatus, writing materials etc. to fulfill a specific purpose within a consumer's premises.

**Final circuit**- a circuit connected directly to current-using equipment's or sockets-outlets or other outlets points.

**Flexible cords**-a flexible cable is in which the cross-sectional area of each conductor does not exceeds  $4\text{mm}^2$ .

**Isolation**-the cutting off circuit or circuits from the source of electrical energy.

**Live(alive)**-a conductor or object is said to be 'live' when a difference of potential exists between it and earth.

**Live part**-a conductor or conductive part intended to be energized in normal use, including a neutral conductor but not including a PEN conductor.

**Ohmmeter**-an indicating instrument for providing a direct reading of resistance. It's used for measuring conductor resistance and insulation resistance and resistances.

**Protective conductor**- a conductor for some measure of protection against electric shock and intended for connecting together parts of the system that are exposed and extraneous which are conductive.

**Residual current device**-a mechanical switching device or Association of devices intended to cause the opening of contacts when device residuals currents attain a given value under specified conditions.

**Socket-outlets**-a device with protected current-carrying contacts intended to be mounted in affixed position and permanently connected to the fixed wiring of the installation, to enable the connection flexible cord or flexible cables by means of a plug.

**Switch gear**-apparatus for controlling the distribution of electrical energy or for controlling or protecting electrical circuits, machines and current using appliances.

a **TN system**-is a system having one or more points of the supply sources directly earthed.

There are three systems which fall in this category:

- I. TN-C system- neutral and protective functions combined in a single conductor through the system.
- II. TN-S system- neutral and protective conductors separated through the system.
- III. TN-S-C system-as in (1) above but only in part of the system.

b. **TT system**-is a system having one point of the supply directly earthed and the exposed conductive parts of installation are connected to an earth electrode which is connected to an earth electrode which is electrically independent of the electrical installation being earthed.

**Trunking (for cables)** –a fabricated casing for cables normally of rectangular cross sectional of which one side is removable or hinged to allow cable (s ) to be laid therein.

In order to make sure that this work is carried out satisfactorily the inspection and test procedure must be carefully planned and carried out and the results correctly documented.

We inspect material after the completion of work for three key reasons to ensure:

- compliance with BS 7671
- compliance with the project specification (commissioning)
- that it is safe to use.

### **Compliance with BS 7671**

BS 7671 Part 6 states that every electrical installation shall, either during construction, on completion, or both, be inspected and tested to verify, so far as is reasonably practicable, that the requirements of the Regulations have been met. In carrying out such inspection and test procedures, precautions must be taken to ensure no danger is caused to any person or livestock and to avoid damage to property and installed equipment.

BS 7671 requires that the following information be provided to the person carrying out the inspection and test of an installation:

- the maximum demand of the installation expressed in amperes per phase
- the number and type of live conductors at the point of supply

- the type of earthing arrangements used by the installation, including details of equipotential bonding arrangements
- the type and composition of circuits, including points of utilization, number and size of conductors and types of cable installed (this should also include details of the 'reference installation method' used)
- the location and description of protective devices (fuses, circuit breakers etc.)
- details of the method selected to prevent danger from shock in the event of an earth fault, e.g. earthed equipotential bonding and automatic disconnection of supply
- the presence of any sensitive electronic devices.

NB: It is important to remember that periodic inspection and testing must be carried out on installations to ensure that the installation has not deteriorated and still meets all requirements. Tests will also need to be carried out in the event of minor alterations or additions being made to existing installations.

### **Compliance with the project specification**

Once the installation is complete, we need to test it against the original specification for the work. This is in order to check that the finished installation matches the requirements laid out by the customer and is fit for use in the environment where it will be used. The tasks involved in checking compliance with project specification are as follows.

- **Pre-commissioning** – this involves a full inspection of the installation and the carrying out of all tests required before the installation is energized (continuity, polarity and insulation resistance).
- **Commissioning** – includes all tests which require power to be available, e.g., the measurement of the earth-fault loop impedance and functional testing of residual current devices (RCDs).

As commissioning involves the initial energizing of an installation, this task has to be carried out in a controlled manner with the knowledge of everyone involved. This means that all other persons working on site at the time of the energizing must be informed that power will be applied to the installation, so that all precautions can be taken to prevent danger. The commissioning process is intended to confirm that the installation complies with the designer's requirements. As such, commissioning includes the functional testing of all equipment, isolation, switching, protective devices and circuit arrangements

### **Safe to use**

The final act of the commissioning process is to ensure the safe and correct operation

of all circuits and equipment which have been installed, and that the customer's requirements have been met. This will also confirm that the installation works and, more importantly, will work under fault conditions; after all, it is under fault conditions that lives and property will be at risk. The testing of electrical installations can cause some degree of danger; it is the responsibility of the person carrying out the tests to ensure the safety of themselves and others. **Health and Safety Executive Guidance Note GS38 (Electrical test equipment for use by electricians)** details relevant safety procedures and should be observed in full.

- When using test instruments the following points will help to achieve a safe working environment. The person carrying out the tests must have a thorough understanding of the equipment being used and its rating.
- The person carrying out the tests must ensure that all safety procedures are being followed, e.g. erection of warning notices and barriers where appropriate.
- The person carrying out the tests should ensure that all instruments being used conform to the appropriate British Standard, i.e. BS EN 61010 or older instruments manufactured to BS 5458 (provided these are in good condition and have been recently calibrated).
- The person carrying out the tests should check that test leads including probes and clips are in good condition, are clean and have no cracked or broken insulation. Where appropriate the requirements of GS38 should be observed, including the use of fused test leads.

### **Purpose of a periodic inspection**

Initial inspection and testing is necessary on all newly completed installations. In addition, because all the electrical installations deteriorate due to a number of factors (such as damage, wear and tear, corrosion, excessive electrical loading, ageing and environmental influences) periodic inspection and testing must be carried out at regular intervals. The purpose of a periodic inspection and test is to:

- Confirm the safety of persons and livestock against the effects of electric shock or burns
- Ensure protection against damage to property by fire or heat arising from an installation defect
- Confirm that the installation has not been damaged and has not deteriorated to the extent that it may impair safety
- Identify any defects in the installation or non-conformity with the current edition of the Regulations that may cause danger.

The intervals between tests is determined by the following.

- Legislation requires that all installations must be maintained in a safe condition and therefore must be periodically inspected and tested. Table 8.01 details the maximum period between inspections of various types of installation.
- Licensing authorities, public bodies, insurance companies and other authorities may require public inspection and testing of electrical installations.
- The installation must comply with BS 7671.
- It is also recommended that inspection and testing should occur when there is a change of use of the premises, any alterations or additions to the original installation, any significant change in the electrical loading of the installation, and where there is reason to believe that damage may have been caused to the installation.

|                                      |          |
|--------------------------------------|----------|
| Domestic or if change of occupancy   | 10 years |
| Highway power supplies               | 6 years  |
| Churches                             | 5 years  |
| Commercial or if change of occupancy | 5 years  |
| Educational premises                 | 5 years  |
| Hotels                               | 5 years  |
| Hospitals                            | 5 years  |
| Laboratories                         | 5 years  |
| Offices                              | 5 years  |
| Public Houses                        | 5 years  |
| Shops                                | 5 years  |
| Village halls                        | 5 years  |
| Agricultural/Horticultural           | 3 years  |
| Caravans                             | 3 years  |
| Cinemas                              | 3 years  |
| Emergency Lighting                   | 3 years  |
| Industrial                           | 3 years  |
| Leisure Complexes                    | 3 years  |
| Places of public entertainment       | 3 years  |
| Theaters                             | 3 years  |
| Caravan parks                        | 1 year   |
| Fire alarms                          | 1 year   |
| Fish farms                           | 1 year   |

|   |          |
|---|----------|
| Launderettes  | 1 year   |
| Marinas   | 1 year   |
| Petrol filling stations                             | 1 year   |
| Residential accommodation or if change of occupancy | 1 year   |
| Swimming pool                                       | 1 year   |
| Construction sites                                  | 3 Months |

Table 3 Frequency of Inspection

In the case of an installation that is under constant supervision while in normal use, such as a factory or other industrial premises, periodic inspection and testing may be replaced by a system of continuous monitoring and maintenance of the installation, provided that adequate records of such maintenance are kept.

When carrying out the design of an electrical installation, and particularly when specifying the type of equipment to be installed, the designer should take into account the likely quality of the maintenance programme and the periods between periodic inspection and testing to be specified on the Electrical Installation Certificate. Both Section 6 of the Health and Safety at Work Act and the Construction (Design and Management) Regulations require information on the requirements for routine checks and periodic inspections to be provided. The advice of the Health and Safety Executive in their Memorandum of Guidance on the Electricity at Work Regulations indicates that practical experience of an installation's use may indicate the need for an adjustment to the frequency of checks and inspections, i.e. more often or less frequent depending on the likely deterioration of the installation during its normal use. This would be a matter of judgement for the duty holder.

### **Routine Checks**

Electrical installations should still be routinely checked in the intervening time between periodic inspection and testing. In domestic premises it is likely that the occupier will soon notice any damage or breakages to electrical equipment and will take steps to have repairs carried out. In commercial or industrial installations, a suitable reporting system should be available for users of the installation to report any potential danger from deteriorating or damaged equipment. In addition to this, a system of routine checks should be set up to take place between formal periodic inspections. The frequency of these checks will depend entirely on the nature of the premises and the usage of the installation. Routine checks are likely to include activities such as those listed in Table

| Activity | Check |
|----------|-------|
|----------|-------|



|                |   |
|----------------|---|
| Defect reports | Check that all reported defects have been rectified and that the installation is safe.  |
| Inspection     | <ul style="list-style-type: none"> <li>• Breakages</li> <li>• Wear or deterioration</li> <li>• Signs of overheating</li> <li>• Missing parts (screws &amp; covers)</li> <li>• Switch gear still accessible</li> <li>• Enclosure door secure</li> <li>• Labels still adequate(readable)</li> <li>• Loose fittings</li> </ul> |
| Operations     | <p>Check operations of</p> <ul style="list-style-type: none"> <li>• Switch gear (where reasonable)</li> <li>• Equipment (switching on and off)</li> <li>• RCD (using test buttons)</li> </ul>   |

Table 4: Routine Checks

The recommended period between both routine checks and formal inspections are given in Table above taken from *IEE Guidance Note 3*. The requirements for such inspections are stated in BS 7671 Chapter 62 and specify that all inspections should provide careful scrutiny of the installation without dismantling or with only partial dismantling where absolutely necessary. It is considered that the unnecessary dismantling of equipment or disconnection of cables could produce a risk of introducing faults that were not there in the first place.

In summary, the inspection should ensure that:

- the installation is safe
- the installation has not been damaged
- the installation has not deteriorated so as to impair safety
- any items that no longer comply with the Regulations or may cause danger are identified.

In practical terms the inspector is carrying out a general inspection to ensure that the installation is safe. However, the inspector is required to record and make recommendations with respect to any items that no longer comply with the current edition of the Regulations.

## Statutory and Non-Statutory Documentation

These include the following

- The Electricity Supply Regulations (1988).
- The Electricity at Work Regulations.
- BS 5266 Pt. 1 Code of Practice for emergency lighting systems (other than cinemas). Other Regulations and intervals cover testing of batteries and generators.
- BS 5839 Pt. 1 Code of Practice for the design, installation and servicing of fire alarm systems.
- Local authority conditions of license.
- SI 1995 No 1129 (clause 27) The Cinematography (Safety) Regulations.

## Inspection Process

In new installations, inspection should be carried out progressively as the installation is installed and must be done before it is energized. As far as is reasonably practicable, an initial inspection should be carried out to verify that:

- all equipment and material is of the correct type and complies with applicable British Standards or acceptable equivalents
- all parts of the fixed installation are correctly selected and erected
- no part of the fixed installation is visibly damaged or otherwise defective
- the equipment and materials used are suitable for the installation relative to the environmental conditions.

The following items must be covered in an inspection.

1. **Connection of conductors:** Every connection between conductors and equipment or other conductors must provide durable electrical continuity and adequate mechanical strength. Requirements for the enclosure and accessibility of connections must be considered.
2. **Identification of each conductor:** BS 7671 provides a schedule of colour identification of each core of a cable and its conductors. It should be checked that each core of a cable is identified as necessary. Where it is desired to indicate a phased rotation or a different function for cores of the same colour, numbered sleeves are permitted.
3. **Routing of cables:** Cable routes shall be selected with regard to the cable's suitability for the environment, i.e. ambient temperature, heat, water, foreign bodies, corrosion, impact, vibration, flora, fauna, radiation, building use and structure. Cables should be routed out of harm's way and protected against mechanical damage where necessary. Permitted cable routes are clearly defined in the *IEE On-Site Guide*; alternatively, cables should be installed in earthed

metal conduit or trunking.

4. **Current-carrying capacity:** Where practicable, the cable size should be assessed against the protective device based upon information provided by the installation designer.
5. **Verification of polarity:** It must be checked that no single pole switch or protective device is installed in any neutral conductor. A check must also be made that all protective devices and switches are connected in the line conductor only (unless the switch is a double pole device) and that the Centre contact of Edison screw lamp holders are connected to the line conductor. No switches are permitted in the Circuit Protective Conductor.
6. **Accessories and equipment:** Correct connection is to be checked. BS 7671 is a schedule of types of plug and socket outlets available, the rating and the associated British Standards. Particular attention should be paid to the requirements for a cable coupler. Lamp holders should comply with BS 5042 and be of temperature rating T2.
7. **Selection and erection to minimize the spread of fire:** A fire barrier or protection against thermal effects should be provided if necessary to meet the requirements of BS 7671. The Regulations require that each ceiling arrangement be inspected to verify that it conforms with the manufacturer's erection instructions. This may be impossible without dismantling the system and it is essential, therefore, that inspection should be carried out at the appropriate stage of the work and that this is recorded at the time for incorporation in the inspection and test documents.
8. **Protection against direct contact:** Direct contact as defined in BS 7671 is the contact of persons or livestock with live parts. Live parts are conductors or conductive parts intended to be energized in normal use including a neutral conductor but by convention not a combined Protective Earthed Neutral (PEN) conductor. Protection is provided using the following methods.
  - **Insulation.** Is the insulation damaged or has too much been removed? Although protection by insulation is the usual method there are other methods of providing basic protection.
  - **Barriers.** Where live parts are protected by barriers or enclosures, these should be checked for adequacy and security. Have all covers, lids and plates been securely fitted?
  - **Obstacles.** Protection by obstacles provides protection only against an intentional contact. If this method is used, the area shall be accessible only to skilled persons or to instructed persons under supervision. Obstacles can include a fence around a transformer sub-station and barbed wire fencing on power pylons.
  - **Out of reach.** Placing out of reach protects against direct contact. Increased distance is necessary where bulky conducting objects are likely to be handled in the vicinity
  - **Fault protection:** Fault protection as defined by BS 7671 is the contact of persons or livestock with exposed conductive parts which have

become live under fault conditions. An exposed conductive part is a conductive part of equipment which can be touched but is not live although it can become live under fault conditions. Examples of exposed conductive parts could include metal trunking, metal conduit and the metal case of an electrical appliance, e.g. a classroom overhead projector.

9. Earthing provides protection against this type of fault. We also need to check that extraneous conductive parts have been correctly bonded with protective conductors. An extraneous conductive part is a conductive part that is liable to introduce a potential, generally earth potential, and not form part of an electrical installation; examples of extraneous conductive parts are metal sink tops and metal water pipes. The purpose of the bonding is to ensure that all extraneous conductive parts which are simultaneously accessible are at the same potential. Methods of fault protection are given in BS 7671 as:
  - earthed equipotential bonding and automatic disconnection of supply (most common)
  - use of class II equipment
  - non-conducting location
  - earth-free local equipotential bonding
  - electrical separation.
10. **Protective devices:** Have they been set correctly for the load? If rewirable fuses have been fitted, has the correct size of fuse wire been used? If a socket is to be provided for outdoor equipment, has a 30 mA rated RCD been fitted?
11. **Checks on documentation:** Diagrams, schedules, charts, instructions and any other information must be available if inspection and testing is to be carried out in a satisfactory manner.
12. **Checks on warning notices:** These should be fixed to equipment operating in excess of 250 volts where this voltage would not normally be expected.

### Preparing for inspection

- ✓ Where a diagram, chart or tables are not available, a degree of exploratory work may be necessary so that inspection and testing can be carried out safely and effectively. Notes should be made of any known changes in environmental conditions, building structure and alterations, which may have affected the suitability of the wiring for its present load and method of installation.

- ✓ A careful check should be made of the type of equipment on site so that the necessary precautions can be taken, where conditions permit, to disconnect or shortout electronic and other equipment which may be damaged by subsequent testing. Special care must be taken where control and protective devices contain electronic components. It is essential to determine the degree of these disconnections before planning the detailed inspection and testing.
- ✓ For safety, it is necessary to carry out a visual inspection of the installation before beginning any tests or opening enclosures, removing covers etc. So far as is reasonably practicable; the visual inspection must verify that the safety of persons, livestock and property is not endangered. A thorough visual inspection should be made of all electrical equipment that is not concealed and should include the accessible internal condition of a sample of the equipment. External conditions should be noted and damage identified or, if the degree of protection has been impaired, the matter should be recorded on the schedule of the report. This inspection should be carried out without power supplies to the installation, wherever possible, in accordance with the Electricity at Work Regulations 1989.
- ✓ The inspection should include a check on the condition of all electrical equipment and materials, taking into account any available manufacturer's information with regard to the following:
  - Safety
  - Damage
  - Age
  - Wear and Tear
  - Excessive loading (overloading)
  - External influences
  - Corrosion
  - Suitability
- ✓ The assessment of condition should take account of known changes in conditions influencing and affecting electrical safety, e.g. extraneous conductive parts, plumbing, structural changes etc. It would not be practicable to inspect all parts of an installation; thus a random sample should be inspected. This should include:
  - checking that joints and connections are properly secured and that

there is no sign of overheating

- checking switches for satisfactory electrical and mechanical conditions
- checking that protective devices are of the correct rating and type; check for accessibility and damage
- checking that conductors have suffered no mechanical damage and have no signs of overheating
- checking that the condition of enclosures remains satisfactory for the type of protection required

### **Periodic inspection and test**

BS 7671 requires that the results of any periodic inspection and test should be recorded on a periodic inspection and test report of the type illustrated in Figure 8.02. The report should include the following:

- a description of the extent of the inspection and tests and what parts of the installation were covered.
- any limitations (e.g. portable appliances not covered)
- details of any damage, deterioration or dangerous conditions which were found
- any non-compliance with BS 7671
- schedule of test results.

If any items are found which may cause immediate danger, these should be rectified immediately. If this is not possible then they must be reported to a responsible person without delay.

When inspecting older installations, which may have been installed in accordance with a previous edition of the *IEE Wiring Regulations*, provided that all items which do not conform to the present edition of BS 7671 are reported, the installation may still be acceptable, provided that no risk of shock, fire or burns exists.

|                                    |
|------------------------------------|
| <b>Details of the client</b> ..... |
|------------------------------------|

Name.....  
.....

Address:.....  
.....  
.....  
.....

**Purpose of the report.....**

**Details of the installation**

Occupier.....  
.....

Installation address (if different from).....  
.....  
.....

Description of premises: Domestic  commercial  Industrial  Other

Estimated age of the installation..... Years

Evidence of alterations or additions..... Yes/No

Date of last  
inspection.....

Records  
availability.....

**Extent and the limitations of the inspection**

Extent of the installation covered by the  
report.....  
.....  
.....  
.....

Limitations.....  
.....  
.....  
.....  
.....

This inspection has been carried out in accordance with BS 7671(IEE wiring regulations). Cables concealed within trunking and conduit cables concealed under floors buried underground installed in roof spaces or generally hidden within the fabric of the building have not been inspected.

**Next inspection**

(we recommend that this installation should be further inspected and tested after an interval of not more than..... months\years providing that any observations requiring urgent are attended without delay.

**Declaration**

Inspected and tested by

Name.....Signature.....  
.....

For and on behalf of

.....Position.....

Address.....

.....  
.....  
.....  
.....

Date.....



## Statutory and Non-statutory regulations

BS 7671 states that, as far as is reasonably practicable, an inspection shall be carried out to verify that:

- all equipment and materials used in the installation are of the correct type and comply with the appropriate British Standards or acceptable equivalent
- all parts of the installation have been correctly selected and installed
- no part of the installation is visibly damaged or otherwise defective
- the installation is suitable for the surrounding environmental conditions

Before carrying out the inspection and test of an installation, BS 7671 requires the person carrying out the work to be provided with the following information:

- the maximum demand of the installation expressed in amperes per phase after diversity has been applied
- the number and type of live conductors, both for the source of energy and for each circuit to be used within the installation (e.g., single-phase two-wire a.c. etc.)
- the type of earthing arrangements e.g., TNS, TNCS, TT etc.
- the nominal voltage ( $U_0$ )
- the prospective short-circuit current at the origin of the installation (kA)
- the earth-fault loop impedance ( $Z_e$ ) of that part of the system external to the installation
- the type and rating of the overcurrent device acting at the origin of the installation

The following information should be provided as part of the design information, which should be checked by the person carrying out the inspection. You may have to sign the electrical installation certificate to confirm that the installation has been designed, installed and tested to comply with BS 7671 with reference to:

- the type and composition of circuits, including points of utilization, number and size of conductors and type of cable used, including the installation method
- the method used to meet the requirements for fault protection

- the information to be able to identify each protective device, isolation and switching and its location.
- any circuit or equipment that may be vulnerable to test.

### **Detailed inspection Requirements**

#### ✓ **Anticipation of Danger**

Identify any equipment that may be damaged if subjected to high-test voltages as well as computer equipment as this may include safety systems such as fire or intruder alarms that could well have electronic components susceptible to test voltages.

#### ✓ **Joints and connections**

Provided the switchgear and distribution boards are accessible as required by the Regulations, then a full inspection of all conductor terminations should be carried out and any signs of overheating or loose connections should be investigated and included in the report. For lighting points and socket outlets a suitable sample should be inspected in the same way

#### ✓ **Conductors**

The means of identification of every conductor, including protective conductors, should be checked and any damage or deterioration to the conductors, their insulation, protective sheathing or armour should be recorded. This inspection should include each conductor at every distribution board within the installation and a suitable sample of lighting points, switching points and socket outlets.

#### ✓ **Flexible cables and cords**

Where flexible cables or cords form part of the fixed installation the inspection should include:

- examination of the cable or cord for damage or deterioration
- examination of the terminations and anchor points for any defects checking the correctness of the installation with regard to additional mechanical protection or the application of heat resistant sleeving where necessary.

#### ✓ **Switches**

The *IEE Guidance Notes 3 (Inspection & Testing)*, recommends that a random sample of at least 10 per cent of all switching devices be given a thorough internal visual inspection to assess their electrical and mechanical condition. Should the inspection reveal excessive wear and tear or signs of damage due to arcing or overheating then, unless it is obvious that the problem is associated with that particular switch, the inspection should be extended to include all remaining switches associated with the installation.

✓ **Protection against thermal effects**

the presence of firebarriers and seals should be checked wherever reasonably practicable.

✓ **Protection against Direct and Indirect contact**

Separate Extra Low Voltage (SELV) is commonly used as a means of protection against both direct and indirect contact. When inspecting this type of system, the points to be checked include the use of a safety isolating transformer, the need to keep the primary and secondary circuits separate and the segregation of exposed conductive parts of the SELV system from any connection with the earthing of the primary circuit or from any other connection with earth.

✓ **Basic Protection**

Inspection of the installation should confirm that all the requirements of the Regulations have been met with regard to basic protection against direct contact with live conductors. This means checking to ensure there has been no damage or deterioration of any of the insulation within the installation, no removal of barriers or obstacles and no alterations to enclosures that may allow access to live conductors.

✓ **Fault Protection**

The method used for fault protection must be established and recorded on the Inspection Schedule. Where earthed equipotential bonding and automatic disconnection of the supply is used, a check on the condition of the main equipotential bonding conductor and the satisfactory connection of all other protective conductors with earth are essential.

✓ **Protective devices**

A check must be made that each circuit is adequately protected with the correct type, size and rating of fuse or circuit breaker. A check should also be made that each protective device is suitable for the type of circuit it is protecting and the earthing system employed, e.g. will the protective device operate within the disconnection time allowed by the Regulations and is the rating of the protective device suitable for the maximum prospective short circuit current likely to flow under fault conditions?

✓ **Enclosures and mechanical protection**

The enclosures of all electrical equipment and accessories should be inspected to ensure that they provide protection not less than IP2X or IPXXB, and where horizontal top surfaces are readily accessible they should have a degree of protection of at least IP4X. IP2X represents the average finger of

12mm diameter and 80mm in length and can be tested by a metal finger of these dimensions. IP4X provides protection against entry by strips greater than 1.0mm thickness or solid objects exceeding 1.0mm in diameter.

## **Visual Inspection**

### **Inspection Requirements**

In order to meet the requirements for the inspection process we should also include the checking of the following relevant items:

#### **1. Requirements for basic and fault protection**

Separate extra low voltage (SELV) is the most common method of providing both basic and fault protection. Requirements for this type of system include:

- an isolated source of supply, e.g. a safety-isolating transformer to BS 3535 (also numbered BS EN 60742 1996)
- electrical separation, which means no electrical connection between the SELV circuit and higher voltage systems
- no connection with earth or the exposed conductive parts or protective conductors of other systems.

#### **2. Specialized systems**

#### **3. Prevention of mutual detrimental influence**

Account must be taken of the proximity of other electrical services of a different voltage band and of non-electrical services and influences, e.g. fire alarm and emergency lighting circuits must be separated from other cables and from each other, and Band 1 and Band 2 circuits must not be present in the same enclosure or wiring system unless they are either segregated or wired with cables suitable for the highest voltage present. Mixed categories of circuits may be contained in multicore cables, subject to certain requirements. This could also mean checking that water taps have not been fitted directly above a socket outlet. Band 1 circuits are circuits that are nominally extra-low voltage, i.e. not exceeding 50 volts a.c. or 120 volts d.c., such as telecommunications or data and signaling. Band 2 circuits are circuits that are nominally low voltage, i.e. exceeding extra-low voltage but not exceeding 1000 volts a.c. between conductors or 600 volts a.c. between conductors and earth.

#### **4. Isolating and switching devices**

BS 7671 requires that effective means suitably positioned and ready to operate should be provided so that all voltage may be cut off from every installation, every circuit within the installation and from all equipment, as

may be necessary to prevent or remove danger. This means that switches and/or isolating devices of the correct rating must be installed as appropriate to meet the above requirements. It may be advisable where practicable to carry out an isolation exercise to check that effective isolation can be achieved. This should include switching off, locking-off and testing to verify that the circuit is dead and no other source of supply is present.

#### **5. Under voltage Protection**

Suitable precautions must be taken where a loss or lowering of voltage or a subsequent restoration of voltage could cause danger. The most common situation would be where a motor-driven machine stops due to a loss of voltage and unexpectedly restarts when the voltage is restored (unless precautions such as the installation of a motor starter containing a contactor are employed). Regulations require that where unexpected restarting of a motor may cause danger, the provision of a motor starter designed to prevent automatic restarting must be provided.

#### **6. Selection of equipment appropriate to external influences**

Items to be considered are ambient temperature, presence of external heat sources, presence of water, likelihood of corrosion, ingress of foreign bodies, impact, vibration, flora, fauna, radiation, building use and structure.

#### **7. Access to switchgear equipment**

The Electricity at Work Regulations 1989 and BS 7671 state that every piece of equipment that requires operation or attention must be installed so that adequate and safe means of access and working space are provided.

#### **8. Presence of Drawings, Charts and other similar information**

Checks should be made for layout drawings, distribution charts and information on circuits vulnerable to a particular test. All distribution boards should be provided with a distribution board schedule that provides information regarding types of circuits, number and size of conductors and type of wiring etc. These should be attached within or adjacent to each distribution board.

#### **9. Erection Methods**

Correct methods of installation should be checked, in particular fixings of switchgear, cables and conduit, etc. which must be adequate and suitable for the environment.

## Inspection Checklist

To ensure that all the requirements of the Regulations have been met, inspection checklists should be drawn up and used as appropriate to the type of installation being inspected. Examples of suitable checklists are given in Table

|   |  |
|---|--|
| <b>Switchgear (tick if satisfactory)</b>  |  |
| Meets requirements of the appropriate BS EN standards                                   |  |
| Securely fixed and suitably labeled   |  |
| Suitable glands and gland plates used (526.1)   |  |
| Correctly earthed   |  |
| Conditions likely to be encountered taken account of, i.e. suitable for the environment |  |
| Correct IP rating   |  |
| Suitable as means of isolation  |  |
| Complies with the requirements for locations containing a bath or shower                |  |
| Need for isolation, mechanical maintenance, emergency and functional switching met      |  |
| Fireman switch provided, where required   |  |
| Switchgear suitably colored, where necessary  |  |
| All connections secure  |  |
| Cables correctly terminated and identified  |  |
| No sharp edges on cable entries, screw heads etc. which could cause damage to cables    |  |
| All covers and equipment in place   |  |
| Adequate access and working space   |  |
| <b>Wiring accessories (General requirements)(tick if satisfactory)</b>                  |  |
| All accessories comply with the appropriate British Standard                            |  |
| Boxes and other enclosures securely fastened  |  |
| Metal boxes and enclosures correctly earthed  |  |

|   |  |
|---|--|
| Flush boxes not projecting above surface of wall  |  |
| No sharp edges which could cause damage to cable insulation   |  |
| Non-sheathed cables not exposed outside box or enclosure  |  |
| Conductors correctly identified   |  |
| Bare protective conductors sleeved green and yellow   |  |
| All terminals tight and contain all strands of stranded conductor   |  |
| Cord grips correctly used to prevent strain on terminals  |  |
| All accessories of adequate current rating  |  |
| Accessories suitable for all conditions likely to be encountered  |  |
| Complies with the requirements for locations containing a bath or shower  |  |
| Cooker control unit sited to one side and low enough for accessibility and to prevent trailing flexes across the radiant plates |  |
| Cable to cooker fixed to prevent strain on connections  |  |
| <b>Socket outlet (tick if satisfactory)</b>   |  |
| Complies with appropriate British Standard and is shuttered for household and similar installations                             |  |
| Mounting height above floor or working surface is suitable  |  |
| All sockets have correct polarity   |  |
| Sockets not installed in bath or shower zones unless they are shaver-type socket or SELV  |  |
| Sockets not within 3m of zone 1   |  |
| Sockets controlled by a switch if the supply is direct current  |  |
| Sockets protected where floor mounted   |  |
| Circuit protective conductor connected directly to the earthing terminal of the socket outlet on asheathed wiring installation  |  |
| Earthing tail provided from the earthed metal box to the earthing terminal of the socket outlet                                 |  |
| Socket outlets not used to supply a water heater with uninsulated elements  |  |

|   |  |
|---|--|
| <b>Lighting controls (tick if satisfactory)</b>                           |  |
| Light switches comply with appropriate British Standard                   |  |
| Switches suitably located   |  |
| Single-pole switches connected in phase conductor only                    |  |
| Correct colour-coding of conductors                                       |  |
| Correct earthing of metal switch plates                                   |  |
| Switches out of reach of a person using bath or shower                    |  |
| Switches for inductive circuits (discharge lamps) de-rated as necessary   |  |
| Switches labelled to indicate purpose where this is not obvious           |  |
| All switches of adequate current rating                                   |  |
| All controls suitable for their associated luminaire                      |  |
| <b>Lighting points (tick if satisfactory)</b>                             |  |
| All lighting points correctly terminated in suitable accessory or fitting |  |
| Ceiling roses comply with appropriate British Standard                    |  |
| No more than one flexible cord unless designed for multiple pendants      |  |
| Devices provided for supporting flex used correctly                       |  |
| All switch wires identified   |  |
| Holes in ceiling above ceiling rose made good to prevent spread of fire   |  |
| Ceiling roses not connected to supply exceeding 250 V                     |  |
| Flexible cords suitable for the mass suspended                            |  |
| Lamp holders comply with appropriate British Standard                     |  |
| <b>Conduits (General)(tick if satisfactory)</b>                           |  |
| All inspection fittings accessible  |  |
| Maximum number of cables not exceeded                                     |  |
| Solid elbows used only as permitted                                       |  |
| Conduit ends reamed and bushed  |  |



|   |  |
|---|--|
| Adequate number of boxes  |  |
| All unused entries blanked off  |  |
| Lowest point provided with drainage holes where required                            |  |
| Correct radius of bends to prevent damage to cables                                 |  |
| Joints and scratches in metal conduit protected by painting                         |  |
| Securely fixed covers in place adequate protection against mechanical damage        |  |
| <b>Rigid metal conduit (tick if satisfactory)</b>                                   |  |
| Complies to the appropriate British standard  |  |
| Connected to the main earth terminal  |  |
| Line and neutral cables contained within the same conduit                           |  |
| Conduits suitable for damp and corrosive situations                                 |  |
| Maximum span between buildings without intermediate support                         |  |
| <b>Rigid non-metallic conduits (tick if satisfactory)</b>                           |  |
| Complies with the appropriate British Standard                                      |  |
| Ambient and working temperature within permitted limits                             |  |
| Provision for expansion and contraction   |  |
| Boxes and fixings suitable for mass of luminaire suspended at expected temperatures |  |
| <b>Flexible metal conduits (tick if appropriate)</b>                                |  |
| Complies with the appropriate British Standard                                      |  |
| Separate protective conductor provided  |  |
| Adequately supported and terminated   |  |
| <b>Trunking (tick if appropriate)</b>   |  |
| Complies to the appropriate British Standard  |  |
| Securely fixed and adequately protected against mechanical damage                   |  |
| Selected, erected and rooted so that no damage is caused by ingress of water        |  |
| Proximity to non-electrical services  |  |

|  |  |
|--|--|
| Internal sealing provided where necessary  |  |
| Hole surrounding trunking made good  |  |
| Band 1 circuits partitioned from band 2 circuits, or insulated for the highest voltage present |  |
| Circuits partitioned from band one circuits, or wired in mineral-insulated and sheathed cable  |  |
| Common outlets for band 1 and band 2 circuits provided with screens, barriers or partitions    |  |
| Cables supported for vertical runs   |  |
| <b>Metal Trunking (Trunking tick if satisfactory)</b>  |  |
| Line and neutral cables contained in the same metal trunking                                   |  |
| Protected against damp corrosion   |  |
| Earthed  |  |
| Joints mechanically sound, and of adequate earth continuity with links fitted                  |  |

Table 5.

### Inspection checklist

#### 1.2.1.4 Learning Activities

##### 1.2.1.4.1 Practical activities

An electrical contractor has completed installation for a small private caravan site. The site comprises of 15 dedicated caravan pitches, a toilet and shower block and a combined reception office and a small shop. The building on the site form part of a TN-C-S system supplied at 400\230v with a Ze of 0.2  $\Omega$ . At the origin of the installation the distribution circuit to the pitch supplies is separated to form a TT system, having an earth electrode resistance of 48 $\Omega$  and a 500mA RCD as the main isolator. The installation is to be inspected and tested before being placed into services.

- a) List all the certification document which particularly relates to the inspection and test for the entire site
- b) State the
  - i) Statutory document which particularly relates to the inspection and testing process
  - ii) Title given to the person carrying out the inspection and test as stated in b(1) above
  - iii) Status of a person carrying out the inspection and test

- c) List three items of information that should be available to the person carrying out the inspection and test

### Self-assessment

1. There are various documents that are relevant to the Inspection and Testing of an installation. State
  - a) one statutory item of documentation
  - b) two non-statutory items of documentation.
2. List the first three tests that should be carried out during a *periodic* inspection and test of an installation
3. State THREE circumstances that would require a periodic inspection and test to be carried out on an installation.
4. The electrical installation in a small food retail outlet is scheduled for a periodic inspection and test for local authority licensing.
  - a) Describe how the safe isolation of the single-phase distribution board located in the office area is to be carried out.
  - b) Explain why the sequence of testing for this periodic inspection may be different to that given in BS 7671 for initial verification.
5. A periodic inspection is to be undertaken in a large community Centre which is open to the public.
  - i) State what must be agreed with the client and recorded before any work is undertaken.
  - ii) State who else must be considered by the inspector in respect to their safety whilst carrying out this work.
  - iii) State three actions the inspector must take to ensure the safety of people using the building during the inspection and testing process.
  - iv) List three documents that should be available to the inspector in order for the inspection and testing to be carried out safely.
6. One of the competence requirements identified in guidance note 3 (GN3), is for the inspector to have sound knowledge and experience relevant to the nature of the installation being inspected and tested. List three other competence requirements given in GN3
7. List three items related to the nature of the supply which should be made available to an inspector
8. Explain briefly inspection and testing of a new electrical installation should be carried out
9. State three items that would need to be inspected during the first fix construction of a PVC conduit installation for lighting in a general purpose workshop
10. State the most appropriate human sense used to identify
  - a) Terminals are correctly tightened
  - b) Terminals are correctly identified
  - c) That a motor has been overloaded

### Model Answers to self assessment

a) For the TNC-S supplied circuits electrical installation certificate, schedule of inspection, schedule of test results.

For the TT supplied caravan pitches, Electrical installation certificate.

Schedule of inspection, schedule of test results.

b)

i) Electricity at work regulation

ii) Duty holder

iii) The duty holder will be competent person

iv) Ensuring no danger to person's livestock property to compare the test results with design criteria to form a view on the state of installation and advice on remedial works to immediately inform the installation owner (and other interested partner's) if dangerous situation exists.

c. Nominal voltage frequency Ze.

1. Electricity at Work act '89 or Health & Safety at Work Act '74

BS 767

On Site Guide

Guidance Notes etc.

2 Continuity of CPC

Polarity

Earth loop impedance

3 End of license (Public buildings)

End of insurance period

Change of ownership

End of recommended period since last test

4 a) Safe Isolation Procedure

1.2.2 Identify the equipment to be worked on and its means of isolation.

1.2.3 Unplug the equipment if possible.

1.2.4 Isolate and lock off.

1.2.5 Prove the voltage tester.

1.2.6 Prove the equipment is dead (phase to neutral and phase to earth).

1.2.7 Re-prove the voltage tester.

1.2.8 Attach temporary earth leads if necessary.

1.2.9 Post caution notices.

1.2.10 Consider the need for additional precautions.

5 Further safety procedures may be set in place. Permits to work come into their own when dealing with an electrical piece of equipment or installation and are part of an overall strategy for safety, called a 'safe system of work'.

b) The tests need not be carried out in the order as for the initial verification procedure as the installation will have been in operation for some time.

The same range and level of testing as for initial testing is not necessarily

required, or indeed possible. Installations that have been previously tested and for which there are comprehensive records of test results may not need the same degree of testing as installations for which no such records exist.

The person carrying out the testing should decide which of the above tests are appropriate by using their experience and knowledge of the installation being inspected and tested and by consulting any available records.

The inspector will need to set a sample size for testing. Where a sample test indicates results significantly different to those previously recorded, further investigation is necessary. Also, if during the course of testing a sample, significant errors were found that would suggest that the same problems may exist in untested items, then the inspector has to take appropriate action.

This action needs to be either increasing the sampling or referring back to the client; it may be that the inspector recommends that 100 per cent testing is carried out in that area.

- 2 i) Prior to carrying out the inspection, the inspector will need to meet with the client or the client's representative to outline the scope and nature of the work required and to highlight likely items that require isolation. That is the degree of disconnection which will be acceptable before planning the detailed inspection and testing must be agreed. Also, the scope, that is, the extent and limitations of the periodic inspection must be agreed, that is, what is to be covered and what is not covered.
  - ii) As required by law, it is the inspector's duty to ensure the safety of himself or herself and that of others during the test procedure.
  - iii)
    - i) The installation must be isolated before disconnecting protective conductors.
    - ii) Ensure people cannot access exposed/extraneous conductive parts when using test voltages greater than 50V.
    - iii) Use correct test equipment to ensure the test limits are met. For example, limitation of earth fault loop impedance test current to 40ms.
  - iv)
    - Design documentation listing type of supply, earthing arrangements, etc.
    - Diagrams.
    - Charts or tables identifying isolation and protection devices.
    - Previous periodic inspection and test results.
- b)
  - Correctly identified breakers (circuit details)
  - Correct type and rating of main switch and breakers (check ratings against conductor sizes)
  - Signs of overheating, thermal damage, etc. (no other visible damage).
  - Single pole devices in line conductor

- Manual operation of breakers
- Breakers firmly fixed
- Barrier for IP 2X protection over the busbar
- BS or BS EN markings (or other recognized standard)
- All connections secure, correctly terminated and mechanically sound.

3 Knowledge of relevant regulations

Fully versed in inspection and test procedures

Knowledge and experience to use suitable test equipment

4 Nominal voltage

Frequency

Ze

5 Progressively throughout the different stages of the erection and before being put into service

6 Capacity conduits cables to be installed later

Mechanical protection of conduits where damage

Correct mechanical support of conduits to bear loading by cable

Single pole switch

7 Smell

Touch

Sight

## **Learning Outcome 3: Perform installation servicing**

### **Presence of storage batteries**

Since an emergency occurring in a building may cause the mains supply to fail, the emergency lighting should be supplied from a source which is independent from the main supply. A battery's ability to provide its output instantly makes it a very satisfactory source of standby power. In most commercial, industrial and public service buildings housing essential services, the alternative power supply would be from batteries. The emergency lighting supply must have an adequate capacity and rating for the specified duration of time (IEE Regulation 313.2). BS 5266 and BS EN 1838 states that after a battery is discharged by being called into operation for its specified duration of time, it should be capable of once again operating for the specified duration of time following a recharge period of no longer than 24 hours. The duration of time for which the emergency lighting should operate will be specified by a statutory authority but is normally 1–3 hours. The British Standard states that escape lighting should operate for a minimum of 1 hour.

The batteries used for the emergency supply should be suitable for this purpose. The British Standard recommends that the full load should be carried by the emergency supply for at least 1 hour in every 6 months. After testing, the emergency system must be carefully restored to its normal operative state. A record should be kept of each item of equipment and the date of each test by a qualified or responsible person. It may be necessary to produce the record as evidence of satisfactory compliance with statutory legislation to a duly authorized person. Self-contained units are suitable for small installations of up to about 12 units. The batteries contained within these units should be replaced about every 5 years, or as recommended by the manufacturer. Storage batteries are secondary cells. A secondary cell has the advantage of being rechargeable. If the cell is connected to a suitable electrical supply, electrical energy is stored on the plates of the cell as chemical energy. When the cell is connected to a load, the chemical energy is converted to electrical energy.

A lead-acid cell is a secondary cell. Each cell delivers about 2 V, and when six cells are connected in series a 12 V battery is formed. A lead-acid battery is constructed of lead plates which are deeply ribbed to give maximum surface area for a given weight of plate. The plates are assembled in groups, with insulating separators between them. The separators are made of a porous insulating material, such as wood or ebonite, and the whole assembly is immersed in a dilute sulphuric acid solution in a plastic container. The capacity of a cell to store charge is a measure of the total quantity of electricity which it can cause to be displaced around a circuit after being fully charged. It is stated in ampere-hours, abbreviation Ah, and calculated at the 10-hour rate which is the steady load current which would completely discharge the battery in 10 hours. Therefore, a 50 Ah battery will provide a steady current of 5A for 10 hours.

### **Maintenance of lead-acid batteries**

- The plates of the battery must always be covered by dilute sulphuric acid. If the level falls, it must be topped up with distilled water.
- Battery connections must always be tight and should be covered with a thin coat of petroleum jelly.
- The specific gravity or relative density of the battery gives the best indication of its state of charge. A discharged cell will have a specific gravity of 1.150, which will rise to 1.280 when fully charged. The specific gravity of a cell can be tested with a hydrometer.
- To maintain a battery in good condition it should be regularly trickle-charged. A rapid charge or discharge encourages the plates to buckle, and may cause permanent damage. Most batteries used for standby supplies today are equipped with constant voltage chargers. The principle of these is that after the battery has been discharged by it being called into operation, the terminal voltage will be depressed and this enables a relatively large current (1–5A) to flow from the charger to recharge the battery. As the battery becomes more fully charged its voltage will rise until it reaches the constant voltage level where the current output from the charger will drop until it is just sufficient to balance the battery's internal losses. The main advantage of this system is that the battery controls the amount of charge it receives and is therefore automatically maintained in a fully charged condition without human intervention and without the use of any elaborate control circuitry.
- The room used to charge the emergency supply storage batteries must be well ventilated because the charged cell gives off hydrogen and oxygen, which are explosive in the correct proportions

Having successfully diagnosed the electrical fault and carried out the necessary repairs or having completed any work in the electro technical industry, we come to the final practical task, leaving the site in a safe and clean condition and the removal of any waste material. This is an important part of company's 'good customer relationships' with the client and having a good attitude to health and safety, working conscientiously and neatly, keeping passageways clear and regularly tidying up the workplace is the sign of a good and competent craftsman. But what do you do with the rubbish that the working environment produces? Well:

- All the packaging material for electrical fittings and accessories usually goes into either your employer's skip or the skip on site designated for that purpose.
- All the off-cuts of conduit, trunking and tray also go into the skip.
- In fact, most of the general site debris will probably go into the skip and the waste disposal company will take the skip contents to a designated local council landfill area for safe disposal. The part coils of cable and any other reusable leftover lengths of conduit, trunking or tray will be taken back to your employer's stores area. Here it will be stored for future use and the returned quantities deducted from the costs allocated to that job.
- What goes into the skip for normal disposal into a landfill site is usually a matter of common sense. However, some substances require special consideration and disposal.



We will now look at asbestos and large quantities of used fluorescent tubes which are classified as 'special waste' or 'hazardous waste'.

Asbestos is a mineral found in many rock formations. When separated it becomes a fluffy, fibrous material with many uses. In the buildings where it was installed some 40 years ago, when left alone, it does not represent a health hazard, but those buildings are increasingly becoming in need of renovation and modernization. It is in the dismantling and breaking up of these asbestos materials that the health hazard increases. Asbestos is a serious health hazard if the dust is inhaled. The tiny asbestos particles find their way into delicate lung tissue and remain embedded for life, causing constant irritation and eventually, serious lung disease. If asbestos is present in situations or buildings where you are expected to work, it should be removed by a specialist contractor before your work commences. Specialist contractors, who will wear fully protective suits and use breathing apparatus, are the only people who can safely and responsibly carry out the removal of asbestos. They will wrap the asbestos in thick plastic bags and store them temporarily in a covered and locked skip. This material is then disposed of in a special landfill site with other toxic industrial waste materials and the site monitored by the local authority for the foreseeable future.

Removing the old fluorescent fittings hanging on chains or fixed to beams and installing a suspended ceiling and an appropriate number of recessed modular fluorescent fittings. These fittings are made of sheet steel, a couple of plastic lamp holders, a little cable, a starter and ballast. All of these materials can go into the ordinary skip. However, the fluorescent tubes contain a little mercury and fluorescent powder with toxic elements, which cannot be disposed of in the normal land fill sites. Hazardous Waste Regulations were introduced in July 2005 and under these regulations lamps and tubes are classified as hazardous. The environmentally responsible way to dispose of fluorescent lamps and tubes is to recycle them. The process usually goes like this:

- Your employer arranges for the local electrical wholesaler to deliver a plastic waste container of an appropriate size for the job.
- Expired lamps and tubes are placed whole into the container, which often has a grating inside to prevent the tubes breaking when being transported.
- When the container is full of used lamps and tubes, you telephone the electrical wholesaler and ask them to pick up the filled container and deliver it to one of the specialist recycling centers.
- Your electrical company will receive a 'Duty of Care Note' and full recycling documents which ought to be filed safely as proof that the hazardous waste was recycled safely.
- The charge is approximately 50p for each 1800mm tube and this cost is passed on to the customer through the final account.

NB:

- Clean up before you leave the job.
- Put waste in the correct skip.
- Recycle used lamps and tubes.

- Get rid of all waste responsibly.

#### Learning outcome 4: Conduct installation tests

Before a completed installation may be connected to the supply a number of tests are required to indicate the general condition of the installation, both with regard to the insulation resistance of the conductors and other current-carrying parts and with regard to the conductance of the earthing system. The tests which are to be made are not a complete guarantee of the quality of the installation for all time, and regular testing is necessary in order that it may be maintained in a proper condition throughout its life.

#### Insulation resistance.

This is the resistance in ohms between the live parts of the installation and earth, measured through insulating covering of the conductors, etc. In the case of metal-covered wiring or conduit wiring, the term 'earth' means in practice the metallic covering or conduit which itself is connected directly to earth. Additionally, the insulation resistance is measured between lines, that is, between the opposite poles of the installation with lamps or other apparatus disconnected and switches on.

The difference between insulation and conductor resistance is shown in the sketches (Figs. 93 and 94). In measuring the resistance of a

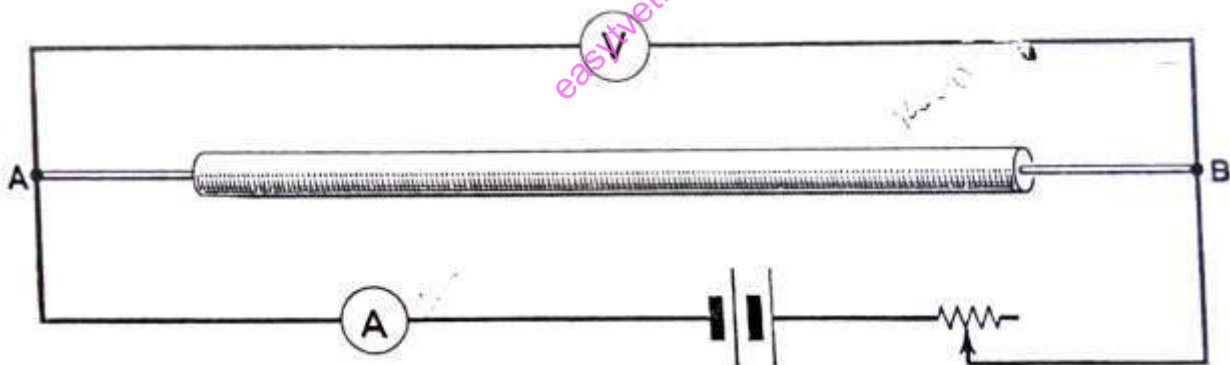


Fig. 1 Measuring conductor resistance

conductor AB, the resistance is measured along the wire from end to end, and increase of conductor length means increase of resistance. In measuring the insulation resistance of the conductor, the measurement is made from the conductor outwards.

The formula for conductor resistance is  $R = \rho l/a$  where  $l$  is the length of the conductor,  $a$  is the cross-sectional area, and  $\rho$  is the resistivity of the conductor material. Using a similar formula for insulation (it is sufficiently true for the purposes of this argument),  $R' = \rho' l/a'$  the thickness of the insulation,  $a'$  is proportional to the length of the wire, and  $\rho'$  is the resistivity of the insulating material.

Conduit or metallic covering

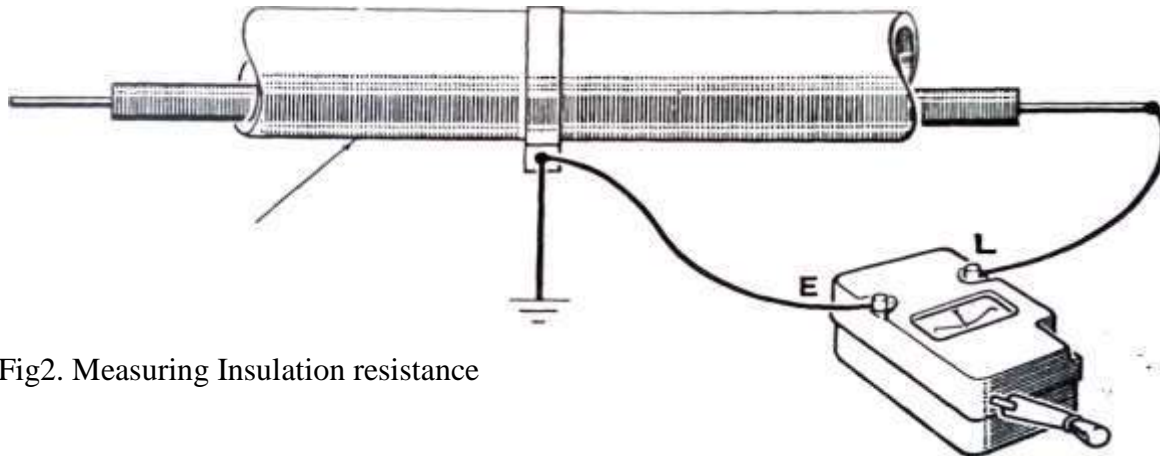


Fig2. Measuring Insulation resistance

Thus, if an insulated wire is increased in length, its conductor resistance increases while its insulation resistance decreases. Therefore, the longer the conductor the less will be its insulation resistance.

### **Inspection of installations.**

During the fitting of the various parts of an installation some form of inspection by the electrical contractor or his staff is both desirable and necessary, Small faults could be brought to light and corrected thus preventing waste of time during the final testing session. Alternatively, a careful inspection should be made immediately prior to the testing.

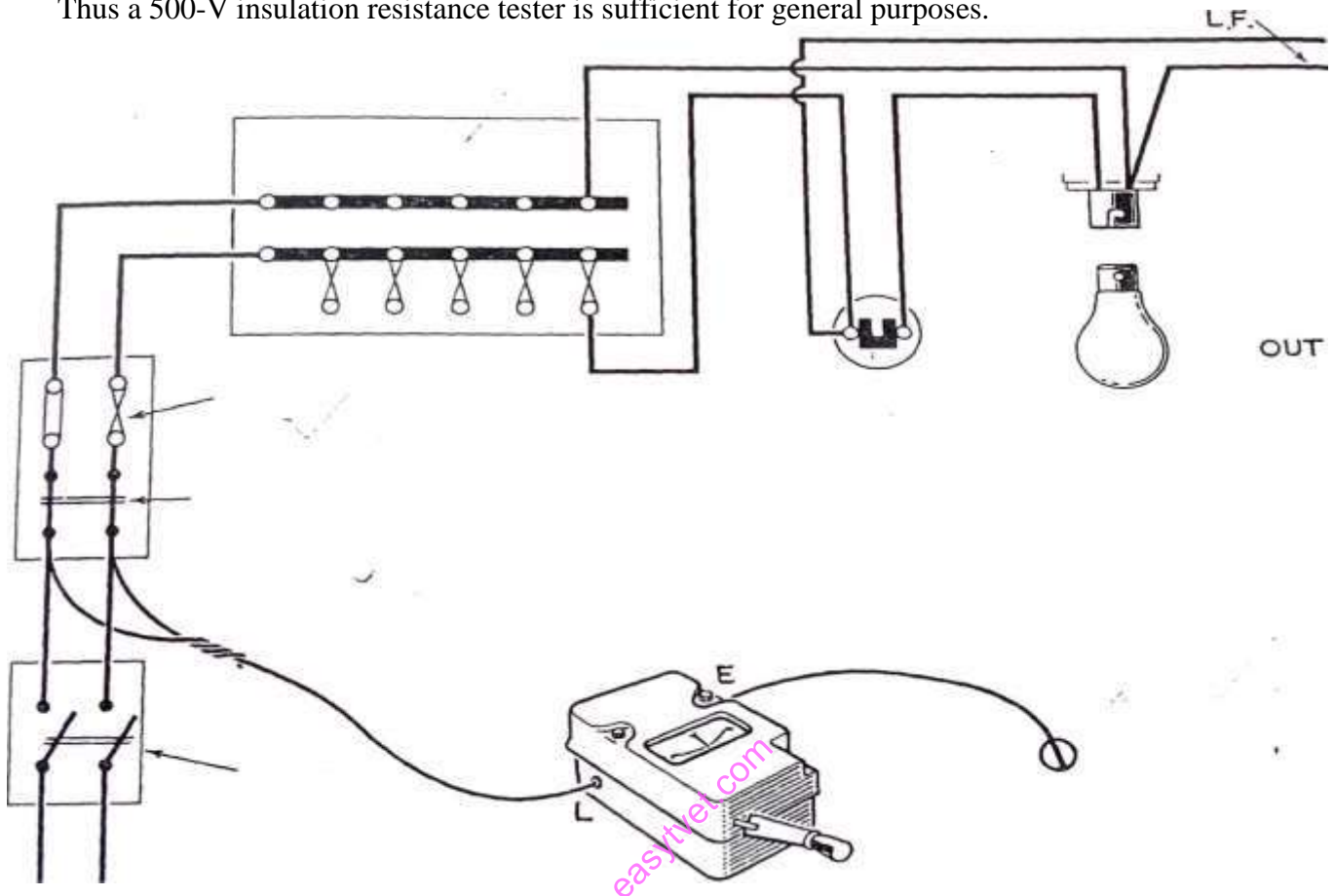
### **Regulations. I.EE.**

Regulations EI to E 14 deal with the testing and inspection of installations. These regulations are discussed below, and methods of complying with them are described in detail.

**Insulation resistance tests,** Regulations E 6 and E 9. The various tests of an installation which follow are to be made before the installation is connected to the supply, For the insulation resistance tests large installations may be divided into groups of not less than 50 outlets. For this purpose, the expression outlet includes every point (position for attachment of lamp, lighting fitting, or current-using appliance) and every switch and socket-outlet. A socket-outlet, appliance or lighting fitting incorporating a switch is regarded as one outlet.

**Testing voltage.** The voltage used for insulation resistance tests shall be a direct current voltage not less than twice the normal direct current voltage, or in the case of alternating current not less

than twice the normal rms. voltage, but it need not exceed 500 V for medium-voltage circuits. Thus a 500-V insulation resistance tester is sufficient for general purposes.



### Testing the installation to earth.

The test shall be made with all fuse links in place, all switches including the main switch closed and, except where earth-concentric wiring is concerned, all poles or phases electrically connected together,

If required, all lamps and appliances may be removed during the test, in which case each piece of apparatus should be separately tested, the measured insulation to earth shall be not less than 1 M $\Omega$ . The insulation

S. W

S.W

TO

NEXT

POINT

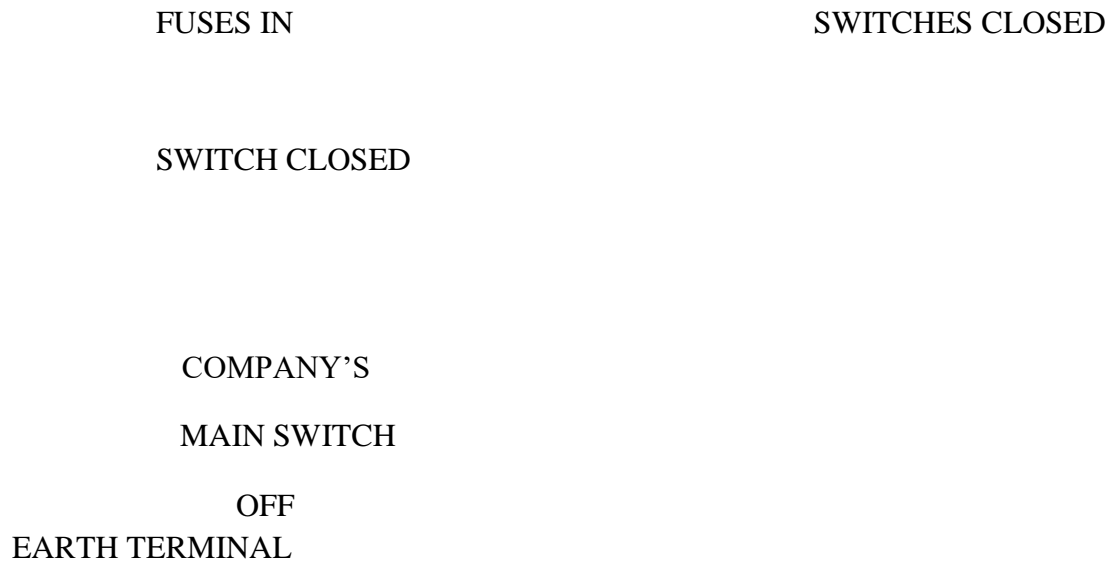


Fig 3 Testing insulation resistance of completed installation

resistance of each piece of apparatus measured separately shall be not less than 0.5 M $\Omega$  to earth (between live parts and frame), and 0.5 M $\Omega$  between poles or phases. The sketch (Fig.) shows the connections for testing the insulation resistance to earth of a completed 2-wire installation with lamps and other apparatus disconnected. The wires of both poles of the supply to the main switch are twisted together and connected to the 'line' terminal of the ohmmeter. The 'earth' terminal of the ohmmeter is connected to the consumer's earthing terminal. The three terminals of 2-way switches should temporarily be connected together.

#### **Testing between conductors.**

This test is made between all the conductors connected to any one pole or phase of the supply, and all conductors connected to any other pole or phase of the supply. The insulation resistance is to be not less than 1 M $\Omega$ .

All lamps should be removed, all current-using apparatus disconnected and all local switches controlling lamps or apparatus closed. When the removal of lamps and apparatus is not practicable, all local switches should be open. The test does not apply to earthed concentric wiring systems. Figure 97 gives the connections for the test of a 2-wire installation. Only one test is required in this case.

## Electrical installation work

For 3 and 4-wire installations more than one between phases test is necessary. A 3-wire direct current installation will require three tests:

1. between positive line and neutral,
2. between negative line and neutral,
3. between positive and negative lines

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L.F

TO NEXT

FUSES IN

S.F.

S.W

POINT

SWITCH CLOSED

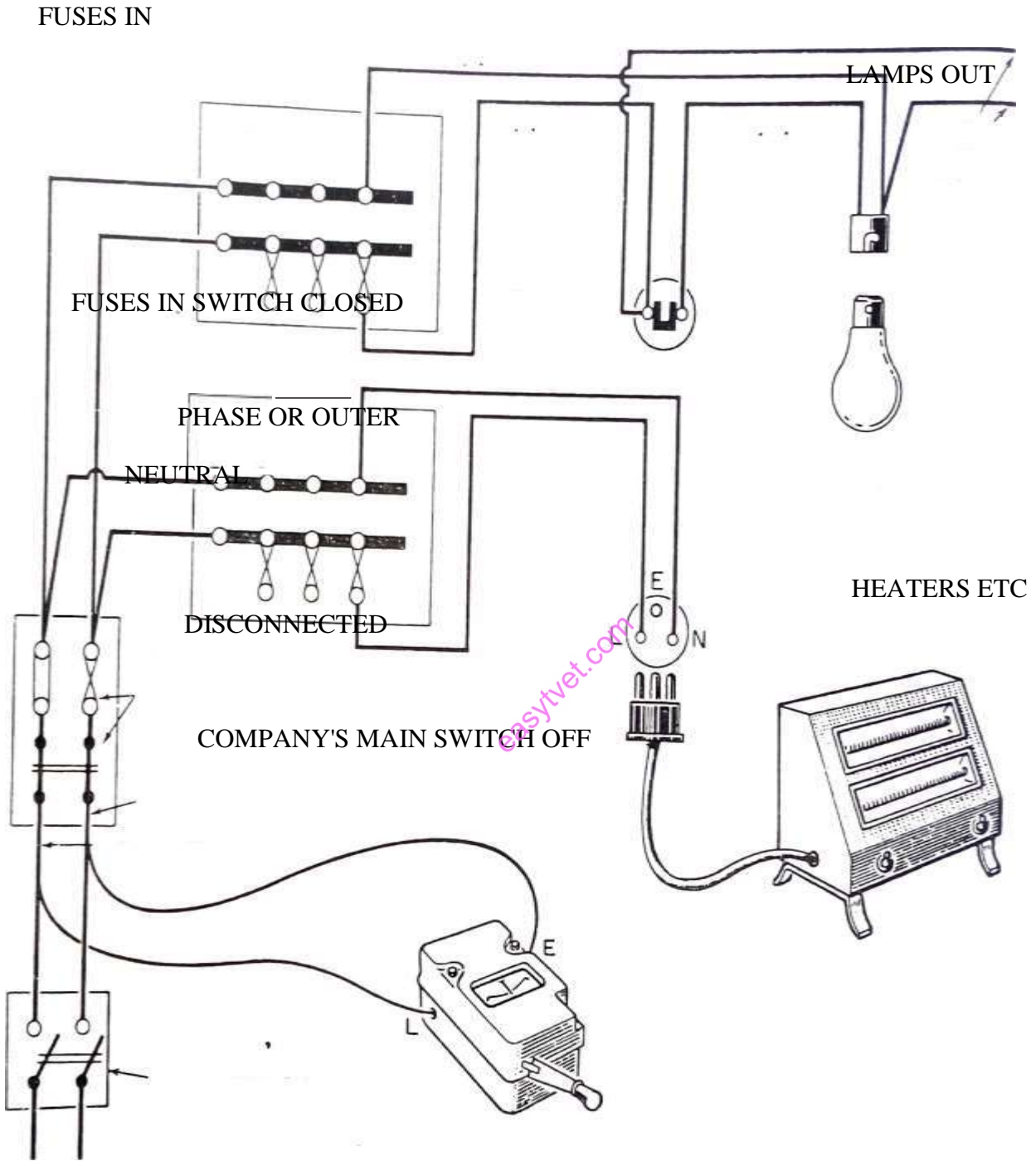


Figure 4.

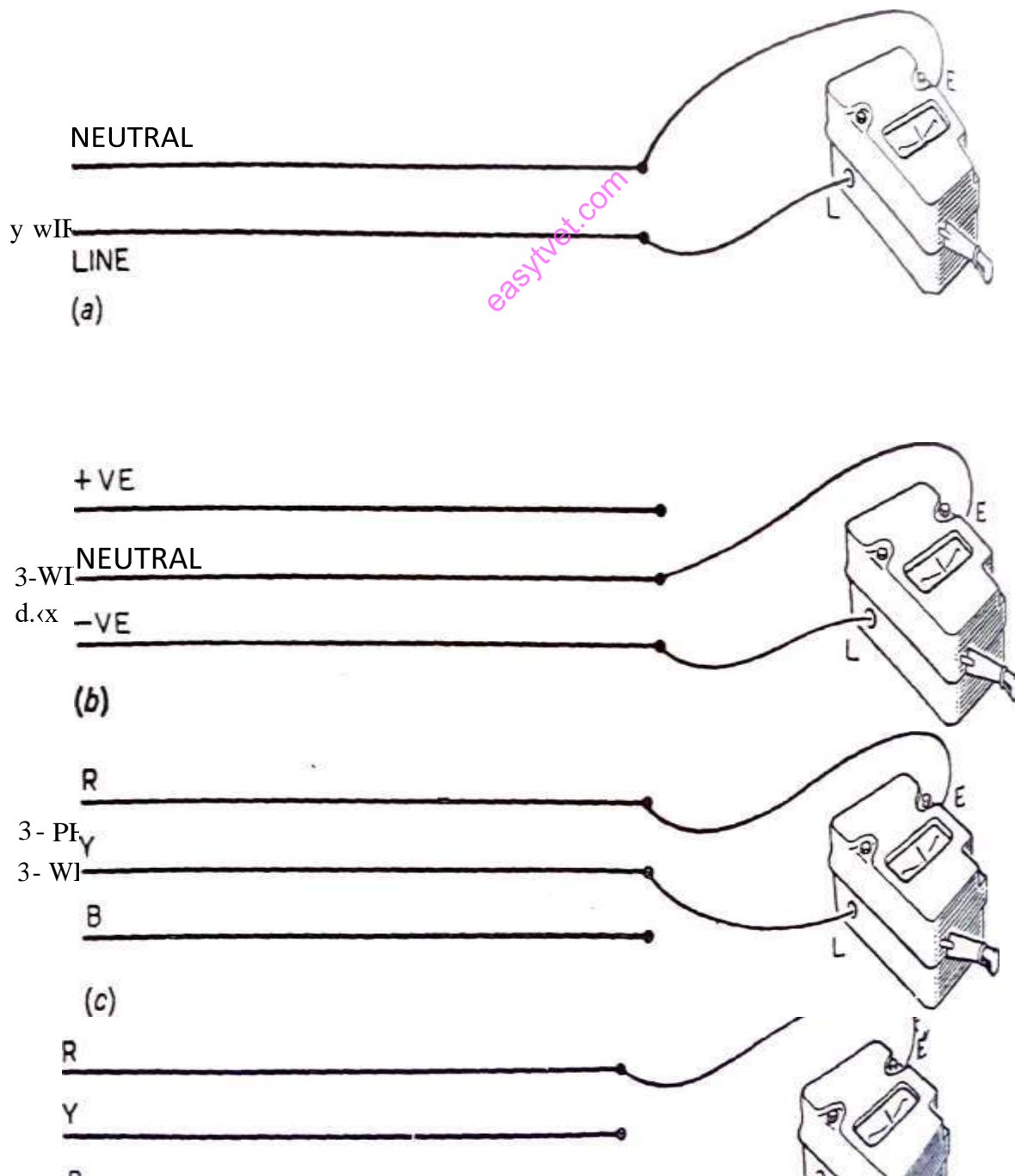
A 3-wire 3-phase installation will also require three tests:

1. between lines R and Y,
2. between lines R and B,
3. between lines Y and B.

A 3-phase 4-wire installation will require six tests:

1. three separate tests between pairs of lines, R-Y, R-B, and Y-B.
2. three separate tests, R-neutral, B-neutral and Y-neutral.

Figures 98 (a) to (d) show the test connections in a simplified form.





3 - PHASE

4 - WIRE

(d)

Fig 5 (a) to (d) Simplified diagrams of tests between conductors

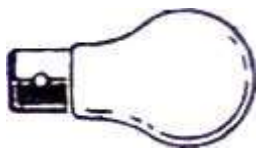
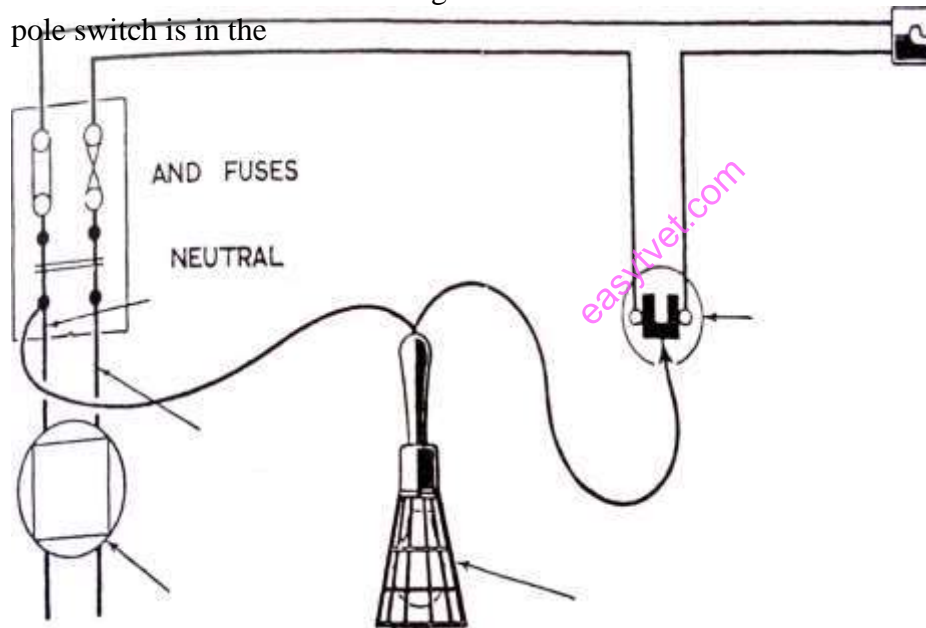
Verification of polarity of single-pole switches, etc. . Regulation E requires that it shall be ensured that all fuses and single-pole control devices are connected in the live conductor only; that the outer contact of Centre-contact bayonet and Edison-type screw lamp holders are C nested to the neutral or earthed conductor; and that plugs and socie outlets have been correctly wired.

On p. 12 it was noted that by I.E.E. Regulation all single-pole or linked switches were to be fitted in the outer or phase conductor. If the proper colored cable is used throughout the installation, i.e., in a2-wi installation, red for switch feeds and switch wires and black for light feeds, no confusion should arise.

Paying for polarity with circuit alive. The simplest way to test is with the circuit alive, switched on the main switch, All single-pole switches would be ON', their covers removed, all lamps should be out, and other Neutral should be disconnected, If the single-pole switches are in the Correct conductor, the phase or outer conductor, they will be alive. A portable lamp with a pair of long insulated leads is used. The leads Should terminate in insulated test prods in the interests of safety. The end of one prod is connected to the known earthed conductor at the main switch, and the other prod is touched to the single-pole switch terminals. The test lamp should light. Should the switch be in the wrong or earthed conductor, the test lamp will not light as the switch will be at earth potential. This procedure is repeated at all the switches in turn. In the case of 2-way switches, the three terminals of the switches should be temporarily connected together for the test. In a large installation the work can be sectionalized by checking the polarity of the busbars at the distribution boards and working from these positions instead of running the test lead back to the main switch. The test should be extended to verify that the three-pin socket outlets are properly connected, that is, with the terminal marked 'L' connected to the outer or phase conductor,

In testing screw-type lamp holders to ensure that the outer contact is earthed, one prod should be touched to the live side of the main switch and the other prod to the outer contact of the lamp holder, when the test lamp should light. It must be remembered that the test is being made on a live circuit, and care must be taken, otherwise unpleasant or dangerous shocks may be sustained; Figures above illustrate the tests.

Testing for polarity with circuit dead. Testing instruments are available by which the polarity of the circuit switches can be tested before the installation is connected to the supply. In its simplest form the instrument consists of a direct-reading ohmmeter and a small dry battery contained in a small case, with two terminals to which a pair of test leads with or without testing spikes may be connected. Figure 103 illustrates the test. The main switch and fuses are out, lamps and other apparatus are out or disconnected, and the single-pole switches are on. One lead of the polarity tester is connected to the phase or outer conductor at the outgoing side of the main fuses. The other lead is touched to the terminals of the single-pole switches in turn. Provided the polarity is correct, the instrument reading will be less than 12 normally, since the instrument is measuring the resistance of the circuit wiring from the main fuse to the switch being tested. If the single-pole switch is in the



CONSUMERS MAIN SWITCH

LAMPS OUT

CONDUCTOR

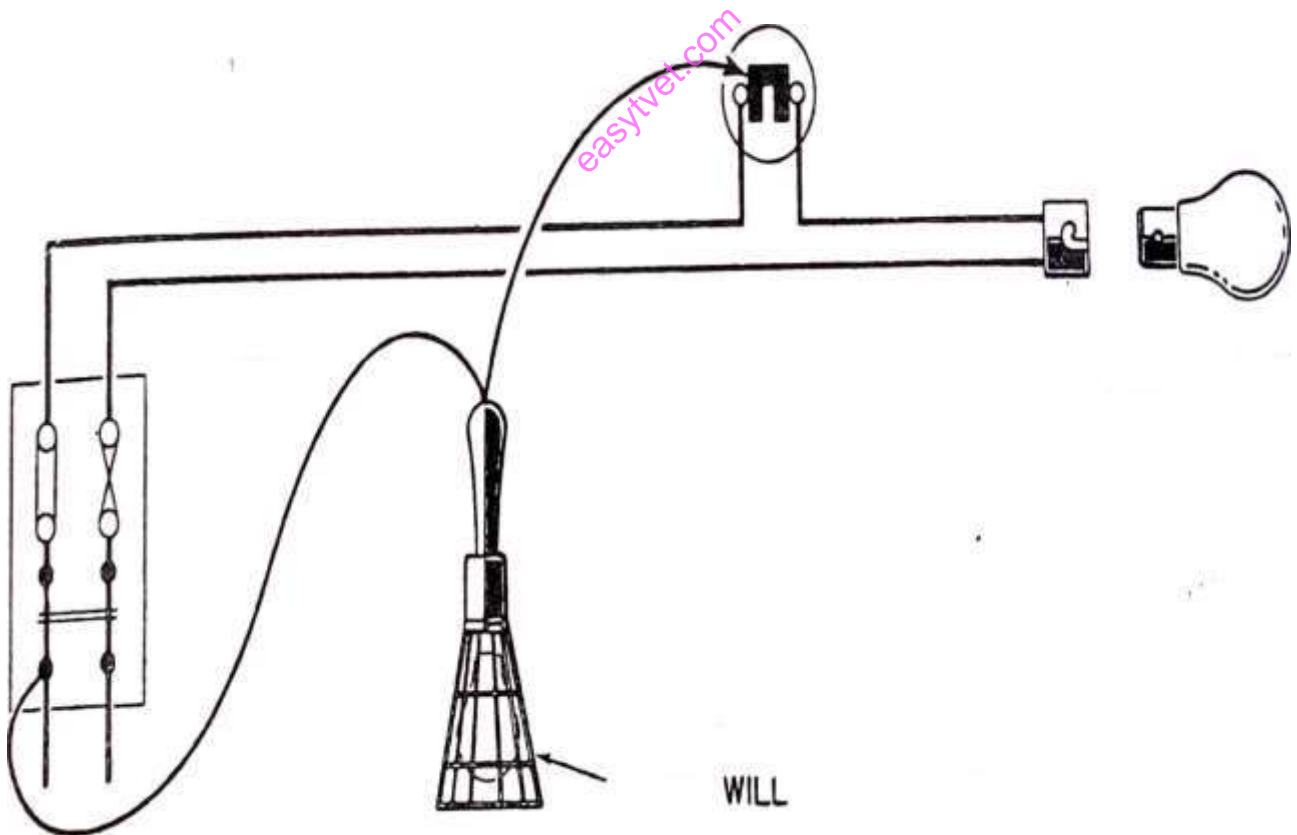
SWITCHES ON

PHASE OR OUTERLAMP WILL LIGHT

CONDUCTOR

METER

Fig5 Testing for polarity of switch, correct

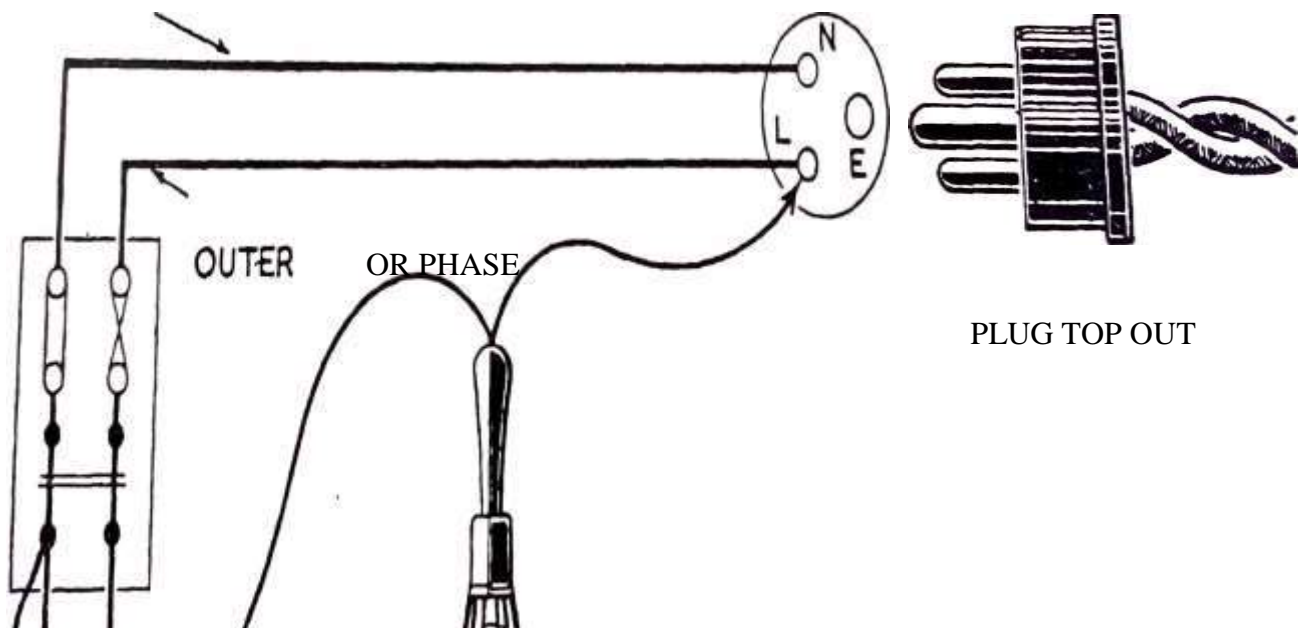


NEUTRAL ↘  
OUT ↙ PHASE OR OUTER LAMPS

LAMPS  
WILL NOT LIGHT

Fig 6 Testing for polarity of switch, incorrect

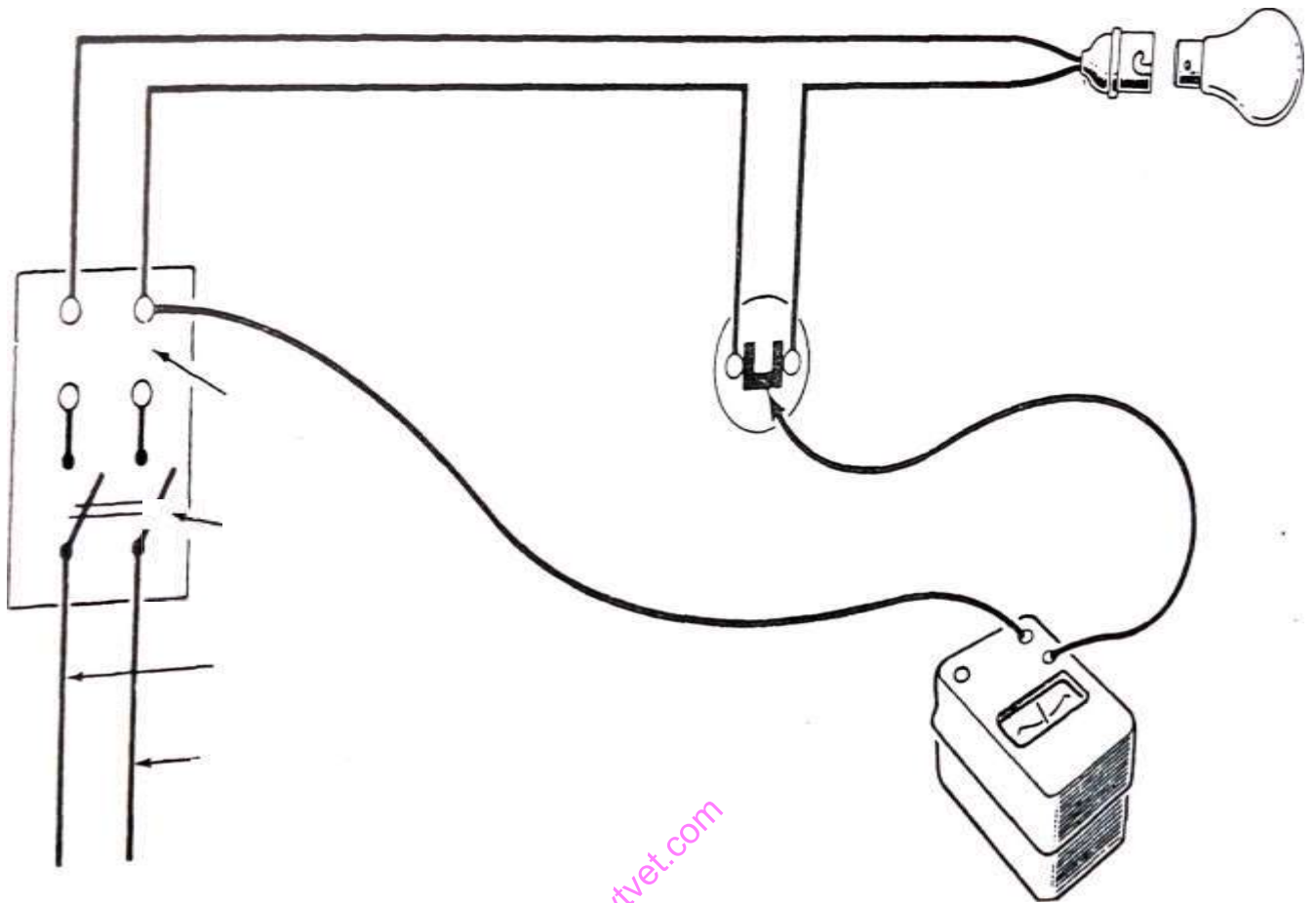
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LAMP WILL LIGHT

Fig 7 Testing 3-pin socket outlet, correct

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incorrect conductor the instrument reading will be a maximum, i.e., infinity. The polarity of the 3-pin socket outlet is tested in a similar way.

LAMPS OUT

YY FUSES OUT

MAIN SWITCH OPEN

NEUTRAL

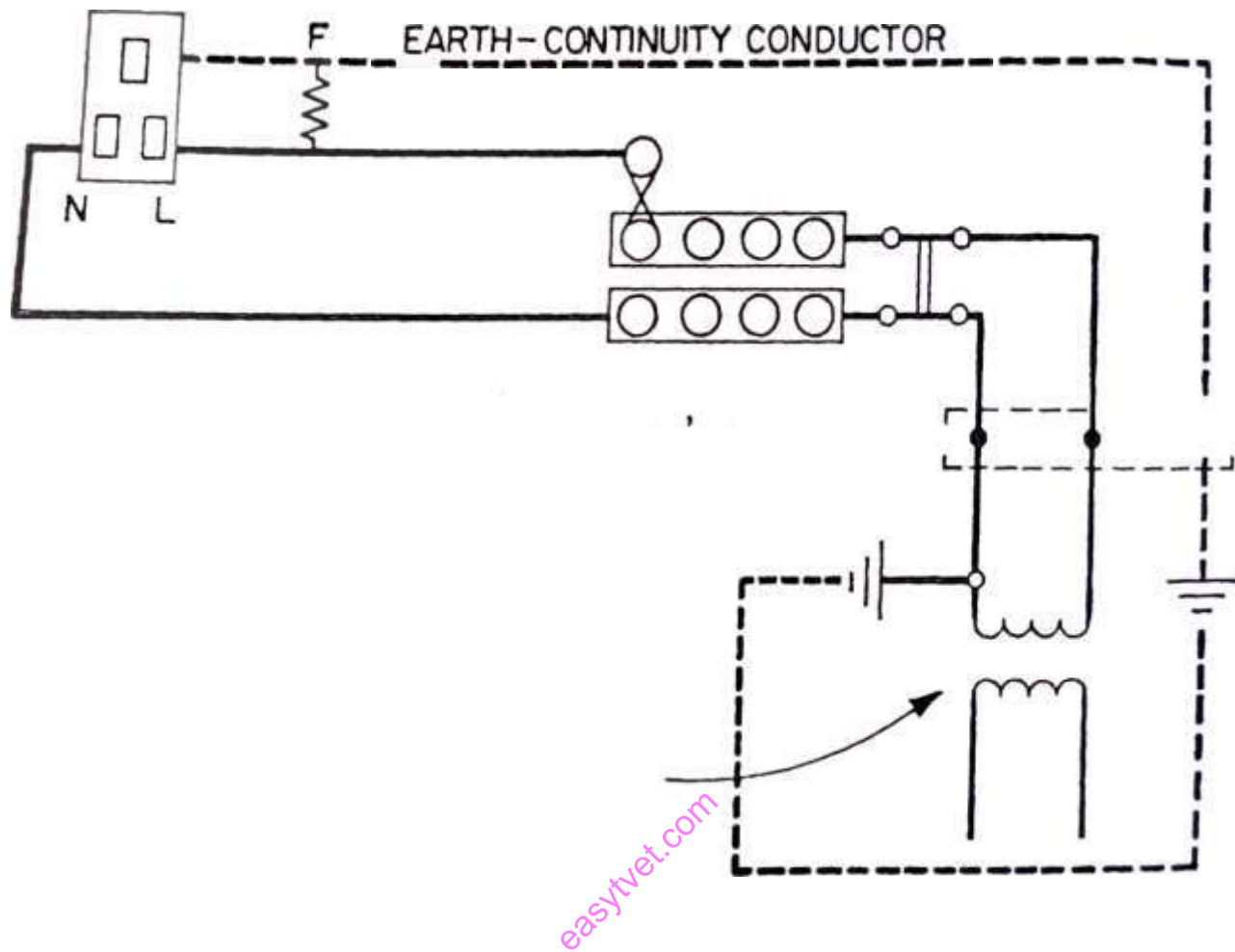
PHASE OR OUTER

Fig. 8 Testing for polarity of switch with circuit dead

**Test of earth-leakage circuit-breaker.**

In accordance with Regulation E 5, the effectiveness of earth-leakage circuit-breakers is to be verified. The IEE Regulations states that a voltage not exceeding 45 V, obtained from a double-wound transformer connected to the mains supply, shall be applied across the neutral and earth terminals (or neutral and frame terminals of a voltage operated Earth leakage circuit-breaker) and the circuit breaker shall trip instantaneously.

**Earth-fault loop testing.** Regulation E 4 requires that when earth leakage protection relies on the operation of fuses or excess-current circuit-breakers, the effectiveness of earthing shall be tested by means of an earth-loop impedance test.



CONSUMER'S TERMINALS

SUPPLY AUTHORITY EARTH ELECTRODE



## SUPPLY TRANSFORMER

EARTH

PATH

Fig 9 .Line-earth loop

The diagram Figure above shows the path of leakage current from an earth fault on a 2-wire final sub-circuit. The path of the leakage current is from the earth fault (F) along the earth-continuity conductor to the consumer's earthing terminal and thence to the consumer's earth electrode. From here the fault current passes through the general mass of earth to the supply authority's earth electrode at the supply transformer, through the transformer winding and along the line through the consumer's wiring to the fault. This path is called the line earth loop, and it is this loop which is to be tested, The Regulations allow the neutral-earth loop to be tested as an alternative.

A line-earth tester such as the Megger line-earth tester would be used. The operation of this instrument is as follows:

The instrument passes a short duration current through the loop, the value of the current depending upon the impedance of the loop as well as upon the voltage of the tester. The current passes through 10 resistors in series with the loop, and the voltage drop across it is measured by means of a ballistic instrument which is calibrated to read directly the loop impedance in ohms. This instrument incorporates a voltmeter and a voltage selection switch, enabling it to be used on supplies of different line-neutral voltages.

### **Test of earth-continuity conductor.**

Regulation E 3 requires that every earth-continuity conductor shall be tested in accordance with Item 1 of Appendix 6. Four methods are given:

- **Alternating current test.**

It is suggested that one of the current conductors of known resistance shall be disconnected and used as part of the test circuit. At the remote end of the final sub-circuit this cable and the earth-continuity conductor are connected together forming a lead and return. At the other end an alternating current supply not exceeding 40 V at approximately supply frequency is applied to the end of the conductor/e.c.c loop. A current of approximately times the rating of the final sub-circuit is passed through the

loop, with a maximum value of 25 A. The impedance of the e.c.c which is the ratio voltage/current, minus the resistance of the known conductor, should not exceed 1Ω.

- **Alternating current test at reduced current.**

preferred, a lower value of current may be applied, at approximately supply frequency, The impedance values allowable are, not more than 0.5Ω where the e.c.c is partly or wholly of steel conduit or pipe, and 1.0Ω where the e.c.c is wholly of copper, copper alloy, or aluminium.

- **Direct current test of an alternating current installation.**

Direct current may be used for the test provided that a proper inspection of the e.c.c ensures that there is no inductor incorporated in the e.c.c. The values of impedance are not to exceed 0.5Ω for steel conduit or pipe, and 1Ω for copper, copper alloy, or aluminium.

- **No current test of direct current installation**

This test can be made, using say, a secondary battery and rheostat, with a current approaching 1-5 times the rating of the sub-circuit under test, subject to a maximum of 25 A. Alternatively, a hand tester may be used with a reduced current. In each case the resistance obtained by the test should not exceed 1 Ω.

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### **Test of ring-circuit continuity**

Regulation E 10 requires that a conductor, including the earth-continuity conductors, shall be verified for continuity, this may be done with a continuity tester, probably a battery type as used for polarity testing on p. 116.

All apparatus must be disconnected from the ring. The ring is disconnected at the distribution board so that the four ends of the ring conductors are exposed. Touching the continuity tester across the two ends of the line conductor will give a very low reading, showing continuity. The neutral conductor is checked in a similar way.

To check the conductors in the spurs, the ring should remain open with ends exposed. A continuity test would be made across line and neutral from the end socket-outlet on any spur, when the indication should be infinite resistance. This could be repeated at every spur end. If one pair of exposed wires, line and neutral, at the exposed ends be now temporarily short-circuited, continuity readings from each spur end should show very low resistance, thus verifying continuity.

The earth-continuity conductors could be checked for continuity at the same time.

### Completion certificate

On completion of a new installation or of a major alteration, and after inspection and testing as described, the installation contractor is required to give a Completion Certificate. This certificate, gives certain details of the installation including the number of appliances, etc., the method of earthing, and the value of the earth-loop impedance. The certificate states that the work has been done in accordance with Regulations. It also recommends periodic testing and inspection.

### Inspection certificate

When the installation is re-inspected and tested at a later date, an inspection certificate is completed and handed to the consumer. It gives the results of the full range of tests of the installation.

### Practical activities

The test results shown in figure below were obtained from a ring final circuit continuity test. State whether reading for each socket are satisfactory or unsatisfactory. give reason for those reading unsatisfactory.

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**Note: line, neutral and c.p.c loops =0.8Ω**

| Socket | L-N         | L-c.p.c    |
|--------|-------------|------------|
| A      | 0.4         | 0.41       |
| B      | Not reading | 0.39       |
| C      | 0.5         | 0.4        |
| D      | 0.4         | No reading |
| E      | 0.41        | 0.41       |

## Self-assessment

1.
  - a. Describe in details the test procedure for insulation resistance on the installation
  - b. The test results indicate an overall value of  $1.5\Omega$ . state with reasons what actions if any should be taken
2. A loop impedance test on the lighting circuit is conducted and 6A type B m.c.b trips repeatedly
  - a. Explain why this is the case

Explain why the problem may be overcome in order to conduct the test

1. Explain briefly the action to be taken if the insulation resistance test of an installation indicates an overall value of 1.25 M-ohms
3. A ring final circuit continuity test revealed incorrect polarity on three socket outlets. The results were

|          | <u>L to N</u> | <u>L to c.p.c.</u> |
|----------|---------------|--------------------|
| Socket A | Open circuit  | Correct            |
| Socket B | Correct       | Open circuit       |
| Socket C | Open circuit  | Open Circuit       |

State which conductors have reversed polarity in each case.

4. For an insulation resistance test on domestic installation, state the
  - I. Instrument to be used
  - II. Resistance range at which this instrument should set
  - III. Measured value below which each circuit would need to be tested separately
5. A live polarity test is to be conducted. State
  - i) Why such a test is necessary
  - ii) The instrument to be used
  - iii) How neutral-earth polarity is checked
6. Earth fault impedance is to be conducted on a radial circuit during an initial verification. State
  - i) Where on circuit the circuit should be conducted
  - ii) Which value measured or corrected should be recorded on the scheduled test results
  - iii) Why the value in b above may not be the same as  $Z_e + (R_1 + R_2)$
- 2.
7. List
  - a. Five relevant test including the individual instrument required on the outer house supply cable following the test for continuity protective conduction
  - b. Five relevant inspection required when inspecting the installation of the outer house supply cable
8.
  - a. Explain why the earth fault loop impedance test results on lighting circuit in the outer house is likely to be significantly higher than a similar circuit in the main property
  - b. Explain briefly

- i) Why the main switch may operate when testing for earth loop impedance on the lighting circuit in the outer building
- ii) How you would overcome the problem encountered in b (1)

### Answers to practical Activity

1. As the line, neutral and c.p.c loops are  $0.8\Omega$ , the outlet readings should be in the order of  $0.4\Omega \pm 0.05\Omega$

Socket A L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

Socket B L-N reading is unacceptable- no continuity

L-CPC reading is acceptable

Conclusion Reverse polarity on P/CPC conductors or Neutral is not connected to terminal

Socket C L-N reading is unacceptable- too high (greater than  $\pm 0.05\Omega$ )

L-CPC reading is acceptable

Conclusion May indicate a loose connection on the neutral conductor

Socket D L-N reading is unacceptable

L-CPC reading is unacceptable- no continuity

Conclusion reverse polarity on P-N conductors or CPC is not connected

Socket E L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

1. a) isolate the supply and loop off

-all switched closed

-all current using equipment removed

- all fuse/M.C. B's in place\on

-all equipment vulnerable to test should be removed

-test performed at meter tails if possible

Test between live conductors (L&N)

live conductors and earth

b) this could indicate a latent defect. Each circuit should be tested individually and its insulation resistance should be greater than  $2\Omega$ .

2.a. As loop impedance tester delivers high current for a short time. It is not.

b. The loop impedance in such cases will have to be determined by a:

- measure  $Z_e$  (incoming side of device)

- measure  $R_1+R_2$  for the circuit

-then  $Z$

3. a 1.  $R_1+R_2$ , low reading ohm meter

2. insulation resistance, high reading ohm meter

3.. polarity, low reading ohm meter.

4..  $Z_s$ . Earth loop impedance tester.

5. Pfc, prospective fault current faster

b. protection against damages

joint mechanically and electrically sound

correct current rating

metal sheaths and armors earthed.

identified at termination

### Answers to self-assessment questions

1. Each circuit should be separately tested & its insulation resistance should be greater than 2 M $\Omega$ .

2. L & C.P.C.

L & N

All **or** N & C.P.C.

3.

a) . insulation resistance tester

b) 500 V dc

c) 2 M $\Omega$

To prove the correct polarity of the incoming supply

Approved voltage indicator

4.a. Test across the line and neutral, voltage should be present

b. Test across the line and earth, voltage should be present

c. Test across the neutral and earth conductors, no voltage should be present

5.a. the remote end of the circuit (point furthest away from the source of supply)

b. measured value

c. the R1+R2 value obtained using a d.c test and does not take into account the impedance (a.c resistance) of the circuit conductors. Also when taking a reading of Ze parallel paths may be present which would lead to lower reading than may otherwise be calculating using the values of Ze and R1+R2

Add notes on test result documentation.

## **CHAPTER 8: ELECTRICAL INSTALLATION MAINTENANCE**

**Unit of learning code** ENG/CU/PO/CR/01/6

**Maintain electrical installation systems**

### **8.1 Introduction to the unit of learning**

This unit covers the competencies required to carry out maintenance in electrical installation systems. The maintenance includes scheduling, inspection of electrical system, preparation of list of tools, material and equipment, system maintenance and tests.

### **8.2 Summary of Learning Outcomes**

13. Prepare maintenance schedule
14. Inspect electrical installation
15. Perform installation servicing
16. Conduct installation tests

#### **8.2.1 Learning Outcome 1: Prepare maintenance schedule**

##### **8.2.1.1 Introduction to learning outcome**

This learning outcome entails definition of maintenance, types of maintenance and procedures, Scheduling maintenance based on service manuals as well as Safety precautions to be observed.

Information sheet

##### **16.2.1.2 Performance standards**

- 16.2.1.2.1 Type of the system to be maintained is identified
- 16.2.1.2.2 The maintenance type and scope are defined
- 16.2.1.2.3 Relevant manual/service instruction is referred to
- 16.2.1.2.4 Maintenance schedule is developed in accordance with the service checklist
- 16.2.1.2.5 Relevant maintenance procedures are referred to where applicable

##### **16.2.1.3 Information sheet**

### **Prepare maintenance schedule**

Maintenance is the keeping of equipment, building and services of the plant in satisfactory repair and operating conditions.

#### **Importance of Maintenance**

- It helps the industry to maintain continuous supply of goods and services.
- Keeps equipment running (operating)
- Keeps the installation efficient

#### **Control of Maintenance Work**

In order that there should be some control over the work of maintenance, four rules should be rigidly enforced.



- All requests for maintenance work must be made preferably in writing) to one central control point (maintenance supervisor). No work should be carried out without the knowledge and approval of the maintenance supervisor. Lack strict adherence to this rule will allow a waste of skilled staff and inability to keany schedule of essential work.
- No maintenance work should be undertaken by productive staff unless the operator is seconded to the maintenance department.
- Maintenance stores must be as carefully controlled as any other of the company's stores,as the absence of a vital, part can lead to an expensive plant shut down.
- Records of work carried out, including a statement of materials required, should be kept as those assist in selling rational maintenance, replacement and depreciation policies

### **Maintenance Policies**

Within the context of maintenance, failure is defined as an inability to produce work in the appropriate manner rather than inability to produce any work. Work carried out before failure is said to be overhaul, or planned maintenance work while that carried out after failure is emergency, breakdown or recovery work.

In order to come up with rational policies there is need to collect and analyze maintenance information and data of the installations to actual times taken and work Involved when carrying out maintenance tasks and also maintenance costs. From here a choice can then be made of one or a combination of several of the following five types of maintenance policies

- Time base ('overhaul every x months')
- Wok based ('overhaul when x volume of work is produced')
- Opportunity based ('maintain when available')
- Condition based ('repair when parameter is at level p')
- Emergency based ('continue to operate until plant fails, then maintain)

The new above policy decisions as an address to the following questions

- Should maintenance consist of service or repair or both?
- What should be the timing of service or preventive work in order to involve minimum effort and cost and yet minimize the probability of breakdown resources?
- How should the repair work be conducted?
- What should be the size of maintenance teams?
- How should information be gathered to enable the above question be answered?

### **Duties of Maintenance**

The duties of maintenance can be classified into five

- Inspection
- Engineering

- Production
  - Clerical
  - Housekeeping
- 6. Inspection**

Inspection is concerned with the routine scheduled checks of the plant, building and its equipment and their conditions and to check or needed repairs. On intensively used production equipment Inspection is much more frequent and detailed than function of housing, eg production machines, motors and belting may be inspected once every week, boilers, furnaces and compression equipment every month, overhead cranes may be Inspected every 4 to 6 months.

Facilities will normally be inspected at Intervals in order to determine whether services and/or preventive maintenance is required is likely to be required in the rear future. Such work may Involve visual inspection or the measurement certain of the physical characteristics of a facility. It may Involve the whole facility or simply these parts, which are known to be liable to failure.

A report should be made after such inspection showing the condition of plants, probable reasons for their development and suggested repairs and replacement. A succession of these reports often indicates their weaknesses, which may be developing or may call for change in the inspection interval.

### **7. Engineering**

Engineering is concerned with developing changes and improvement in the plant building or the operating equipment. Recurring breakdowns in certain equipment may suggest a need for engineering by the maintenance department to determine what has caused the difficulty. After the study, maintenance would then develop some modification to prevent or at least reduce such future recurrences. In its engineering capacity, for example, maintenance might be deciding to study and develop ways of directing sufficient illumination towards a particular job through stronger fixture brazing arrangement.

### **8. Production**

This puts into operation the ideas developed by the engineering phase. It is also concerned with the performing work suggested by inspection function as well as performing other tasks such as servicing and lubricating of equipment. The implementation aspects of maintenance are the part that will the classified under this heading.

### **9. Clerical Work**

This is largely keeping records of cost, time progress on jobs etc. It is also responsible for maintaining records to the important features of the plant, equipment and other properties. These may include records of property maps, complete building drawing. Complete wiring and power line drawings, maps of underground piping of water, steam, air and similar lines, complete layout drawings of whole machinery, showing types, location and date purchased, spares parts required etc, and records of all inspection, adjustment, repairs, and replacement by department, equipment and date.

## **10. House keeping**

As the name suggest, it means taking care of the detail of the upkeep and cleaning of the buildings, equipment, tools and plant facilities.

These five functions are in essence the total duties of maintenance department.

### **Types of Maintenance**

Fundamentally there are only two types of maintenance,

- c. preventive maintenance carried out before failure
- d. breakdown maintenance carried out after failure.

### **Preventive Maintenance**

This is also called overhaul, schedule or planned maintenance.

It is generally defined orderly routine of inspecting, cleaning, testing, furnishing, adjusting, and lubricating machines. The main objective of this of program is to avoid or reduce the number of avoidable breakdowns. It is a cores mechanical tear and wear.

A good preventive maintenance program provides for plant shut down during periods of inactivity or least usage for purpose of major overhauls. This ensures continuity of operation and lessens the danger of breakdowns at peak loads.

When preparing routine inspection schedule, it must be recognized that too frequent inspection are a waste time and money and that insufficient inspection places equipment in virtual jeopardy. The frequency of inspection should depend on the equipment' contribution to profitable production, its duty cycle, age, overload etc.

In order to carry out a preventive maintenance schedule it is first necessary to produce an inventory of every item, its service, its role and method required for maintenance, the

acceptable frequency of maintenance and attention needed. The selection would be based on the consequences in failure in regard to such factors as safety, productivity and the frequency based on analysis of the past records.

This program is a corrective measure carried out on an item before it fails prevent failure. In most cases, the whole factory would be closed due to overhauls. It embraces type 1 and 3 of maintenance policies.

### **Planning a preventive maintenance program**

A) The most important phase of a preventive maintenance program is the recording and interpretation of data pertinent to each piece of equipment.

B) Maintenance personnel should be selected to the basis of qualification on the job.

C) A skilled maintenance force should be kept abreast of the latest techniques and developments in the field. Files of equipment, manufacturer's bulletins and instructions should be available to all maintenance personnel.

D) Only modern testing equipment, proper tools and latest methods should be used

(e) A carefully selected assortment of spare parts is essential to a good maintenance program and represents insurance against prolonged shutdowns. Overstocking and understocking should be avoided, since overstocking in excessive holding of funds as well as losses due to theft and obsolescence of equipment, while under stocking leads to production in jeopardy if a break down occurs.

F) Safe operation of machines and safety to personnel should be the uppermost when planning any maintenance program.

### **Objectives of Preventive Maintenance**

(a) To minimize the possibilities of anticipated production interruption by identifying any condition which might lead to it.

(b) To make plant equipment and machines available and ready for use.

(C) To reduce the work content of maintenance Jobs that would be occasioned by breakdowns

(d) to ensure safety of employees.

**Advantages (Benefits) of Preventive Maintenance**(a) A good preventive maintenance ensures cost and lessens the chances of breakdown at peak load.

(b) It enables troubles to be detected in their early stages so that corrective action can be taken before expensive damage is done

(c) The relatively high cost of down time due to equipment failure is avoided particularly in processing plants, assembly.

(e) The total cost of down time and emergency and clock repairs, which can be staggering are minimized (f) The probability of law suits that may arise from Injury to personnel and failure to meet commitments because of unavoidable break down are eliminated

(g) Leads to better spare parts control leading to minimum Inventory level and reduction in maintenance.

### **Running Maintenance**

This is part of preventive maintenance, which is done more routinely. It involves walking around and inspecting machines through observation while in operation in order to ascertain loose parts like nuts, screws, parts which by their nature require oiling, greasing, etc. and being able to take the necessary action i.e. tightening or replacing loose nuts, rivets, clips, etc., oiling, greasing, adjusting offset parts, etc.

### **Total Preventive maintenance**

This is where you have workers perform preventive maintenance activities. It's based on the machines they operate, rather than use separate personnel for the task. It is a system where employees are given greater responsibility for quality productivity and the general functioning of the system.

### **Predictive Maintenance**

It is an attempt to determine when maintenance activities. It is based on historical records, analysis of technical data to predict when a piece of equipment of a plant is about to fall. The better the predictions of failures are, the more effective preventive maintenance will be. A good preventive maintenance effort relies on complete records for each piece of equipment. Records must include information such as data of installation, operating hours, dates and types of insurance and dates and types of repairs

### **Break Down Maintenance**

It is also called corrective, emergency or recovery work. it is type 4 and 5 of maintenance policies.

This is a maintenance, which is carried out on an item, which has failed in its service. It is repair work, which is carried out through fault diagnosis, analysis and identification to

establish its position it is done by repairing the faulty part so as to restore its operation. Some of the worn out or broken parts are removed and replaced.

Repair or breakdown maintenance is remedial; taking place after an item has ceased to operate. The need to repair is not necessarily that result of inefficient or insufficient inspection, service or preventive maintenance, since in some cases the cost of repairs will be less than the accumulated cost of preventive work.

### **Causes of Breakdown**

- (a) Failure to identify and replace worn out parts
- (b) Lack of lubrication.
- (C) Inefficient cooling system
- (d) indifference towards minor faults
- (e) Use of standard or wrong fluids.

### **Disadvantages of Breakdown Maintenance**

- (a) It is expensive since It results in high cost of down time due to outage for during repair work the equipment is scheduled out of service.
- (b) It results to disruption of production and losses thereof, excessive delays or reduction in output.
- (c) Failure of machines may cause accident leading to losses and strained industrial relations.

### **Reasons why breakdowns should be avoided**

- (a) Avoid production disruptions
- (b) Prevent addition to production costs
- (c) Maintain high quality products,
- (d) Avoid missed delivery dates

### **Adverse consequences when breakdown occurs**

- (a) Production capacity is reduced and orders are delayed
- (b) There is on production but overheads continue increasing the cost per unit.
- (c) There are quality issues, product may be damaged
- (d) There are safety issues, employees or customers may be injured

## **Handling Breakdowns**

The following are some are some major approaches used to deal with breakdown maintenances.

- (a) Have standby or back up and that can be quickly pressed into service.
- (b) Have inventories, of spare parts that can be installed as needed, thereby avoiding lead times involved in ordering parts and buffer inventories, so that other equipment will be less likely to be affected by short-term downtime of a particular piece of equipment.
- (c) Have operators who are able to perform at least minor repairs on the equipment.
- (d) Repair people who are well trained and readily available to diagnose and correct problem with equipment.

## 2. **Learning Outcome 2:** Inspect electrical installation

### 1.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to inspect electrical installation in the electrical installation maintenance. It includes recording of inspection findings, Identification and documentation of maintenance tools, materials and equipment specifications of identified tools, materials and equipment against safety standards Inspection procedure

#### 8. **Performance Standard**

3. System is inspected according to the established procedure
4. Instances where the maintenance activities cannot be fully met or where there are defects outside the planned schedule are identified and recorded

### 1.2.1.3 Information Sheet

#### **Definition of terms**

**Double installation**-insulation comprising both basic (functional) insulation and supplementary (protective) insulation.

**Earth fault loop impedance**- the impedance (total opposition to flow of current) of the earth fault current loop (phase to earth loop) starting and ending at point of earth fault.

**Earthing conductor**- a protective conductor which connects a main earthing terminal of an installation to the earth electrode or to the other means of earthing.

**Electrical installation**-an assembly of associated electrical equipment such as machines, apparatus, writing materials etc. to fulfill a specific purpose within a consumer's premises.

**Final circuit**- a circuit connected directly to current-using equipment's or sockets-outlets or other outlets points.

**Flexible cords**-a flexible cable is in which the cross-sectional area of each conductor does not exceeds  $4\text{mm}^2$ .

**Isolation**-the cutting off circuit or circuits from the source of electrical energy.

**Live(alive)**-a conductor or object is said to be 'live' when a difference of potential exists between it and earth.

**Live part**-a conductor or conductive part intended to be energized in normal use, including a neutral conductor but not including a PEN conductor.

**Ohmmeter**-an indicating instrument for providing a direct reading of resistance. It's used for measuring conductor resistance and insulation resistance and resistances.

**Protective conductor**- a conductor for some measure of protection against electric shock and intended for connecting together parts of the system that are exposed and extraneous which are conductive.

**Residual current device**-a mechanical switching device or Association of devices intended to cause the opening of contacts when device residuals currents attain a given value under specified conditions.



**Socket-outlets**-a device with protected current-carrying contacts intended to be mounted in affixed position and permanently connected to the fixed wiring of the installation, to enable the connection flexible cord or flexible cables by means of a plug.

**Switch gear**-apparatus for controlling the distribution of electrical energy or for controlling or protecting electrical circuits, machines and current using appliances.

a **TN system**-is a system having one or more points of the supply sources directly earthed.

There are three systems which fall in this category:

- IV. TN-C system- neutral and protective functions combined in a single conductor through the system.
- V. TN-S system- neutral and protective conductors separated through the system.
- VI. TN-S-C system-as in (1) above but only in part of the system.

b. A **TT system**-is a system having one point of the supply directly earthed and the exposed conductive parts of installation are connected to an earth electrode which are connected to an earth electrode which is electrically independent of the electrical installation being earthed.

**Trunking (for cables)** –a fabricated casing for cables normally of rectangular cross sectional of which one side is removable or hinged to allow cable (s ) to be laid therein.

In order to make sure that this work is carried out satisfactorily the inspection and test procedure must be carefully planned and carried out and the results correctly documented.

We inspect material after the completion of work for three key reasons to ensure:

- compliance with BS 7671
- compliance with the project specification (commissioning)
- that it is safe to use.

### **Compliance with BS 7671**

BS 7671 Part 6 states that every electrical installation shall, either during construction, on completion, or both, be inspected and tested to verify, so far as is reasonably practicable, that the requirements of the Regulations have been met. In carrying out such inspection and test procedures, precautions must be taken to ensure no danger is caused to any person or livestock and to avoid damage to property and installed equipment.

BS 7671 requires that the following information be provided to the person carrying out the inspection and test of an installation:

- the maximum demand of the installation expressed in amperes per phase
- the number and type of live conductors at the point of supply

- the type of earthing arrangements used by the installation, including details of equipotential bonding arrangements
- the type and composition of circuits, including points of utilization, number and size of conductors and types of cable installed (this should also include details of the 'reference installation method' used)
- the location and description of protective devices (fuses, circuit breakers etc.)
- details of the method selected to prevent danger from shock in the event of an earth fault, e.g. earthed equipotential bonding and automatic disconnection of supply
- the presence of any sensitive electronic devices.

NB: It is important to remember that periodic inspection and testing must be carried out on installations to ensure that the installation has not deteriorated and still meets all requirements. Tests will also need to be carried out in the event of minor alterations or additions being made to existing installations.

### **Compliance with the project specification**

Once the installation is complete, we need to test it against the original specification for the work. This is in order to check that the finished installation matches the requirements laid out by the customer and is fit for use in the environment where it will be used. The tasks involved in checking compliance with project specification are as follows.

- **Pre-commissioning** – this involves a full inspection of the installation and the carrying out of all tests required before the installation is energized (continuity, polarity and insulation resistance).
- **Commissioning** – includes all tests which require power to be available, e.g., the measurement of the earth-fault loop impedance and functional testing of residual current devices (RCDs).

As commissioning involves the initial energizing of an installation, this task has to be carried out in a controlled manner with the knowledge of everyone involved. This means that all other persons working on site at the time of the energizing must be informed that power will be applied to the installation, so that all precautions can be taken to prevent danger. The commissioning process is intended to confirm that the installation complies with the designer's requirements. As such, commissioning includes the functional testing of all equipment, isolation, switching, protective devices and circuit arrangements

### **Safe to use**

The final act of the commissioning process is to ensure the safe and correct operation

of all circuits and equipment which have been installed, and that the customer's requirements have been met. This will also confirm that the installation works and, more importantly, will work under fault conditions; after all, it is under fault conditions that lives and property will be at risk. The testing of electrical installations can cause some degree of danger; it is the responsibility of the person carrying out the tests to ensure the safety of themselves and others. **Health and Safety Executive Guidance Note GS38 (Electrical test equipment for use by electricians)** details relevant safety procedures and should be observed in full.

- When using test instruments the following points will help to achieve a safe working environment. The person carrying out the tests must have a thorough understanding of the equipment being used and its rating.
- The person carrying out the tests must ensure that all safety procedures are being followed, e.g. erection of warning notices and barriers where appropriate.
- The person carrying out the tests should ensure that all instruments being used conform to the appropriate British Standard, i.e. BS EN 61010 or older instruments manufactured to BS 5458 (provided these are in good condition and have been recently calibrated).
- The person carrying out the tests should check that test leads including probes and clips are in good condition, are clean and have no cracked or broken insulation. Where appropriate the requirements of GS38 should be observed, including the use of fused test leads.

### **Purpose of a periodic inspection**

Initial inspection and testing is necessary on all newly completed installations. In addition, because all the electrical installations deteriorate due to a number of factors (such as damage, wear and tear, corrosion, excessive electrical loading, ageing and environmental influences) periodic inspection and testing must be carried out at regular intervals. The purpose of a periodic inspection and test is to:

- Confirm the safety of persons and livestock against the effects of electric shock or burns
- Ensure protection against damage to property by fire or heat arising from an installation defect
- Confirm that the installation has not been damaged and has not deteriorated to the extent that it may impair safety
- Identify any defects in the installation or non-conformity with the current edition of the Regulations that may cause danger.

The intervals between tests is determined by the following.

- Legislation requires that all installations must be maintained in a safe condition and therefore must be periodically inspected and tested. Table 8.01 details the maximum period between inspections of various types of installation.
- Licensing authorities, public bodies, insurance companies and other authorities may require public inspection and testing of electrical installations.
- The installation must comply with BS 7671.
- It is also recommended that inspection and testing should occur when there is a change of use of the premises, any alterations or additions to the original installation, any significant change in the electrical loading of the installation, and where there is reason to believe that damage may have been caused to the installation.

|                                      |          |
|--------------------------------------|----------|
| Domestic or if change of occupancy   | 10 years |
| Highway power supplies               | 6 years  |
| Churches                             | 5 years  |
| Commercial or if change of occupancy | 5 years  |
| Educational premises                 | 5 years  |
| Hotels                               | 5 years  |
| Hospitals                            | 5 years  |
| Laboratories                         | 5 years  |
| Offices                              | 5 years  |
| Public Houses                        | 5 years  |
| Shops                                | 5 years  |
| Village halls                        | 5 years  |
| Agricultural/Horticultural           | 3 years  |
| Caravans                             | 3 years  |
| Cinemas                              | 3 years  |
| Emergency Lighting                   | 3 years  |
| Industrial                           | 3 years  |
| Leisure Complexes                    | 3 years  |
| Places of public entertainment       | 3 years  |
| Theaters                             | 3 years  |
| Caravan parks                        | 1 year   |
| Fire alarms                          | 1 year   |
| Fish farms                           | 1 year   |

|   |          |
|---|----------|
| Launderettes  | 1 year   |
| Marinas   | 1 year   |
| Petrol filling stations                             | 1 year   |
| Residential accommodation or if change of occupancy | 1 year   |
| Swimming pool                                       | 1 year   |
| Construction sites                                  | 3 Months |

Table 3 Frequency of Inspection

In the case of an installation that is under constant supervision while in normal use, such as a factory or other industrial premises, periodic inspection and testing may be replaced by a system of continuous monitoring and maintenance of the installation, provided that adequate records of such maintenance are kept.

When carrying out the design of an electrical installation, and particularly when specifying the type of equipment to be installed, the designer should take into account the likely quality of the maintenance programme and the periods between periodic inspection and testing to be specified on the Electrical Installation Certificate. Both Section 6 of the Health and Safety at Work Act and the Construction (Design and Management) Regulations require information on the requirements for routine checks and periodic inspections to be provided. The advice of the Health and Safety Executive in their Memorandum of Guidance on the Electricity at Work Regulations indicates that practical experience of an installation's use may indicate the need for an adjustment to the frequency of checks and inspections, i.e. more often or less frequent depending on the likely deterioration of the installation during its normal use. This would be a matter of judgement for the duty holder.

### **Routine Checks**

Electrical installations should still be routinely checked in the intervening time between periodic inspection and testing. In domestic premises it is likely that the occupier will soon notice any damage or breakages to electrical equipment and will take steps to have repairs carried out. In commercial or industrial installations, a suitable reporting system should be available for users of the installation to report any potential danger from deteriorating or damaged equipment. In addition to this, a system of routine checks should be set up to take place between formal periodic inspections. The frequency of these checks will depend entirely on the nature of the premises and the usage of the installation. Routine checks are likely to include activities such as those listed in Table

| Activity | Check |
|----------|-------|
|----------|-------|

|                |   |
|----------------|---|
| Defect reports | Check that all reported defects have been rectified and that the installation is safe.  |
| Inspection     | <ul style="list-style-type: none"> <li>• Breakages</li> <li>• Wear or deterioration</li> <li>• Signs of overheating</li> <li>• Missing parts (screws &amp; covers)</li> <li>• Switch gear still accessible</li> <li>• Enclosure door secure</li> <li>• Labels still adequate(readable)</li> <li>• Loose fittings</li> </ul> |
| Operations     | <p>Check operations of</p> <ul style="list-style-type: none"> <li>• Switch gear (where reasonable)</li> <li>• Equipment (switching on and off)</li> <li>• RCD (using test buttons)</li> </ul>   |

Table 4: Routine Checks

The recommended period between both routine checks and formal inspections are given in Table above taken from *IEE Guidance Note 3*. The requirements for such inspections are stated in BS 7671 Chapter 62 and specify that all inspections should provide careful scrutiny of the installation without dismantling or with only partial dismantling where absolutely necessary. It is considered that the unnecessary dismantling of equipment or disconnection of cables could produce a risk of introducing faults that were not there in the first place.

In summary, the inspection should ensure that:

- the installation is safe
- the installation has not been damaged
- the installation has not deteriorated so as to impair safety
- any items that no longer comply with the Regulations or may cause danger are identified.

In practical terms the inspector is carrying out a general inspection to ensure that the installation is safe. However, the inspector is required to record and make recommendations with respect to any items that no longer comply with the current edition of the Regulations.

## Statutory and Non-Statutory Documentation

These include the following

- The Electricity Supply Regulations (1988).
- The Electricity at Work Regulations.
- BS 5266 Pt. 1 Code of Practice for emergency lighting systems (other than cinemas). Other Regulations and intervals cover testing of batteries and generators.
- BS 5839 Pt. 1 Code of Practice for the design, installation and servicing of fire alarm systems.
- Local authority conditions of license.
- SI 1995 No 1129 (clause 27) The Cinematography (Safety) Regulations.

## Inspection Process

In new installations, inspection should be carried out progressively as the installation is installed and must be done before it is energized. As far as is reasonably practicable, an initial inspection should be carried out to verify that:

- all equipment and material is of the correct type and complies with applicable British Standards or acceptable equivalents
- all parts of the fixed installation are correctly selected and erected
- no part of the fixed installation is visibly damaged or otherwise defective
- the equipment and materials used are suitable for the installation relative to the environmental conditions.

The following items must be covered in an inspection.

13. **Connection of conductors:** Every connection between conductors and equipment or other conductors must provide durable electrical continuity and adequate mechanical strength. Requirements for the enclosure and accessibility of connections must be considered.
14. **Identification of each conductor:** BS 7671 provides a schedule of colour identification of each core of a cable and its conductors. It should be checked that each core of a cable is identified as necessary. Where it is desired to indicate a phased rotation or a different function for cores of the same colour, numbered sleeves are permitted.
15. **Routing of cables:** Cable routes shall be selected with regard to the cable's suitability for the environment, i.e. ambient temperature, heat, water, foreign bodies, corrosion, impact, vibration, flora, fauna, radiation, building use and structure. Cables should be routed out of harm's way and protected against mechanical damage where necessary. Permitted cable routes are clearly defined in the *IEE On-Site Guide*; alternatively, cables should be installed in earthed

metal conduit or trunking.

16. **Current-carrying capacity:** Where practicable, the cable size should be assessed against the protective device based upon information provided by the installation designer.
17. **Verification of polarity:** It must be checked that no single pole switch or protective device is installed in any neutral conductor. A check must also be made that all protective devices and switches are connected in the line conductor only (unless the switch is a double pole device) and that the Centre contact of Edison screw lamp holders are connected to the line conductor. No switches are permitted in the Circuit Protective Conductor.
18. **Accessories and equipment:** Correct connection is to be checked. BS 7671 is a schedule of types of plug and socket outlets available, the rating and the associated British Standards. Particular attention should be paid to the requirements for a cable coupler. Lamp holders should comply with BS 5042 and be of temperature rating T2.
19. **Selection and erection to minimize the spread of fire:** A fire barrier or protection against thermal effects should be provided if necessary to meet the requirements of BS 7671. The Regulations require that each ceiling arrangement be inspected to verify that it conforms with the manufacturer's erection instructions. This may be impossible without dismantling the system and it is essential, therefore, that inspection should be carried out at the appropriate stage of the work and that this is recorded at the time for incorporation in the inspection and test documents.
20. **Protection against direct contact:** Direct contact as defined in BS 7671 is the contact of persons or livestock with live parts. Live parts are conductors or conductive parts intended to be energized in normal use including a neutral conductor but by convention not a combined Protective Earthed Neutral (PEN) conductor. Protection is provided using the following methods.
  - **Insulation.** Is the insulation damaged or has too much been removed? Although protection by insulation is the usual method there are other methods of providing basic protection.
  - **Barriers.** Where live parts are protected by barriers or enclosures, these should be checked for adequacy and security. Have all covers, lids and plates been securely fitted?
  - **Obstacles.** Protection by obstacles provides protection only against an intentional contact. If this method is used, the area shall be accessible only to skilled persons or to instructed persons under supervision. Obstacles can include a fence around a transformer sub-station and barbed wire fencing on power pylons.
  - **Out of reach.** Placing out of reach protects against direct contact. Increased distance is necessary where bulky conducting objects are likely to be handled in the vicinity
  - **Fault protection:** Fault protection as defined by BS 7671 is the contact of persons or livestock with exposed conductive parts which have



become live under fault conditions. An exposed conductive part is a conductive part of equipment which can be touched but is not live although it can become live under fault conditions. Examples of exposed conductive parts could include metal trunking, metal conduit and the metal case of an electrical appliance, e.g. a classroom overhead projector.

21. Earthing provides protection against this type of fault. We also need to check that extraneous conductive parts have been correctly bonded with protective conductors. An extraneous conductive part is a conductive part that is liable to introduce a potential, generally earth potential, and not form part of an electrical installation; examples of extraneous conductive parts are metal sink tops and metal water pipes. The purpose of the bonding is to ensure that all extraneous conductive parts which are simultaneously accessible are at the same potential. Methods of fault protection are given in BS 7671 as:

- earthed equipotential bonding and automatic disconnection of supply (most common)
- use of class II equipment
- non-conducting location
- earth-free local equipotential bonding
- electrical separation.

22. **Protective devices:** Have they been set correctly for the load? If rewirable fuses have been fitted, has the correct size of fuse wire been used? If a socket is to be provided for outdoor equipment, has a 30 mA rated RCD been fitted?

23. **Checks on documentation:** Diagrams, schedules, charts, instructions and any other information must be available if inspection and testing is to be carried out in a satisfactory manner.

24. **Checks on warning notices:** These should be fixed to equipment operating in excess of 250 volts where this voltage would not normally be expected.

### Preparing for inspection

- ✓ Where a diagram, chart or tables are not available, a degree of exploratory work may be necessary so that inspection and testing can be carried out safely and effectively. Notes should be made of any known changes in environmental conditions, building structure and alterations, which may have affected the suitability of the wiring for its present load and method of installation.

- ✓ A careful check should be made of the type of equipment on site so that the necessary precautions can be taken, where conditions permit, to disconnect or shortout electronic and other equipment which may be damaged by subsequent testing. Special care must be taken where control and protective devices contain electronic components. It is essential to determine the degree of these disconnections before planning the detailed inspection and testing.
- ✓ For safety, it is necessary to carry out a visual inspection of the installation before beginning any tests or opening enclosures, removing covers etc. So far as is reasonably practicable; the visual inspection must verify that the safety of persons, livestock and property is not endangered. A thorough visual inspection should be made of all electrical equipment that is not concealed and should include the accessible internal condition of a sample of the equipment. External conditions should be noted and damage identified or, if the degree of protection has been impaired, the matter should be recorded on the schedule of the report. This inspection should be carried out without power supplies to the installation, wherever possible, in accordance with the Electricity at Work Regulations 1989.
- ✓ The inspection should include a check on the condition of all electrical equipment and materials, taking into account any available manufacturer's information with regard to the following:
  - Safety
  - Damage
  - Age
  - Wear and Tear
  - Excessive loading (overloading)
  - External influences
  - Corrosion
  - Suitability
- ✓ The assessment of condition should take account of known changes in conditions influencing and affecting electrical safety, e.g. extraneous conductive parts, plumbing, structural changes etc. It would not be practicable to inspect all parts of an installation; thus a random sample should be inspected. This should include:
  - checking that joints and connections are properly secured and that

there is no sign of overheating

- checking switches for satisfactory electrical and mechanical conditions
- checking that protective devices are of the correct rating and type; check for accessibility and damage
- checking that conductors have suffered no mechanical damage and have no signs of overheating
- checking that the condition of enclosures remains satisfactory for the type of protection required

### **Periodic inspection and test**

BS 7671 requires that the results of any periodic inspection and test should be recorded on a periodic inspection and test report of the type illustrated in Figure 8.02. The report should include the following:

- a description of the extent of the inspection and tests and what parts of the installation were covered.
- any limitations (e.g. portable appliances not covered)
- details of any damage, deterioration or dangerous conditions which were found
- any non-compliance with BS 7671
- schedule of test results.

If any items are found which may cause immediate danger, these should be rectified immediately. If this is not possible then they must be reported to a responsible person without delay.

When inspecting older installations, which may have been installed in accordance with a previous edition of the *IEE Wiring Regulations*, provided that all items which do not conform to the present edition of BS 7671 are reported, the installation may still be acceptable, provided that no risk of shock, fire or burns exists.

|  |
|--|
| <p><b>Details of the client</b>.....</p> |
|--|

Name.....  
.....

Address:.....  
.....  
.....  
.....

**Purpose of the report.....**

**Details of the installation**

Occupier.....  
.....

Installation address (if different from).....  
.....  
.....

Description of premises: Domestic  commercial  Industrial  Other

Estimated age of the installation..... Years

Evidence of alterations or additions..... Yes/No

Date of last  
inspection.....

Records  
availability.....

**Extent and the limitations of the inspection**

Extent of the installation covered by the  
report.....  
.....  
.....  
.....

Limitations.....  
.....  
.....  
.....  
.....

This inspection has been carried out in accordance with BS 7671(IEE wiring regulations). Cables concealed within trunking and conduit cables concealed under floors buried underground installed in roof spaces or generally hidden within the fabric of the building have not been inspected.

**Next inspection**

(we recommend that this installation should be further inspected and tested after an interval of not more than..... months\years providing that any observations requiring urgent are attended without delay.

**Declaration**

Inspected and tested by

Name.....Signature.....  
.....

For and on behalf of

.....Position.....

Address.....  
.....  
.....  
.....  
.....

Date.....

Table Periodic inspection and test Report

**Statutory and Non-statutory regulations**

BS 7671 states that, as far as is reasonably practicable, an inspection shall be carried out to verify that:

- all equipment and materials used in the installation are of the correct type and comply with the appropriate British Standards or acceptable equivalent
- all parts of the installation have been correctly selected and installed
- no part of the installation is visibly damaged or otherwise defective
- the installation is suitable for the surrounding environmental conditions

Before carrying out the inspection and test of an installation, BS 7671 requires the person carrying out the work to be provided with the following information:

- the maximum demand of the installation expressed in amperes per phase after diversity has been applied
- the number and type of live conductors, both for the source of energy and for each circuit to be used within the installation (e.g., single-phase two-wire a.c. etc.)
- the type of earthing arrangements e.g., TNS, TNCS, TT etc.
- the nominal voltage ( $U_0$ )
- the prospective short-circuit current at the origin of the installation (kA)
- the earth-fault loop impedance ( $Z_e$ ) of that part of the system external to the installation
- the type and rating of the overcurrent device acting at the origin of the installation

The following information should be provided as part of the design information, which should be checked by the person carrying out the inspection. You may have to sign the electrical installation certificate to confirm that the installation has been designed, installed and tested to comply with BS 7671 with reference to:

- the type and composition of circuits, including points of utilization, number and size of conductors and type of cable used, including the installation method
- the method used to meet the requirements for fault protection
- the information to be able to identify each protective device, isolation and switching and its location.
- any circuit or equipment that may be vulnerable to test.

## Detailed inspection Requirements

### ✓ **Anticipation of Danger**

Identify any equipment that may be damaged if subjected to high-test voltages as well as computer equipment as this may include safety systems such as fire or intruder alarms that could well have electronic components susceptible to test voltages.

### ✓ **Joints and connections**

Provided the switchgear and distribution boards are accessible as required by the Regulations, then a full inspection of all conductor terminations should be carried out and any signs of overheating or loose connections should be investigated and included in the report. For lighting points and socket outlets a suitable sample should be inspected in the same way

### ✓ **Conductors**

The means of identification of every conductor, including protective conductors, should be checked and any damage or deterioration to the conductors, their insulation, protective sheathing or armour should be recorded. This inspection should include each conductor at every distribution board within the installation and a suitable sample of lighting points, switching points and socket outlets.

### ✓ **Flexible cables and cords**

Where flexible cables or cords form part of the fixed installation the inspection should include:

- examination of the cable or cord for damage or deterioration
- examination of the terminations and anchor points for any defects checking the correctness of the installation with regard to additional mechanical protection or the application of heat resistant sleeving where necessary.

### ✓ **Switches**

The *IEE Guidance Notes 3 (Inspection & Testing)*, recommends that a random sample of at least 10 per cent of all switching devices be given a thorough internal visual inspection to assess their electrical and mechanical condition. Should the inspection reveal excessive wear and tear or signs of damage due to arcing or overheating then, unless it is obvious that the problem is associated with that particular switch, the inspection should be extended to include all remaining switches associated with the installation.

### ✓ **Protection against thermal effects**

the presence of firebarriers and seals should be checked wherever reasonably practicable.

### ✓ **Protection against Direct and Indirect contact**

Separate Extra Low Voltage (SELV) is commonly used as a means of protection against both direct and indirect contact. When inspecting this type of system, the points to be checked include the use of a safety isolating transformer, the need to keep the primary and secondary circuits separate and the segregation of exposed conductive parts of the SELV system from any connection with the earthing of the primary circuit or from any other connection with earth.

✓ **Basic Protection**

Inspection of the installation should confirm that all the requirements of the Regulations have been met with regard to basic protection against direct contact with live conductors. This means checking to ensure there has been no damage or deterioration of any of the insulation within the installation, no removal of barriers or obstacles and no alterations to enclosures that may allow access to live conductors.

✓ **Fault Protection**

The method used for fault protection must be established and recorded on the Inspection Schedule. Where earthed equipotential bonding and automatic disconnection of the supply is used, a check on the condition of the main equipotential bonding conductor and the satisfactory connection of all other protective conductors with earth are essential.

✓ **Protective devices**

A check must be made that each circuit is adequately protected with the correct type, size and rating of fuse or circuit breaker. A check should also be made that each protective device is suitable for the type of circuit it is protecting and the earthing system employed, e.g. will the protective device operate within the disconnection time allowed by the Regulations and is the rating of the protective device suitable for the maximum prospective short circuit current likely to flow under fault conditions?

✓ **Enclosures and mechanical protection**

The enclosures of all electrical equipment and accessories should be inspected to ensure that they provide protection not less than IP2X or IPXXB, and where horizontal top surfaces are readily accessible they should have a degree of protection of at least IP4X. IP2X represents the average finger of 12mm diameter and 80mm in length and can be tested by a metal finger of these dimensions. IP4X provides protection against entry by strips greater than 1.0mm thickness or solid objects exceeding 1.0mm in diameter.

## **Visual Inspection**



## **Inspection Requirements**

In order to meet the requirements for the inspection process we should also include the checking of the following relevant items:

### **10. Requirements for basic and fault protection**

Separate extra low voltage (SELV) is the most common method of providing both basic and fault protection. Requirements for this type of system include:

- an isolated source of supply, e.g. a safety-isolating transformer to BS 3535 (also numbered BS EN 60742 1996)
- electrical separation, which means no electrical connection between the SELV circuit and higher voltage systems
- no connection with earth or the exposed conductive parts or protective conductors of other systems.

### **11. Specialized systems**

### **12. Prevention of mutual detrimental influence**

Account must be taken of the proximity of other electrical services of a different voltage band and of non-electrical services and influences, e.g. fire alarm and emergency lighting circuits must be separated from other cables and from each other, and Band 1 and Band 2 circuits must not be present in the same enclosure or wiring system unless they are either segregated or wired with cables suitable for the highest voltage present. Mixed categories of circuits may be contained in multicore cables, subject to certain requirements. This could also mean checking that water taps have not been fitted directly above a socket outlet. Band 1 circuits are circuits that are nominally extra-low voltage, i.e. not exceeding 50 volts a.c. or 120 volts d.c., such as telecommunications or data and signaling. Band 2 circuits are circuits that are nominally low voltage, i.e. exceeding extra-low voltage but not exceeding 1000 volts a.c. between conductors or 600 volts a.c. between conductors and earth.

### **13. Isolating and switching devices**

BS 7671 requires that effective means suitably positioned and ready to operate should be provided so that all voltage may be cut off from every installation, every circuit within the installation and from all equipment, as may be necessary to prevent or remove danger. This means that switches and/or isolating devices of the correct rating must be installed as appropriate to meet the above requirements. It may be advisable where practicable to

carry out an isolation exercise to check that effective isolation can be achieved. This should include switching off, locking-off and testing to verify that the circuit is dead and no other source of supply is present.

#### **14. Under voltage Protection**

Suitable precautions must be taken where a loss or lowering of voltage or a subsequent restoration of voltage could cause danger. The most common situation would be where a motor- driven machine stops due to a loss of voltage and unexpectedly restarts when the voltage is restored (unless precautions such as the installation of a motor starter containing a contactor are employed). Regulations require that where unexpected restarting of a motor may cause danger, the provision of a motor starter designed to prevent automatic restarting must be provided.

#### **15. Selection of equipment appropriate to external influences**

Items to be considered are ambient temperature, presence of external heat sources, presence of water, likelihood of corrosion, ingress of foreign bodies, impact, vibration, flora, fauna, radiation, building use and structure.

#### **16. Access to switchgear equipment**

The Electricity at Work Regulations 1989 and BS 7671 state that every piece of equipment that requires operation or attention must be installed so that adequate and safe means of access and working space are provided.

#### **17. Presence of Drawings, Charts and other similar information**

Checks should be made for layout drawings, distribution charts and information on circuits vulnerable to a particular test. All distribution boards should be provided with a distribution board schedule that provides information regarding types of circuits, number and size of conductors and type of wiring etc. These should be attached within or adjacent to each distribution board.

#### **18. Erection Methods**

Correct methods of installation should be checked, in particular fixings of switchgear, cables and conduit, etc. which must be adequate and suitable for the environment.

### **Inspection Checklist**

To ensure that all the requirements of the Regulations have been met, inspection

checklists should be drawn up and used as appropriate to the type of installation being inspected. Examples of suitable checklists are given in Table

|   |  |
|---|--|
| <b>Switchgear (tick if satisfactory)</b>  |  |
| Meets requirements of the appropriate BS EN standards                                   |  |
| Securely fixed and suitably labeled   |  |
| Suitable glands and gland plates used (526.1)   |  |
| Correctly earthed   |  |
| Conditions likely to be encountered taken account of, i.e. suitable for the environment |  |
| Correct IP rating   |  |
| Suitable as means of isolation  |  |
| Complies with the requirements for locations containing a bath or shower                |  |
| Need for isolation, mechanical maintenance, emergency and functional switching met      |  |
| Fireman switch provided, where required   |  |
| Switchgear suitably colored, where necessary  |  |
| All connections secure  |  |
| Cables correctly terminated and identified  |  |
| No sharp edges on cable entries, screw heads etc. which could cause damage to cables    |  |
| All covers and equipment in place   |  |
| Adequate access and working space   |  |
| <b>Wiring accessories (General requirements) (tick if satisfactory)</b>                 |  |
| All accessories comply with the appropriate British Standard                            |  |
| Boxes and other enclosures securely fastened  |  |
| Metal boxes and enclosures correctly earthed  |  |
| Flush boxes not projecting above surface of wall  |  |
| No sharp edges which could cause damage to cable insulation                             |  |

|   |  |
|---|--|
| Non-sheathed cables not exposed outside box or enclosure  |  |
| Conductors correctly identified   |  |
| Bare protective conductors sleeved green and yellow   |  |
| All terminals tight and contain all strands of stranded conductor   |  |
| Cord grips correctly used to prevent strain on terminals  |  |
| All accessories of adequate current rating  |  |
| Accessories suitable for all conditions likely to be encountered  |  |
| Complies with the requirements for locations containing a bath or shower  |  |
| Cooker control unit sited to one side and low enough for accessibility and to prevent trailing flexes across the radiant plates |  |
| Cable to cooker fixed to prevent strain on connections  |  |
| <b>Socket outlet (tick if satisfactory)</b>   |  |
| Complies with appropriate British Standard and is shuttered for household and similar installations                             |  |
| Mounting height above floor or working surface is suitable  |  |
| All sockets have correct polarity   |  |
| Sockets not installed in bath or shower zones unless they are shaver-type socket or SELV  |  |
| Sockets not within 3m of zone 1   |  |
| Sockets controlled by a switch if the supply is direct current  |  |
| Sockets protected where floor mounted   |  |
| Circuit protective conductor connected directly to the earthing terminal of the socket outlet on asheathed wiring installation  |  |
| Earthing tail provided from the earthed metal box to the earthing terminal of the socket outlet                                 |  |
| Socket outlets not used to supply a water heater with uninsulated elements  |  |
| <b>Lighting controls (tick if satisfactory)</b>   |  |
| Light switches comply with appropriate British Standard   |  |

|   |  |
|---|--|
| Switches suitably located   |  |
| Single-pole switches connected in phase conductor only                    |  |
| Correct colour-coding of conductors                                       |  |
| Correct earthing of metal switch plates                                   |  |
| Switches out of reach of a person using bath or shower                    |  |
| Switches for inductive circuits (discharge lamps) de-rated as necessary   |  |
| Switches labelled to indicate purpose where this is not obvious           |  |
| All switches of adequate current rating                                   |  |
| All controls suitable for their associated luminaire                      |  |
| <b>Lighting points (tick if satisfactory)</b>                             |  |
| All lighting points correctly terminated in suitable accessory or fitting |  |
| Ceiling roses comply with appropriate British Standard                    |  |
| No more than one flexible cord unless designed for multiple pendants      |  |
| Devices provided for supporting flex used correctly                       |  |
| All switch wires identified   |  |
| Holes in ceiling above ceiling rose made good to prevent spread of fire   |  |
| Ceiling roses not connected to supply exceeding 250 V                     |  |
| Flexible cords suitable for the mass suspended                            |  |
| Lamp holders comply with appropriate British Standard                     |  |
| <b>Conduits (General)(tick if satisfactory)</b>                           |  |
| All inspection fittings accessible  |  |
| Maximum number of cables not exceeded                                     |  |
| Solid elbows used only as permitted                                       |  |
| Conduit ends reamed and bushed  |  |
| Adequate number of boxes  |  |
| All unused entries blanked off  |  |

|   |  |
|---|--|
| Lowest point provided with drainage holes where required                            |  |
| Correct radius of bends to prevent damage to cables                                 |  |
| Joints and scratches in metal conduit protected by painting                         |  |
| Securely fixed covers in place adequate protection against mechanical damage        |  |
| <b>Rigid metal conduit (tick if satisfactory)</b>                                   |  |
| Complies to the appropriate British standard  |  |
| Connected to the main earth terminal  |  |
| Line and neutral cables contained within the same conduit                           |  |
| Conduits suitable for damp and corrosive situations                                 |  |
| Maximum span between buildings without intermediate support                         |  |
| <b>Rigid non-metallic conduits (tick if satisfactory)</b>                           |  |
| Complies with the appropriate British Standard                                      |  |
| Ambient and working temperature within permitted limits                             |  |
| Provision for expansion and contraction   |  |
| Boxes and fixings suitable for mass of luminaire suspended at expected temperatures |  |
| <b>Flexible metal conduits (tick if appropriate)</b>                                |  |
| Complies with the appropriate British Standard                                      |  |
| Separate protective conductor provided  |  |
| Adequately supported and terminated   |  |
| <b>Trunking (tick if appropriate)</b>   |  |
| Complies to the appropriate British Standard  |  |
| Securely fixed and adequately protected against mechanical damage                   |  |
| Selected, erected and rooted so that no damage is caused by ingress of water        |  |
| Proximity to non-electrical services  |  |
| Internal sealing provided where necessary   |  |
| Hole surrounding trunking made good   |  |

|  |  |
|--|--|
| Band 1 circuits partitioned from band 2 circuits, or insulated for the highest voltage present |  |
| Circuits partitioned from band one circuits, or wired in mineral-insulated and sheathed cable  |  |
| Common outlets for band 1 and band 2 circuits provided with screens, barriers or partitions    |  |
| Cables supported for vertical runs   |  |
| <b>Metal Trunking (Trunking tick if satisfactory)</b>  |  |
| Line and neutral cables contained in the same metal trunking                                   |  |
| Protected against damp corrosion   |  |
| Earthed  |  |
| Joints mechanically sound, and of adequate earth continuity with links fitted                  |  |

Table 5.

### Inspection checklist

#### 7.2.1.4 Learning Activities

##### 7.2.1.4.1 Practical activities

An electrical contractor has completed installation for a small private caravan site. The site comprises of 15 dedicated caravan pitches, a toilet and shower block and a combined reception office and a small shop. The building on the site form part of a TN-C-S system supplied at 400\230v with a Ze of 0.2  $\Omega$ . At the origin of the installation the distribution circuit to the pitch supplies is separated to form a TT system, having an earth electrode resistance of 48 $\Omega$  and a 500mA RCD as the main isolator. The installation is to be inspected and tested before being placed into services.

- d) List all the certification document which particularly relates to the inspection and test for the entire site
- e) State the
  - iv) Statutory document which particularly relates to the inspection and testing process
  - v) Title given to the person carrying out the inspection and test as stated in b(1) above
  - vi) Status of a person carrying out the inspection and test
- f) List three items of information that should be available to the person carrying out the inspection and test

### Self-assessment

11. There are various documents that are relevant to the Inspection and Testing of an installation. State
  - a) one statutory item of documentation
  - b) two non-statutory items of documentation.
12. List the first three tests that should be carried out during a *periodic* inspection and test of an installation
13. State THREE circumstances that would require a periodic inspection and test to be carried out on an installation.
14. The electrical installation in a small food retail outlet is scheduled for a periodic inspection and test for local authority licensing.
  - a) Describe how the safe isolation of the single-phase distribution board located in the office area is to be carried out.
  - b) Explain why the sequence of testing for this periodic inspection may be different to that given in BS 7671 for initial verification.
15. A periodic inspection is to be undertaken in a large community Centre which is open to the public.
  - v) State what must be agreed with the client and recorded before any work is undertaken.
  - vi) State who else must be considered by the inspector in respect to their safety whilst carrying out this work.
  - vii) State three actions the inspector must take to ensure the safety of people using the building during the inspection and testing process.
  - viii) List three documents that should be available to the inspector in order for the inspection and testing to be carried out safely.
16. One of the competence requirements identified in guidance note 3 (GN3), is for the inspector to have sound knowledge and experience relevant to the nature of the installation being inspected and tested. List three other competence requirements given in GN3
17. List three items related to the nature of the supply which should be made available to an inspector
18. Explain briefly inspection and testing of a new electrical installation should be carried out
19. State three items that would need to be inspected during the first fix construction of a PVC conduit installation for lighting in a general purpose workshop
20. State the most appropriate human sense used to identify
  - d) Terminals are correctly tightened
  - e) Terminals are correctly identified
  - f) That a motor has been overloaded

### Model Answers to self-assessment

- a) For the TNC-S supplied circuits electrical installation certificate, schedule of inspection, schedule of test results.  
For the TT supplied caravan pitches, Electrical installation certificate.



Schedule of inspection, schedule of test results.

b)

- v) Electricity at work regulation
  - vi) Duty holder
  - vii) The duty holder will be competent person
  - viii) Ensuring no danger to person's livestock property to compare the test results with design criteria to form a view on the state of installation and advice on remedial works to immediately inform the installation owner (and other interested partner's) if dangerous situation exists.
- c. Nominal voltage frequency Ze.

2. Electricity at Work act '89 **or** Health & Safety at Work Act '74

BS 767

On

Site Guide  
Guidance Notes etc.

2 Continuity of CPC

Polarity  
Earth loop impedance

3 End of license (Public buildings)

End of insurance period  
Change of ownership  
End of recommended period since last test

4 Safe Isolation Procedure

- a) Identify the equipment to be worked on and its means of isolation.
- b) Unplug the equipment if possible.
- c) Isolate and lock off.
- d) Prove the voltage tester.
- e) Prove the equipment is dead (phase to neutral and phase to earth).
- f) Re-prove the voltage tester.
- g) Attach temporary earth leads if necessary.
- h) Post caution notices.
- i) Consider the need for additional precautions.

5 Further safety procedures may be set in place. Permits to work come into their own when dealing with an electrical piece of equipment or installation and are part of an overall strategy for safety, called a 'safe system of work'.

- b) The tests need not be carried out in the order as for the initial verification procedure as the installation will have been in operation for some time.

The same range and level of testing as for initial testing is not necessarily required, or indeed possible. Installations that have been previously tested and for which there are comprehensive records of test results may not need the same degree of testing as installations for which no such records exist.

The person carrying out the testing should decide which of the above tests are appropriate by using their experience and knowledge of the installation

being inspected and tested and by consulting any available records.

The inspector will need to set a sample size for testing. Where a sample test indicates results significantly different to those previously recorded, further investigation is necessary. Also, if during the course of testing a sample, significant errors were found that would suggest that the same problems may exist in untested items, then the inspector has to take appropriate action.

This action needs to be either increasing the sampling or referring back to the client; it may be that the inspector recommends that 100 per cent testing is carried out in that area.

- 8
- i) Prior to carrying out the inspection, the inspector will need to meet with the client or the client's representative to outline the scope and nature of the work required and to highlight likely items that require isolation. That is the degree of disconnection which will be acceptable before planning the detailed inspection and testing must be agreed. Also, the scope, that is, the extent and limitations of the periodic inspection must be agreed, that is, what is to be covered and what is not covered.
    - iv) As required by law, it is the inspector's duty to ensure the safety of himself or herself and that of others during the test procedure.
    - v)
      - i) The installation must be isolated before disconnecting protective conductors.
      - ii) Ensure people cannot access exposed/extraneous conductive parts when using test voltages greater than 50V.
      - iii) Use correct test equipment to ensure the test limits are met. For example, limitation of earth fault loop impedance test current to 40ms.
    - iv) - Design documentation listing type of supply, earthing arrangements, etc.
      - Diagrams.
      - Charts or tables identifying isolation and protection devices.
      - Previous periodic inspection and test results.
  - c) - Correctly identified breakers (circuit details)
    - Correct type and rating of main switch and breakers (check ratings against conductor sizes)
    - Signs of overheating, thermal damage, etc. (no other visible damage).
    - Single pole devices in line conductor
    - Manual operation of breakers
    - Breakers firmly fixed
    - Barrier for IP 2X protection over the busbar
    - BS or BS EN markings (or other recognized standard)
    - All connections secure, correctly terminated and mechanically sound.

9 Knowledge of relevant regulations

- Fully versed in inspection and test procedures
- Knowledge and experience to use suitable test equipment
- 10 Nominal voltage
  - Frequency
  - Ze
- 11 Progressively throughout the different stages of the erection and before being put into service
- 12 Capacity conduits cables to be installed later
  - Mechanical protection of conduits where damage
- Correct mechanical support of conduits to bear loading by cable
- Single pole switch
- 13 Smell
  - Touch
  - Sight

### **Learning Outcome 3: Perform installation servicing Presence of storage batteries**

Since an emergency occurring in a building may cause the mains supply to fail, the emergency lighting should be supplied from a source which is independent from the main supply. A battery's ability to provide its output instantly makes it a very satisfactory source of standby power. In most commercial, industrial and public service buildings housing essential services, the alternative power supply would be from batteries. The emergency lighting supply must have an adequate capacity and rating for the specified duration of time (IEE Regulation 313.2). BS 5266 and BS EN 1838 states that after a battery is discharged by being called into operation for its specified duration of time, it should be capable of once again operating for the specified duration of time following a recharge period of no longer than 24 hours. The duration of time for which the emergency lighting should operate will be specified by a statutory authority but is normally 1–3 hours. The British Standard states that escape lighting should operate for a minimum of 1 hour.

The batteries used for the emergency supply should be suitable for this purpose. The British Standard recommends that the full load should be carried by the emergency supply for at least 1 hour in every 6 months. After testing, the emergency system must be carefully restored to its normal operative state. A record should be kept of each item of equipment and the date of each test by a qualified or responsible person. It may be necessary to produce the record as evidence of satisfactory compliance with statutory legislation to a duly authorized person. Self-contained units are suitable for small installations of up to about 12 units. The batteries contained within these units should be replaced about every 5 years, or as recommended by the manufacturer. Storage batteries are secondary cells. A secondary cell has the advantage of being rechargeable. If the cell is connected to a suitable electrical supply, electrical energy is stored on the plates of the cell as chemical energy. When the cell is connected to a load, the chemical energy is converted to electrical energy.

A lead-acid cell is a secondary cell. Each cell delivers about 2 V, and when six cells are connected in series a 12 V battery is formed. A lead-acid battery is constructed of lead plates which are deeply ribbed to give maximum surface area for a given weight of plate. The plates are assembled in groups, with insulating separators between them. The separators are made of a porous insulating material, such as wood or ebonite, and the whole assembly is immersed in a dilute sulphuric acid solution in a plastic container. The capacity of a cell to store charge is a measure of the total quantity of electricity which it can cause to be displaced around a circuit after being fully charged. It is stated in ampere-hours, abbreviation Ah, and calculated at the 10-hour rate which is the steady load current which would completely discharge the battery in 10 hours. Therefore, a 50 Ah battery will provide a steady current of 5A for 10 hours.

### **Maintenance of lead-acid batteries**

- The plates of the battery must always be covered by dilute sulphuric acid. If the level falls, it must be topped up with distilled water.
- Battery connections must always be tight and should be covered with a thin coat of petroleum jelly.
- The specific gravity or relative density of the battery gives the best indication of its state of charge. A discharged cell will have a specific gravity of 1.150, which will rise to 1.280 when fully charged. The specific gravity of a cell can be tested with a hydrometer.
- To maintain a battery in good condition it should be regularly trickle-charged. A rapid charge or discharge encourages the plates to buckle, and may cause permanent damage. Most batteries used for standby supplies today are equipped with constant voltage chargers. The principle of these is that after the battery has been discharged by it being called into operation, the terminal voltage will be depressed and this enables a relatively large current (1–5A) to flow from the charger to recharge the battery. As the battery becomes more fully charged its voltage will rise until it reaches the constant voltage level where the current output from the charger will drop until it is just sufficient to balance the battery's internal losses. The main advantage of this system is that the battery controls the amount of charge it receives and is therefore automatically maintained in a fully charged condition without human intervention and without the use of any elaborate control circuitry.
- The room used to charge the emergency supply storage batteries must be well ventilated because the charged cell gives off hydrogen and oxygen, which are explosive in the correct proportions

Having successfully diagnosed the electrical fault and carried out the necessary repairs or having completed any work in the electro technical industry, we come to the final practical task, leaving the site in a safe and clean condition and the removal of any waste material. This is an important part of company's 'good customer relationships' with the client and having a good attitude to health and safety, working conscientiously and neatly, keeping passageways clear and regularly tidying up the workplace is the sign of a good and competent craftsman. But what do you do with the rubbish that the working environment produces? Well:

- All the packaging material for electrical fittings and accessories usually goes into either your employer's skip or the skip on site designated for that purpose.
- All the off-cuts of conduit, trunking and tray also go into the skip.
- In fact, most of the general site debris will probably go into the skip and the waste disposal company will take the skip contents to a designated local council landfill area for safe disposal. The part coils of cable and any other reusable leftover lengths of conduit, trunking or tray will be taken back to your employer's stores area. Here it will be stored for future use and the returned quantities deducted from the costs allocated to that job.
- What goes into the skip for normal disposal into a landfill site is usually a matter of common sense. However, some substances require special consideration and disposal. We will now look at asbestos and large quantities of used fluorescent tubes which are classified as 'special waste' or 'hazardous waste'.

Asbestos is a mineral found in many rock formations. When separated it becomes a fluffy, fibrous material with many uses. In the buildings where it was installed some 40 years ago, when left alone, it does not represent a health hazard, but those buildings are increasingly becoming in need of renovation and modernization. It is in the dismantling and breaking up of these asbestos materials that the health hazard increases. Asbestos is a serious health hazard if the dust is inhaled. The tiny asbestos particles find their way into delicate lung tissue and remain embedded for life, causing constant irritation and eventually, serious lung disease. If asbestos is present in situations or buildings where you are expected to work, it should be removed by a specialist contractor before your work commences. Specialist contractors, who will wear fully protective suits and use breathing apparatus, are the only people who can safely and responsibly carry out the removal of asbestos. They will wrap the asbestos in thick plastic bags and store them temporarily in a covered and locked skip. This material is then disposed of in a special landfill site with other toxic industrial waste materials and the site monitored by the local authority for the foreseeable future.

Removing the old fluorescent fittings hanging on chains or fixed to beams and installing a suspended ceiling and an appropriate number of recessed modular fluorescent fittings. These fittings are made of sheet steel, a couple of plastic lamp holders, a little cable, a starter and ballast. All of these materials can go into the ordinary skip. However, the fluorescent tubes contain a little mercury and fluorescent powder with toxic elements, which cannot be disposed of in the normal land fill sites. Hazardous Waste Regulations were introduced in July 2005 and under these regulations lamps and tubes are classified as hazardous. The environmentally responsible way to dispose of fluorescent lamps and tubes is to recycle them. The process usually goes like this:

- Your employer arranges for the local electrical wholesaler to deliver a plastic waste container of an appropriate size for the job.
- Expired lamps and tubes are placed whole into the container, which often has a grating inside to prevent the tubes breaking when being transported.

- When the container is full of used lamps and tubes, you telephone the electrical wholesaler and ask them to pick up the filled container and deliver it to one of the specialist recycling centers.
- Your electrical company will receive a 'Duty of Care Note' and full recycling documents which ought to be filled safely as proof that the hazardous waste was recycled safely.
- The charge is approximately 50p for each 1800mm tube and this cost is passed on to the customer through the final account.

NB:

- Clean up before you leave the job.
- Put waste in the correct skip.
- Recycle used lamps and tubes.
- Get rid of all waste responsibly.

#### Learning outcome 4: Conduct installation tests

Before a completed installation may be connected to the supply a number of tests are required to indicate the general condition of the installation, both with regard to the insulation resistance of the conductors and other current-carrying parts and with regard to the conductance of the earthing system. The tests which are to be made are not a complete guarantee of the quality of the installation for all time, and regular testing is necessary in order that it may be maintained in a proper condition throughout its life.

#### Insulation resistance.

This is the resistance in ohms between the live parts of the installation and earth, measured through insulating covering of the conductors, etc. In the case of metal-covered wiring or conduit wiring, the term 'earth' means in practice the metallic covering or conduit which itself is connected directly to earth. Additionally, the insulation resistance is measured between lines, that is, between the opposite poles of the installation with lamps or other apparatus disconnected and switches on.

The difference between insulation and conductor resistance is shown in the sketches (Figs. 93 and 94). In measuring the resistance of a

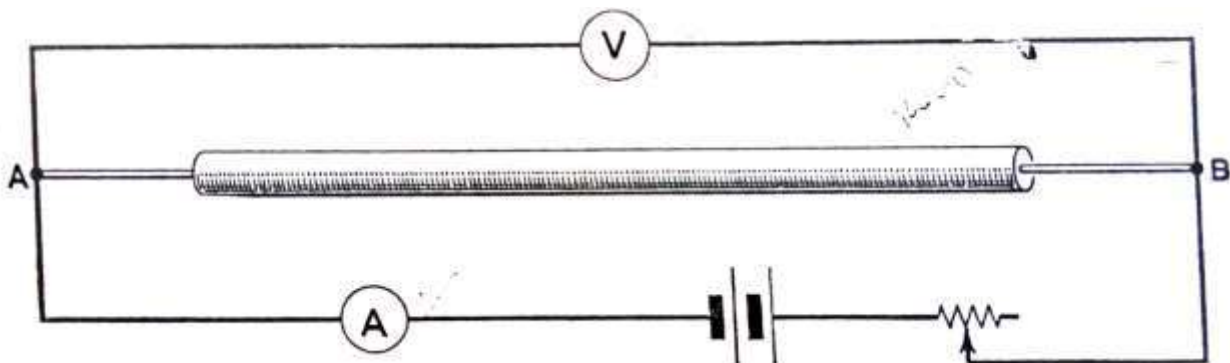


Fig. 1 Measuring conductor resistance

conductor AB, the resistance is measured along the wire from end to end, and increase of conductor length means increase of resistance. In measuring the insulation resistance of the conductor, the measurement is made from the conductor outwards.

The formula for conductor resistance is  $R = \rho l / a$  where  $l$  is the length of the conductor,  $a$  is the cross-sectional area, and  $\rho$  is the resistivity of the conductor material. Using a similar formula for insulation (it is sufficiently true for the purposes of this argument),  $R' = \rho' l / a'$  the thickness of the insulation,  $a'$  is proportional to the length of the wire, and  $\rho'$  is the resistivity of the insulating material.

Conduit or metallic covering

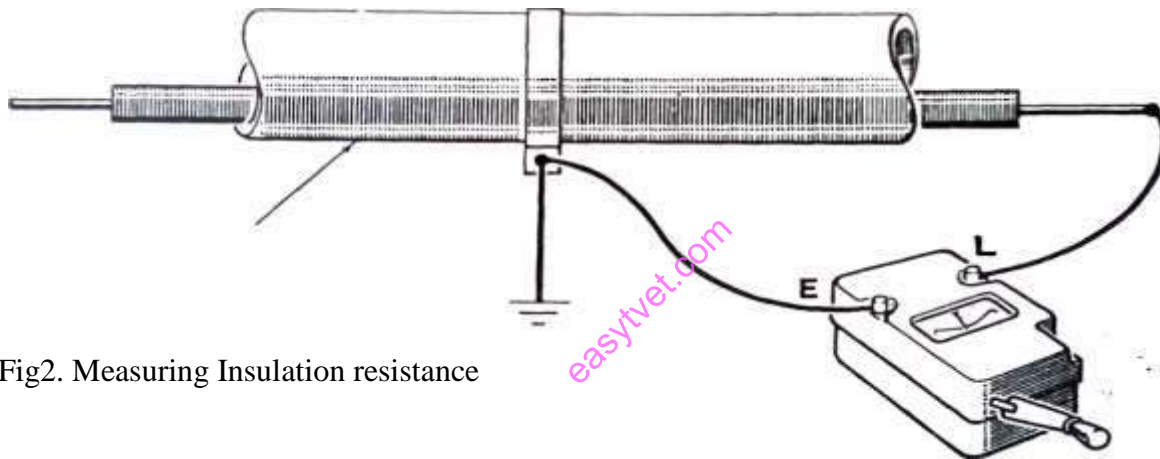


Fig2. Measuring Insulation resistance

Thus, if an insulated wire is increased in length, its conductor resistance increases while its insulation resistance decreases. Therefore, the longer the conductor the less will be its insulation resistance.

### **Inspection of installations.**

During the fitting of the various parts of an installation some form of inspection by the electrical contractor or his staff is both desirable and necessary, Small faults could be brought to light and corrected thus preventing waste of time during the final testing session. Alternatively, a careful inspection should be made immediately prior to the testing.

### **Regulations. I.EE.**

Regulations EI to E 14 deal with the testing and inspection of installations. These regulations are discussed below, and methods of complying with them are described in detail.

**Insulation resistance tests**, Regulations E 6 and E 9. The various tests of an installation which follow are to be made before the installation is connected to the supply, For the insulation

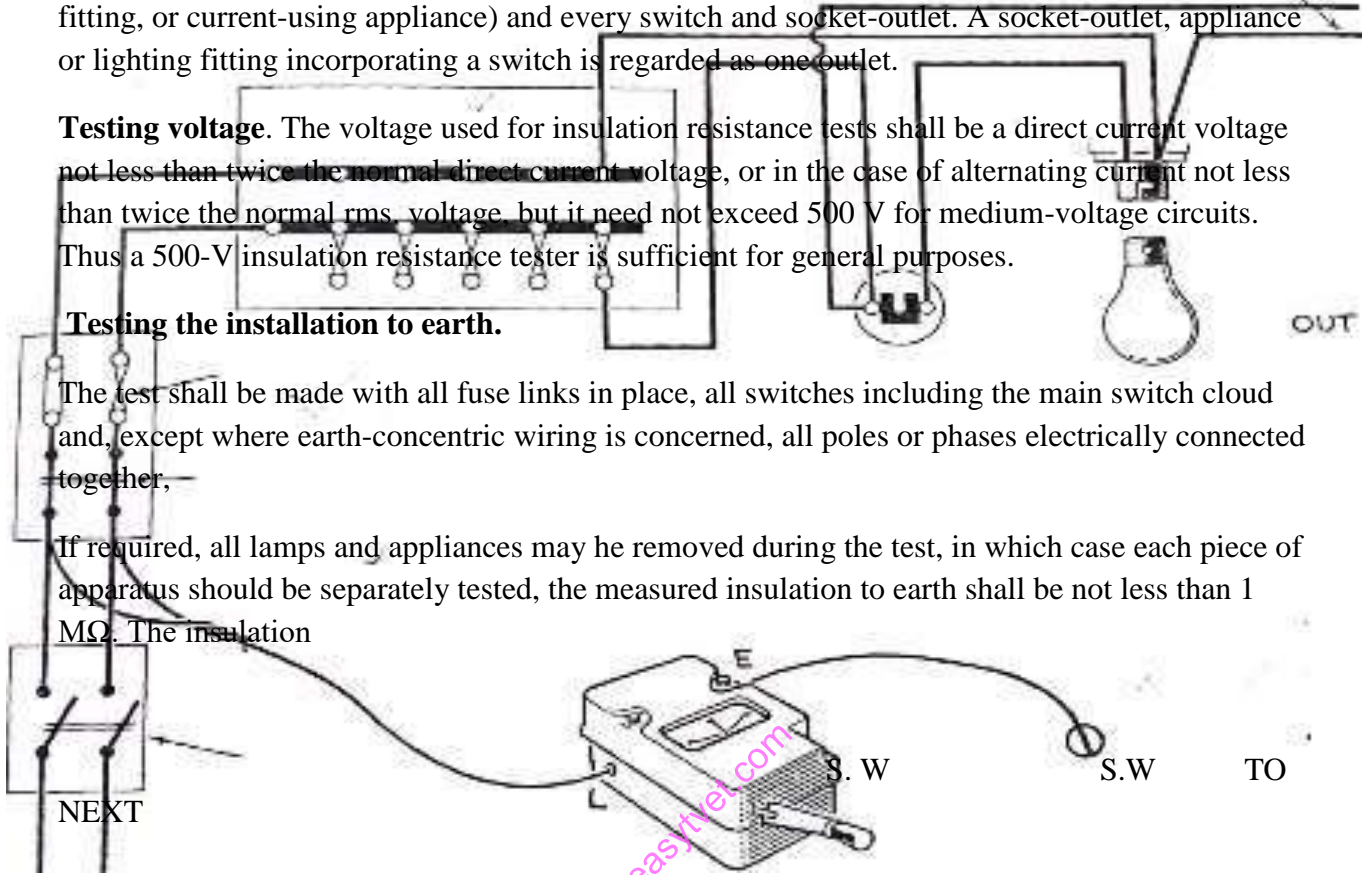
resistance tests large installations may be divided into groups of not less than 50 outlets. For this purpose, the expression outlet includes every point (position for attachment of lamp, lighting fitting, or current-using appliance) and every switch and socket-outlet. A socket-outlet, appliance or lighting fitting incorporating a switch is regarded as one outlet.

**Testing voltage.** The voltage used for insulation resistance tests shall be a direct current voltage not less than twice the normal direct current voltage, or in the case of alternating current not less than twice the normal rms. voltage, but it need not exceed 500 V for medium-voltage circuits. Thus a 500-V insulation resistance tester is sufficient for general purposes.

**Testing the installation to earth.**

The test shall be made with all fuse links in place, all switches including the main switch closed and, except where earth-concentric wiring is concerned, all poles or phases electrically connected together,

If required, all lamps and appliances may be removed during the test, in which case each piece of apparatus should be separately tested, the measured insulation to earth shall be not less than 1 MΩ. The insulation



POINT

LAMPS

FUSES IN

SWITCHES CLOSED

SWITCH CLOSED

COMPANY'S

**MAIN SWITCH**



OFF

EARTH TERMINAL

Fig 3 Testing insulation resistance of completed installation

resistance of each piece of apparatus measured separately shall be not less than 0.5 M $\Omega$  to earth (between live parts and frame), and 0.5 M $\Omega$  between poles or phases. The sketch (Fig.) shows the connections for testing the insulation resistance to earth of a completed 2-wire installation with lamps and other apparatus disconnected. The wires of both poles of the supply to the main switch are twisted together and connected to the 'line' terminal of the ohmmeter. The 'earth' terminal of the ohmmeter is connected to the consumer's earthing terminal. The three terminals of 2-way switches should temporarily be connected together.

### **Testing between conductors.**

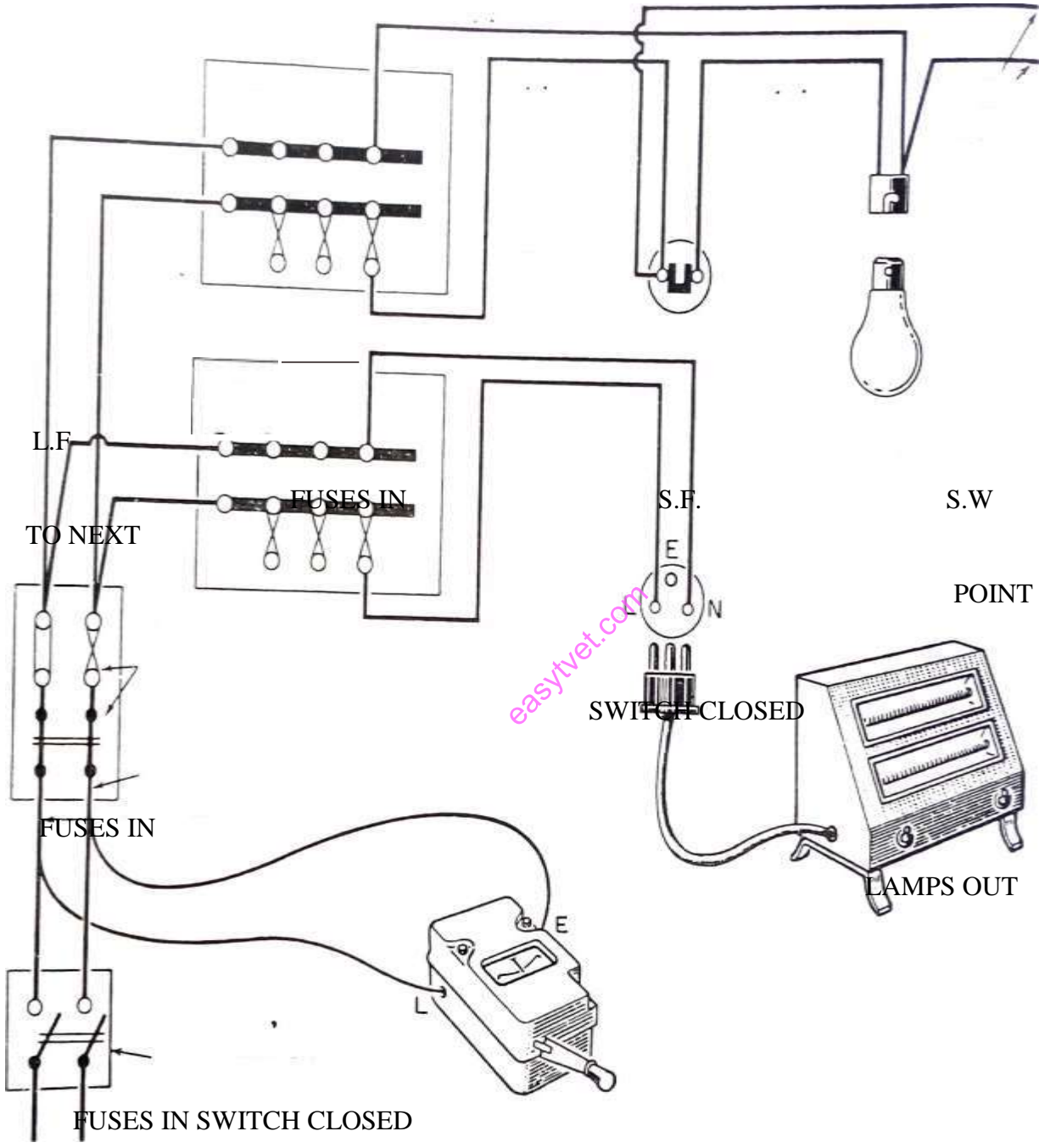
This test is made between all the conductors connected to any one pole or phase of the supply, and all conductors connected to any other pole or phase of the supply. The insulation resistance is to be not less than 1 M $\Omega$ .

All lamps should be removed, all current-using apparatus disconnected and all local switches controlling lamps or apparatus closed. When the removal of lamps and apparatus is not practicable, all local switches should be open. The test does not apply to earthed concentric wiring systems. Figure 97 gives the connections for the test of a 2-wire installation. Only one test is required in this case.

### **Electrical installation work**

For 3 and 4-wire installations more than one between phases test is necessary. A 3-wire direct current installation will require three tests:

1. between positive line and neutral,
2. between negative line and neutral,
3. between positive and negative lines



PHASE OR OUTER  
 NEUTRAL

DISCONNECTED

COMPANY'S MAIN SWITCH OFF

Figure 4.

*easyvet.com*

A 3-wire 3-phase installation will also require three tests:

1. between lines R and Y,
2. between lines R and B,
3. between lines Y and B.

A 3-phase 4-wire installation will require six tests:

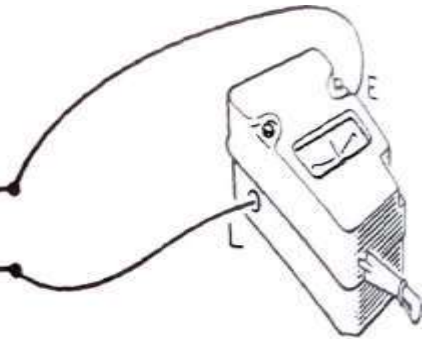
1. three separate tests between pairs of lines, R-Y, R-B, and Y-B.
2. three separate tests, R-neutral, B-neutral and Y-neutral.

Figures 98 (a) to (d) show the test connections in a simplified form.

NEUTRAL

LINE

(a)



y WIRE

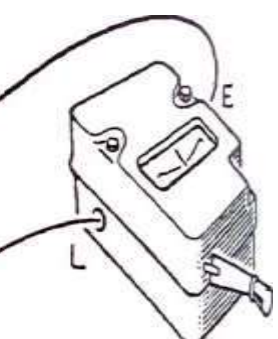
+ VE

3-WI  
d.c.x NEUTRAL

- VE

(b)

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3- PF

3- WI

# EARTH-CONTINUITY CONDUCTOR



R

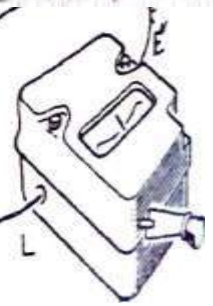
5 -

Y

6 -

B

NEUTRA



(d)

Fig 5 (a) to (d) Simplified diagrams of tests between conductors

Verification of polarity of single-pole switches, etc. . Regulation E requires that it shall be ensured that all fuses and single-pole control devices are connected in the live conductor only; that the outer contact of Centre-contact bayonet and Edison-type screw lamp holders are connected to the neutral or earthed conductor; and that plugs and socket outlets have been correctly wired.

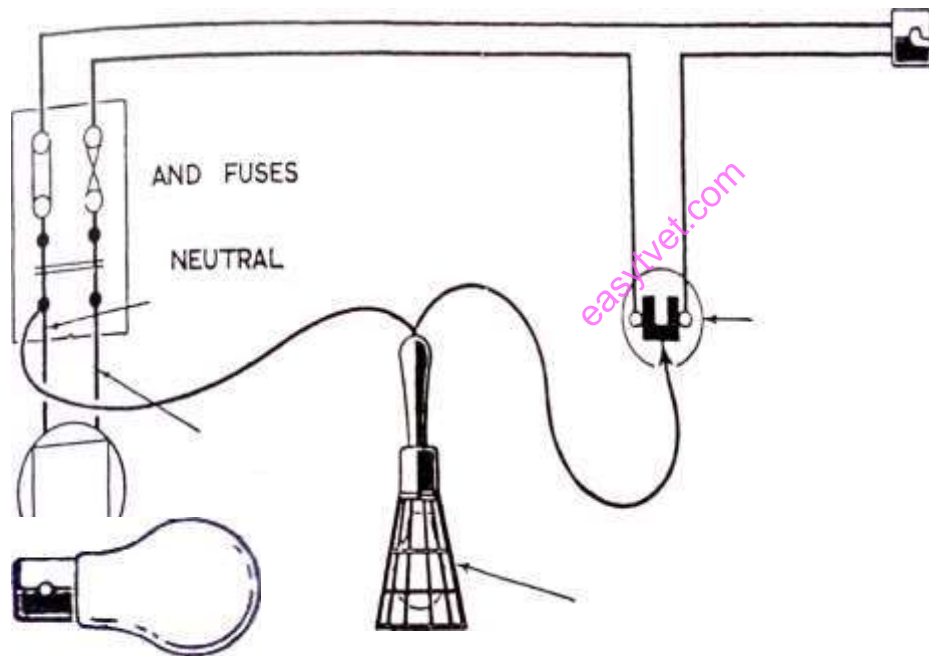
On p. 12 it was noted that by I.E.E. Regulation all single-pole or linked switches were to be fitted in the outer or phase conductor. If the proper colored cable is used throughout the installation, i.e., in a 2-wire installation, red for switch feeds and switch wires and black for light feeds, no confusion should arise.

Testing for polarity with circuit alive. The simplest way to test is with the circuit alive, switched on the main switch, All single-pole switches would be ON, their covers removed, all lamps should be out, and other Neutral should be disconnected, If the single-pole switches are in the Correct conductor, the phase or outer conductor, they will be alive. A portable lamp with a pair of long insulated leads is used. The leads Should terminate in insulated test prods in the interests of safety. The end of one prod is connected to the known earthed conductor at the main switch, and the other prod is touched to the single-pole switch terminals. The test lamp should light. Should the switch be in the wrong or earthed conductor, the test lamp will not light as the switch will be at earth potential. This procedure is repeated at all the switches in turn. In the case of 2-way switches, the three terminals of the switches should be temporarily connected together for the test. In a large installation the work can be sectionalized by checking the polarity of the busbars at the distribution boards and working from these positions instead of running the test lead back to the main switch. The test should be extended to verify that the three-pin socket outlets are properly connected, that is, with the terminal marked 'L' connected to the outer or phase conductor,

In testing screw-type lamp holders to ensure that the outer contact is earthed, one prod should be touched to the live side of the main switch and the other prod to the outer contact of the lamp holder, when the test lamp should light. It must be remembered that the test is being made on a live circuit, and care must be taken, otherwise unpleasant or dangerous shocks may be sustained; Figures above illustrate the tests.

Testing for polarity with circuit dead. Testing instruments are available by which the polarity of the circuit switches can be tested before the installation is connected to the supply. In its simplest form the instrument consists of a direct-reading ohmmeter and a small dry battery contained in a

small case, with two terminals to which a pair of test leads with or without testing spikes may be connected. Figure 103 illustrates the test. The main switch and fuses are out, lamps and other apparatus are out or disconnected, and the single-pole switches are on. One lead of the polarity tester is connected to the phase or outer conductor at the outgoing side of the main fuses. The other lead is touched to the terminals of the single-pole switches in turn. Provided the polarity is correct, the instrument reading will be less than 12 normally, since the instrument is measuring the resistance of the circuit wiring from the main fuse to the switch being tested. If the single-pole switch is in the



CONSUMERS MAIN SWITCH

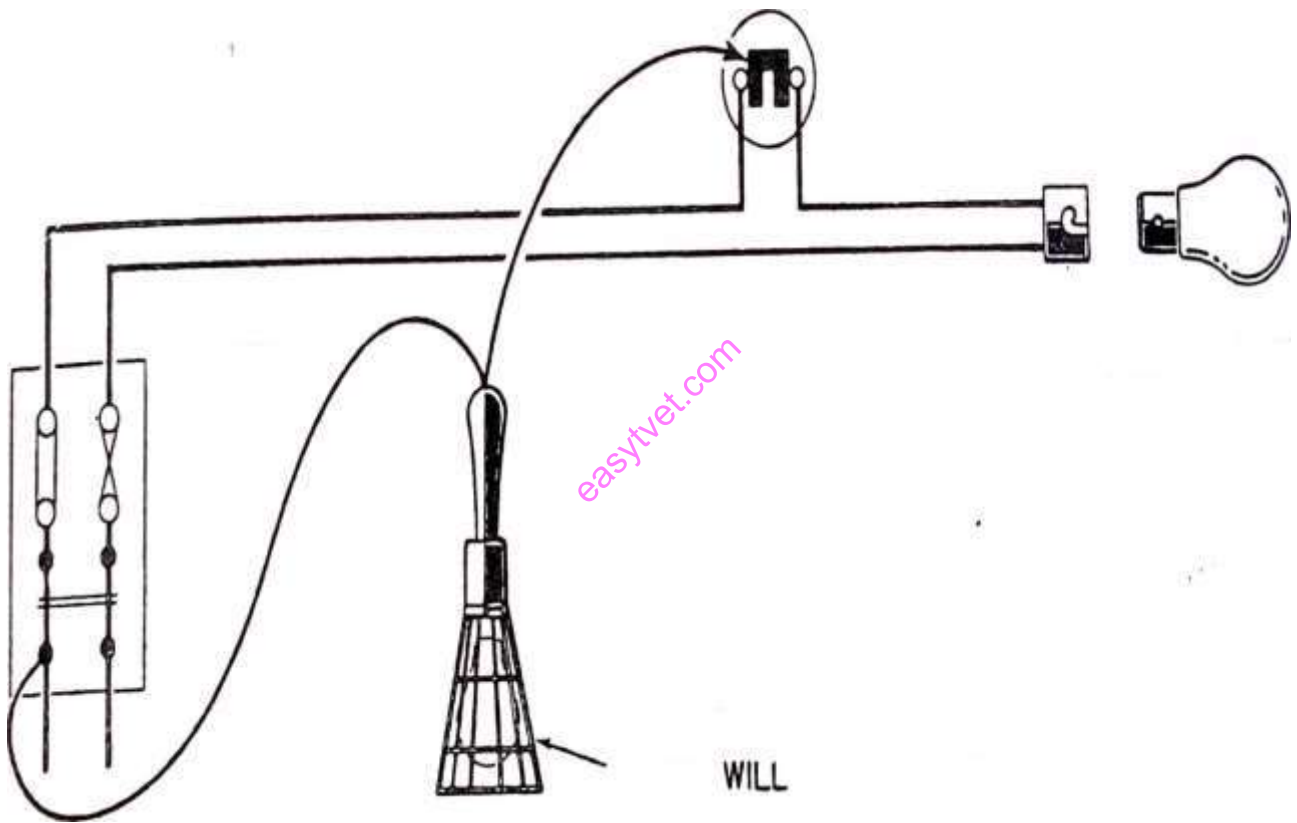
LAMPS OUT

CONDUCTOR

SWITCHES ON

PHASE OR OUTERLAMP WILL LIGHT  
CONDUCTOR  
METER

Fig5 Testing for polarity of switch, correct



NEUTRAL

PHASE OR OUTER

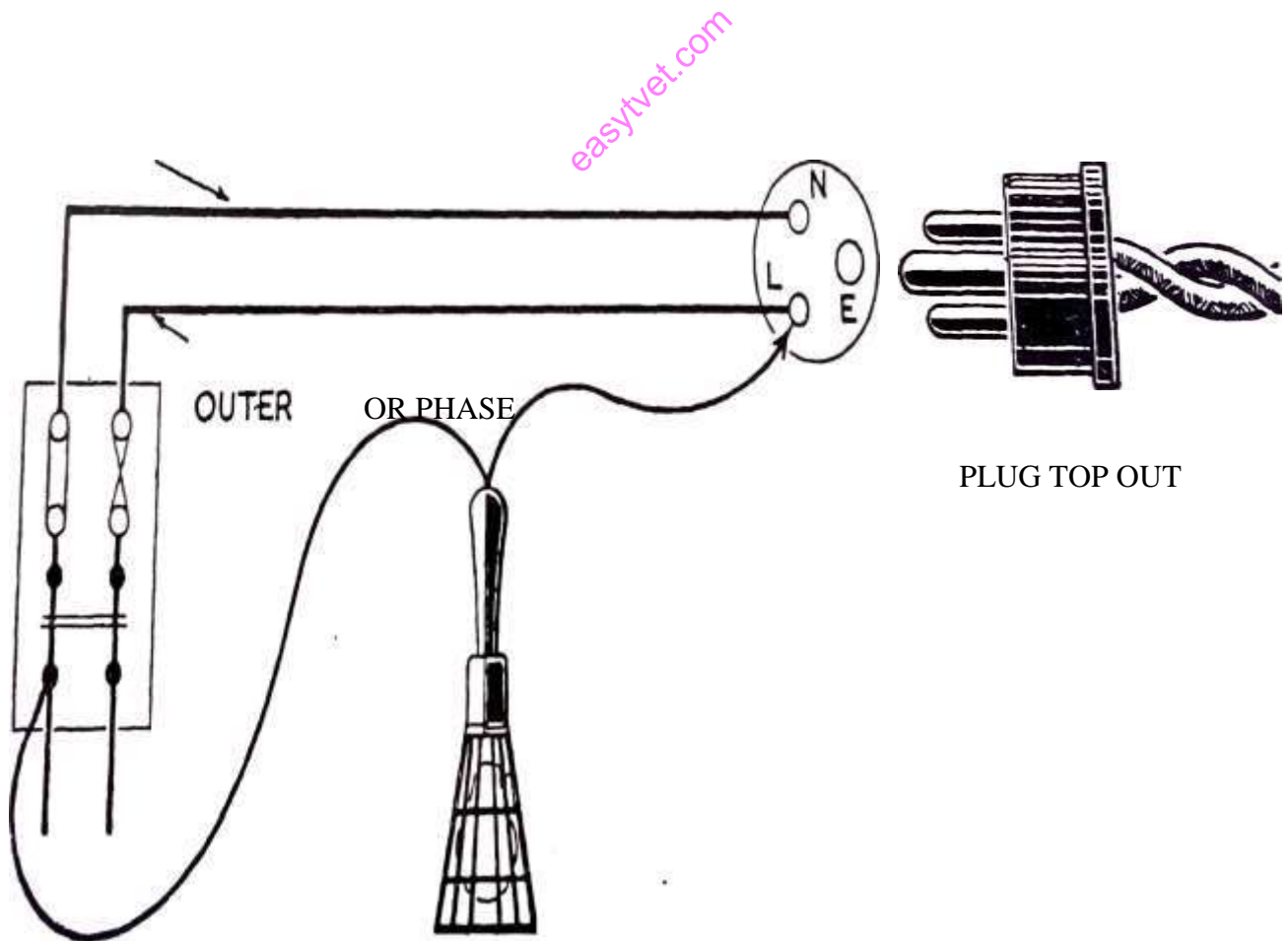
OUT

LAMPS

LAMPS

WILL NOT LIGHT

Fig 6 Testing for polarity of switch, incorrect

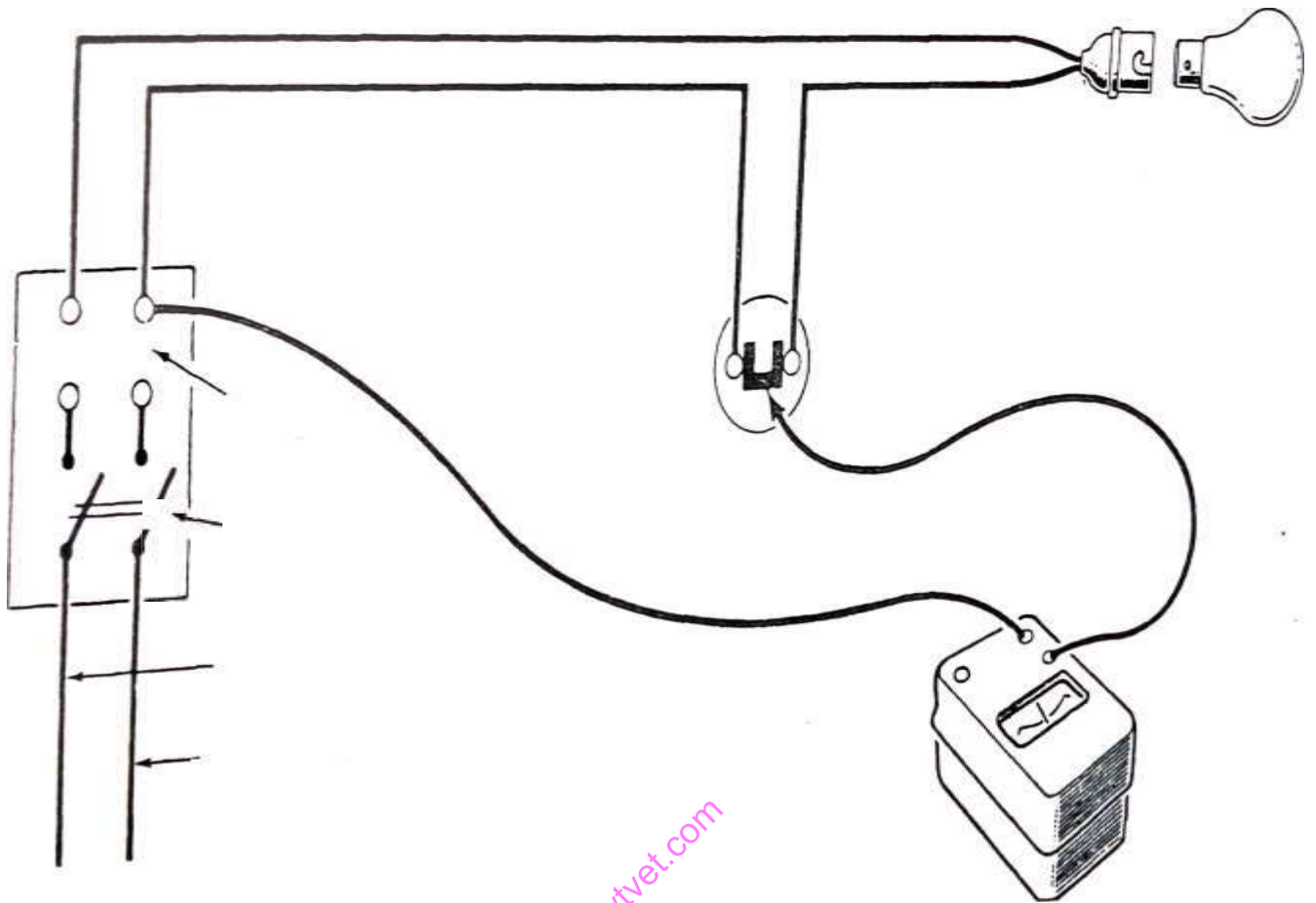




LAMP WILL LIGHT

Fig 7 Testing 3-pin socket outlet, correct

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incorrect conductor the instrument reading will be a maximum, i.e., infinity. The polarity of the 3-pin socket outlet is tested in a similar way.

LAMPS OUT

YY FUSES OUT

MAIN SWITCH OPEN

NEUTRAL

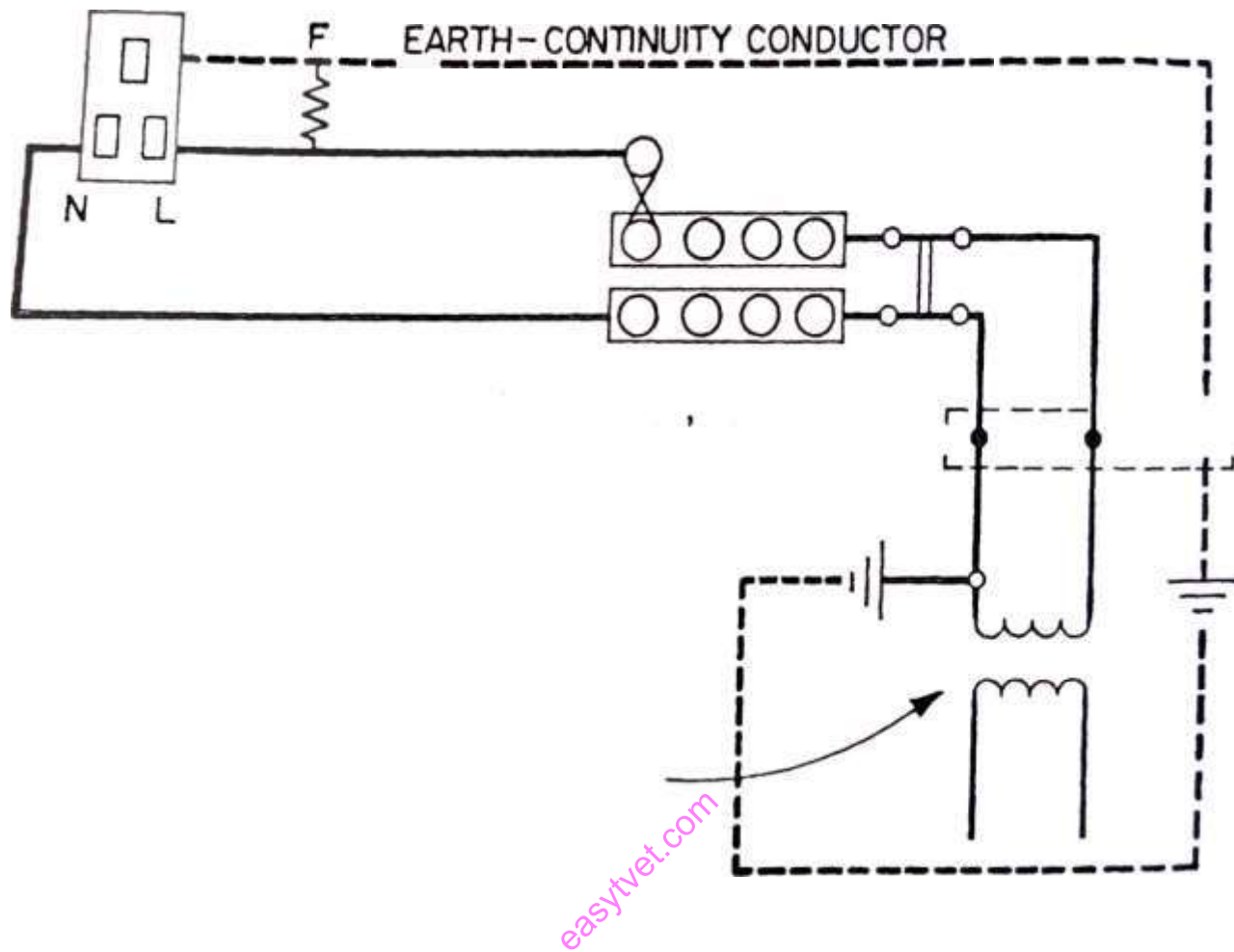
PHASE OR OUTER

Fig. 8 Testing for polarity of switch with circuit dead

**Test of earth-leakage circuit-breaker.**

In accordance with Regulation E 5, the effectiveness of earth-leakage circuit-breakers is to be verified. The IEE Regulations states that a voltage not exceeding 45 V, obtained from a double-wound transformer connected to the mains supply, shall be applied across the neutral and earth terminals (or neutral and frame terminals of a voltage operated Earth leakage circuit-breaker) and the circuit breaker shall trip instantaneously.

**Earth-fault loop testing.** Regulation E 4 requires that when earth leakage protection relies on the operation of fuses or excess-current circuit-breakers, the effectiveness of earthing shall be tested by means of an earth-loop impedance test.



CONSUMER'S TERMINALS

SUPPLY AUTHORITY EARTH ELECTRODE

## SUPPLY TRANSFORMER

EARTH

PATH

Fig 9 .Line-earth loop

The diagram Figure above shows the path of leakage current from an earth fault on a 2-wire final sub-circuit. The path of the leakage current is from the earth fault (F) along the earth-continuity conductor to the consumer's earthing terminal and thence to the consumer's earth electrode. From here the fault current passes through the general mass of earth to the supply authority's earth electrode at the supply transformer, through the transformer winding and along the line through the consumer's wiring to the fault. This path is called the line earth loop, and it is this loop which is to be tested, The Regulations allow the neutral-earth loop to be tested as an alternative.

A line-earth tester such as the Megger line-earth tester would be used. The operation of this instrument is as follows:

The instrument passes a short duration current through the loop, the value of the current depending upon the impedance of the loop as well as upon the voltage of the tester. The current passes through 10 resistors in series with the loop, and the voltage drop across it is measured by means of a ballistic instrument which is calibrated to read directly the loop impedance in ohms. This instrument incorporates a voltmeter and a voltage selection switch, enabling it to be used on supplies of different line-neutral voltages.

### **Test of earth-continuity conductor.**

Regulation E 3 requires that every earth-continuity conductor shall be tested in accordance with Item 1 of Appendix 6. Four methods are given:

- **Alternating current test.**

It is suggested that one of the current conductors of known resistance shall be disconnected and used as part of the test circuit. At the remote end of the final sub-circuit this cable and the earth-continuity conductor are connected together forming a lead and return. At the other end an alternating current supply not exceeding 40 V at approximately supply frequency is applied to the end of the conductor/e.c.c loop. A current of approximately times the rating of the final sub-circuit is passed through the

loop, with a maximum value of 25 A. The impedance of the e.c.c which is the ratio voltage/current, minus the resistance of the known conductor, should not exceed  $1\Omega$ .

- **Alternating current test at reduced current.**  
preferred, a lower value of current may be applied, at approximately supply frequency, The impedance values allowable are, not more than 0.50 where the e.c.c is partly or wholly of steel conduit or pipe, and 1.0 where the e.c.c is wholly of copper, copper alloy, or aluminium.
- **Direct current test of an alternating current installation.**  
Direct current may be used for the test provided that a proper inspection of the e.c.c ensures that there is no inductor incorporated in the e.c.c. The values of impedance are not to exceed 0.5 for steel conduit or pipe, and  $1\Omega$  for copper, copper alloy, or aluminium.
- **No current test of direct current installation**  
This test can be made, using say, a secondary battery and rheostat, with a current approaching 1.5 times the rating of the sub-circuit under test, subject to a maximum of 25 A. Alternatively, a hand tester may be used with a reduced current. In each case the resistance obtained by the test should not exceed  $1\Omega$ .

### **Test of ring-circuit continuity**

Regulation E 10 requires that a conductor, including the earth-continuity conductors, shall be verified for continuity, this may be done with a continuity tester, probably a battery type as used for polarity testing on p. 116.

All apparatus must be disconnected from the ring. The ring is disconnected at the distribution board so that the four ends of the ring conductors are exposed. Touching the continuity tester across the two ends of the line conductor will give a very low reading, showing continuity. The neutral conductor is checked in a similar way.

To check the conductors in the spurs, the ring should remain open with ends exposed. A continuity test would be made across line end neutral from the end socket-outlet on any spur, when the indication should be infinite resistance. This could be repeated at every spur end. If one pair of exposed wires, line and neutral, at the exposed ends be now temporarily short-circuited, continuity readings from each spur end should show very low resistance, thus verifying continuity.

The earth-continuity conductors could be checked for continuity at the same time.

### **Completion certificate**

On completion of a new installation or of a major alteration, and after inspection and testing as described, the installation contractor is required to give a Completion Certificate. This certificate, gives certain details of the installation including the number of appliances, etc., the method of earthing, and the value of the earth-loop impedance. The certificate states that the work has been done in accordance with Regulations. It also recommends periodic testing and inspection.

## Inspection certificate

When the installation is re-inspected and tested at a later date, an inspection certificate is completed and handed to the consumer. It gives the results of the full range of tests of the installation.

## Practical activities

The test results shown in figure below were obtained from a ring final circuit continuity test. State whether reading for each socket are satisfactory or unsatisfactory. give reason for those reading unsatisfactory.

**Note: line, neutral and c.p.c loops =0.8Ω**

| Socket | L-N         | L-c.p.c    |
|--------|-------------|------------|
| A      | 0.4         | 0.41       |
| B      | Not reading | 0.39       |
| C      | 0.5         | 0.4        |
| D      | 0.4         | No reading |
| E      | 0.41        | 0.41       |

- 9.
- Describe in details the test procedure for insulation resistance on the installation
  - The test results indicate an overall value of  $1.5\Omega$ . state with reasons what actions if any should be taken
10. A loop impedance test on the lighting circuit is conducted and 6A type B m.c.b trips repeatedly
- Explain why this is the case

Explain why the problem may be overcome in order to conduct the test

- Explain briefly the action to be taken if the insulation resistance test of an installation indicates an overall value of 1.25 M-ohms
11. A ring final circuit continuity test revealed incorrect polarity on three socket outlets. The results were

|          | <u>L to N</u> | <u>L to c.p.c.</u> |
|----------|---------------|--------------------|
| Socket A | Open circuit  | Correct            |
| Socket B | Correct       | Open circuit       |
| Socket C | Open circuit  | Open Circuit       |

State which conductors have reversed polarity in each case.

12. For an insulation resistance test on domestic installation, state the
- IV. Instrument to be used
  - V. Resistance range at which this instrument should set
  - VI. Measured value below which each circuit would need to be tested separately
13. A live polarity test is to be conducted. State
- iv) Why such a test is necessary
  - v) The instrument to be used
  - vi) How neutral-earth polarity is checked
14. Earth fault impedance is to be conducted on a radial circuit during an initial verification. State
- iv) Where on circuit the circuit should be conducted
  - v) Which value measured or corrected should be recorded on the scheduled test results
  - vi) Why the value in b above may not be the same as  $Z_e + (R_1 + R_2)$
- 4.
15. List
- c. Five relevant test including the individual instrument required on the outer house supply cable following the test for continuity protective conduction
  - d. Five relevant inspection required when inspecting the installation of the outer house supply cable
- 16.
- c. Explain why the earth fault loop impedance test results on lighting circuit in the outer house is likely to be significantly higher than a similar circuit in the main property
  - d. Explain briefly
    - iii) Why the main switch may operate when testing for earth loop impedance on the lighting circuit in the outer building
    - iv) How you would overcome the problem encountered in b (1)

### Answers to practical Activity

1. As the line, neutral and c.p.c loops are  $0.8\Omega$ , the outlet readings should be in the order of  $0.4\Omega + 0.05\Omega$

Socket A L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

Socket B L-N reading is unacceptable- no continuity

L-CPC reading is acceptable

Conclusion Reverse polarity on P/CPC conductors or Neutral is not connected to terminal

Socket C L-N reading is unacceptable- too high (greater than  $\pm 0.05\Omega$ )



L-CPC reading is acceptable

Conclusion May indicate a loose connection on the neutral conductor

Socket D L-N reading is unacceptable

L-CPC reading is unacceptable- no continuity

Conclusion reverse polarity on P-N conductors or CPC is not connected

Socket E L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

1. a) isolate the supply and loop off

-all switches closed

-all current using equipment removed

- all fuse/M.C. B's in place/on

-all equipment vulnerable to test should be removed

-test performed at meter tails if possible

Test between live conductors (L&N)

live conductors and earth

b) this could indicate a latent defect. Each circuit should be tested individually and its insulation resistance should be greater than  $2\Omega$ .

2.a. As loop impedance tester delivers high current for a short time. It is not.

b. The loop impedance in such cases will have to be determined by a:

- measure  $Z_e$  (incoming side of device)

- measure  $R_1+R_2$  for the circuit

-then  $Z$

3. a 1.  $R_1+R_2$ , low reading ohm meter

2. insulation resistance, high reading ohm meter

- 3.. polarity, low reading ohm meter.
- 4.. Zs. Earth loop impedance tester.
5. Pfc, prospective fault current faster

b. protection against damages

joint mechanically and electrically sound

correct current rating

metal sheaths and armors earthed.

identified at termination

### Answers to self-assessment questions

4. Each circuit should be separately tested & its insulation resistance should be greater than 2 M $\Omega$ .
5. L & C.P.C.  
L & N  
All or N & C.P.C.
6.
  - d) . insulation resistance tester
  - e) 500 V dc
  - f) 2 M $\Omega$

To prove the correct polarity of the incoming supply  
Approved voltage indicator

4.a. Test across the line and neutral, voltage should be present

b. Test across the line and earth, voltage should be present

c. Test across the neutral and earth conductors, no voltage should be present

5.a. the remote end of the circuit (point furthest away from the source of supply)

b. measured value

c. the R1+R2 value obtained using a d.c test and does not take into account the impedance (a.c resistance) of the circuit conductors. Also when taking a reading of Ze parallel paths may be present which would lead to lower reading than may otherwise be calculating using the values of Ze and R1+R2

## CHAPTER 9: ELECTRICAL INSTALLATION BREAKDOWN MAINTENANCE

Unit of learning code: ENG/CU/EI/CR/05/5

**Related Unit of Competency in Occupational Standard:** This unit addresses the unit of competency: Conduct Electrical Installation Breakdown Maintenance

### 9.1 Introduction to the unit of learning

This unit specifies the competencies required to conduct breakdown maintenance of an electrical installation. It includes fault identification, repairing, testing and generating maintenance report.

### 9.2 Summary of Learning Outcomes

1. Identify system failure
2. Troubleshoot cause of failure
3. Repair the system
4. Test the repaired system

#### 9.2.1 Learning Outcome 1: Identify System Failure

##### 9.2.1.1 Introduction to the learning outcome

This learning outcome requires the trainee to identify why the system has failed it involves visual inspection of the system and carrying out various tests to identify why the system has failed

##### 9.2.1.2 Performance Standard

9.2.1.2.1 The necessary information about the failure is obtained from the user, as per set procedures.

9.2.1.2.2 Manuals for the system are referred to identify test points and measured parameters where applicable.

##### 9.2.1.3 Information Sheet

- **Breakdown maintenance:** is a form of material or equipment remediation that is performed after the equipment or material has lost its functioning capabilities or property.
- **Failure:** the fact of system not working, or stopping working as well as it should
- **Manual:** a book giving instructions or information
- **Maintenance:** the process of keeping the system in good working condition by checking it regularly and repairing it when necessary
- **Tool:** a piece of equipment that you use with your hands to make or repair a system.
- **Visual inspection:** It is the process of looking over a piece of equipment using the naked eye to look for flaws. It requires no equipment except the naked eye of a trained inspector.
- **Process:** a series of actions or steps taken in order to achieve a particular end

- **System failure:** a breakdown of any system hardware which prevent the accomplishment of the system intended functions
- **Partial failure:** means that the equipment is functioning at less than the set rate that it is required to perform
- **Total failure:** to stop functioning because of breakage or wear
- **as-built drawing:** is a revised set of drawings submitted by a contractor upon completion of a construction project.
- **Fault:** in an electric power system can be defined as any abnormal condition of the system that involves the electrical failure of the equipment, such as transformers, generators, bursars, etc.
- **Short Circuits:** A short circuit refers to a specific condition in which electricity strays outside the established pathway of an electrical circuit.

## Gathering Information

### Principle of operation

Usually, the identification of the symptoms only helps to suspect what items need to be checked for malfunction. To properly identify fault in an electric circuit, you must know how each electrical component in the unit should function and be able to evaluate the performance of each component. Electrical records, prints, schematics, and manufacturers' literature—combined with your knowledge and experience—will help you determine how each component is expected to operate. After determining the expected operating characteristics, the next step is to identify the actual problem by finding the faulty part or component. this may be done by visual inspection or test using instruments.

Some situations also require testing for power, power factor, frequency, phase rotation, inductance, capacitance, and impedance

- Accurately define the problem
- identify all potential failure causes
- Objectively evaluate the likelihood of each failure cause

### Visual inspection

Visual Inspection, or Visual Testing (VT), is the oldest and most basic method of inspection

Before actual electrical measurements and tests are considered, the defective equipment should be visually inspected. Sometimes the problem will immediately appear and remedy quickly

applied to restore the equipment without much trouble. When conducting visual inspection, the serviceman should look for broken wires, dry joints damaged printed circuits board trucks, burnt or damaged components, displaced fuses and loose connections. Terminals should be inspected and seen to be well secured. Visual inspection may be carried out when power is off and when it is on. Visual inspection can be used for internal and external surface inspection of a variety of equipment types, including storage tanks, pressure vessels, piping, and other equipment.

### **Interview of users**

Many machine operators are responsible for performing safety or quality checks on their equipment prior to putting it to use each day. It is important to interview them to understand the probable cause of the problem questions may include

- Does the machine have a manual?
- How often does the machine break?
- How often is the machine repaired?
- When was the last maintenance done and the results?
- Has the machine been Overrunning?
- Is there any part that has been replaced replacing worn parts?
- How is the machine stored?

### **Types of failures**

Electrical networks, machines and equipment are often subjected to various types of faults while they are in operation. When a fault occurs, the characteristic values (such as impedance) of the machines may change from existing values to different values till the fault is cleared. After all the symptoms have been accurately noted, performance test of the equipment should be carried out. By doing this, the repair serviceman may discover other symptoms that the client may not have known, or been able to communicate on the account of little technical understanding. In some cases, a system may be reported faulty while in fact the failure is the result of incorrect operation due to the customer not being well conversant with his equipment.

### **Partial Failures**

Failure exists in varying degrees but in the most basic terms, Partial failure simply means that some of system, component, or device can no longer produce specific desired results. Even if a piece of manufacturing equipment is still running and producing items, it has failed if it doesn't deliver the expected quantities.

### **Total failure**

Total failure means that most of the system, component, or device can no longer produce specific desired results. This lead to slow down of operation for the machine can no longer produce

### **Referring to as-built drawings**

As-built drawing: is a revised set of drawings submitted by a contractor upon completion of a construction project. As-built drawings show the dimensions, geometry, and location of all components of the project forming an integral part of a structure)

### **Manuals**

A service manual is a collection of technical data and information for a specific model of equipment. It is compiled and supplied by the manufacture for use when servicing the equipment.

A service manual has the following useful features

- Description of specification
- Performance specifications
- Block diagrams
- Schematic diagrams
- Component's layout
- Hints on maintenance
- Procedures for dismantling, testing, and fault diagnosis
- Fault location guides
- Mechanical layout of the entire equipment
- Spare part lists

### **NB**

Use of a service manual turns what could otherwise be an infuriating guessing game to a quick straight forward repair job

#### **9.2.1.4 Learning activities**

- a) conduct visual inspection in a defective iron box
- b) carry out short circuit test on defective cooker
- c) demonstrate how to carry out performance test by simulating faults in an iron box and carrying out performance test

#### **9.2.1.5 Self-Assessment**

- a) What are the advantages of breakdown maintenance?
- b) What are the disadvantages of breakdown maintenance?
- c) What are the causes of breakdown maintenance?
- d) How do you analyze system failure?
- e) Give causes of electrical equipment failure

### **9.2.1.6 Tools, Equipment, Supplies and Materials**

#### **Tools**

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

#### **Materials and supplies**

- Stationery
- Lubricants
- Service parts

#### **Equipment**

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Phase sequence meter

### **9.2.1.7 References**

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### **9.2.1.8 Model Answers to Self-Assessment**

- 1) Explain what is meant by breakdown maintenance

Ans

- Occurs when an asset completely breaks down and needs repair to resume operation

2) What are the disadvantages of breakdown maintenance?

Ans

- Faster plant deterioration
- Increased chances of accidents or injuries
- Breakdown generally occurs inappropriate times leading to poor and hurried maintenance
- Longer repair time in comparison to any other maintenance type
- It is difficult to find the root cause of breakdown
- costly because it causes downtime and interrupts production

3) What are the advantages of breakdown maintenance?

Ans

- Minimal planning is required
- The process is very simple so it is easy to understand
- Fewer staff are required as less work is done day-to-day

4) What are the causes of system breakdown?

Ans

- Failure to read the operators manual
- Improper maintenance
- Poor electrical connections
- Overrunning machines
- Not replacing worn parts
- Misaligned tighteners
- Improper storage
- Weather related issues
- Ignoring warning signals
- Untrained operators

5) What are the causes of system failure?

Ans

- Short circuit
- Open circuit
- Multiple failure of a part after initial replacement



6) Give causes of electrical equipment failure why systems

Ans

- Loose connection or parts
- Moisture
- Power line disturbance
- Defective or inadequate installation
- Lighting
- Foreign object or short circuit
- Collision
- Overloading or inadequate power capacity

7) Explain visual inspection-

Inspection of equipment and structures using either or all of raw human senses such as vision, hearing, touch and smell and or specialized inspection equipment

## 9.2.2 Learning Outcome 2: Troubleshoot cause of failure

### 9.2.2.1 Introduction to the learning outcome

This section requires the trainee to select the right instruments for trouble shooting faulty electrical system. It involves taking the necessary safety procedure and use the correct tools and equipment to diagnose and record failure results

### 9.2.2.2 Performance Standard

9.2.2.2.1 Safety procedures are applied in accordance with the safety standards

9.2.2.2.2 system trouble shooting is conducted in accordance with the set procedure

9.2.2.2.3 System is diagnosed for failure according to standard operating procedure

9.2.2.2.4 System failure results are recorded as per established procedure.

9.2.2.2.5 Parameters are compared against the standards values

9.2.2.2.6 Decision is made, and recommendations are recorded

### 9.2.2.3 Information sheet

**Trouble shoot:** is the process of identifying planning and resolving a problem in a mechanical or electronics system

**Failure diagnosis:** is the process of tracing a fault by means of its symptoms, applying knowledge, and analyzing test results

**Parameters:** a limit or boundary which defines a scope or particular process or activity

**Systems:** a set of things working together as parts of a mechanism or interconnecting network

**Failure:** the fact of system not working, or stopping working as well as it should

**Closed circuit:** means a complete electrical connection around which current flows or circulate

**Open Circuit** - any break (open) in the current path of a series circuit makes the entire circuit inoperative. In a parallel circuit, only the branch effected by the open is inoperative.

**Short Circuit** - this can be a short-to-ground or short-to-voltage. This may cause a component to continuously operate regardless of switch position, or a fuse to repeatedly blow, depending on the fault

**Earth Fault** is an inadvertent fault between the live conductor and the earth

**Records:** a piece of information or a description of an event that is written on paper or store on a computer

**Specification:** it is made exactly as the person who designed it said it should be done

**Conducting fault diagnosis**

### Introduction

The ability to rapidly diagnose the case of faults in electrical and electronics system is an important skill for every electrician. The use of electrical and electronics equipment in domestic and industrial situations is increasing rapidly. It is therefore important that the electrician or electronic technician be able to repair and service them.

Naturally, fault diagnosis skills are not achieved easily. Trouble shooting and repair should be a logical step by step procedure not a haphazard, hit and miss trial and error practice. A good understanding of component and circuit operation together with sound instruments is prerequisite to successful servicing. In addition, the defective equipment, components and diagnostic tools.

A service technician cannot repair and service electrical gadgets profitably without the appropriate service instruments. However, having the instruments is not enough, the technician must know their specifications and understand their uses. The ability to use measuring instruments and apply appropriate testing methods greatly assist in accurate pinpointing of faults in components and circuits.

The test instruments considered may include multimeter, cathode ray oscilloscope and the megger.

### **Open Circuits**

Current will only flow in a circuit. That is, around a continuous path (or multiple paths) from and back to the source of electromagnetic force (EMF). Any interruption in the circuit, such as an open switch, a break in the wiring, or a component such as a resistor that has changed its resistance to an extremely high value will cause current to cease. The EMF will still be present, but voltages and currents around the circuit will have changed or ceased altogether. The open switch or the fault has caused what is commonly called an open circuit.

### **Troubleshooting open circuit**

Basically, an open circuit fault is any fault that will halt the operation of a machine due to an open component

Find the open by measuring voltage:

1. Measure voltage level at the fuse.
2. Work your way point by point toward the circuit ground.
3. Continue until you find a point where voltage is no longer present. The open is between the last two measured points.

**NB**

Electrical Troubleshooting an Open Circuit The best method for diagnosing an open circuit is by measuring voltage. When that is not possible, measure resistance following the steps below.

1. Remove the circuit fuse
2. Measure resistance between circuit ground and a circuit point closest to fuse
3. Work your way toward ground, point by point. Continue until you find a point where continuity is present. The open is between the last two measured points. From this point you may have to further isolate.

### **Short circuit**

A short circuit is an electrical circuit that allows a current to travel along an unintended path with no or very low electrical impedance. This results in excessive current flowing through the circuit

### **Causes of short circuits**

There are several causes for short circuits, including three that are most often to blame.

- a) faulty circuit wire insulation

Old or damaged insulation may allow neutral and hot wires to touch, which can cause a short circuit. Nail and screw punctures, as well as age, can cause wire casings or insulation to deteriorate and create short circuits. Or, if animal pests such as mice, rats, or squirrels gnaw on circuit wiring, the inner wire conductors can be exposed to cause short circuits.

- b) loose wire connections

Attachments can loosen, sometimes allowing neutral and live wires to touch. Fixing faulty wire connections is tricky and is best handled by those thoroughly familiar with wiring work.

- c) faulty appliance wiring

When an appliance is plugged into a wall outlet, its wiring effectively becomes an extension of the circuit, and any problems in the appliance wiring become circuit problems. Old or broken appliances can develop inner short circuits over time. Short circuits in appliances can occur in the plugs, in the power cords, or inside the device itself. It's best to have a technician look at shorts in larger appliances such as ovens and dishwashers. Smaller appliances such as lamps often can be rewired yourself.

### **Effects**

- Abnormal operation of the system
- Danger to the personnel as well as animals

Follow this procedure if you suspect a short circuit:

1. **Locate the tripped circuit breaker:** At the main service panel, look for an individual
2. Circuit breaker with a handle that has snapped to the OFF position. Some breakers may have a red or orange window indicator to make it easy to spot. This tripped breaker will identify the circuit where the problem exists. Leave the circuit breaker OFF as you inspect along the circuit.
3. **Inspect appliance power cords:** Inspect all the power cords plugged into outlets along the circuit that has tripped. If you find any that are damaged or on which the plastic insulation has melted, there is a good chance the short circuit is within the appliance or device itself. Unplug these appliances from the circuit. If you find suspect appliances, switch the circuit breaker back on after unplugging them. If the circuit now remains active without tripping again, it is very certain that your problem existed in the appliance. However, if the circuit breaker trips again immediately, proceed to the next step.
4. **Turn off all light and appliance switches** along the circuit. Then, turn the circuit breaker back to the ON position.
5. **Turn on each light switch or appliance switch**, one at a time. If you reach a switch that causes the circuit breaker to trip again, you have identified the section of circuit wiring where a loose connection or wiring problem exists.
6. **Repair the circuit wiring problem.** This is a step that may require the help of a professional electrician. Do not attempt this unless you are very confident about your knowledge and skill level. This repair will involve shutting off the circuit, then opening up outlet and switch boxes to inspect the wires and wire connections and making any repairs that are necessary.

## **Earth fault**

A transformer circuit consists of a number of subscribers connected to a distribution transformer. The number of subscribers varies depending on size and power output per subscriber. Most instances of earth faults in a transformer circuit are due to insulation faults in the electrical installation of the individual subscriber. Common earth faults include:

- Earth faults in water heaters
- Earth faults in old stoves

- Faults in lighting equipment
- Faults in the fixed installation in the building
- Faults as a result of incorrect connection

A direct earth fault at a given subscriber in a transformer circuit will not normally affect the other subscribers connected to the same circuit provided that the earthing system for the individual installation satisfies current requirements. The individual owner/user is responsible for reporting the fault and having it repaired by an authorized electrical contractor. There is a requirement for earth fault

### **Causes of earth Fault.**

1. Earth faults occur when the hot wire or live wire comes into contact with the ground wire
2. Moisture in the Receptacle Box. The accumulation of moisture is another major cause
3. Overloaded Circuit. Circuit overload occurs when more amperage flows through

### **Troubleshooting Earth/Ground Faults**

- i. Locate the problem. Many homes are equipped with ground fault circuit interrupters or GFCI outlets. These outlets detect ground faults and shut off power to the affected circuit. Some model's alert homeowners with a light or by tripping a reset switch on the outlet. Look for these alerts to locate the ground fault. If your home doesn't have GFCI-equipped outlets, look at your breaker box. Tripped breakers will be in the off position. It's important to note that ground faults don't always trip breakers. If your electrical issue is overloading breakers, you could be dealing with an electrical short or too many appliances running on the same circuit.
- ii. Disconnect your appliances. Unplug your appliances from the outlet and reset the breaker or GFCI.
- iii. Plug in your appliances. Plug each item back into the outlet until it trips again. This will determine which appliance is causing the ground fault. If nothing trips your outlet, or if your outlet doesn't reset, your ground fault is likely located in another part of your home. Call a professional to look. Faults can occur due to other outlets leaking current, problems with exterior circuits, and other faulty appliances.

### **Mechanical fault**

A machine that has been designed and manufactured to perform a certain function, is expected to do so when installed in a plant for its designed life span. However, for reasons beyond one's control, such a machine may fail to do so for several reasons including

- i. a faulty design of the machine,
- ii. inferior material and workmanship,
- iii. incorrect installation and wrong operational procedure,

Excessive component heating are signs that something is going in the wrong direction. In the case of non-typical vibrations, the main causes are:

- i. Defective bearings and gears
- ii. Electrical and mechanical failures in motors,
- iii. Problems caused by misalignments,
- iv. Unbalances or unstable bases,
- v. Bent shafts, pulley or belt failures
- vi. Mechanical gaps,
- vii. Aerodynamic or hydraulic problems
- viii. Water and oil leaks
- ix. Corroded pipes,
- x. Smells and abnormal sounds.
- xi. Lack of or inadequate lubrication
- xii. Not attending equipment
- xiii. Safety stops when recommended
- xiv. Incorrect operation of the machinery
- xv. Lack of or improper maintenance

## **Electrical Tools and Equipment**

Before you tackle any electrical project, having the proper tools is essential to getting the job done efficiently, correctly, and more importantly, safely! The old saying, use the right tool for the job, couldn't be more relevant, especially when it comes to electrical work.

Some of the tools and equipment's are:

### **Personal protective equipment (PPE)**

Your personal safety should be the most important consideration. Goggles and safety glasses, gloves, long-sleeve shirts, long pants or blue jeans, hard hat, etc. A large dose of common sense is required here. Think about the hazards and protect yourself accordingly before taking on any task.



### **Circuit Testers**

You need to have a voltage tester of some type for electrical work, and one that you trust is working properly. The important thing is to ensure that it is working so you can verify that you have the power off on any circuit you may be working with. Check it on a known live source before trusting it to determine if your circuit is dead.

### **Screwdrivers**

It is essential to have a good quality set of screwdrivers. It is best to purchase them in a complete set rather than individually, as this will save you money, and increase the chances that you will have the driver that best fits the need.



### **Cordless Screwdriver/Drill**

If you are going to take on any project beyond the most basic of jobs, such as, for example, changing out an individual receptacle or switch, you should have a good cordless drill and driver tool, along with a complete set of screwdriver bits and drill bits. This will save you a lot of time and when used properly, a power driver can be used in place of a screwdriver for most jobs.

I recommend purchasing a driver and drill instead of a basic cordless screwdriver as the quality is usually better, and one tool will perform both functions. Get the best quality you can afford, and make sure it has a 1/2" drive, and that it has sufficient power to drill a 1" hole using an auger bit.



If you will be using it a lot as a screwdriver, then give some consideration to the weight and size when selecting the tool.



### **Electric Drill**

For larger projects, with a lot of drilling required (wood studs, etc.), then an electric drill is more practical. A 1/2" medium duty drill is a minimum for driving a wood auger bit.

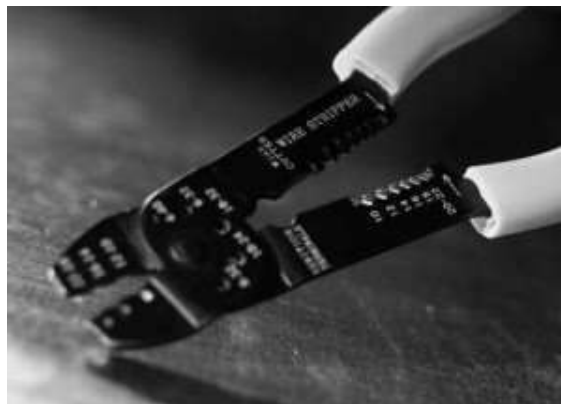
### **Knife**

You will need to have a good knife, and I prefer a standard utility knife for stripping the PVC jacket from Romex, stripping large gauge wire, and for many other jobs as well.

### **Wire Strippers**

Have a good quality wire stripper. I prefer a T-Stripper with a wire cutter, light-duty plier nose, and holes for bending termination loops on wires for most home electrical work. A combination crimper, cutter, stripper, bolt cutter and more, like those found in automotive electrical repair kits can be very handy as well, but the multi-purpose aspect means that the wire stripping function is compromised.

A mechanical wire stripper does a really good job, especially for commercial or industrial applications.



### **Lineman's Plier**

A lineman's plier, or a bull nose plier with a wire cutter, and at least 8" or 9" handles is also an essential part of the electrical tool list. We use these for cutting, bending, twisting wires, etc.



### **Standard, Long-Nosed Pliers**

Also known as needle-nosed pliers. These tools are also very handy to have as a part of your electrical tool kit. They should have wire cutting knives as well.

### **Hammer**

Have a good quality, 16oz. claw hammer. You will need this for driving staples, nails, etc.



### **Tape Measure**

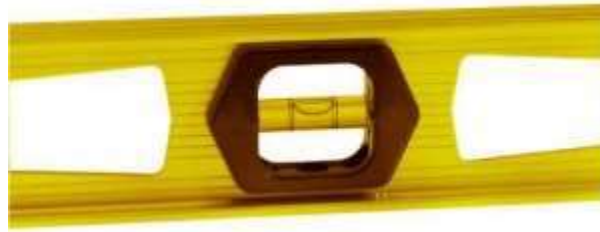
Have a good quality, locking tape measure and a 25' length, 1" blade is maybe over-kill, but will come in handy for other projects around the home.



### **Level**

A 6" plastic torpedo level is essential for levelling outlet boxes, cover plates, wall fixtures, etc. A plastic level is less likely to leave marks.

Always check to make sure the level is indeed “level”. Before purchasing, check on a flat surface and note the position of the bubble, even if not quite at center. Then flip the level end for end in the exact same location and see if the bubble is in the same spot. You would be surprised how many you will find that don’t pass this test. Especially in the lower quality price range.



### **Crescent wrench**

Have one or two sizes of crescent wrenches in your kit.

### **Pump Pliers**

Very handy, and essential if you are working with conduit, such as, flexible conduit.

### **Pipe Wrench**

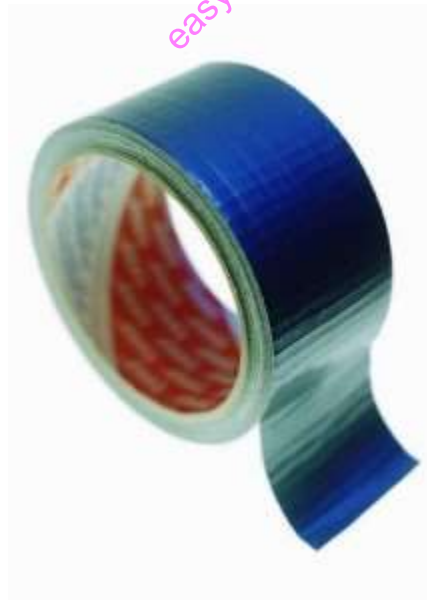
Essential if working with conduit

### **Electrical Tape**

Every electrical tool kit should have at least a roll of black electrical tape, and having a few colours like red and blue helps as well for identifying wires, etc.

### **Duct Tape**

Every tool kit, electrical or otherwise, must have the universal repair tool that is a roll of duct tape!



### **Tool Box or Chest**

You need something, even if it’s just a big pail, to keep everything together, and to have a place to put all your tools away. It’s nice to have a good tool box with many compartments to help you keep organized.



### **Ladders and Step Stools**

They won't fit in your toolbox, but you will need the appropriate size for the height you will be working at.

### **Bandages**

No matter how careful you are, accidents happen. Just do all you can to protect yourself and to minimize the potential for injury. Have a first aid kit handy, just in case!

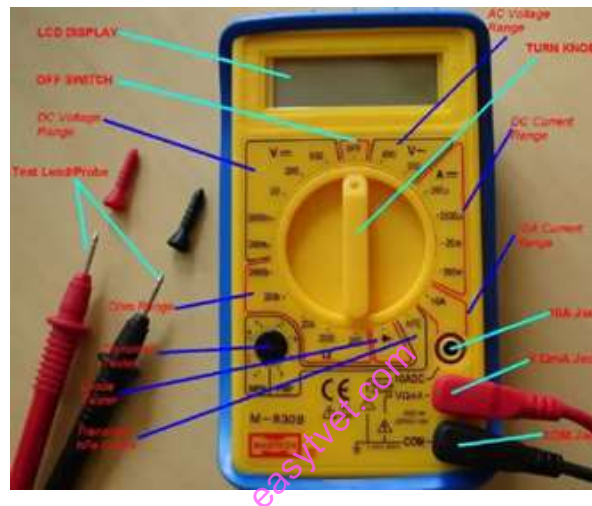
### **Hacksaw**

Critical if working with EMT conduit, flex, etc. If cutting a lot of metal, then an electric reciprocating saw will save you time.



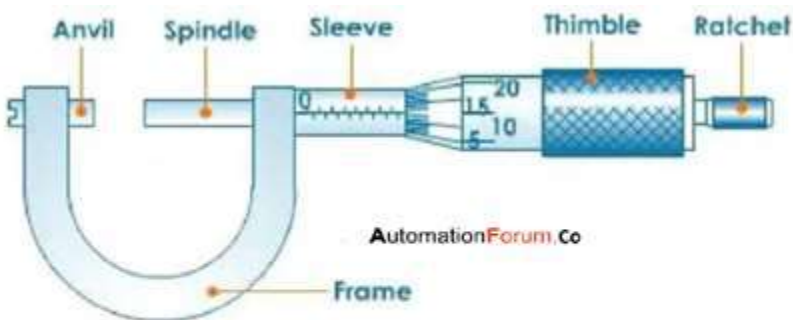
### **Flashlight/Headlamp**

For when you need some extra light for dark places, or when the power is off while working on existing systems.



## Micrometer

A micrometer can be used to measure small and large sizes of wires, it is also used to remove the diameter of circular wires. A micrometer can measure the diameter of thin wire accurately or thickness of sheet metal.



## **Wrenches**

Wrenches are instruments that can be used to turn nuts or hold the piece of stock when tightening screws, nuts, and bolts. There are different types of wrenches like adjustable wrenches, pipe wrench, vice grip wrench.

## **Specification of Tools**

Electrical engineers are required to work in hazardous environments near energized equipment. There are certain tools they require to carry out their job effectively and safely without causing any harm to themselves and those around them. Here's a sneak peek into some electrical engineering tools and their uses.

As with any tool purchase, you'll get longer life and better performance from higher-quality tools. Better electrical hand tools, such as wire cutters and linesman pliers, have insulated handles to help guard against shock.

## **Recording of Installation Failure Results**

Fault records are one of the most important pieces of evidence that event analysts can have during system event investigations. They can provide the reasons for premature equipment failure, supply waveforms and status of equipment behavior during an event, and give necessary information to perform post-fault event analysis. Proper use and interpretation of event records can lead to corrective action for a given system problem resulting in improved performance and reliability of any generation, transmission, and distribution system. Fault recording has been used for decades now, and it is generally used for the following purposes:

- Provide the reasons for premature equipment failure
- Supply waveforms and status of equipment behavior during event
- Give necessary information to perform post-fault event analysis

### **9.2.2.4 Learning Activities**

- a) Demonstrate the use of ohmmeter in testing for continuity short and open circuits
- b) Demonstrate the use of voltmeter in measuring voltages in circuits
- c) The trainees to carry out activities involving the use of the multimeter function in carrying various tests
  - i. The trainer to construct a single stage amplifier as shown in figure 1 below
  - ii. Ascertain the normal working voltages

iii. Simulate the following problems in sequence to demonstrate how the voltages levels will be affected

- R1 Open circuit
- R2 10pen circuit
- R3 Open circuit
- R4 0pen circuit
- B-E Junction shorted
- C-B Junction shorted
- Collector

The trainer should record the results and then then help the trainee to interpret the cause of changes in the circuit voltage level

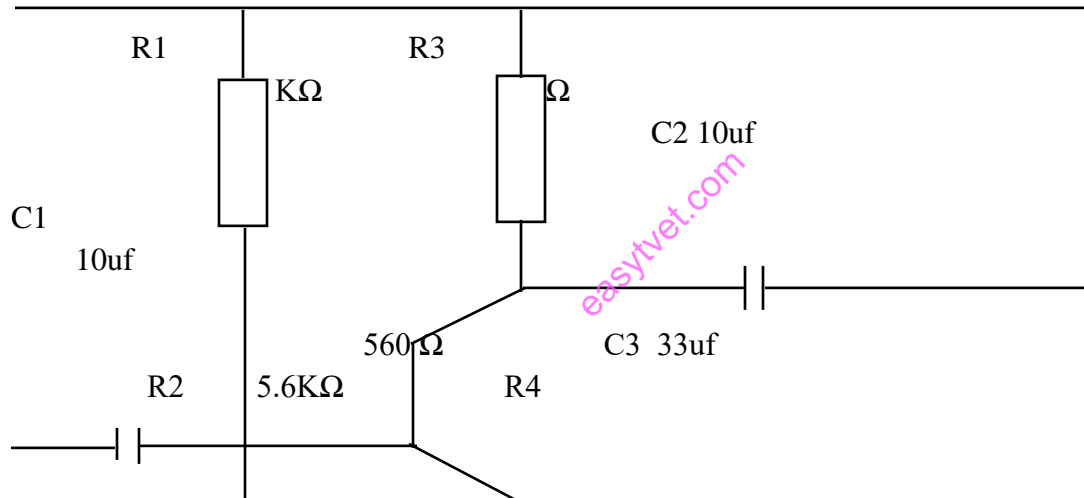


Figure 1: Single stage amplifier

| NO    |                      | VB | VE | VC | Remarks |
|-------|----------------------|----|----|----|---------|
| i.    | Norm                 |    |    |    |         |
| ii.   | R1                   |    |    |    |         |
| iii.  | R2                   |    |    |    |         |
| iv.   | R3                   |    |    |    |         |
| v.    | R4                   |    |    |    |         |
| vi.   | B-E junction shorted |    |    |    |         |
| vii.  | C-B junction shorted |    |    |    |         |
| viii. | Collector open       |    |    |    |         |

### 9.2.2.5 Self-Assessment

- a) What are the six steps in the trouble shooting process?
- b) What are the common trouble shooting problems?
- c) Explain what is meant by PPE
- d) Discuss how to deduce what actual faults could possibly be
- e) Discuss the three functions of a multi meter
- f) Discuss the appropriate ohmmeter ranges for testing different components

#### **9.2.2.6 Tools, Equipment, Supplies and Materials**

##### **Tools**

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

##### **Equipment**

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

##### **Materials and supplies**

- Stationery
- Electrical component

#### **9.2.2.7 References**

Kiameh, P. (2003). *Electrical Equipment Handbook : Troubleshooting & Maintenance*. McGraw-Hill.

KLB. (2010). Trouble Shooting, Repair and Service. In KLB, *KLB Electricity Level 4* (pp. 118-147). Nairobi: KLB.

Moeller, B. M. (1994). *RV Electrical Systems: A Basic Guide to Troubleshooting, Repairing and Improvement*. McGraw-Hill Education.

Patil, M. B. (2004). *Practical troubleshooting of electrical equipment and control circuits 1st Edition*. Newnes.

#### **9.2.2.8 Model Answers to self-assessment**



- a) What are the six steps in the trouble shooting process?
- Identify the problem
  - Establish the theory of the cause
  - Test probable cause theory to determine actual cause
  - Establish an action plan and execute the plan
  - Verify the system functionality
  - Document the process
- b) What are the common trouble shooting problems?
- Electrical surges
  - Overloading
  - Switches of light not working
  - Flickering light
  - Tripping circuit breaker
  - Electrical shock
- c) Explain what is meant by PPE

It is equipment worn to minimize exposure to a variety of hazards.

- d) Examples include such items as gloves, foot and eye protections, protective hearing devices and hats, respirators and full body suits
- e) Discuss how to deduce what actual faults could possibly be
- f) ) Discuss the three functions of a multimeter
- g) Discuss the appropriate ohmmeter ranges for testing different components

## 9.2.3 Learning Outcome 3: Repair the installation

### 9.2.3.1 Introduction to the learning outcome

This section requires the trainee to repair a faulty electrical system using the correct set of tools, equipment, materials and observing all the safety procedures

### 9.2.3.2 Performance Standard

9.2.3.2.1 Maintenance tools, equipment and materials are identified

9.2.3.2.2 Specifications and functionality of tools, equipment and materials are checked in accordance with the applicable technical and safety standards

### 9.2.3.3 Information Sheet

**Repair:** restore (damage system, faulty, or worn) to a good condition

**Manual:** a booklet that instructs on the usage of a particular machine

**Procedures:** a sequence of actions to be followed in solving a problem or accomplishing task

**Activity:** a situation in which a lot of things are happening or being done

**Planning:** is the process of thinking about the activities required to achieve a desired goal.

- Repair/replace
- Meaning of repair

**Repair:** restore (damaged system, faulty or worn) to a good condition

- Isolating the installation

Prior to beginning work on any installation, regulation 14 of Electricity at work Regulation 1989 require that three conditions must be met These include

- The isolation process which is also known in industry as lockout/tag out and is used to isolate machinery and equipment from energy source. It is important to ensure the isolation of any unsafe machinery/equipment from potential uncontrolled energy sources during repair, service or maintenance work.
- Isolation can be used as a standalone method of ensuring the safety of maintenance staff.
- The isolator should be in locked position (for example by a padlock) and a sign should be used to indicate that maintenance work is in progress.

Any stored energy (hydraulic or pneumatic power for instance) should also be dissipated before work starts. Before working on the equipment, it is essential that the effectiveness of the isolation is verified by a suitably competent person. Minimum safety isolation procedure includes the following:

- i. Identification of correct isolation point or device
- ii. Check the condition of voltage indicating device such as the test lamp two pole voltage detector
- iii. Switch of installation/circuit to be isolated
- iv. Verify with voltage indicating device that no voltage is present
- v. Reconfirm that voltage indicating device functions correctly
- vi. Lock-out device used to isolate installation circuit
- vii. Post warning notice- suitable labeling of the disconnected conductors

### **Conducting repair activities**

After the primary work of problem diagnosis and identification has been carried out, the real task of repairing the fault in the system must be undertaken. Appropriate techniques, tools and procedures must be selected for each type of fault or component. The relevant safety precautions must be taken when removing and replacing the faulty components.

### **Selection of Appropriate Technique**

The appropriate methods of repair of equipment often depend on the type of fault, component and its location

### **Replacing of defective components**

When a certain component is found to be defective, it is necessary to first ascertain the cause of the defect before replacing it with a new one. This is especially important in relation to blown fuses, and shorted transistors. It is necessary to clear the fault that caused the fuse to blow or the transistor to short before making the replacement

### **Fault Finding and Repair**

Electrical faults are a health and safety hazard and could be putting your life in danger. Whether in the home or work environment, electrical faults put people at risk of electrocution and electrical fire. The problem must be solved by replacing only defective equipment or components.

### **Procedure**

- Analyse the symptoms of the electrical fault(s).

- Determine the type of electrical fault: open circuit, short circuit, insulation breakdown.
- Design the most effective and efficient strategy to solve
- Explain to the customer exactly what needs fixing and the budget required
- Carry out the work with minimal disruption to the customer's environment.

### **Recording repair activities**

Maintenance workers and their supervisors need to follow some basic rules in order to ensure the safe conduction of the work.

### **Planning**

Maintenance can be seen as either reactive or proactive. Reactive maintenance means engaging in maintenance activity to resolve equipment and machinery which are not functioning properly. Proactive maintenance occurs when steps are taken to maintain, clean and ensure optimum functioning of machinery and equipment to prevent lack of optimum functioning. Maintenance and particularly proactive maintenance are important management issues:

The results of a suitable and sufficient risk assessment should enable to choose which good practice measures are most appropriate in preventing risks in general and also in preventing risks to any individuals identified as

being particular risk. The implementation may mean making changes to the organisation and working procedures, working environment, equipment and products used. Changes could also be necessary in training management and staff as well as improving communications.

### **Special issues Qualification**

Based on the conducted risk assessment the following issues need special attention:

1. A qualification level has to be determined for the specific repair and maintenance tasks
2. Enough time and appropriate resources have to be allocated.

### **Providing a safe working area**

Only authorised personnel should be allowed to do repair or maintenance work. This becomes all the more important the machines and structures are more sophisticated. Only then can it be guaranteed that the right steps are followed and the correct equipment is used.

Sometimes, it can be necessary to conduct the repair or maintenance work at running machines. In this case special measures have to be taken. The normal safeguards should be in place and should be used.

If that is not possible, special protection devices have to be used (special tools, mobile switches), the speed of the machine has to be reduced, and special covers for dangerous areas have to be provided.

- If this should, in some very special cases, not be possible, special measures have to be taken based on a detailed risk assessment. Supervision must be provided throughout the process.

### **Work Execution**

The work has to be conducted in a safe manner. Only workers with the appropriate qualification should be allowed to conduct specified work (e.g. welders must not repair their welding machines; this must be left to electricians; Site-specific instructions should also be given, which is especially important in the case of contracted out maintenance. That way the workers will be aware of any company specific characteristics.

Safe procedures need to be followed as established in the planning phase, even when under time pressure. Procedures for unexpected events have to be in place: “Part of the safe system of work should be to stop work when faced with an unforeseen problem or a problem exceeding one’s own competence

#### **9.2.3.4 Learning Activities**

a) Carry out repairs of the following appliances

- Iron box
- Cooker
- Hair drier
- Electric fan
- Fluorescent fitting

#### **9.2.3.5 Self-Assessment**

- a) How do you identify that a machine has a problem?
- b) State the general rule to be observed when selecting components for replacement.
- c) State importance of running the repaired equipment in its disassembled condition before reassembling.
- d) Discuss the criteria for selection of specific type of repair technique
- e) Discuss the considerations taken in the selection of replacement of parts
- f) Discuss the importance of testing the equipment for proper operation before replacing its covers

### 9.2.3.6 Tools, Equipment, Supplies and Materials

#### Tools

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

#### Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts and components

#### Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

easyvet.com

#### Reference materials

- IEE regulations
- Organizational procedures manual
- charts

### 9.2.3.7 Reference

Electrical repair and maintenance- study. Com

Maintenance repair and operations/ EC&M- [www.ecmweb.com](http://www.ecmweb.com)

EElectricity level 4 by klb

### 9.2.3.8 Model Answers to Self-Assessment Questions

a) How do you identify the problem?

- It is identified by finding the faulty part or component through visual inspection or tests using instruments

b) State the general rule to be observed when selecting components for replacement

- The component must have the same or higher performance characteristics

c) What is the importance of testing a repaired equipment?

- To ensure the that the equipment function well at all settings

## 9.2.4 Learning Outcome 4: Test the repaired system

### 9.2.4.1 Introduction to the learning outcome

This section requires the trainee to test the repaired system. It involves identifying the test points, carrying out test and recording the results

### 9.2.4.2 Performance Standard

- 9.2.4.2.1 Appropriate tests and test points are identified Safety procedures are adhered to
- 9.2.4.2.2 System is tested as per test procedure
- 9.2.4.2.3 Test results are recorded according to the established procedures
- 9.2.4.2.4 Parameters are compared against the standard values
- 9.2.4.2.5 Maintenance report is prepared according to approved format

### 9.2.4.3 Information Sheet

A **report**: is a short, sharp, concise document which with respect to the maintenance of the equip

**Testing**: the means by which the presence, quality or genuineness of anything is determined, a means of trails

**Parameters**: a numerical or measurable factor forming one of a set that defines a system or sets of conditions of its operation

**Standards**: something used as a measure norm or model in comparative evaluations

#### **Identification of test and test points**

Testing the system's operation once the problem is "fixed" is the last step before signing off the job ticket and walking away from a machine repair.

Before beginning any test, answer the following five questions:

- Is the circuit on or off?
- What is the condition of the fuses or breakers?
- What are the results of a visual inspection?
- Are there bad terminations?
- Is the meter working?

Meters and test equipment, as well as print tools, such as operating logs and schematics, will all help you diagnose and solve electrical problems. The fundamental diagnostic tools and test equipment are the voltmeter, ammeter, and ohmmeter. The basic functions of these meters are combined in a multimeter.

#### **Test point**



A **test point** is a location within an electronic circuit that is used to either monitor the state of the circuitry or to inject test signals. Test points have two primary uses:

- During manufacturing they are used to verify that a newly assembled device is working correctly. Any equipment that fails this testing is either discarded or sent to a rework station to attempt to repair the manufacturing defects.
- After sale of the device to a customer, test points may be used at a later time to repair the device if it malfunctions, or if the device needs to be re-calibrated after having components replaced.

Test points can be labelled and may include pins for attachment of alligator clips or may have complete connectors for test clips.

Modern miniature surface-mount electronics often simply have a row of unlabeled, tinned solder pads. The device is placed into a test fixture that holds the device securely, and a special surface-contact connector plate is pressed down onto the solder pads to connect them all as a group.

#### **4-Step Approach to Utilizing Test Points**

An excellent approach to implementing the use of test points is to follow the following 4-step approach. It provides a systematic, organized methodology that will enable consistency in utilizing test points across a range of different applications.

1. **Define** – The first step is to define a test point. A standard set of test point guidelines should be developed which can be used to verify which artefacts/objects are determined to be test points. And to help standardize the process of defining test points, test point detail & summary templates should be created.
2. **Create** – This step involves identifying potential test points at detail level.
3. **Validate and refine** – The procedure of creating and implementing test points should regularly be reviewed and refined. Creating firm timelines for the validation process — once every quarter, for example, or upon the release of every 6 service packs — can help assure consistency in the validate/refine process.
4. **Implement and Measure** – Implementing test points for a defined release should involve conducting an impact analysis. It's also a time to look for ways to improve the process — searching for opportunities to increase test coverage, for example, or identifying opportunities for improving test productivity. It can also be helpful to incorporate metric impacts in a release scorecard.

## Test parameters

It is the job of a test technician to know which piece of test equipment to use for the task at hand and also understand the limitations of the test equipment they are using

Electrical testing in its most basic form is the act of applying a voltage or current to a circuit and comparing the measured value to an expected result. Electrical test equipment verifies the math behind a circuit and each piece of test equipment is designed for a specific application.

Electrical test equipment should be considered a source of lethal electrical energy. Technicians must observe all safety warnings and follow all practical safety precautions to prevent contact with energized parts of the equipment and related circuits, including the use of appropriate Personal Protective Equipment.

## Tests

The correct tests need to be carried out in the following order:

- a) Visual Inspection This is very important as approximately 90% of faults can be found by this inspection alone. The Visual Inspection is not just an inspection; it basically is *'everything but'* what is done during the actual electrical testing process. This part of the testing process may involve:
  - Smelling
  - Pulling on leads
  - Tapping the appliance
  - Shaking
  - Turning some part/s
  - Checking by trying to see that retractable guards actually retract and all manner of other things may be done to ensure that it is safe to operate.
- b) Earth Continuity Test
- c) Insulation Resistance Test
- d) Leakage Test
- e) Further tests have to be performed on leads, RCDs etc

## Test parameters

The use of test parameters is a powerful practice to enhance your testing scenarios. In other words, the concept of parameters in testing is that your test cases may define and likewise use some parameters. Scaling up your test cases effectively usually involves the practice of parametrization.

## 10 Voltage

The a.c voltmeter may be used to test the presence and level of a.c supply and signal in electric circuit. Care must be to use the correct range. In the case of mains voltages, all necessary safety precautions must be observed to prevent electric shocks.

The d.c voltmeter functions used for testing voltage levels in electronic circuits, most components failure in electronic circuits alter the d.c operating conditions of the circuit. intensity in the range of 10 A with the accuracy of 1  $\mu$ A, voltages in the range of 1 kV with the accuracy of 1  $\mu$ V

## 11 Resistance

The ohmmeter is useful for testing continuity of heating elements, stator, coils, armature winding and operation of switches.

When tested with an ohmmeter, switches should show continuity in closed position. the resistance of a closed circuit is zero. The resistance of an open switch is infinity. Any intermediate resistance reading between switch contacts would indicate loose contact, the presence of dirt or moisture.

## 12 Current

Just like the voltmeter the ammeter can be used to infer faults in system. In case of fault the ammeter shows a higher-than-normal charge for longer, even though you know you have not used more electricity

### **Testing**

A final test should be done to ascertain that the equipment is functioning by the client. This is done by connecting power supply to the equipment and manipulating its controls to ensure that the equipment functions well at all settings

### **Documenting results**

Maintenance and repair documentation must be updated frequently to reflect equipment upgrades and technology advances, as well as changes in safety standards. For this reason, tracking previous versions of documentation is yet another key consideration.

The aim of documentation is to give those carrying out the works the information they need. Documents are also used to prepare cost estimates and to obtain tenders from potential contractors. Documentation should be prepared by qualified specialists. The key to good documentation is to correctly identify the problem to be solved, and hence to specify an appropriate solution. The nature and extent of the work must then be clearly conveyed to those who will do it. This information sheet discusses firstly what to document and secondly how. The central maintenance and repair record can be used to keep track of all other maintenance, including maintenance done by the in-house team, by vendors, or by service agents. The information captured should include the date, the equipment reference number, what was done, who did the work, and when next maintenance is due

## **Maintenance report writing**

A report is a short, sharp, concise document which is written for a particular purpose and audience. It generally sets out and analyses a situation or problem, often making recommendations for future action. It is a factual paper, and needs to be clear and well-structured.

### **5 Steps to Create a Maintenance Report in MS Word**

#### **Step 1: Create the Cover Page**

The title should contain the information as to what the maintenance report is being created. Write the name of your company and enter the logo as well. Write down the details as well, like the address the contact details, email, etc.

#### **Step 2: Cover Letter**

On the next page include the cover letter. The person, depending on who your client is, might not be able to make sense of the technical information that you might be presenting later. That is why, in the cover letter, write down, in brief, the results of the checking. Mention what needs repairing and other such basic details.

#### **Step 3: Device Information**

In the next section, write down in detail all the information related to the device or machine. List out all the components and write down what condition they are in. You might want to make a table for the purpose as it will help you to present and record the information in a much more efficient way.

#### **Step 4: New Parts Cost Details**

Write down the parts that need repairing. Some of the parts might need a full replacement. In each case, there will be a charge incurred. It is convenient, just to put the information in this document. Mention each of the charges clearly and separately. Write the total cost involved and consider putting it in the cover letter as well.

### Step 5: Suggestions and Signature

Despite repairing certain parts, there might be something on the client's end that he can do to squeeze some extra performance out of the machine. Also, you might have noticed some negligence on the client's part, which you might want to point out to him so that his machine lasts longer. Finally, put your name and signature at the bottom.

#### Maintenance Report Form Template

|  |  |
|--|--|
| <b>Contact Details</b>                   |  |
| <b>Name</b>                              |  |
| <b>Date</b>                              |  |
| <b>Property Address</b>                  |  |
| <b>Description of maintenance issue:</b> |  |
|  |  |
|  |  |
| <b>For office use:</b>                   |  |
|  |  |
|  |  |
|  |  |
| <b>Date Received</b>                     |  |
| <b>Action Taken</b>                      |  |
|  |  |
|  |  |
|  |  |
|  |  |
| <b>Works Completed</b>                   |  |
|  |  |
|  |  |
|  |  |
|  |  |

#### 9.2.4.4 Learning Activities

- a) Demonstrate how to carry out the final test after the equipment has been reassembled
- b) Perform the final test on the repaired equipment
- c) Prepare a report on the repair carried out

#### 9.2.4.5 Self-Assessment

1. What is testing in electrical equipment?
2. Name types of test carried
3. What is the basic instrument for testing?

#### 9.2.5.6 Tools, Equipment, Supplies and Materials

##### Tools

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

##### Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts and components

##### Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

#### 9.2.5.7 References

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### **9.2.5.7 Model Answers to Self-Assessments Questions**

#### **Self-Assessment**

1. What is testing in electrical equipment –it makes sure that system work the way they are supposed to
2. Name types of test carried
  - -visual inspection,
  - earth continuity
  - insulation resistance,
  - earth leakage, polarity
  - loop impedance functional
3. What are the basic instrument for testing?
  - Multimeter
  - Oscilloscope
  - Signal generators
  - Signal tracers
  - The megger

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## CHAPTER 9: ELECTRICAL INSTALLATION BREAKDOWN MAINTENANCE

**Unit of learning code: ENG/CU/EI/CR/05/5**

**Related Unit of Competency in Occupational Standard:** This unit addresses the unit of competency: Conduct Electrical Installation Breakdown Maintenance

### 9.1 Introduction to the unit of learning

This unit specifies the competencies required to conduct breakdown maintenance of an electrical installation. It includes fault identification, repairing, testing and generating maintenance report.

### 9.2 Summary of Learning Outcomes

5. Identify system failure
6. Troubleshoot cause of failure
7. Repair the system
8. Test the repaired system

#### 9.2.1 Learning Outcome 1: Identify System Failure

##### 9.2.1.1 Introduction to the learning outcome

This learning outcome requires the trainee to identify why the system has failed it involves visual inspection of the system and carrying out various tests to identify why the system has failed

##### 9.2.1.2 Performance Standard

- The necessary information about the failure is obtained from the user, as per set procedures.
- Manuals for the system are referred to identify test points and measured parameters where applicable.

##### 9.2.1.3 Information Sheet

###### 9.2.1.3.1 Definitions of Terms,

- **Breakdown maintenance:** is a form of material or equipment remediation that is performed after the equipment or material has lost its functioning capabilities or property.
- **Failure:** the fact of system not working, or stopping working as well as it should
- **Manual:** a book giving instructions or information
- **Maintenance:** the process of keeping the system in good working condition by checking it regularly and repairing it when necessary
- **Tool:** a piece of equipment that you use with your hands to make or repair a system.



- **Visual inspection:** It is the process of looking over a piece of equipment using the naked eye to look for flaws. It requires no equipment except the naked eye of a trained inspector.
- **Process:** a series of actions or steps taken in order to achieve a particular end
- **System failure:** a breakdown of any system hardware which prevent the accomplishment of the system intended functions
- **Partial failure:** means that the equipment is functioning at less than the set rate that it is required to perform
- **Total failure:** to stop functioning because of breakage or wear
- **as-built drawing:** is a revised set of drawings submitted by a contractor upon completion of a construction project.
- **Fault:** in an electric power system can be defined as any abnormal condition of the system that involves the electrical failure of the equipment, such as transformers, generators, bursars, etc.
- **Short Circuits:** A short circuit refers to a specific condition in which electricity strays outside the established pathway of an electrical circuit.

#### 9.2.1.3.2 Gathering Information

##### Principle of operation

Usually, the identification of the symptoms only helps to suspect what items need to be checked for malfunction. To properly identify fault in an electric circuit, you must know how each electrical component in the unit should function and be able to evaluate the performance of each component. Electrical records, prints, schematics, and manufacturers' literature—combined with your knowledge and experience—will help you determine how each component is expected to operate. After determining the expected operating characteristics, the next step is to identify the actual problem by finding the faulty part or component. this may be done by visual inspection or test using instruments.

Some situations also require testing for power, power factor, frequency, phase rotation, inductance, capacitance, and impedance

- Accurately define the problem
- identify all potential failure causes
- Objectively evaluate the likelihood of each failure cause

##### Visual inspection

Visual Inspection, or Visual Testing (VT), is the oldest and most basic method of inspection

Before actual electrical measurements and tests are considered, the defective equipment should be visually inspected. Sometimes the problem will immediately appear and remedy quickly applied to restore the equipment without much trouble. When conducting visual inspection, the serviceman should look for broken wires, dry joints damaged printed circuits board trucks, burnt or damaged components, displaced fuses and loose connections. Terminals should be inspected and seen to be well secured. Visual inspection may be carried out when power is off and when it is on. Visual inspection can be used for internal and external surface inspection of a variety of equipment types, including storage tanks, pressure vessels, piping, and other equipment.

### **Interview of users**

Many machine operators are responsible for performing safety or quality checks on their equipment prior to putting it to use each day. It there important to interview them to understand the probable cause of the problem questions may include

- Does the machine have a manual?
- How often the does the machine brake
- How often is the machine repaired?
- When was the last maintenance done and the results?
- Has the machine been Overrunning?
- Is there any part that has been replaced replacing worn parts?
- How is the machine stored?

### **Types of failures**

Electrical networks, machines and equipment are often subjected to various types of faults while they are in operation. When a fault occurs, the characteristic values (such as impedance) of the machines may change from existing values to different values till the fault is cleared After all the symptoms have been accurately noted, performance test of the equipment should be carried out. By doing this, the repair serviceman may discover other symptoms that the client may not have known, or been able to communicate on the account of little technical understanding. In some cases, a system may be reported faulty while in fact the failure is the result of incorrect operation due to the customer not being well conversant with his equipment.

### **Partial Failures**

Failure exists in varying degrees but in the most basic terms, Partial failure simply means that some of system, component, or device can no longer produce specific desired results. Even if a

piece of manufacturing equipment is still running and producing items, it has failed if it doesn't deliver the expected quantities.

### **Total failure**

Total failure means that most of the system, component, or device can no longer produce specific desired results. This leads to a slow down of operation for the machine can no longer produce

### **Referring to as-built drawings**

As-built drawing: is a revised set of drawings submitted by a contractor upon completion of a construction project. As-built drawings show the dimensions, geometry, and location of all components of the project forming an integral part of a structure)

### **Manuals**

A service manual is a collection of technical data and information for a specific model of equipment. It is compiled and supplied by the manufacturer for use when servicing the equipment.

A service manual has the following useful features

- Description of specification
- Performance specifications
- Block diagrams
- Schematic diagrams
- Components layout
- Hints on maintenance
- Procedures for dismantling, testing, and fault diagnosis
- Fault location guides
- Mechanical layout of the entire equipment
- Spare part lists

### **NB**

Use of a service manual turns what could otherwise be an infuriating guessing game to a quick straight forward repair job

#### **9.2.1.4 Learning activities**

- d) conduct visual inspection in a defective iron box

- e) carry out short circuit test on defective cooker
- f) demonstrate how to carry out performance test by simulating faults in an iron box and carrying out performance test

#### **9.2.1.5 Self-Assessment**

- f) What are the advantages of breakdown maintenance?
- g) What are the disadvantages of breakdown maintenance?
- h) What are the causes of breakdown maintenance?
- i) How do you analyze system failure?
- j) Give causes of electrical equipment failure

#### **9.2.1.6 Tools, Equipment, Supplies and Materials**

##### **Tools**

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

##### **Materials and supplies**

- Stationery
- Lubricants
- Service parts

##### **Equipment**

- PPE –hand gloves, dust coat, dust masks
- Multimeter

Phase sequence meter

#### **9.2.1.7 References**

KLB. (2010). Trouble Shooting, Repair and Service. In KLB, *KLB Electricity Level 4* (pp. 118-147). Nairobi: KLB.

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### Answers for Self-Assessment

8) Explain what is meant by breakdown maintenance

Ans

- Occurs when an asset completely breaks down and needs repair to resume operation

9) What are the disadvantages of breakdown maintenance?

Ans

- Faster plant deterioration
- Increased chances of accidents or injuries
- Breakdown generally occurs inappropriate times leading to poor and hurried maintenance
- Longer repair time in comparison to any other maintenance type
- It is difficult to find the root cause of breakdown
- costly because it causes downtime and interrupts production

10) What are the advantages of breakdown maintenance?

Ans

- Minimal planning is required
- The process is very simple so it is easy to understand
- Fewer staff are required as less work is done day-to-day

11) What are the causes of system breakdown?

Ans

- Failure to read the operators manual
- Improper maintenance
- Poor electrical connections
- Overrunning machines
- Not replacing worn parts
- Misaligned tighteners
- Improper storage
- Weather related issues
- Ignoring warning signals

- Untrained operators

12) What are the causes of system failure?

Ans

- Short circuit
- Open circuit
- Multiple failure of a part after initial replacement

13) Give causes of electrical equipment failure why systems

Ans

- Loose connection or parts
- Moisture
- Power line disturbance
- Defective or inadequate installation
- Lighting
- Foreign object or short circuit
- Collision
- Overloading or inadequate power capacity

14) Explain visual inspection-

ans

Inspection of equipment and structures using either or all of raw human senses such as vision, hearing, touch and smell and or specialized inspection equipment

## 9.2.2 Learning Outcome 2: Troubleshoot cause of failure

### 9.2.2.1 Introduction to the learning outcome

This section requires the trainee to select the right instruments for trouble shooting faulty electrical system. It involves taking the necessary safety procedure and use the correct tools and equipment to diagnose and record failure results

### 9.2.2.2 Performance Standard

- Safety procedures are applied in accordance with the safety standards
- system trouble shooting is conducted in accordance with the set procedure
- System is diagnosed for failure according to standard operating procedure
- System failure results are recorded as per established procedure.
- Parameters are compared against the standards values
- Decision is made, and recommendations are recorded

### 9.2.2.3 Information sheet

#### Definitions of terms

**Trouble shoot:** is the process of identifying planning and resolving a problem in a mechanical or electronics system

**Failure diagnosis:** is the process of tracing a fault by means of its symptoms, applying knowledge, and analyzing test results

**Parameters:** a limit or boundary which defines a scope or particular process or activity

**Systems:** a set of things working together as parts of a mechanism or interconnecting network

**Failure:** the fact of system not working, or stopping working as well as it should

**Closed circuit:** means a complete electrical connection around which current flows or circulate

**Open Circuit** - any break (open) in the current path of a series circuit makes the entire circuit inoperative. In a parallel circuit, only the branch effected by the open is inoperative.

**Short Circuit** - this can be a short-to-ground or short-to-voltage. This may cause a component to continuously operate regardless of switch position, or a fuse to repeatedly blow, depending on the fault

**Earth Fault** is an inadvertent fault between the live conductor and the earth

**Records:** a piece of information or a description of an event that is written on paper or store on a computer

**Specification:** it is made exactly as the person who designed it said it should be done

## **Conducting fault diagnosis**

### **Introduction**

The ability to rapidly diagnose the case of faults in electrical and electronics system is an important skill for every electrician. The use of electrical and electronics equipment in domestic and industrial situations is increasing rapidly. It is therefore important that the electrician or electronic technician be able to repair and service them.

Naturally, fault diagnosis skills are not achieved easily. Trouble shooting and repair should be a logical step by step procedure not a haphazard, hit and miss trial and error practice. A good understanding of component and circuit operation together with sound instruments is prerequisite to successful servicing. In addition, the defective equipment, components and diagnostic tools.

A service technician cannot repair and service electrical gadgets profitably without the appropriate service instruments. However, having the instruments is not enough, the technician must know their specifications and understand their uses. The ability to use measuring instruments and apply appropriate testing methods greatly assist in accurate pinpointing of faults in components and circuits.

The test instruments considered may include multimeter, cathode ray oscilloscope and the megger.

### **Open Circuits**

Current will only flow in a circuit. That is, around a continuous path (or multiple paths) from and back to the source of electromagnetic force (EMF). Any interruption in the circuit, such as an open switch, a break in the wiring, or a component such as a resistor that has changed its resistance to an extremely high value will cause current to cease. The EMF will still be present, but voltages and currents around the circuit will have changed or ceased altogether. The open switch or the fault has caused what is commonly called an open circuit.

### **Troubleshooting open circuit**

Basically, an open circuit fault is any fault that will halt the operation of a machine due to an open component

Find the open by measuring voltage:

4. Measure voltage level at the fuse.
5. Work your way point by point toward the circuit ground.
6. Continue until you find a point where voltage is no longer present. The open is between the last two measured points.



## **NB**

Electrical Troubleshooting an Open Circuit The best method for diagnosing an open circuit is by measuring voltage. When that is not possible, measure resistance following the steps below.

4. Remove the circuit fuse
5. Measure resistance between circuit ground and a circuit point closest to fuse
6. Work your way toward ground, point by point. Continue until you find a point where continuity is present. The open is between the last two measured points. From this point you may have to further isolate.

## **Short circuit**

A short circuit is an electrical circuit that allows a current to travel along an unintended path with no or very low electrical impedance. This results in excessive current flowing through the circuit

### **Causes of short circuits**

There are several causes for short circuits, including three that are most often to blame.

- d) faulty circuit wire insulation

Old or damaged insulation may allow neutral and hot wires to touch, which can cause a short circuit. Nail and screw punctures, as well as age, can cause wire casings or insulation to deteriorate and create short circuits. Or, if animal pests such as mice, rats, or squirrels gnaw on circuit wiring, the inner wire conductors can be exposed to cause short circuits.

- e) loose wire connections

Attachments can loosen, sometimes allowing neutral and live wires to touch. Fixing faulty wire connections is tricky and is best handled by those thoroughly familiar with wiring work.

- f) faulty appliance wiring

When an appliance is plugged into a wall outlet, its wiring effectively becomes an extension of the circuit, and any problems in the appliance wiring become circuit problems. Old or broken appliances can develop inner short circuits over time. Short circuits in appliances can occur in the plugs, in the power cords, or inside the device itself. It's best to have a technician look at shorts in larger appliances such as ovens and dishwashers. Smaller appliances such as lamps often can be rewired yourself.

## Effects

- Abnormal operation of the system
- Danger to the personnel as well as animals

Follow this procedure if you suspect a short circuit:

7. **Locate the tripped circuit breaker:** At the main service panel, look for an individual
8. Circuit breaker with a handle that has snapped to the OFF position. Some breakers may have a red or orange window indicator to make it easy to spot. This tripped breaker will identify the circuit where the problem exists. Leave the circuit breaker OFF as you inspect along the circuit.
9. **Inspect appliance power cords:** Inspect all the power cords plugged into outlets along the circuit that has tripped. If you find any that are damaged or on which the plastic insulation has melted, there is a good chance the short circuit is within the appliance or device itself. Unplug these appliances from the circuit. If you find suspect appliances, switch the circuit breaker back on after unplugging them. If the circuit now remains active without tripping again, it is very certain that your problem existed in the appliance. However, if the circuit breaker trips again immediately, proceed to the next step.
10. **Turn off all light and appliance switches** along the circuit. Then, turn the circuit breaker back to the ON position.
11. **Turn on each light switch or appliance switch**, one at a time. If you reach a switch that causes the circuit breaker to trip again, you have identified the section of circuit wiring where a loose connection or wiring problem exists.
12. **Repair the circuit wiring problem.** This is a step that may require the help of a professional electrician. Do not attempt this unless you are very confident about your knowledge and skill level. This repair will involve shutting off the circuit, then opening up outlet and switch boxes to inspect the wires and wire connections and making any repairs that are necessary.

## Earth fault

A transformer circuit consists of a number of subscribers connected to a distribution transformer. The number of subscribers varies depending on size and power output per subscriber. Most instances of earth faults in a transformer circuit are due to insulation faults in the electrical installation of the individual subscriber. Common earth faults include:

- Earth faults in water heaters

- Earth faults in old stoves
- Faults in lighting equipment
- Faults in the fixed installation in the building
- Faults as a result of incorrect connection

A direct earth fault at a given subscriber in a transformer circuit will not normally affect the other subscribers connected to the same circuit provided that the earthing system for the individual installation satisfies current requirements. The individual owner/user is responsible for reporting the fault and having it repaired by an authorized electrical contractor. There is a requirement for earth fault

### **Causes of earth Fault.**

4. Earth faults occur when the hot wire or live wire comes into contact with the ground wire
5. Moisture in the Receptacle Box. The accumulation of moisture is another major cause
6. Overloaded Circuit. Circuit overload occurs when more amperage flows through

### **Troubleshooting Earth/Ground Faults**

- iv. Locate the problem. Many homes are equipped with ground fault circuit interrupters or GFCI outlets. These outlets detect ground faults and shut off power to the affected circuit. Some models alert homeowners with a light or by tripping a reset switch on the outlet. Look for these alerts to locate the ground fault. If your home doesn't have GFCI-equipped outlets, look at your breaker box. Tripped breakers will be in the off position. It's important to note that ground faults don't always trip breakers. If your electrical issue is overloading breakers, you could be dealing with an electrical short or too many appliances running on the same circuit.
- v. Disconnect your appliances. Unplug your appliances from the outlet and reset the breaker or GFCI.
- vi. Plug in your appliances. Plug each item back into the outlet until it trips again. This will determine which appliance is causing the ground fault. If nothing trips your outlet, or if your outlet doesn't reset, your ground fault is likely located in another part of your home. Call a professional to look. Faults can occur due to other outlets leaking current, problems with exterior circuits, and other faulty appliances.

## **Mechanical fault**

A machine that has been designed and manufactured to perform a certain function, is expected to do so when installed in a plant for its designed life span. However, for reasons beyond one's control, such a machine may fail to do so for several reasons including

- iv. a faulty design of the machine,
- v. inferior material and workmanship,
- vi. incorrect installation and wrong operational procedure,

Excessive component heating are signs that something is going in the wrong direction. In the case of non-typical vibrations, the main causes are:

- xvi. Defective bearings and gears
- xvii. Electrical and mechanical failures in motors,
- xviii. Problems caused by misalignments,
- xix. Unbalances or unstable bases,
- xx. Bent shafts, pulley or belt failures
- xxi. Mechanical gaps,
- xxii. Aerodynamic or hydraulic problems
- xxiii. Water and oil leaks
- xxiv. Corroded pipes,
- xxv. Smells and abnormal sounds.
- xxvi. Lack of or inadequate lubrication
- xxvii. Not attending equipment
- xxviii. Safety stops when recommended
- xxix. Incorrect operation of the machinery
- xxx. Lack of or improper maintenance

## **Electrical Tools and Equipment**

Before you tackle any electrical project, having the proper tools is essential to getting the job done efficiently, correctly, and more importantly, safely! The old saying, use the right tool for the job, couldn't be more relevant, especially when it comes to electrical work.

Some of the tools and equipment's are:

### **Personal protective equipment (PPE)**

Your personal safety should be the most important consideration. Goggles and safety glasses, gloves, long-sleeve shirts, long pants or blue jeans, hard hat, etc. A large dose of common sense is required here. Think about the hazards and protect yourself accordingly before taking on any task.



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### **Circuit Testers**

You need to have a voltage tester of some type for electrical work, and one that you trust is working properly. The important thing is to ensure that it is working so you can verify that you have the power off on any circuit you may be working with. Check it on a known live source before trusting it to determine if your circuit is dead.

### **Screwdrivers**

It is essential to have a good quality set of screwdrivers. It is best to purchase them in a complete set rather than individually, as this will save you money, and increase the chances that you will have the driver that best fits the need.



### **Cordless Screwdriver/Drill**

If you are going to take on any project beyond the most basic of jobs, such as, for example, changing out an individual receptacle or switch, you should have a good cordless drill and driver tool, along with a complete set of screwdriver bits and drill bits. This will save you a lot of time and when used properly, a power driver can be used in place of a screwdriver for most jobs.

I recommend purchasing a driver and drill instead of a basic cordless screwdriver as the quality is usually better, and one tool will perform both functions. Get the best quality you can afford, and make sure it has a 1/2" drive, and that it has sufficient power to drill a 1" hole using an auger bit.

If you will be using it a lot as a screwdriver, then give some consideration to the weight and size when selecting the tool.



### **Electric Drill**

For larger projects, with a lot of drilling required (wood studs, etc.), then an electric drill is more practical. A 1/2" medium duty drill is a minimum for driving a wood auger bit.

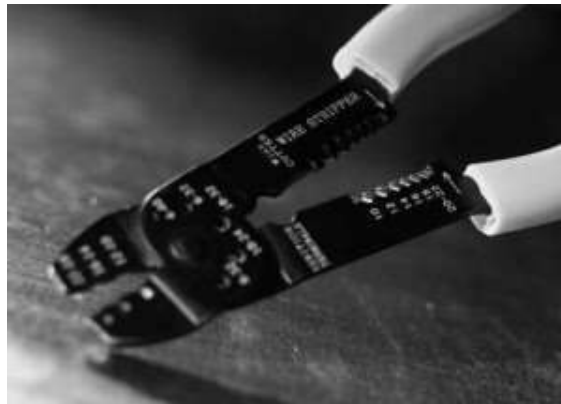
### **Knife**

You will need to have a good knife, and I prefer a standard utility knife for stripping the PVC jacket from Romex, stripping large gauge wire, and for many other jobs as well.

### **Wire Strippers**

Have a good quality wire stripper. I prefer a T-Stripper with a wire cutter, light-duty plier nose, and holes for bending termination loops on wires for most home electrical work. A combination crimper, cutter, stripper, bolt cutter and more, like those found in automotive electrical repair kits can be very handy as well, but the multi-purpose aspect means that the wire stripping function is compromised.

A mechanical wire stripper does a really good job, especially for commercial or industrial applications.



### **Lineman's Plier**

A lineman's plier, or a bull nose plier with a wire cutter, and at least 8" or 9" handles is also an essential part of the electrical tool list. We use these for cutting, bending, twisting wires, etc.



### **Standard, Long-Nosed Pliers**

Also known as needle-nosed pliers. These tools are also very handy to have as a part of your electrical tool kit. They should have wire cutting knives as well.

### **Hammer**

Have a good quality, 16oz. claw hammer. You will need this for driving staples, nails, etc.



### **Tape Measure**

Have a good quality, locking tape measure and a 25' length, 1" blade is maybe over-kill, but will come in handy for other projects around the home.

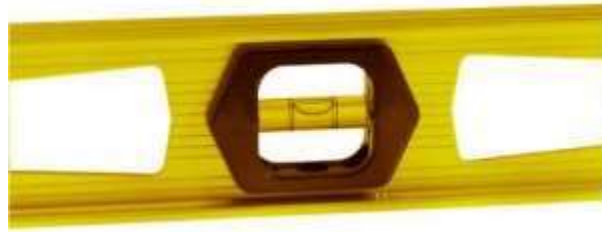


### **Level**

A 6" plastic torpedo level is essential for levelling outlet boxes, cover plates, wall fixtures, etc. A plastic level is less likely to leave marks.



Always check to make sure the level is indeed “level”. Before purchasing, check on a flat surface and note the position of the bubble, even if not quite at center. Then flip the level end for end in the exact same location and see if the bubble is in the same spot. You would be surprised how many you will find that don’t pass this test. Especially in the lower quality price range.



### **Crescent wrench**

Have one or two sizes of crescent wrenches in your kit.

### **Pump Pliers**

Very handy, and essential if you are working with conduit, such as, flexible conduit.

### **Pipe Wrench**

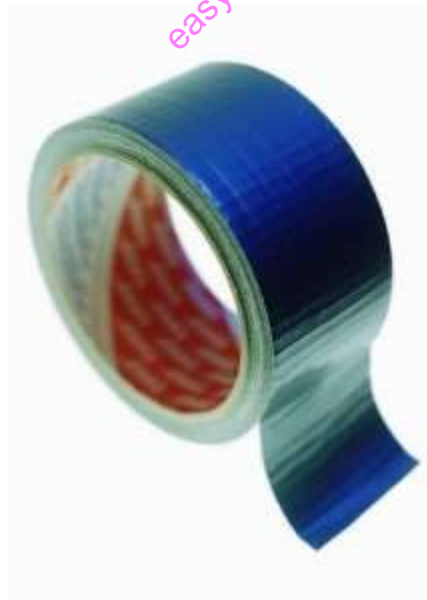
Essential if working with conduit

### **Electrical Tape**

Every electrical tool kit should have at least a roll of black electrical tape, and having a few colours like red and blue helps as well for identifying wires, etc.

### **Duct Tape**

Every tool kit, electrical or otherwise, must have the universal repair tool that is a roll of duct tape!



### **Tool Box or Chest**

You need something, even if it’s just a big pail, to keep everything together, and to have a place to put all your tools away. It’s nice to have a good tool box with many compartments to help you keep organized.



### **Ladders and Step Stools**

They won't fit in your toolbox, but you will need the appropriate size for the height you will be working at.

### **Bandages**

No matter how careful you are, accidents happen. Just do all you can to protect yourself and to minimize the potential for injury. Have a first aid kit handy, just in case!

### **Hacksaw**

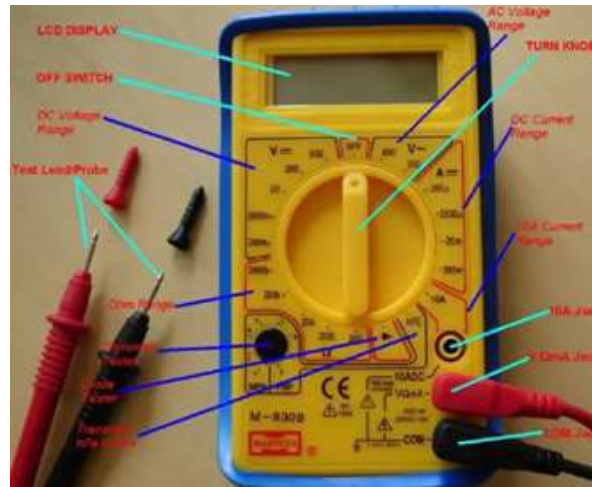
Critical if working with EMT conduit, flex, etc. If cutting a lot of metal, then an electric reciprocating saw will save you time.



### **Flashlight/Headlamp**

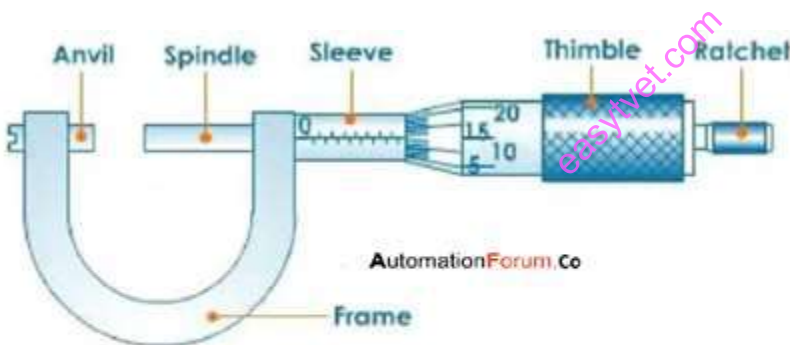
For when you need some extra light for dark places, or when the power is off while working on existing systems.





## Micrometer

A micrometer can be used to measure small and large sizes of wires, it is also used to remove the diameter of circular wires. A micrometer can measure the diameter of thin wire accurately or thickness of sheet metal.



## Wrenches

Wrenches are instruments that can be used to turn nuts or hold the piece of stock when tightening screws, nuts, and bolts. There are different types of wrenches like adjustable wrenches, pipe wrench, vice grip wrench.

## Specification of Tools

Electrical engineers are required to work in hazardous environments near energized equipment. There are certain tools they require to carry out their job effectively and safely without causing

any harm to themselves and those around them. Here's a sneak peek into some electrical engineering tools and their uses.

As with any tool purchase, you'll get longer life and better performance from higher-quality tools. Better electrical hand tools, such as wire cutters and linesman pliers, have insulated handles to help guard against shock.

### **Recording of Installation Failure Results**

Fault records are one of the most important pieces of evidence that event analysts can have during system event investigations. They can provide the reasons for premature equipment failure, supply waveforms and status of equipment behavior during an event, and give necessary information to perform post-fault event analysis. Proper use and interpretation of event records can lead to corrective action for a given system problem resulting in improved performance and reliability of any generation, transmission, and distribution system. Fault recording has been used for decades now, and it is generally used for the following purposes:

- Provide the reasons for premature equipment failure
- Supply waveforms and status of equipment behavior during event
- Give necessary information to perform post-fault event analysis

#### **9.2.2.4 Learning Activities**

- d) Demonstrate the use of ohmmeter in testing for continuity short and open circuits
- e) Demonstrate the use of voltmeter in measuring voltages in circuits
- f) The trainees to carry out activities involving the use of the multimeter function in carrying various tests
  - iv. The trainer to construct a single stage amplifier as shown in figure 1 below
  - v. Ascertain the normal working voltages
  - vi. Simulate the following problems in sequence to demonstrate how the voltages levels will be affected
    - R1 Open circuit
    - R2 10open circuit
    - R3 Open circuit
    - R4 Open circuit
    - B-E Junction shorted

- C-B Junction shorted
- Collector

The trainer should record the results and then help the trainee to interpret the cause of changes in the circuit voltage level

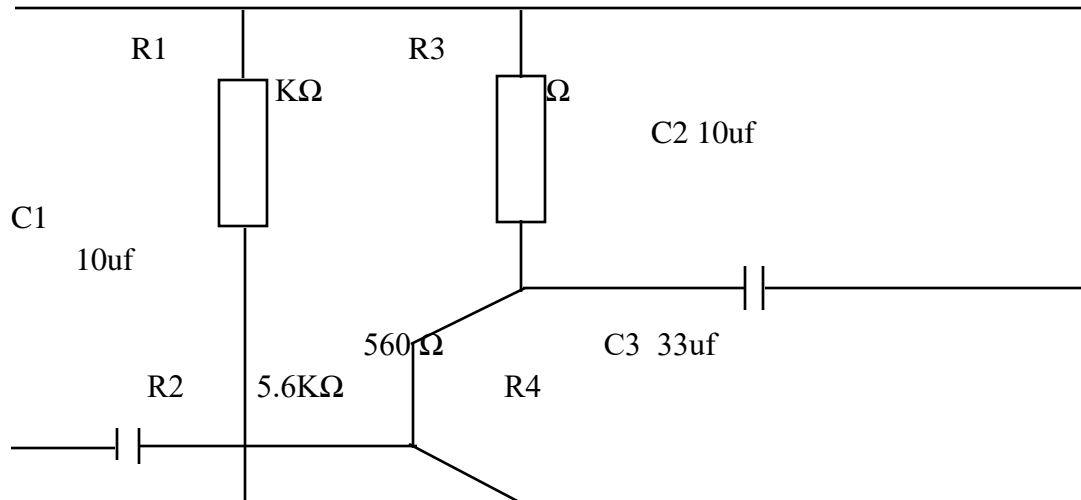


Figure 1: Single stage amplifier

| NO    |                      | VB | VE | VC | Remarks |
|-------|----------------------|----|----|----|---------|
| ix.   | Norm                 |    |    |    |         |
| x.    | R1                   |    |    |    |         |
| xi.   | R2                   |    |    |    |         |
| xii.  | R3                   |    |    |    |         |
| xiii. | R4                   |    |    |    |         |
| xiv.  | B-E junction shorted |    |    |    |         |
| xv.   | C-B junction shorted |    |    |    |         |
| xvi.  | Collector open       |    |    |    |         |

### 9.2.2.5 Self-Assessment

- g) What are the six steps in the trouble shooting process?
- h) What are the common trouble shooting problems?
- i) Explain what is meant by PPE
- j) Discuss how to deduce what actual faults could possibly be
- k) Discuss the three functions of a multi meter
- l) Discuss the appropriate ohmmeter ranges for testing different components

### 9.2.2.6 Tools, Equipment, Supplies and Materials

## Tools

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

## Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

## Materials and supplies

- Stationery
- Electrical component

### 9.2.2.7 References

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## Answers to self-assessment

- h) What are the six steps in the trouble shooting process?
- Identify the problem
  - Establish the theory of the cause
  - Test probable cause theory to determine actual cause
  - Establish an action plan and execute the plan
  - Verify the system functionality
  - Document the process

i) What are the common trouble shooting problems?

- Electrical surges
- Overloading
- Switches of light not working
- Flickering light
- Tripping circuit breaker
- Electrical shock

j) Explain what is meant by PPE

It is equipment worn to minimize exposure to a variety of hazards.

k) Examples include such items as gloves, foot and eye protections, protective hearing devices and hats, respirators and full body suits

l) Discuss how to deduce what actual faults could possibly be

m) ) Discuss the three functions of a multimeter

n) Discuss the appropriate ohmmeter ranges for testing different components



### 9.2.3 Learning Outcome 3: Repair the installation

#### 9.2.3.1 Introduction to the learning outcome

This section requires the trainee to repair a faulty electrical system using the correct set of tools, equipment, materials and observing all the safety procedures

#### 9.2.3.2 Performance Standard

1. Maintenance tools, equipment and materials are identified
2. Specifications and functionality of tools, equipment and materials are checked in accordance with the applicable technical and safety standards

### 5.2.3.3 Information Sheet

#### Definitions of terms

**Repair:** restore (damage system, faulty, or worn) to a good condition

**Manual:** a booklet that instructs on the usage of a particular machine

**Procedures:** a sequence of actions to be followed in solving a problem or accomplishing task

**Activity:** a situation in which a lot of things are happening or being done

**Planning:** is the process of thinking about the activities required to achieve a desired goal.

- Repair/replace
- Meaning of repair

**Repair:** restore (damaged system, faulty or worn) to a good condition

- Isolating the installation

Prior to beginning work on any installation, regulation 14 of Electricity at work Regulation 1989 require that three conditions must be met These include

- The isolation process which is also known in industry as lockout/tag out and is used to isolate machinery and equipment from energy source. It is important to ensure the isolation of any unsafe machinery/equipment from potential uncontrolled energy sources during repair, service or maintenance work.
- Isolation can be used as a standalone method of ensuring the safety of maintenance staff.
- The isolator should be in locked position (for example by a padlock) and a sign should be used to indicate that maintenance work is in progress.

Any stored energy (hydraulic or pneumatic power for instance) should also be dissipated before work starts. Before working on the equipment, it is essential that the effectiveness of the isolation is verified by a suitably competent person. Minimum safety isolation procedure includes the following:

- viii. Identification of correct isolation point or device
- ix. Check the condition of voltage indicating device such as the test lamp two pole voltage detector
- x. Switch of installation/circuit to be isolated
- xi. Verify with voltage indicating device that no voltage is present
- xii. Reconfirm that voltage indicating device functions correctly
- xiii. Lock-out device used to isolate installation circuit
- xiv. Post warning notice- suitable labeling of the disconnected conductors

### **Conducting repair activities**

After the primary work of problem diagnosis and identification has been carried out, the real task of repairing the fault in the system must be undertaken. Appropriate techniques, tools and procedures must be selected for each type of fault or component. The relevant safety precautions must be taken when removing and replacing the faulty components.

### **Selection of Appropriate Technique**

The appropriate methods of repair of equipment often depend on the type of fault, component and its location

### **Replacing of defective components**

When a certain component is found to be defective, it is necessary to first ascertain the cause of the defect before replacing it with a new one. This is especially important in relation to blown fuses, and shorted transistors. It is necessary to clear the fault that caused the fuse to blow or the transistor to short before making the replacement

### **Fault Finding and Repair**

Electrical faults are a health and safety hazard and could be putting your life in danger. Whether in the home or work environment, electrical faults put people at risk of electrocution and electrical fire. The problem must be solved by replacing only defective equipment or components.

### **Procedure**

- Analyse the symptoms of the electrical fault(s).

- Determine the type of electrical fault: open circuit, short circuit, insulation breakdown.
- Design the most effective and efficient strategy to solve
- Explain to the customer exactly what needs fixing and the budget required
- Carry out the work with minimal disruption to the customer's environment.

### **Recording repair activities**

Maintenance workers and their supervisors need to follow some basic rules in order to ensure the safe conduction of the work.

### **Planning**

Maintenance can be seen as either reactive or proactive. Reactive maintenance means engaging in maintenance activity to resolve equipment and machinery which are not functioning properly. Proactive maintenance occurs when steps are taken to maintain, clean and ensure optimum functioning of machinery and equipment to prevent lack of optimum functioning. Maintenance and particularly proactive maintenance are important management issues:

The results of a suitable and sufficient risk assessment should enable to choose which good practice measures are most appropriate in preventing risks in general and also in preventing risks to any individuals identified as

being particular risk. The implementation may mean making changes to the organisation and working procedures, working environment, equipment and products used. Changes could also be necessary in training management and staff as well as improving communications.

### **Special issues Qualification**

Based on the conducted risk assessment the following issues need special attention:

3. A qualification level has to be determined for the specific repair and maintenance tasks
4. Enough time and appropriate resources have to be allocated.

Only authorised personnel should be allowed to do repair or maintenance work. This becomes all the more important the machines and structures are more sophisticated. Only then can it be guaranteed that the right steps are followed and the correct equipment is used.

Sometimes, it can be necessary to conduct the repair or maintenance work at running machines. In this case special measures have to be taken. The normal safeguards should be in place and should be used.

If that is not possible, special protection devices have to be used (special tools, mobile switches), the speed of the machine has to be reduced, and special covers for dangerous areas have to be provided.

- If this should, in some very special cases, not be possible, special measures have to be taken based on a detailed risk assessment. Supervision must be provided throughout the process.

### **Work Execution**

The work has to be conducted in a safe manner. Only workers with the appropriate qualification should be allowed to conduct specified work (e.g. welders must not repair their welding machines; this must be left to electricians; Site-specific instructions should also be given, which is especially important in the case of contracted out maintenance. That way the workers will be aware of any company specific characteristics.

Safe procedures need to be followed as established in the planning phase, even when under time pressure. Procedures for unexpected events have to be in place: “Part of the safe system of work should be to stop work when faced with an unforeseen problem or a problem exceeding one’s own competence

#### **9.2.3.4 Learning Activities**

b) Carry out repairs of the following appliances

- Iron box
- Cooker
- Hair drier
- Electric fan
- Fluorescent fitting

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#### **9.2.3.5 Self-Assessment**

- g) How do you identify that a machine has a problem?
- h) State the general rule to be observed when selecting components for replacement.
- i) State importance of running the repaired equipment in its disassembled condition before reassembling.
- j) Discuss the criteria for selection of specific type of repair technique
- k) Discuss the considerations taken in the selection of replacement of parts
- l) Discuss the importance of testing the equipment for proper operation before replacing its covers

#### **9.2.3.6 Tools, Equipment, Supplies and Materials**

##### **Tools**

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

### **Materials and supplies**

- Stationery
- Cables
- Lubricants
- Service parts and components

### **Equipment**

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

### **Reference materials**

- IEE regulations
- Organizational procedures manual
- charts

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### **9.2.3.7 Reference**

1. Eletrical repair and maintenance- study. Com
2. Maintenance repair and operations/ EC&M- [www.ecmweb.com](http://www.ecmweb.com)
3. EElectricity level 4 by klb

### **Answers to Self-Assessment Questions**

d) How do you identify the problem?

- It is identified by finding the faulty part or component through visual inspection or tests using instruments

e) State the general rule to be observed when selecting components for replacement

- The component must have the same or higher performance characteristics

f) What is the importance of testing a repaired equipment?

- To ensure the that the equipment function well at all settings

## 9.2.4 Learning Outcome 4: Test the repaired system

### 9.2.4.1 Introduction to the learning outcome

This section requires the trainee to test the repaired system. It involves identifying the test points, carrying out test and recording the results

### 9.2.4.2 Performance Standard

- Appropriate tests and test points are identified Safety procedures are adhered to
- System is tested as per test procedure
- Test results are recorded according to the established procedures
- Parameters are compared against the standard values
- Maintenance report is prepared according to approved format

### 9.2.4.3 Information Sheet

#### Definitions of terms

A **report**: is a short, sharp, concise document which with respect to the maintenance of the equip

**Testing**: the means by which the presence, quality or genuineness of anything is determined, a means of trails

**Parameters**: a numerical or measurable factor forming one of a set that defines a system or sets of conditions of its operation

**Standards**: something used as a measure norm or model in comparative evaluations

#### Identification of test and test points

Testing the system's operation once the problem is "fixed" is the last step before signing off the job ticket and walking away from a machine repair.

Before beginning any test, answer the following five questions:

- Is the circuit on or off?
- What is the condition of the fuses or breakers?
- What are the results of a visual inspection?
- Are there bad terminations?
- Is the meter working?

Meters and test equipment, as well as print tools, such as operating logs and schematics, will all help you diagnose and solve electrical problems. The fundamental diagnostic tools and test

equipment are the voltmeter, ammeter, and ohmmeter. The basic functions of these meters are combined in a multimeter.

## Test point

A **test point** is a location within an electronic circuit that is used to either monitor the state of the circuitry or to inject test signals. Test points have two primary uses:

- During manufacturing they are used to verify that a newly assembled device is working correctly. Any equipment that fails this testing is either discarded or sent to a rework station to attempt to repair the manufacturing defects.
- After sale of the device to a customer, test points may be used at a later time to repair the device if it malfunctions, or if the device needs to be re-calibrated after having components replaced.

Test points can be labelled and may include pins for attachment of alligator clips or may have complete connectors for test clips.

Modern miniature surface-mount electronics often simply have a row of unlabeled, tinned solder pads. The device is placed into a test fixture that holds the device securely, and a special surface-contact connector plate is pressed down onto the solder pads to connect them all as a group.

## 4-Step Approach to Utilizing Test Points

An excellent approach to implementing the use of test points is to follow the following 4-step approach. It provides a systematic, organized methodology that will enable consistency in utilizing test points across a range of different applications.

5. **Define** – The first step is to define a test point. A standard set of test point guidelines should be developed which can be used to verify which artefacts/objects are determined to be test points. And to help standardize the process of defining test points, test point detail & summary templates should be created.
6. **Create** – This step involves identifying potential test points at detail level.
7. **Validate and refine** – The procedure of creating and implementing test points should regularly be reviewed and refined. Creating firm timelines for the validation process — once every quarter, for example, or upon the release of every 6 service packs — can help assure consistency in the validate/refine process.
8. **Implement and Measure** – Implementing test points for a defined release should involve conducting an impact analysis. It's also a time to look for ways to improve the process –



searching for opportunities to increase test coverage, for example, or identifying opportunities for improving test productivity. It can also be helpful to incorporate metric impacts in a release scorecard.

## **Test parameters**

It is the job of a test technician to know which piece of test equipment to use for the task at hand and also understand the limitations of the test equipment they are using

Electrical testing in its most basic form is the act of applying a voltage or current to a circuit and comparing the measured value to an expected result. Electrical test equipment verifies the math behind a circuit and each piece of test equipment is designed for a specific application.

Electrical test equipment should be considered a source of lethal electrical energy. Technicians must observe all safety warnings and follow all practical safety precautions to prevent contact with energized parts of the equipment and related circuits, including the use of appropriate Personal Protective Equipment.

## **Tests**

The correct tests need to be carried out in the following order:

- f) Visual Inspection This is very important as approximately 90% of faults can be found by this inspection alone. The Visual Inspection is not just an inspection; it basically is *'everything but'* what is done during the actual electrical testing process. This part of the testing process may involve:
- Smelling
  - Pulling on leads
  - Tapping the appliance
  - Shaking
  - Turning some part/s
  - Checking by trying to see that retractable guards actually retract and all manner of other things may be done to ensure that it is safe to operate.
- g) Earth Continuity Test
- h) Insulation Resistance Test
- i) Leakage Test

- j) Further tests have to be performed on leads, RCDs etc

### **Test parameters**

The use of test parameters is a powerful practice to enhance your testing scenarios. In other words, the concept of parameters in testing is that your test cases may define and likewise use some parameters. Scaling up your test cases effectively usually involves the practice of parametrization.

- Voltage

The a.c voltmeter may be used to test the presence and level of a.c supply and signal in electric circuit. Care must be to use the correct range. In the case of mains voltages, all necessary safety precautions must be observed to prevent electric shocks.

The d.c voltmeter functions used for testing voltage levels in electronic circuits, most components failure in electronic circuits alter the d.c operating conditions of the circuit. intensity in the range of 10 A with the accuracy of 1  $\mu$ A, voltages in the range of 1 kV with the accuracy of 1  $\mu$ V

- Resistance

The ohmmeter is useful for testing continuity of heating elements, stator, coils, armature winding and operation of switches.

When tested with an ohmmeter, switches should show continuity in closed position. the resistance of a closed circuit is zero. The resistance of an open switch is infinity. Any intermediate resistance reading between switch contacts would indicate loose contact, the presence of dirt or moisture.

- Current

Just like the voltmeter the ammeter can be used to infer faults in system. In case of fault the ammeter shows a higher than normal charge for longer, even though you know you have not used more electricity

### **Testing**

A final test should be done to ascertain that the equipment is functioning by the client. This is done by connecting power supply to the equipment and manipulating its controls to ensure that the equipment functions well at all settings

### **Documenting results**

Maintenance and repair documentation must be updated frequently to reflect equipment upgrades and technology advances, as well as changes in safety standards. For this reason, tracking previous versions of documentation is yet another key consideration.

The aim of documentation is to give those carrying out the works the information they need. Documents are also used to prepare cost estimates and to obtain tenders from potential contractors. Documentation should be prepared by qualified specialists. The key to good documentation is to correctly identify the problem to be solved, and hence to specify an appropriate solution. The nature and extent of the work must then be clearly conveyed to those who will do it. This information sheet discusses firstly what to document and secondly how. The central maintenance and repair record can be used to keep track of all other maintenance, including maintenance done by the in-house team, by vendors, or by service agents. The information captured should include the date, the equipment reference number, what was done, who did the work, and when next maintenance is due

### **Maintenance report writing**

A report is a short, sharp, concise document which is written for a particular purpose and audience. It generally sets out and analyses a situation or problem, often making recommendations for future action. It is a factual paper, and needs to be clear and well-structured.

## **5 Steps to Create a Maintenance Report in MS Word**

### **Step 1: Create the Cover Page**

The title should contain the information as to what the maintenance report is being created. Write the name of your company and enter the logo as well. Write down the details as well, like the address the contact details, email, etc.

### **Step 2: Cover Letter**

On the next page include the cover letter. The person, depending on who your client is, might not be able to make sense of the technical information that you might be presenting later. That is why, in the cover letter, write down, in brief, the results of the checking. Mention what needs repairing and other such basic details.

### **Step 3: Device Information**

In the next section, write down in detail all the information related to the device or machine. List out all the components and write down what condition they are in. You might want to make a table for the purpose as it will help you to present and record the information in a much more efficient way.

### **Step 4: New Parts Cost Details**

Write down the parts that need repairing. Some of the parts might need a full replacement. In each case, there will be a charge incurred. It is convenient, just to put the information in this document. Mention each of the charges clearly and separately. Write the total cost involved and consider putting it in the cover letter as well.

### **Step 5: Suggestions and Signature**

Despite repairing certain parts, there might be something on the client's end that he can do to squeeze some extra performance out of the machine. Also, you might have noticed some negligence on the client's part, which you might want to point out to him so that his machine lasts longer. Finally, put your name and signature at the bottom.

## Maintenance Report Form Template

|                         |  |
|-------------------------|--|
| <b>Contact Details</b>  |  |
| <b>Name</b>             |  |
| <b>Date</b>             |  |
| <b>Property Address</b> |  |

**Description of maintenance issue:**

**For office use:**

**Date Received**

**Action Taken**

**Works Completed**

### 9.2.4.4 Learning Activities

- d) Demonstrate how to carry out the final test after the equipment has been reassembled
- e) Perform the final test on the repaired equipment
- f) Prepare a report on the repair carried out

### 9.2.4.5 Self-Assessment

- 4. What is testing in electrical equipment?
- 5. Name types of test carried

6. What are the basic instrument for testing?

#### **9.2.4.6 Tools, Equipment, Supplies and Materials**

##### **Tools**

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

##### **Materials and supplies**

- Stationery
- Cables
- Lubricants
- Service parts and components

##### **Equipment**

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

#### **9.2.4.7 References**

Kiameh, P. (2003). *Electrical Equipment Handbook : Troubleshooting & Maintenance*. McGraw-Hill.

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### **Answers to Self-Assessments Questions**

#### **Self-Assessment**

4. What is testing in electrical equipment –

- it makes sure that system work the way they are supposed to

5. Name types of test carried

- -visual inspection,
- earth continuity
- insulation resistance,
- earth leakage, polarity
- loop impedance functional

6. What are the basic instrument for testing?

- Multimeter
- Oscilloscope
- Signal generators
- Signal tracers
- The megger