REPUBLIC OF KENYA

LEARNING GUIDE

FOR

PLUMBING

LEVEL 5

TVET CDACC
P.O. BOX 15745-00100
NAIROBI

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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 Plumbing 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 the construction 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 plumbing 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.

CHAIRPERSON, 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 construction sector.

COUNCIL SECRETARY/CEO
TVET CDACC

ACRONYMS

BC	Basic Competency
CDACC	Curriculum Development, Assessment and Certification Council
CR	Core Competency
CAD	Computer Aided Design
CM	Common Competency
CON	Construction Sector
PL	Plumbing
OS	Occupational Standard
OSHA	Occupation Safety and Health Act
PPE	Personal Protective equipment
TVET	Technical and Vocational Education and Training
TSA	Total Surface Area
CSA	Curved Surface Area

TABLE OF CONTENT

LIST OF FIGURES AND TABLES

BACKGROUND INFORMATION

This unit specifies the competencies required to install sanitary appliances. It involves selecting and fixing sanitary appliances in buildings. It applies in the construction industry.

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 of Learning Code	Unit of Learning Title
CON/CU/PL/CC/01/5/A	Basic Mathematics
CON/CU/PL/CC/02/5/A	Technical drawing
CON/CU/PL/CC/02/5/A	Scientific principles

Table 2: Core Units of Learning

Unit of Learning Code	Unit of Learning Title
CON/CU/PL/CR/01/5/A	Water supply systems
CON/CU/PL/CR/02/5/A	Rainwater harvest and disposal
CON/CU/PL/CR/03/5/A	Drainage systems
CON/CU/PL/CR/04/5/A	Sanitary appliances
CON/CU/PL/CR/05/5/A	Water Storage systems
CON/CU/PL/CR/06/5/A	Maintenance of plumbing systems
CON/CU/PL/CR/07/5/A	Fire control system

COMMON UNITS

CHAPTER 1: BASIC MATHEMATICS

Unit of learning code CON/CU/PL/CC/01/5/A

Related Unit of Competency in Occupational Standard Apply Basic Mathematics

1.1 Introduction to the unit of learning

This unit describes the competencies required in applying basic: algebra, trigonometry statistics, indices and logarithms and ratio. It also involves performing geometrical calculations, business calculations, carrying out basic mensuration and plotting simple graphs.

1.2 Summary of Learning Outcomes

1. Apply basic algebra
2. Apply basic trigonometry
3. Perform geometrical calculations
4. Carry out basic mensuration
5. Apply basic statistics
6. Plot simple graphs
7. Apply Indices and Logarithms
8. Perform business calculations
9. Apply Ratios

1.2.1 Learning Outcome 1: Apply Basic Algebra

1.2.1.1. Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics on algebra.

1.2.1.2. Performance Standard

1. Calculations involving Indices are performed based on the concept
2. Linear equations are represented based on the concept
3. Scientific calculator is used in solving mathematical problems in line with manufacturer's manual
4. Simultaneous equations are performed based on mathematical rules
5. Simple algebraic equations are formed based on the concept
6. Simple algebraic equations are solved based on the concept

1.2.1.3. Information Sheet

Laws of indices

1. Law of Multiplication $a^n x a^m = a^{n+m}$
2. $Law\ of\ Division\ a^n \div a^m = a^{n-m}$
3. $Law\ of\ Power\ to\ power\ (a^n)^m = a^{nxm}$

Example leaving answers on indices form

i. $\mathbf{2^2 x 2^4 = 2^{2+4} = 2^2}$

ii. $\mathbf{3^2 x 3^3 = 2^{2+3} = 2^5}$

iii. $\mathbf{5^4 \div 5^2 = 5^{4-2} = 5^2}$

iv. $\mathbf{\frac{2^3 x 2^4}{2^7 x 2^5} = \frac{2^{3+4}}{2^{7+5}} = \frac{2^7}{2^{12}} = 2^{7-12} = 2^{-5}}$

v. **Evaluate:** $\mathbf{\frac{(10^2)^3}{10^4 x 10^2} = \frac{10^6}{10^6} = 10^{6-6} = 10^0 = 1}$

vi. **Find the value of:** $\mathbf{\frac{2^3 x 3^5 x (7^2)^2}{7^4 x 2^4 x 3^3} = 2^{3-4} x 3^{5-2} x 7^{2x2-4}}$

$\mathbf{= 2^{-1} x 3^2 x 7^0}$

$\mathbf{= \frac{1}{2} x 9 x 1}$

=4.5

Linear equations; are equations of the first order.

Examples:

Solve for x

- 2x – 3 = 0,

  2x=3

  x=3/2

  x=1.5

- 2y = 8

  y=8/2

  y=4

- m + 1 = 0,

m=-1

- x/2 = 3

x=3x2

x=6

- x + y = 2

x=2-y

- 3x – y + z = 3

3x-y=3-z

3x=3-z+y

$X=\frac{3-z+y}{3}$

Formulas

There are different forms to write linear equations. Some of them are:

Linear Equation	General Form	Example
Slope intercept form	$y = mx + c$	$y + 2x = 3$
Point–slope form	$y – y_1 = m (x – x_1)$	$y – 3 = 6(x – 2)$
General Form	$Ax + By + C = 0$	$2x + 3y – 6 = 0$
Intercept form	$x/x_0 + y/y_0 = 1$	$x/2 + y/3 = 1$

Example:

i. Solve (2x – 10)/2 = 3(x – 1)

Step 1: Clear the fraction

x – 5 = 3(x – 1)

Step 2: Simplify both sides equations

2x – 5 = 3x – 3

x = 3x + 2

x – 3x = 2

Step 3: Isolate x

-2x = 2

x = -1

ii. **Solve x = 12(x +2)Solution:**

x = 12(x + 2)

x = 12x + 24

Subtract 24 from each side

x – 24 = 12x + 24 – 24

x – 24 = 12x

Simplify

11x = -24

Isolate x, by dividing each side by 11

11x / 11 = -24/11

x = -24/11

iii. **Solve x – y = 12 and 2x + y = 22**

Solution:

Name the equations

x – y = 12 ———- (1)

2x + y = 22 ———- (2)

Isolate Equation (1) for x,

x = y + 12

Substitute y + 12 for x in equation (2)

2(y+12) + y = 22

3y + 24 = 22

3y = -2

or y = -2/3

Substitute the value of y in x = y + 12

x = y + 12

x = -2/3 + 12

x = 34/3

Answer: x = 34/3 and y = -2/3

Simultaneous equations

They're several methods of solving simultaneous equations including

1) Elimination method
2) Substitution method
3) Graphical method
4) Matrix method

Let us discuss the first two;

1) Elimination method

Example1.

Solve the following pair of simultaneous linear equations:

Equation 1: $2x + 3y = 8$

Equation 2: $3x + 2y = 7$

Step 1: Multiply each equation by a suitable number so that the two equations have the same leading coefficient. An easy choice is to multiply Equation 1 by 3, the coefficient of x in Equation 2, and multiply Equation 2 by 2, the x coefficient in Equation 1:

3×Eqn 1….>3×(2x +3y)=8)…..

>6x +9y=24

2×Eqn 2…..>2×(3x+2y)=7)…..>6x+4y=14 Both equations now have the same leading coefficient

Step 2: Subtract the second equation from the first.

$-(6x + 9y = 24$

$-(6x + 4y = 14)$

$5y = 10$

Step 3: Solve this new equation for y.

$y = 10/5 = 2$

Step 4: Substitute $y = 2$ into either Equation 1 or Equation 2 above and solve for x. We'll use Equation 1.

$2x + 3(2) = 8$

$2x + 6 = 8$ Subtract 6 from both sides

$2x = 2$ Divide both sides by 2

$x = 1$

Solution: $x = 1$, $y = 2$ or (1,2).

Substitution Method

$$x + y = 24$$
$$2x - y = -6$$

In the substitution method, we manipulate one of the equations such that one variable is defined in terms of the other:

$$x + y = 24$$
$$\downarrow$$
$$y = 24 - x$$

Defining y in terms of x

Then, we take this new *definition* of one variable and *substitute* it for the same variable in the other equation.

In this case, we take the definition of y, which is 24 - x and substitute this for the y term found in the other equation:

$$y = 24 - x$$
$$\downarrow \text{ Substitute}$$
$$2x - y = -6$$
$$\downarrow$$
$$2x - (24 - x) = -6$$

$$2x-24+x=-6$$

$$3x=-6+24$$

$3x=18$

$X=6$

$Y=24-x$

$Y=24-6$

$Y=1$

1.2.1.4. Learning Activities

With guidance from the trainer, manipulate different algebraic expressions through addition, subtraction, multiplication and Simplification.

1.2.1.5. Self-Assessment

Solve the following linear equations:

1. $5y-11=3y+9$
2. $3x + 4 = 7 – 2x$
3. $9 – 2(y – 5) = y + 10$

Solve the simultaneous questions below

4. $5x + 3y = 41$

   $2x + 3y = 20$

5. $4x - 4y = 24$

   $x - 4y = 3$

1.2.1.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Scientific Calculators • Rulers	• Charts with presentations of data • Graph books

• Pencils • Erasers • Computers with internet connection	• Text books

1.2.1.7. References

Ministry of Education (2003). *Secondary Mathematics Students' Book One (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Two (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Three (3rd ed)*. Nairobi: Kenya Literature Bureau

John Bird (2007). *Engineering Mathematics (5th Ed).* MA: Elsevier ltd

John Bird (2005). *Basic Engineering Mathematics, (4th Ed).* MA: Elsevier ltd

1.2.1.8. Model answers

1. 5y-11=3y+9

Solution:

Putting like times together

$5y - 3y = 9 + 11$

$2y = 20$

$\frac{\cancel{2}y}{\cancel{2}} = \frac{\cancel{20}10}{\cancel{2}} = 10$

$y = 10$

2. 3x + 4 = 7 – 2x

Solution:

Putting like terms together

$3x + 2x = 7 - 4$

$5x = 3$

$\frac{\cancel{5}x}{\cancel{5}} = \frac{3}{5}$

$x = \frac{3}{5}$

3. 9 – 2(y – 5) = y + 10

Solution:

Opening the brackets: $9 - 2y + 10 = y + 10$

Putting like terms together: $9 + 10 - 10 = y + 2y$

Simplify: $9 = 3y$

$\frac{\cancel{9}3}{\cancel{3}} = \frac{\cancel{3}y}{\cancel{3}}$

$3 = y$

4. 5x + 3y = 41

2x + 3y = 20

Solution by subtraction method:

$$\begin{array}{r} 5x + 3y = 41 \\ 2x + 3y = 20 \\ \hline 3x + 00 = 21 \\ 3x = 21 \end{array} -$$

$$\frac{\cancel{3}x}{\cancel{3}} = \frac{\cancel{21}7}{\cancel{3}}$$

$x = 7$

5. **4x − 4y = 24**

    x − 4y = 3

Solution: Adding the equations

$$\begin{array}{r} 4x - 4y = 24 - \\ x - 4y = 3 \\ \hline 3x - 0y = 21 \end{array}$$

$3x = 21$

$$\frac{\cancel{3}x}{\cancel{3}} = \frac{\cancel{21}7}{\cancel{3}}$$

$x = 7$

1.2.2 Learning Outcome 2: Apply basic trigonometry

1.2.2.1. Introduction to the learning outcome

This unit describes the competencies required in applying basic trigonometry.

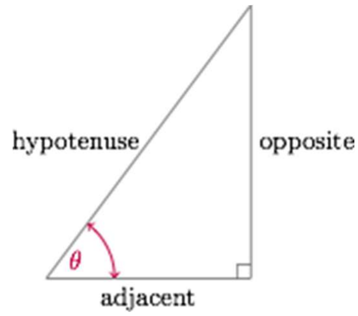
1.2.2.2. Performance Standard

1. Trigonometric ratios are derived based on trigonometric rules.
2. Calculations are performed based on trigonometric rules

1.2.2.3. Information Sheet

Trigonometric relationships

- There are six trigonometric ratios, sine, cosine, tangent, cosecant, secant and cotangent.
- These six trigonometric ratios are abbreviated as sin, cos, tan, csc, sec, cot.
- These are referred to as ratios since they can be expressed in terms of the sides of a right-angled triangle for a specific angle θ.



- Using the triangle above:
- $\sin\theta = \frac{opposite}{hypotenuse}$
- $\cos\theta = \frac{adjascent}{hypotenuse}$
- $\tan\theta = \frac{opposite}{adjascent}$

➢ $\frac{1}{sin\theta} = \csc\theta = \frac{hypotenus}{opposite}$

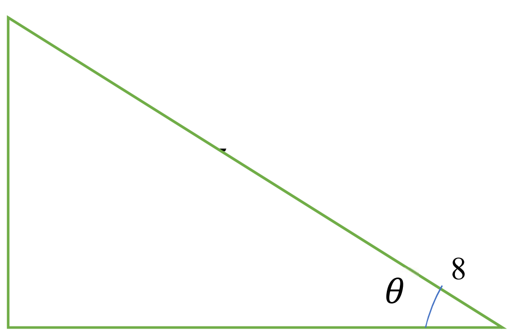
➢ $\frac{1}{cos\theta} = \sec\theta = \frac{hypotenuse}{adjascent}$

➢ $\frac{1}{tan\theta} = \cot\theta = \frac{adjascent}{opposite}$

Examples

1. Given the right triangle below, find

sin A, cos A, tan A, sec A, csc A and cot A.



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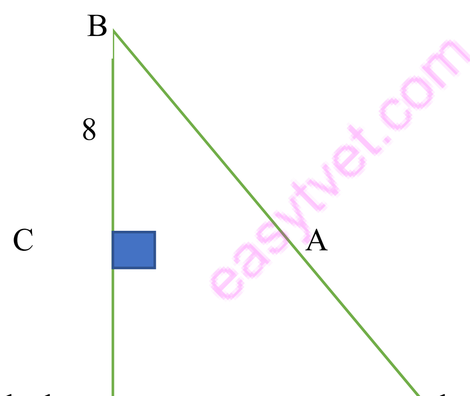
84

Given the lengths of the three sides of a right-angled triangle find the values of the trig functions, corresponding to the angle θ. (Round your answers to 2 decimal places)

2. Given the right triangle below, find
   sin A, cos A, tan A, sec A, csc A and cot A.



Solution ;

First we need to find the hypotenuse using Pythagora's theorem.

$(\text{hypotenuse})^2 = 8^2 + 6^2 = 100$

and hypotenuse = 10

We now use the definitions of the six trigonometric ratios given above to find sin A, cos A, tan A, sec A, csc A and cot A.

sin A = side opposite angle A / hypotenuse = 8 / 10 = 4 / 5

cos (A) = side adjacent to angle A / hypotenuse = 6 / 10 = 3 / 5

tan (A) = side opposite angle A / side adjacent to angle A

= 8 / 6 = 4 / 3

sec (A) = hypotenuse / side adjacent to angle A = 10 / 6

= 5 / 3

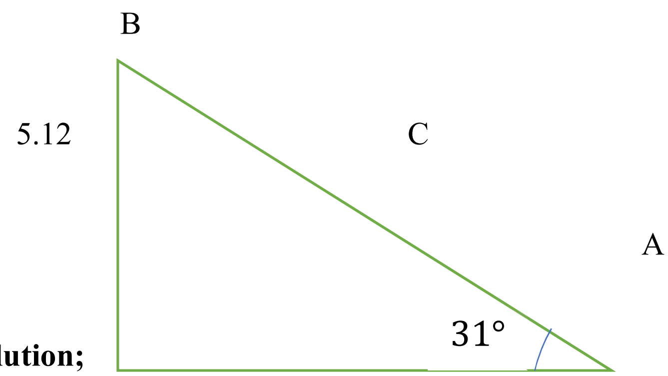
csc (A) = hypotenuse / side opposite to angle A

= 10 / 8 = 5 / 4

cot (A) = side adjacent to angle A / side opposite angle A

= 6 / 8 = 3 / 4

3. Find c in the figure below.



Solution;

We are given angle A and the side opposite to it with c the hypotenuse. The sine ratio gives a relationship between the angle, the side opposite to it and the hypotenuse as follows

sin A = opposite / hypotenuse

Angle A and opposite side are known, hence

sin 31 ^{o} = 5.12 / c

Solve for c

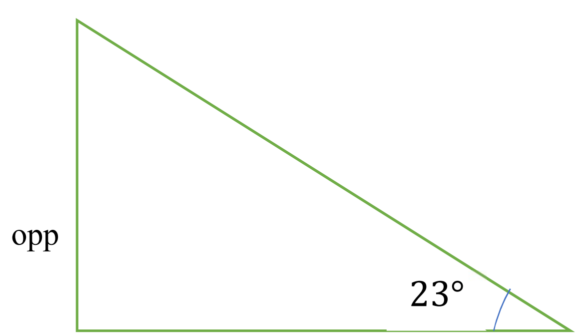
c = 5.12 / sin 31 ^{o}

and use a calculator to obtain

c (approximately) = 9.94

4. An electricity pylon stands on horizontal ground. At a point 80 m from the base of the pylon, the angle of elevation of the top of the pylon is 23◦. Calculate the height of the pylon to the nearest metre.

Solution;



80m

From the ratios we shall use tan

$$\tan 23° = \frac{opp}{80}$$

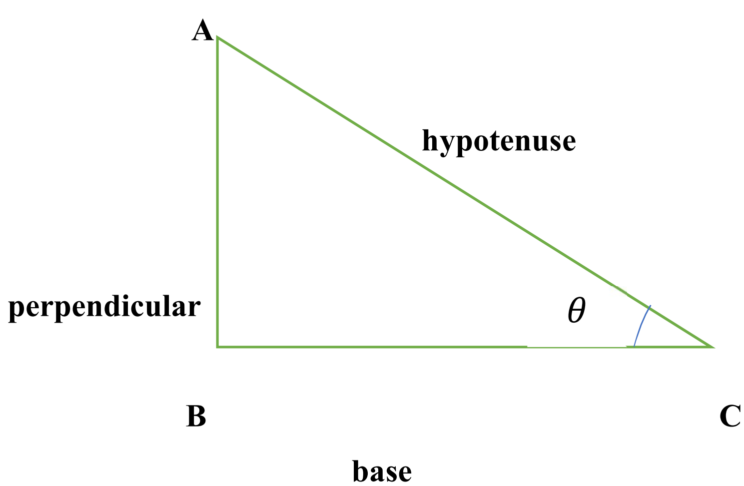
Opp=80 tan23°

=33.96m

=34m to the nearest metres

5. A surveyor measures the angle of elevation of the top of a perpendicular building as 19◦. He moves 120 m nearer the building and finds the angle of elevation is now 47◦. Determine the height of the building.

Trigonometric identities



In a right-angled triangle, by the Pythagorean theorem, we know,

$(\text{Perpendicular})^2 + (\text{Base})^2 = (\text{Hypotenuse})^2$

Therefore, in ΔABC, we have;

$AB^2 + BC^2 = AC^2$ ….. (1)

Dividing equation (1) by AC^2, we get

$$\left(\frac{AB}{AC}\right)^2 + \left(\frac{BC}{AC}\right)^2 = \left(\frac{AC}{AC}\right)^2$$

$(\text{Sin}\theta)^2 + (\text{Cos}\theta)^2 = 1^2$

$\text{Cos}^2\,\theta + \text{Sin}^2\,\theta = 1$ …...(2)

If $\theta = 0$, then,

- $\text{Cos}^2\,0 + \text{Sin}^2\,0 = 1$
- $1^2 + 0^2 = 1$
- $1 + 0 = 1$
- $1 = 1$

And if we put $\theta = 90$, then

- $\text{Cos}^2\,90 + \text{Sin}^2\,90 = 1$
- $0^2 + 1^2 = 1$
- $0 + 1 = 1$
- $1 = 1$

For all angles, $0° \leq \theta \leq 90°$, equation (2) is satisfied. Hence, equation (2) is a trigonometric identity.

Again, divide equation (1) by AB^2, we get

$$\left(\frac{AB}{AB}\right)^2 + \left(\frac{BC}{AB}\right)^2 = \left(\frac{AC}{AB}\right)^2$$

$\text{Cot}^2\,\theta + 1 = \text{Cosec}^2\,\theta$

$(1)^2 + (\text{Cot})^2 = (\text{Csc}\ \theta)^2$

$1 + (\text{Cot}\theta)^2 = (\text{Csc}\ \theta)^2$

$\text{Cot}^2\,\theta + 1 = \text{Cosec}^2\,\theta$ …. (3)

If $\theta = 0$, then equation (3) can be written as;

- $Cot^2 0 + 1 = Cosec^2 0$
- $\infty + 1 = \infty$
- $\infty = \infty$

Both the sides are equal.

And if θ = 90, then equation (3) can be written as;

- $Cot^2 90 + 1 = Cosec^2 90$
- $0^2 + 1 = 1^2$
- $1 = 1$

Let's see what we get if we divide equation (1) by BC^2, we get,

$\left(\frac{AB}{BC}\right)^2 + \left(\frac{BC}{BC}\right)^2 = \left(\frac{AC}{BC}\right)^2$

$(\text{Tan}\theta)^2 + (1)^2 = (\sec\theta)^2$

$(\text{Tan}\theta)^2 + (1)^2 = (\sec\theta)^2$

If θ = 0, then,

- $1 + \tan^2 0 = \sec^2 0$
- $1 + 0^2 = 1^2$
- $1 = 1$

And if we put θ = 90, then

- $1 + \tan^2 90 = \sec^2 90$
- $1 + \infty = \infty$
- $\infty = \infty$

As you can see, the values of both sides are equal. Therefore, it proves that for all the values between 0^0 and 90^0, the equation (4) is satisfied. So, it is also a trigonometric identity.

Examples involving identities

1. $(1 - \sin A)/(1 + \sin A) = (\sec A - \tan A)^2$

Solution:

L.H.S = $(1 - \sin A)/(1 + \sin A)$

= $(1 - \sin A)^2/(1 - \sin A)\ (1 + \sin A)$,[Multiply both numerator and denominator by $(1 - \sin A)$

= $(1 - \sin A)^2/(1 - \sin^2 A)$

= $(1 - \sin A)^2/(\cos^2 A)$, [Since $\sin^2 \theta + \cos^2 \theta = 1 \Rightarrow \cos^2 \theta = 1 - \sin^2 \theta$]

= $\{(1 - \sin A)/\cos A\}^2$

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

= $(\sec A – \tan A)^2$ = R.H.S. *Proved.*

2. Prove that, $\sqrt{\{(\sec \theta – 1)/(\sec \theta + 1)\}} = \operatorname{cosec} \theta - \cot \theta$.

Solution:

L.H.S.= $\sqrt{\{(\sec \theta – 1)/(\sec \theta + 1)\}}$

= $\sqrt{[\{(\sec \theta - 1)\ (\sec \theta - 1)\}/\{(\sec \theta + 1)\ (\sec \theta - 1)\}]}$; [multiplying numerator and denominator by $(\sec \theta - l)$ under radical sign]

= $\sqrt{\{(\sec \theta - 1)^2/(\sec^2 \theta - 1)\}}$

=$\sqrt{\{(\sec \theta -1)^2/\tan^2 \theta\}}$; [since, $\sec^2 \theta = 1 + \tan^2 \theta \Rightarrow \sec^2 \theta - 1 = \tan^2 \theta$]

= $(\sec \theta – 1)/\tan \theta$

$= (\sec\theta/\tan\theta) - (1/\tan\theta)$

$= \{(1/\cos\theta)/(\sin\theta/\cos\theta)\} - \cot\theta$

$= \{(1/\cos\theta) \times (\cos\theta/\sin\theta)\} - \cot\theta$

$= (1/\sin\theta) - \cot\theta$

$= \operatorname{cosec}\theta - \cot\theta$ = R.H.S. *Proved.*

3. $\tan^4\theta + \tan^2\theta = \sec^4\theta - \sec^2\theta$

Solution:

L.H.S $= \tan^4\theta + \tan^2\theta$

$= \tan^2\theta\,(\tan^2\theta + 1)$

$= (\sec^2\theta - 1)(\tan^2\theta + 1)$ [since, $\tan^2\theta = \sec^2\theta - 1$]

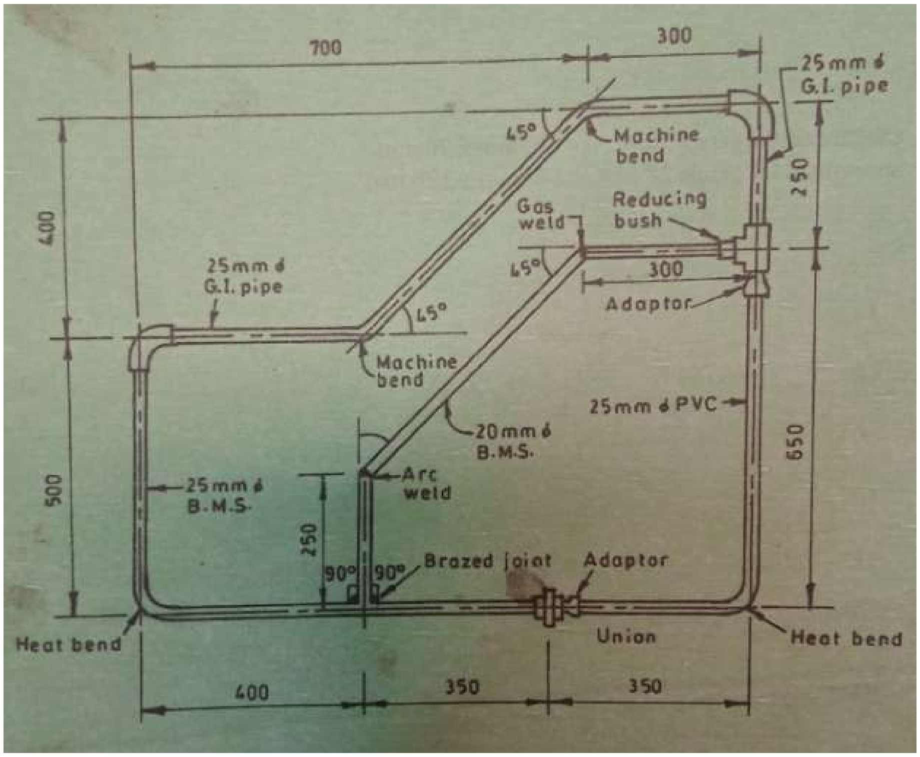
$= (\sec^2\theta - 1)\sec^2\theta$ [since, $\tan^2\theta + 1 = \sec^2\theta$]

$= \sec^4\theta - \sec^2\theta$ = R.H.S. *Proved.*

1.2.2.4. Learning Activities

1. Using knowledge in trigonometry, calculate the lengths of pipework required for the projects given
2. Fig 1

3.



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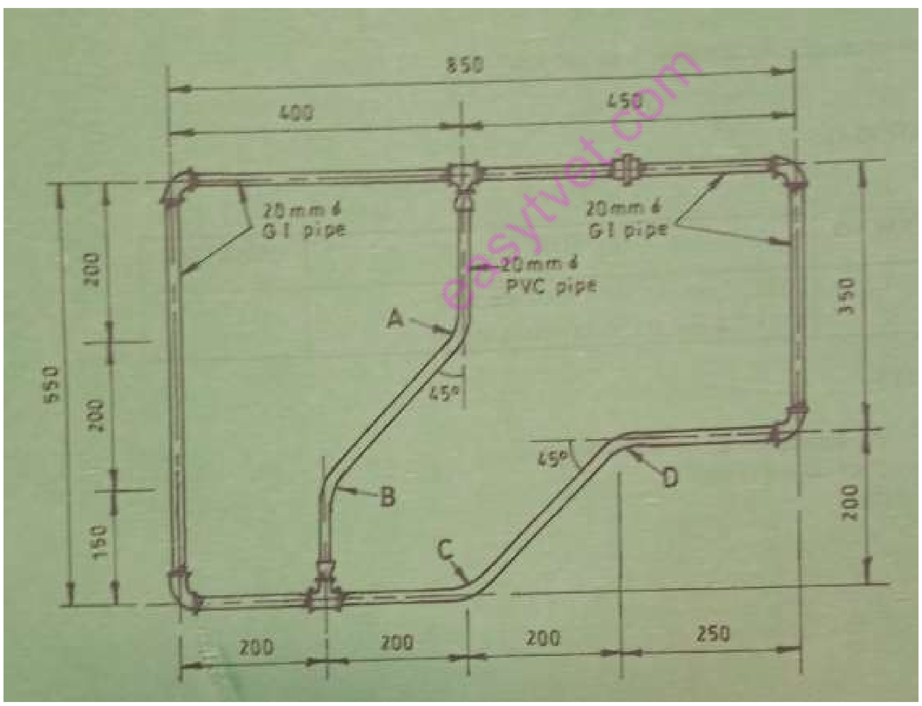


1.2.2.5. Self-Assessment

Prove the following identities

1. $\cos\theta/(1 - \tan\theta) + \sin\theta/(1 - \cot\theta) = \sin\theta + \cos\theta$

2. Show that, $1/(\csc A - \cot A) - 1/\sin A = 1/\sin A - 1/(\csc A + \cot A)$

3. $(\tan \theta + \sec \theta - 1)/(\tan \theta - \sec \theta + 1) = (1 + \sin \theta)/\cos \theta$

1.2.2.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	Materials:
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection	• Charts with presentations of data • Graph books • Text books

1.2.2.7. References

Ministry of Education (2003). *Secondary Mathematics Students' Book One (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Two (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Three (3rd ed)*. Nairobi: Kenya Literature Bureau

John Bird (2007). *Engineering Mathematics (5th Ed).* MA: Elsevier ltd

John Bird (2005). *Basic Engineering Mathematics, (4th Ed).* MA: Elsevier ltd

1.2.2.8. Model Answers

1. **$\cos\theta/(1 - \tan\theta) + \sin\theta/(1 - \cot\theta) = \sin\theta + \cos\theta$**

Solution:

L.H.S = $\cos\theta/(1 - \tan\theta) + \sin\theta/(1 - \cot\theta)$

$= \cos\theta/\{1 - (\sin\theta/\cos\theta)\} + \sin\theta/\{1 - (\cos\theta/\sin\theta)\}$

$= \cos\theta/\{(\cos\theta - \sin\theta)/\cos\theta\} + \sin\theta/\{(\sin\theta - \cos\theta/\sin\theta)\}$

$= \cos^2\theta/(\cos\theta - \sin\theta) + \sin^2\theta/(\cos\theta - \sin\theta)$

$= (\cos^2 \theta - \sin^2 \theta)/(\cos \theta - \sin \theta)$

$= [(\cos \theta + \sin \theta)(\cos \theta - \sin \theta)]/(\cos \theta - \sin \theta)$

$= (\cos \theta + \sin \theta)$ = R.H.S. *Proved.*

2. Show that, 1/(csc A - cot A) - 1/sin A = 1/sin A - 1/(csc A + cot A)

Solution:

We have,

1/(csc A - cot A) + 1/(csc A + cot A)

= (csc A + cot A + csc A - cot A)/($\csc^2$ A - $\cot^2$ A)

= (2 csc A)/1; [since, $\csc^2$ A = 1 + $\cot^2$ A ⇒ $\csc^2$A - $\cot^2$ A = 1]

= 2/sin A; [since, csc A = 1/sin A]

Therefore,

1/(csc A - cot A) + 1/(csc A + cot A) = 2/sin A

⇒ 1/(csc A - cot A) + 1/(csc A + cot A) = 1/sin A + 1/sin A

Therefore, 1/(csc A - cot A) - 1/sin A = 1/sin A - 1/(csc A + cot A) *Proved.*

3. $(\tan\theta + \sec\theta - 1)/(\tan\theta - \sec\theta + 1) = (1 + \sin\theta)/\cos\theta$

Solution:

L.H.S = $(\tan\theta + \sec\theta - 1)/(\tan\theta - \sec\theta + 1)$

$= [(\tan\theta + \sec\theta) - (\sec^2\theta - \tan^2\theta)]/(\tan\theta - \sec\theta + 1)$, [Since, $\sec^2\theta - \tan^2\theta = 1$]

$= \{(\tan\theta + \sec\theta) - (\sec\theta + \tan\theta)(\sec\theta - \tan\theta)\}/(\tan\theta - \sec\theta + 1)$

$= \{(\tan\theta + \sec\theta)(1 - \sec\theta + \tan\theta)\}/(\tan\theta - \sec\theta + 1)$

$= \{(\tan\theta + \sec\theta)(\tan\theta - \sec\theta + 1)\}/(\tan\theta - \sec\theta + 1)$

$= \tan\theta + \sec\theta$

$= (\sin\theta/\cos\theta) + (1/\cos\theta)$

$= (\sin\theta + 1)/\cos\theta$

$= (1 + \sin\theta)/\cos\theta$ = R.H.S. *Proved.*

1.2.3 Learning Outcome 3:Perform Geometrical Calculations

1.2.3.1. Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics it involves performing geometrical calculations.

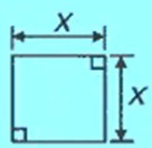
1.2.3.2. Performance Standard

1. Areas of regular figures are calculated based on the given formulae
2. Areas of irregular figures are calculated based on concept
3. Apply Pythagoras' theorem based on the concept

1.2.3.3. Information Sheet

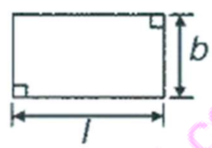
Area refers to the space that is occupies by a two-dimensional object. Or the space occupied by a flat object or a figure. There are different types of figures. Squares, Rectangles, Circles, Rhombus, Parallelogram, Trapezium, Sector & Segments. Each shape has its own applicable formula dependent on the shape of the edges and the outline.

(i) Square



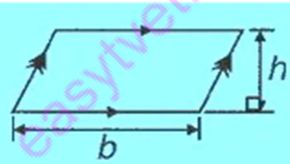
Area $= x^2$

(ii) Rectangle



Area $= l \times b$

(iii) Parallelogram

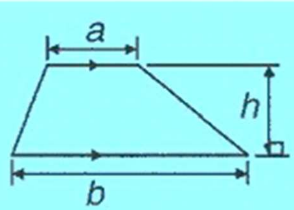


Area $= b \times h$

(iv) Triangle

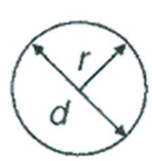
Area $= \frac{1}{2} \times b \times h$

(v) Trapezium



Area $= \frac{1}{2}(a+b)h$

(vi) Circle



Area $= \pi r^2$ or $\dfrac{\pi d^2}{4}$

Figure 1: Geometric Shapes

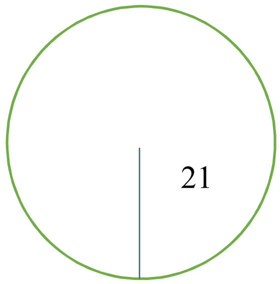
Table 3: Fomulae of Different Shapes

Shape Name	Area	Perimeter (or Circumference)
Circle	πr^2	$2\pi r$
Square	a^2	4a
Rectangle	$l \times b$	$2(l + b)$
Triangle	½ × height × base	$a + b + c$
Parallelogram	$b \times h$	$2(l + b)$
Rhombus	$\frac{1}{2} \times d_1 \times d_2$	4 × side
Trapezium	$\frac{1}{2} \times h\,(a + b)$	$a + b + c + d$

Shape Name	TSA	LSA (or CSA)	Volume
Cube	$6a^2$	$4a^2$	a^3
Cuboid	$2\,(lb + bh + hl)$	$2h\,(l + b)$	$l \times b \times h$
Cone	$\pi r\,(r + l)$	Πrl	$(\frac{1}{3}) \times \pi r^2 h$
Cylinder	$2\pi rh + 2\pi r^2$	$2\pi rh$	$\pi r^2\,h$
Sphere	$4\pi r^2$	$4\pi r^2$	$(4/3) \times \pi r^3$
Hemisphere	$3\pi r^2$	$2\pi r^2$	$(\frac{2}{3}) \times \pi r^3$

Areas

1. A circle has a radius of 21 cm. Find its circumference and area. (Use $\pi = 22/7$)



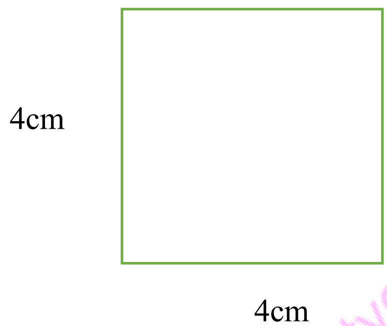
Solution: We know,

Circumference of circle = $2\pi r = 2 \times (22/7) \times 21 = 2 \times 22 \times 3 = 132$ cm

Area of circle = $\pi r^2 = (22/7) \times 21^2 = 22/7 \times 21 \times 21 = 22 \times 3 \times 21$

Area of circle with radius, 21cm = 1386 cm^2

2.2.1.1 If one side of a square is 4 cm, then what will be its area and perimeter?



Solution: Given,

Length of side of square = 4 cm

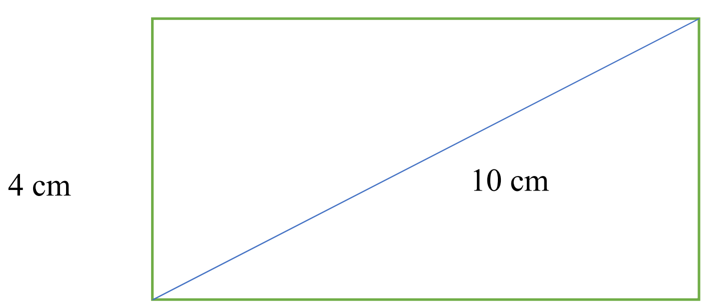
Area = $side^2 = 4^2 = 4 \times 4 = 16$ cm^2

Perimeter of square = sum of all its sides

Since, all the sides of the square are equal, therefore;

Perimeter = 4+4+4+4 = 16 cm

2.2.1.1 Suppose a quadrilateral having a diagonal of length 10 cm, which divides the quadrilateral into two triangles and the heights of triangles with diagonals as the base, are 4 cm and 6 cm. Find the area of the quadrilateral.



Solution: Given,

Diagonal, $d = 10$ cm

Height of one triangle, $h_1 = 4$cm

Height of another triangle, $h_2 = 6$cm

Area of quadrilateral = $\frac{1}{2} d(h_1+h_2) = \frac{1}{2} \times 10 \times (4+6) = 5 \times 10 = 50$ sq.cm.

4. A rhombus having diagonals of length 10 cm and 16 cm, respectively. Find its area.

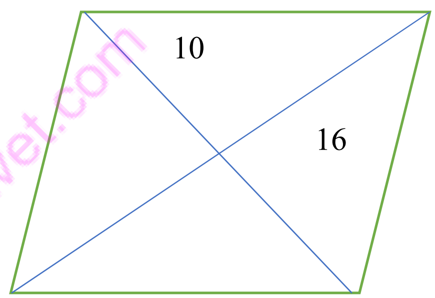
Solution: $d_1 = 10$ cm

$d_2 = 16$ cm

Area of rhombus = $\frac{1}{2} d_1 d_2$

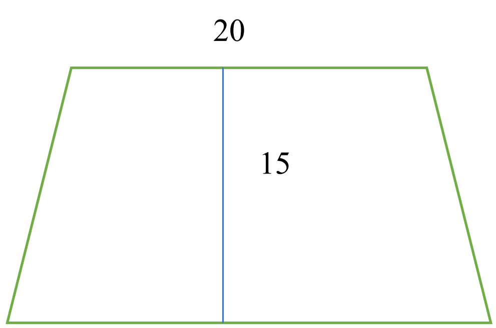
$A = \frac{1}{2} \times 10 \times 16$

$A = 80 \text{ cm}^2$



5. The area of a trapezium shaped field is 480 m², the distance between two parallel sides is 15 m and one of the parallel sides is 20 m. Find the other parallel side.

Solution: One of the parallel sides of the trapezium is $a = 20$ m, let another parallel side be b, height $h = 15$ m.



The given area of trapezium = 480 m^2

We know, by formula;

Area of a trapezium = ½ h (a+b)

480 = ½ (15) (20+b)

20 + b = (480×2)/15

b = 64 – 20 = 44 m

1.2.3.4. Learning Activities

With the trainers guidance, estimate the dimension of a given workshop and all the walk ways and find the area.

1.2.3.5. Self-Assessment

1. The height, length and width of a cuboidal box are 20 cm, 15 cm and 10 cm, respectively. Find its area.
2. If a cube has its side-length equal to 5cm, then its area is?
3. Find the height of a cylinder whose radius is 7 cm and the total surface area is 968 cm^2.
4. Find the height of a cuboid whose volume is 275 cm3 and base area is 25 cm^2.
5. A rectangular piece of paper 11 cm × 4 cm is folded without overlapping to make a cylinder of height 4 cm. Find the volume of the cylinder.

1.2.3.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection •	• Charts with presentations of data • Graph books • Text books •

1.2.3.7. References

Ministry of Education (2003). *Secondary Mathematics Students' Book One (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Two (3rd ed)*. Nairobi: Kenya Literature Bureau

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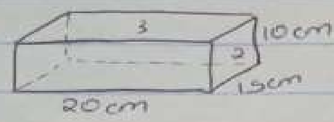
1.2.3.8. Model Answers

1. The height, length and width of a cuboidal box are 20cm 15cm and 10cm. Find the area?



Cuboid = 6 faces (rectangular)

$A = L \times W$

Area 1 $= 20 \times 10 \times 2 = 400 cm^2$

2 $= 15 \times 10 \times 2 = 300 cm^2$

3 $= 20 \times 15 \times 2 = \underline{600 cm^2}$

AREA $= 1300 cm^2$

2. If a cube has its sidelength equal to 5cm, then its area is?

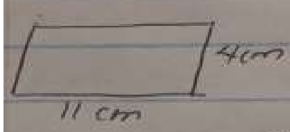
Solution

A cube is a composition of squares.

$A = L \times L$

$= 5 \times 5 \times 6 \text{squares} = 150 cm^2$

3. A rectangular piece of paper is folded without overlapping to make a cylinder of height 4cm. Find the volume.



length of paper is the circumference the base of the cylinder

circumference $(\pi D) = 11cm$ $\pi = 3.142$ or $22/7$

$\frac{3.142 \times D}{3.142} = \frac{11cm}{3.142} = 3.5cm$ (diametre)

V of a cylinder $= \pi r^2 h = \frac{22}{7} \times \frac{3.5}{2} \times \frac{3.5}{2} \times 4$

$= 38.5 cm^3$

1.2.4 Learning Outcome 4: Carry out basic mensuration

1.2.4.1. Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics on carrying out basic mensuration.

1.2.4.2. Performance Standard

1. Various ***units of measurements*** are identified based on the course requirements
2. Units are converted based on best practices
3. Perimeter and areas of regular ***figures*** are obtained based on known formulae
4. Area of irregular figures are obtained based on best practice
5. Volume and Surface area of solids are obtained based on given formulae.

1.2.4.3. Information Sheet

There are different units of measurement and subsequent conversion factors

Units of Length Conversion Charts

1 kilometre (km)	= 10 Hectometres (hm)	= 1000 m	
1 Hectometre (hm)	= 10 Decametres (dcm)	= 100 m	
1 Decametre (dcm)	= 10 Metres (m)		
1 Metre (m)	= 10 Decimetres (dm)	= 100 cm	= 1000 mm
1 Decimetre (dm)	= 10 Centimetres (cm)		
1 decimeter	= 0.1 meter		
1 Centimetre (cm)	= 10 Millimetres (mm)		
1 centimeter	= 0.01 meter		
1 millimeter	= 0.001 meter		

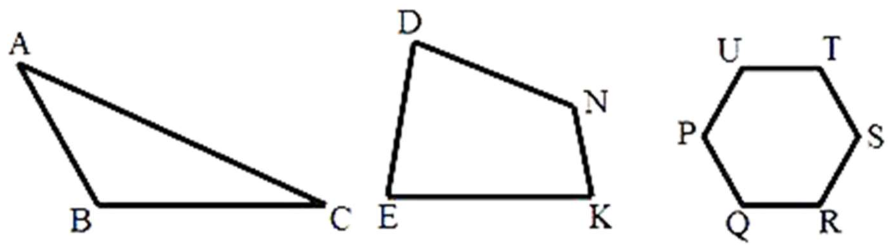
The different units of length and their equivalents are given here:

1 kilometer (km)	= 10 Hectometers (hm) = 1000 m
1 Hectometer (hm)	= 10 Decathletes (dcm) = 100 m
1 Demetre (dcm)	= 10 Metres (m)
1 Meter (m)	= 10 Decimeters (dm) = 100 cm = 1000 mm

1 Decimeter (dm) = 10 Centimetres (cm)

1 Centimeter (cm) = 10 Millimetres (mm)

The perimeter of a simple closed figure is the sum of the measures of line-segments which have surrounded the figure.



Perimeter of ΔABC = length (AB + BC + CA)

Perimeter of the quadrilateral DEKN = length (DE + EK + KN + ND)

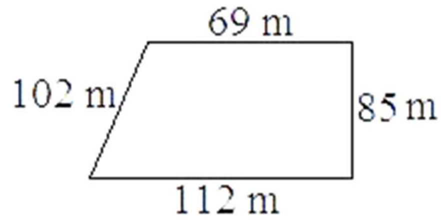
Perimeter of the hexagon PQRSTU = length (PQ + QR + RS + ST + TU + UP)

Calculation of perimeters will be applied in the determination of total length of pipework needed for a project.

Examples

1. Ken walks around a playground in his daily morning walk. How far does he walk every morning? The playground is of the shape of a quadrilateral having sides of length 112 m, 85 m, 69 m and 102 m.

   Solution:



Perimeter of the playground

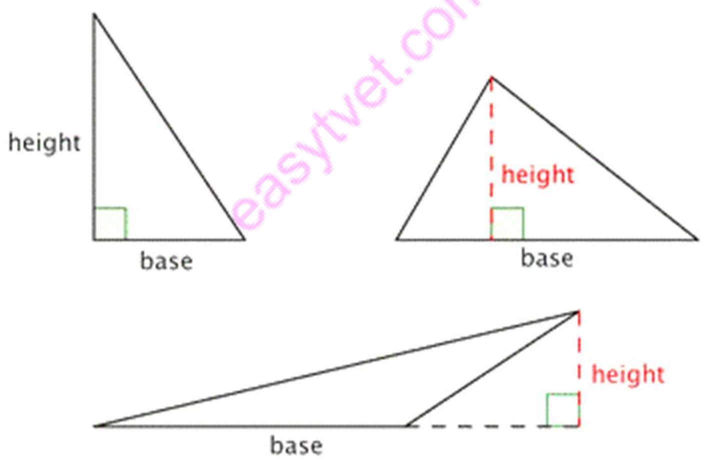
= 112 m + 85 m + 69 m + 102 m

= 368m

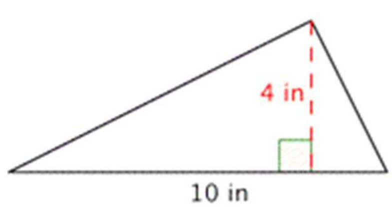
Ken walks 368 m around the playground, i.e. around the perimeter, every morning.

Area of Triangles and Trapezoids

$A = \frac{1}{2}bh$



2. **A triangle has a height of 4 inches and a base of 10 inches. Find the area.**



$A = \frac{1}{2}bh$ Start with the formula for the area of a triangle.

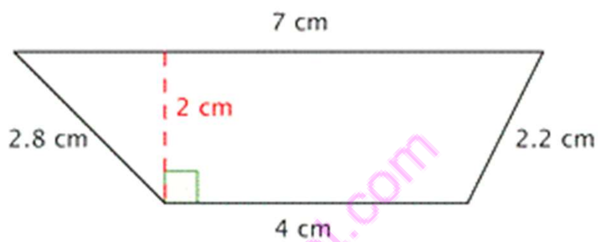
$A = \frac{1}{2} \bullet 10 \bullet 4$ Substitute 10 for the base and 4 for the height.

$A = \frac{1}{2} \bullet 40$

$A = 20$

$A = 20\ \text{in}^2$

3. **Find the area of the trapezoid.**



Start with the formula for the area of a trapezoid

$A = \frac{(b_1 + b_2)}{2}h$

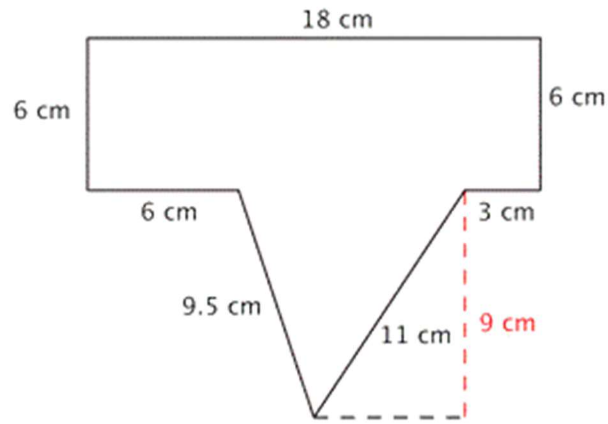
$A = \frac{(4+7)}{2} \bullet 2$

$A = \frac{11}{2} \bullet 2$

$A = 11$

The area of the trapezoid is 11 cm^2

4. **Find the area and perimeter of the polygon.**

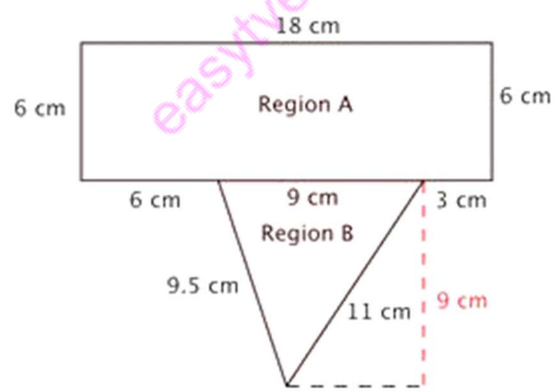


5. To find the perimeter, add together the lengths of the sides. Start at the top and work clockwise around the shape.

$P = 18 + 6 + 3 + 11 + 9.5 + 6 + 6$

$P = 59.5$ cm

6. To find the area, divide the polygon into two separate, simpler regions. The area of the entire polygon will equal the sum of the areas of the two regions.



Area of Polygon = (Area of A) + (Area of B)

Region A is a rectangle. To find the area, multiply the length (18) by the width (6).

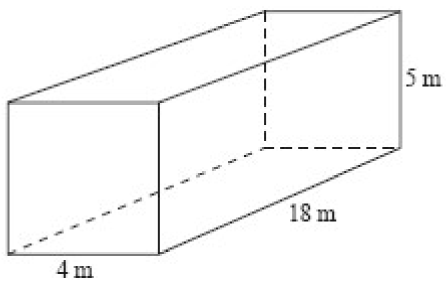
$$\begin{aligned}\text{Area of Region A} &= l \cdot w \\ &= 18 \cdot 6 \\ &= 108\end{aligned}$$

Region B is a triangle

$$\text{Area of Region B} = \frac{1}{2} b \cdot h$$
$$= \frac{1}{2} \cdot 9 \cdot 9$$
$$= \frac{1}{2} \cdot 81$$
$$= 40.5$$

$108\ cm^2 + 40.5\ cm^2 = 148.5\ cm^2$

7. Calculate the volume of the cuboid shown.



Volume = $4 \times 18 \times 5 = 360\ m^3$

(b)

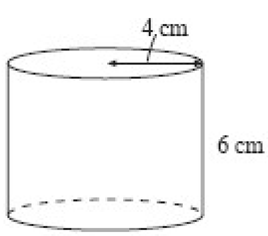
Calculate the surface area of the cuboid shown.

Surface area $= (2 \times 4 \times 18) + (2 \times 4 \times 5) + (2 \times 5 \times 18)$

$= 144 + 40 + 180$

$= 364\ m^2$

8. Calculate the volume and total surface area of the cylinder shown.



Volume $= \pi r^2 h = \pi \times 4^2 \times 6$

$= 96\pi$

$= 301.5928\ cm^3$

$= 302\ cm^3$

Area of curved surface = $2\pi rh = 2 \times \pi \times 4 \times 6$

= 48π

= $150.7964cm^2$

Area of each end = $\pi r^2 = \pi \times 4^2$

= 16π

= $50.2654cm^2$

Total surface area = $150.7964 + (2 \times 50.2654)$

= $251.327cm^2$

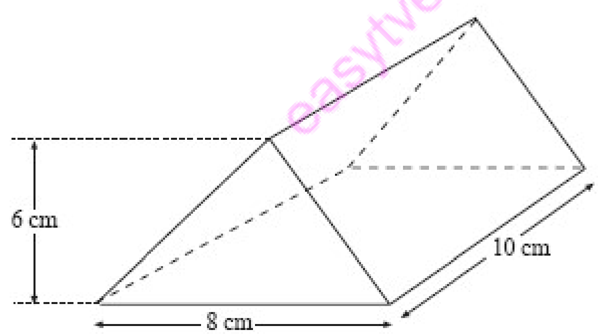
= $251\ cm^2$

Calculation of Areas will be applied during site clearance, site/ trench excavation and laying of drainage pipes.

1.2.4.4. Learning Activities

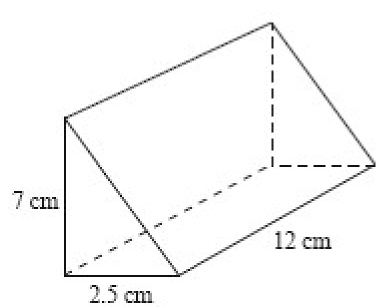
In groups of two or more discuss the following

1. Calculate the *volume* of this prism.

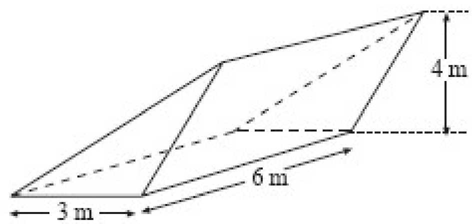


2. Calculate the *volume* of each of the following prisms:

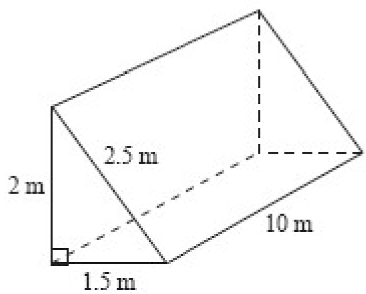
(a)



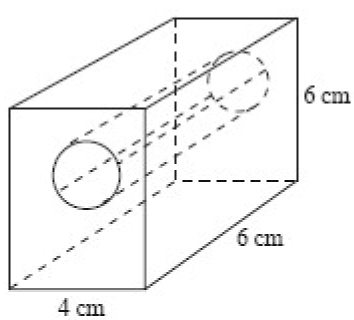
(b)



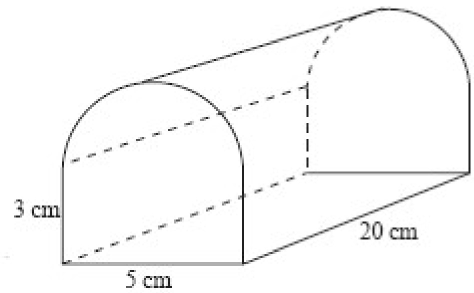
3.Calculate the volume and surface area of the following prism:



4. The diagram shows a wooden block that has had a hole drilled in it. The diameter of the hole is 2 cm. Calculate the volume of this solid, giving your answer correct to 2 decimal places.



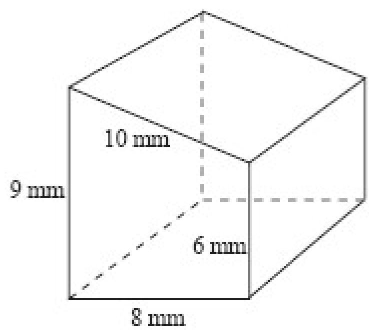
5. The diagram shows a prism.
   The cross-section of the prism consists of a rectangle and a semicircle.



(a) Calculate the *volume* of the prism. Give your answer to the nearest cm³.

(b) Calculate the *total surface area* of the prism. Give your answer to the nearest cm².

6. The volume of the prism shown is 720 mm³.



(a) Determine the *length* of the prism.

(b) Calculate the *surface area* of the prism.

7. A cylinder has a diameter of 12 cm and a curved surface area of 132π or 415 cm² (to 3 significant figures).

(a) Determine the *height* of the cylinder.

(b) Calculate the *volume* of the cylinder, giving your answer to the nearest cm³.

1.2.4.5. Self-Assessment

1. Find the total surface area of the cylinder, whose radius is 5cm and height is 10cm?

2. What is the volume of a cylindrical shape water container that has a height of 7cm and diameter of 10cm?

3. Calculate the cost required to paint a container which is in the shape of a right circular cylinder having a base radius of 7 m and height 13 m. If the painting cost of the container is Ksh 2.5/m2. (Take $\pi = 22/7$)

4. Find the total surface area of a container in cylindrical shape whose diameter is 28 cm and height is 15 cm.

1.2.4.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection	• Charts with presentations of data • Graph books • Text books

1.2.4.7. References

Ministry of Education (2003). *Secondary Mathematics Students' Book One (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Two (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Three (3rd ed)*. Nairobi: Kenya Literature Bureau

John Bird (2007). *Engineering Mathematics (5th Ed).* MA: Elsevier ltd

John Bird (2005). *Basic Engineering Mathematics, (4th Ed).* MA: Elsevier ltd

1.2.4.8. Model Answers

1. Surface Area of a cylinder $= \pi r^2 + \pi r^2 + 2\pi r h$

$$= \underbrace{3.142 \times 5^2}_{\text{Top}} + \underbrace{3.142 \times 5^2}_{\text{Bottom}} + \underbrace{2 \times 3.142 \times 5 \times 10}_{\text{Curved surface}}$$

$$78.55 + 78.55 + 314.2$$

$$= 471.3\ cm^2.$$

2. Vol of cylinder $= \pi r^2 h$

$$= \frac{22}{7} \times 5 \times 5 \times 7$$

$$= 550 cm^3$$

3. Calculate cost required to paint

SA of cylinder container $= \pi r^2 + 2\pi r h$

Because the top is hollow since it is a container

$$= \frac{22}{7} \times 7 \times 7 + 2 \frac{22}{7} \times 7 \times 13$$

$$154 + 572 = 726 cm^2$$

Cost of painting $= 2.50$ sh per m^2

$$? = 726$$

$$= 726 \times 2.50 = \text{Sh } 957.$$

4. SA of cylindrical container

$$= \pi r^2 + 2\pi r h$$

$$= \frac{22}{7} \times \cancel{14}^{2} \times 14 + 2 \times \frac{22}{7} \times \cancel{14}^{2} \times 15$$

$$616 + 1320$$

$$= 1936 cm^2$$

1.2.5 Learning Outcome 5: Apply Basic Statistics

1.2.5.1 Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics on basic statistics.

1.2.5.2 Performance Standard

1. Grouped and ungrouped data is identified and interpreted based on given sample
2. Ungrouped data is organized based on the concept
3. Data is represented in frequency tables based on the concept
4. The median, mode and mean of grouped and ungrouped data is calculated based on the concept
5. Data is presented in a chart form based on the concept

1.2.5.3 Information Sheet

Statistics refers to the science of collecting and analyzing numerical data in large quantities for the purpose of proportioning into a representative sample.
There are different methods of data presentation: Frequency Tables, Pie-charts, Bar charts, Line graphs, Histograms, Frequency polygons e.t.c.

Data representation in frequency tables

A **frequency table** is constructed by arranging collected data values in ascending order of magnitude with their corresponding frequencies.

Example 1

The marks awarded for an assignment set for a Year 4 class of 20 students were as follows:

6	7	5	7	7	8	7	6	9	7
4	10	6	8	8	9	5	6	4	8

Present this information in a frequency table.

Solution

To construct a frequency table, we proceed as follows:

Step 1:

Construct a table with three columns. The first column shows what is being arranged in ascending order from 4 in the first column to 10 as shown below.

Mark	Tally	Frequency
4		
5		
6		
7		
8		
9		
10		

Step 2:

Go through the list of marks. The first mark in the list is 6, so put a tally mark against 6 in the second column. The second mark in the list is 7, so put a tally mark against 7 in the second column. The third mark in the list is 5, so put a tally mark against 5 in the third column as shown below.

Mark	Tally	Frequency
4		
5	|	
6	|	
7	|	
8		
9		
10		

We continue this process until all marks in the list are tallied.

Step 3:

Count the number of tally marks for each mark and write it in third column. The finished frequency table is as follows:

Mark	Tally	Frequency
4	II	2
5	II	2
6	IIII	4
7	~~IIII~~	5
8	IIII	4
9	II	2
10	I	1

For Grouped Data;

When the set of data values are spread out, it is difficult to set up a frequency table for every data value as there will be too many rows in the table. So we group the data into class intervals /groups to help us organize, interpret and analyze the data.

Example 1

The number of calls from motorists per day for roadside service was recorded for the month of December 2003. The results were as follows:

28	122	217	130	120	86	80	90	120	140
70	40	145	187	113	90	68	174	194	170
100	75	104	97	75	123	100	82	109	120
81									

Set up a frequency table for this set of data values.

Solution:

To construct a frequency table, we proceed as follows:

Smallest data value = 28

Highest data value = 217

$$\begin{aligned}\text{Difference} &= \text{Highest value} - \text{Smallest value}\\ &= 217 - 28\\ &= 189\end{aligned}$$

Let the width of the class interval be 40.

$\therefore$ Number of class intervals $= \frac{189}{40} = 4.7 = 5$ {Round up to the next integer}

There are at least 5 class intervals. This is reasonable for the given data.

Step 1: Construct a table with three columns, and then write the data groups or class intervals in the first column. The size of each group is 40. So, the groups will start at 0, 40, 80, 120, 160 and 200 to include all of the data. Note that in fact we need 6 groups (1 more than we first thought).

Class interval	Tally	Frequency
0 - 39		
40 - 79		
80 - 119		
120 - 159		
160 - 199		
200 - 239		

Step 2: Go through the list of data values. For the first data value in the list, 28, place a tally mark against the group 0-39 in the second column. For the second data value in the list, 122, place a tally mark against the group 120-159 in the second column. For the third data value in the list, 217, place a tally mark against the group 200-239 in the second column.

Class interval	Tally	Frequency
0 - 39	I	
40 - 79		
80 - 119		
120 - 159	I	
160 - 199		
200 - 239	I	

We continue this process until all of the data values in the set are tallied.

Step 3: Count the number of tally marks for each group and write it in the third column. The finished frequency table is as follows:

Class interval	Tally	Frequency
0 - 39	|	1
40 - 79	卌	5
80 - 119	卌 卌 ||	12
120 - 159	卌 |||	8
160 - 199	||||	4
200 - 239	|	1
	Sum =	31

Example 2

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

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

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

Now, using the above data, you can present the data using histograms, bar graphs and others.

Measures of Central Tendency

Median

The median is the middle score for a set of data that has been arranged in order of magnitude. (from the largest to smallest or vice versa). In order to calculate the median, suppose we have the data below:

65 55 89 56 35 14 56 55 87 45 92

We first need to rearrange that data into order of magnitude (smallest first):

14 35 45 55 55 **56** 56 65 87 89 92

Our median mark is the middle mark - in this case, 56 (highlighted in bold). It is the middle mark because there are 5 scores before it and 5 scores after it.

This works fine when you have an odd number of scores, but what happens when you have an even number of scores? What if you had only 10 scores? Well, you simply have to take the middle two scores and average the result. So, if we look at the example below:

65 55 89 56 35 14 56 55 87 45

We again rearrange that data into order of magnitude (smallest first):

14 35 45 55 **55** **56** 56 65 87 89

Only now we have to take the 5th and 6th score in our data set and average them to get a median of 55.5.

1.2.5.4 Learning Activities

Take a sample of 30 different persons and collect data on : their age, gender, favourite sports team, favorite food, favorite day of the week.

Represent this data in the form of Pie Charts, Frequency Tables and Pictograms.

1.2.5.5 Self-Assessment

1. The data below shows the mass of 40 students in a class. The measurement is to the nearest kg.

55	70	57	73	55	59	64	72
60	48	58	54	69	51	63	78
75	64	65	57	71	78	76	62
49	66	62	76	61	63	63	76
52	76	71	61	53	56	67	71

Construct a frequency table for the data using an appropriate scale.

2. Find the mean of the following data.

(a) 9, 7, 11, 13, 2, 4, 5, 5

(b) 16, 18, 19, 21, 23, 23, 27, 29, 29, 35

(c) 2.2, 10.2, 14.7, 5.9, 4.9, 11.1, 10.5

(d) $1^1/_4$, $2^1/_2$, $5^1/_2$, $3^1/_4$, $2^1/2$

1.2.5.6 Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection	• Charts with presentations of data • Graph books • Text books

1.2.5.7 References

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John Bird (2005). *Basic Engineering Mathematics, (4th Ed).* MA: Elsevier ltd

1.2.5.8 Model Answers

1.**Step 1**: Find the range.

The range of a set of numbers is the difference between the least number and the greatest number in the set.

In this example, the greatest mass is 78 and the smallest mass is 48. The range of the masses is then 78 – 48 = 30. The scale of the frequency table must contain the range of masses.

Step 2: Find the intervals
the **intervals** separate the scale into equal parts.
We could choose intervals of 5. We then begin the scale with 45 and end with 79

Step 3: Draw the frequency table using the selected scale and intervals.

Mass (kg)	Frequency
45 – 49	2
50 – 54	4
55 – 59	7
60 – 64	10
65 – 69	4
70 – 74	6
75 – 79	7

2.

(a) 7
(b) 24
(c) 8.5
(d) 3

1.2.6 Learning Outcome 6: Plot simple graphs

1.2.6.1 Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics it involves plotting simple graphs.

1.2.6.2 Performance Standard

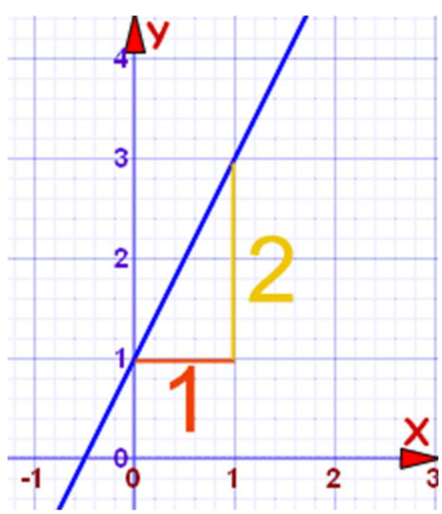
1. A ***graph*** is plotted for given set of data based on data
2. Information from a given graph is interpreted based on data

1.2.6.3 Information Sheet

We've different types of graphs that are drawn for data representation like the line graphs, bar graphs, histograms etc

We plot graphs of equations of different lines of the y=mx +c where m is the gradient of the line and c is the y-intercept.

Example 1



m = ***21*** = 2

b = 1 *(value of* ***y*** *when x=0)*

$$\text{So: } y = 2x + 1$$

With that equation you can now choose any value for x and find the matching value for y

For example, when x is 1:

$$y = 2\times\mathbf{1} + 1 = 3$$

Check for yourself that x=1 and y=3 is actually on the line.

Or we could choose another value for x, such as 7:

$$y = 2\times\mathbf{7} + 1 = 15$$

And so when x=7 you will have y=15

Positive or Negative Slope

Going from left-to-right, the cyclist has to **P**ush on a **P**ositive Slope:

Example 2

If $m = \frac{3}{1} = -3$

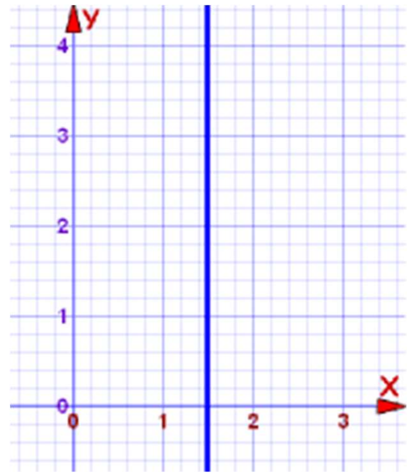
$b = 0$

This gives us $\mathbf{y = -3x + 0}$

We do not need the zero!

So: $y = -3x$

Example 3: Vertical Line



What is the equation for a vertical line?

The slope is **undefined** ... and where does it cross the Y-Axis?

In fact, this is a **special case**, and you use a different equation, not "**y**=...", but instead you use "**x**=...".

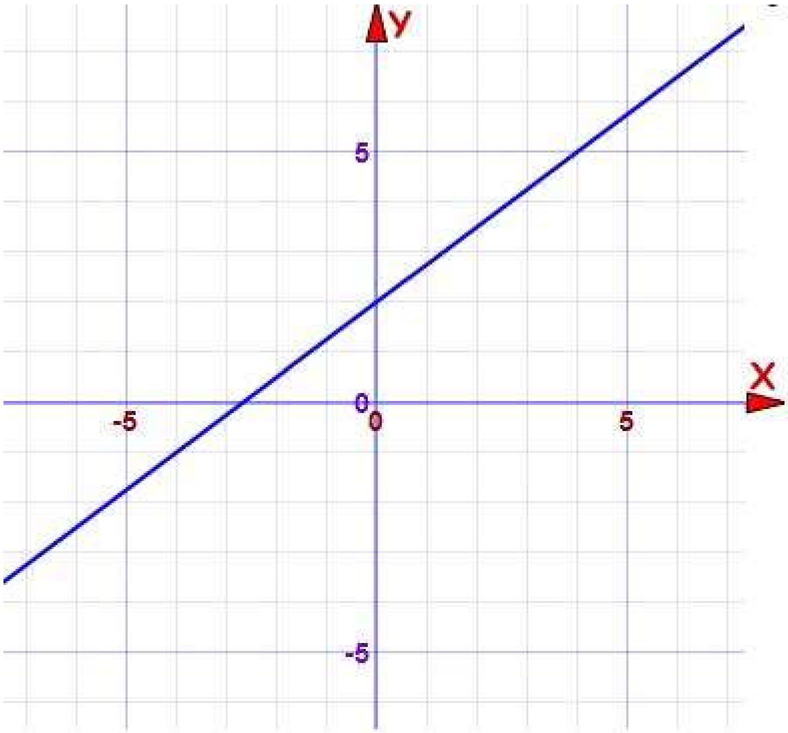
Like this:

x = 1.5

Every point on the line has **x** coordinate **1.5**,

that is why its equation is **x = 1.5**

What is the equation of the following line?



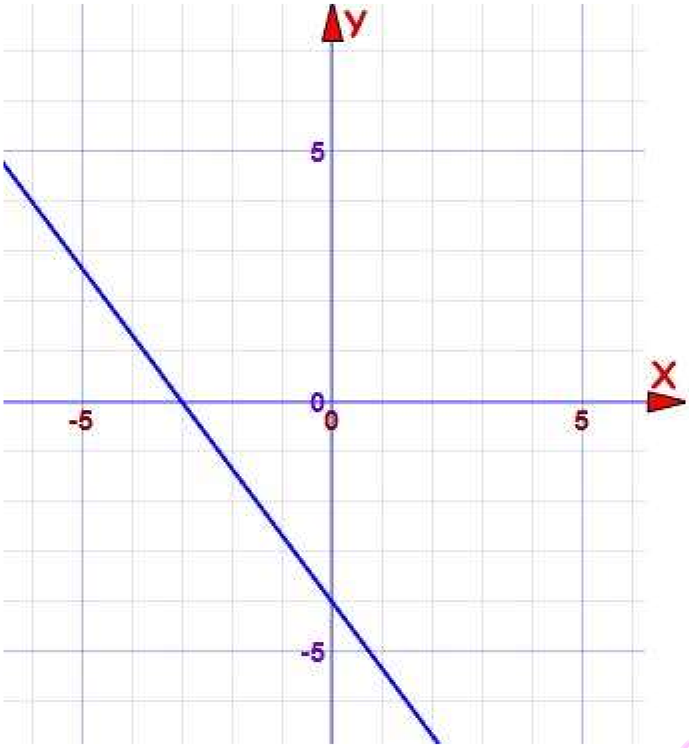
From the graph we can see m = rise/run = 3/4 = 0.75

and b is the y coordinate of the y-intercept, so b = 2

Substitute into y = mx + b

Therefore y = 0.75x + 2

What is the equation of the straight line shown in the diagram?



First find the Slope (also called the Gradient):

Slope = (change in y) / (change in x) = -4/3

Now find the y-intercept:

y-intercept = (0, -4)

So b = -4

The general equation of a straight line is y = mx + b

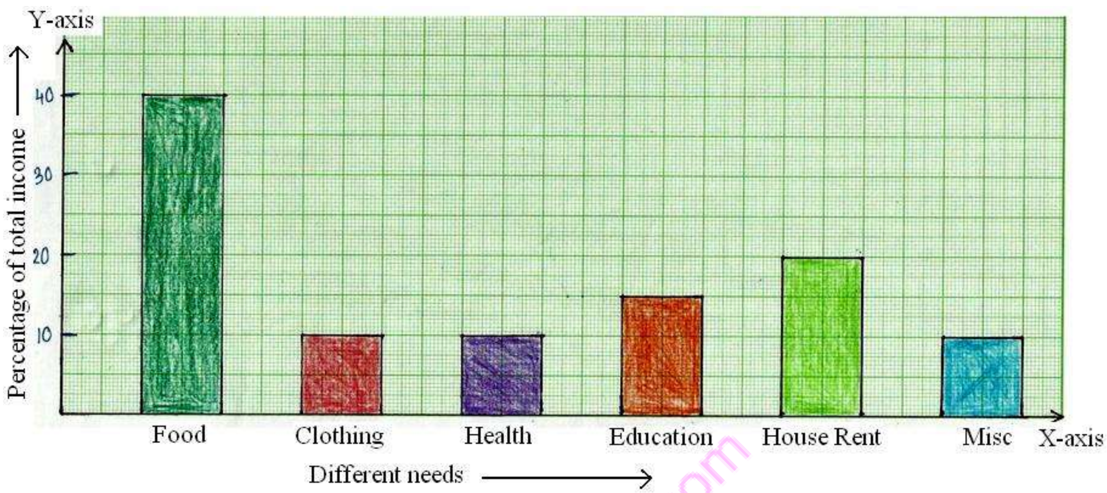
So the given line has equation

y= $-\frac{-4}{3}\, x$ -4

The percentage of total income spent under various heads by a family is given below.

Different Heads	Food	Clothing	Health	Education	House Rent	Miscellaneous
% Age of Total Number	40%	10%	10%	15%	20%	5%

Represent the above data in the form of bar graph.



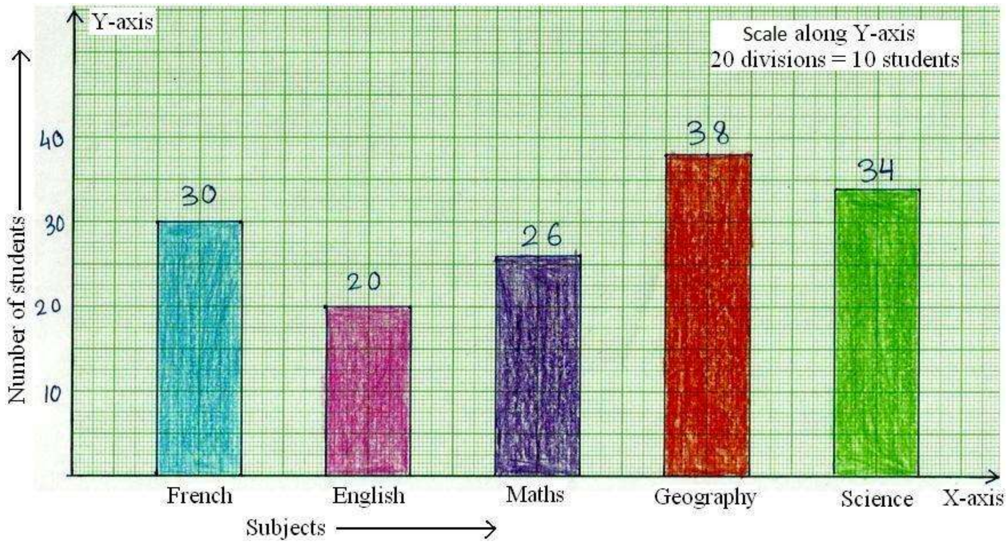
2. 150 students of class VI have popular school subjects as given below:

Subject	French	English	Maths	Geography	Science
Number of Students	30	20	26	38	34

Draw the column graph/bar graph representing the above data.

Solution:

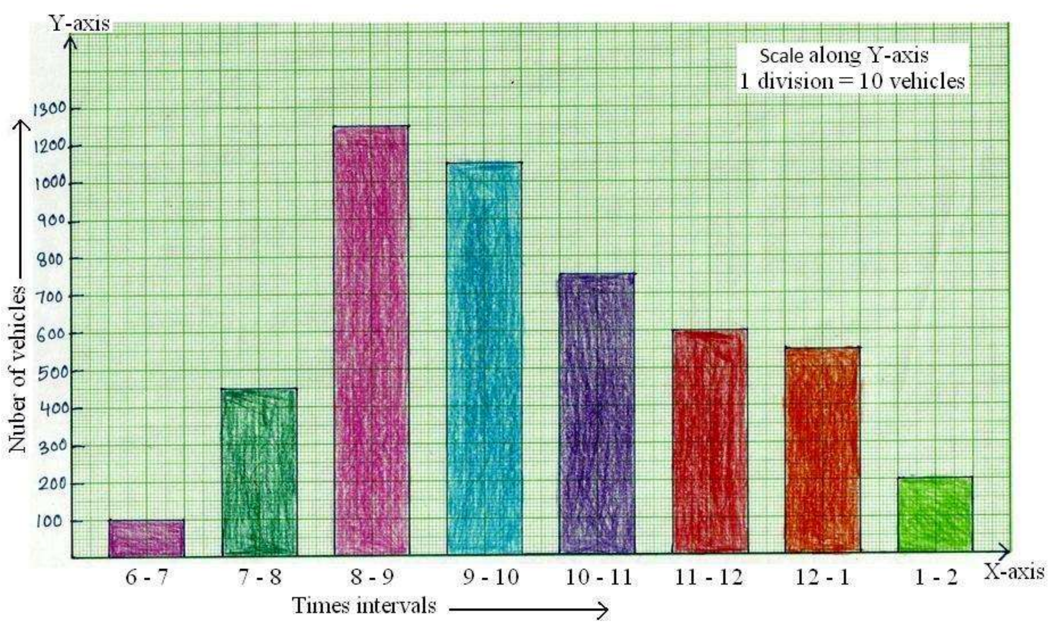
Take the subjects along **x-axis**, and the number of students along **y-axis**



Bar graph gives the information of favorite subjects of 150 students.

3. The vehicular traffic at a busy road crossing in a particular place was recorded on a particular day from 6am to 2 pm and the data was rounded off to the nearest tens.

Time in Hours	6 - 7	7 - 8	8 - 9	9 – 10	10 - 11	11 - 12	12 - 1	1 - 2
Number of Vehicles	100	450	1250	1050	750	600	550	200



Bar graph gives the information of number of vehicles passing through the crossing during different intervals of time.

1.2.6.4 Learning Activities

Graphs can also be used to find solutions of simultaneous equations. Plot the following pairs and give solutions of;

1. $5x + 3y = 41$

   $2x + 3y = 20$

2. $5x + y = 11$

   $3x - y = 9$

3. $x + 7y = 64$

   $x + 3y = 28$

4. $4x - 4y = 24$

   $x - 4y = 3$

1.2.6.5 Self-Assessment

1. ((a) Complete the table of values for $y = 2x + 5$
   (b) On the grid, draw the graph of $y = 2x + 5$ for the values from $x = -2$ to $x = 2$

2. Complete the table of values for $y = 2x – 3$

   (b) On the grid, draw the graph of $y = 2x – 3$

   (c) Use your graph to find
   (i) the value of y when $x = -1.5$
   (ii) the value of x when $y = 6$

1.2.6.6 Tools, Equipment, Supplies and Materials

Tools/Equipment:	Materials:
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection	• Charts with presentations of data • Graph books • Text books

1.2.6.7 References

Ministry of Education (2003). *Secondary Mathematics Students' Book One (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Two (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Three (3rd ed)*. Nairobi: Kenya Literature Bureau

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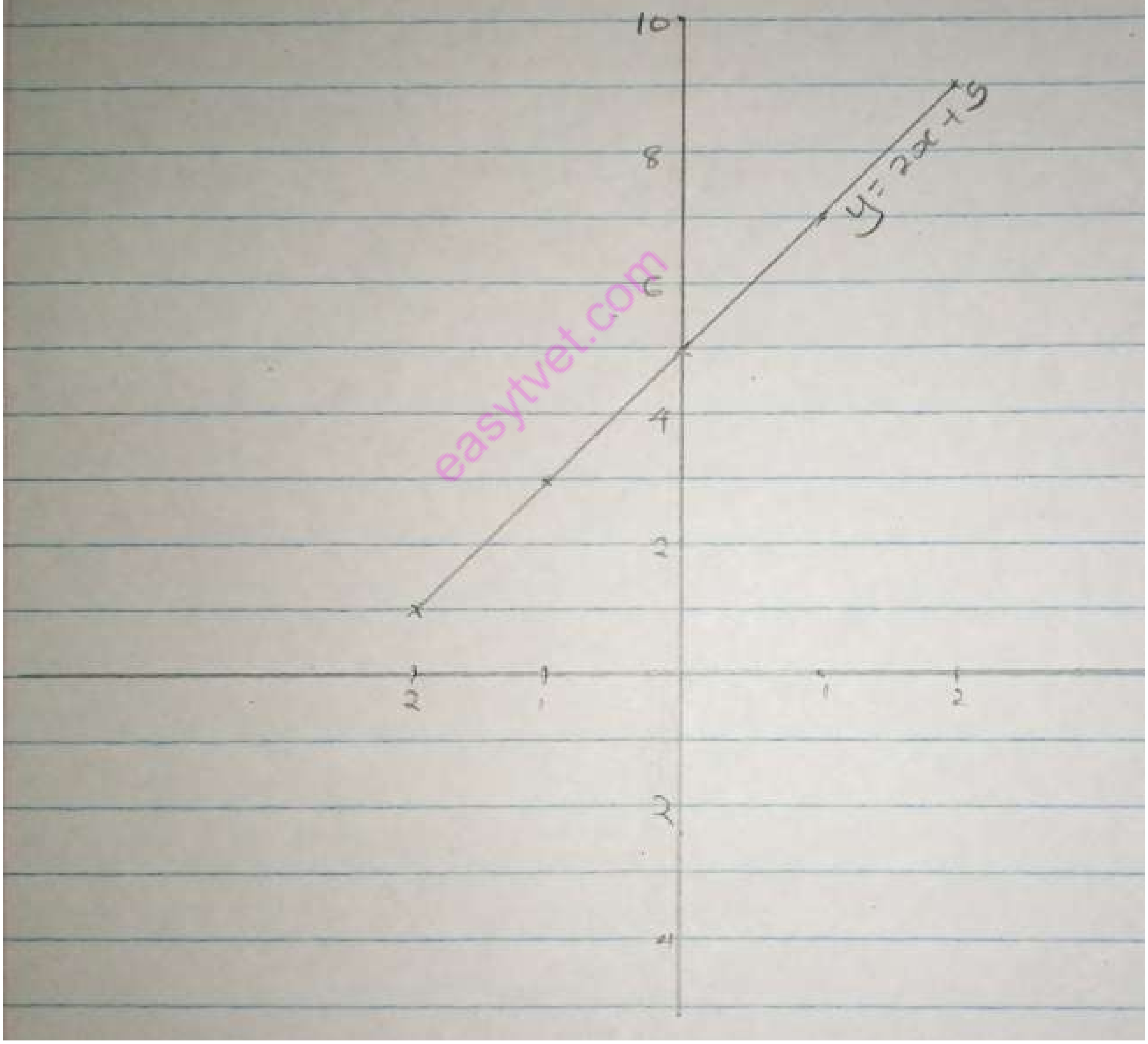
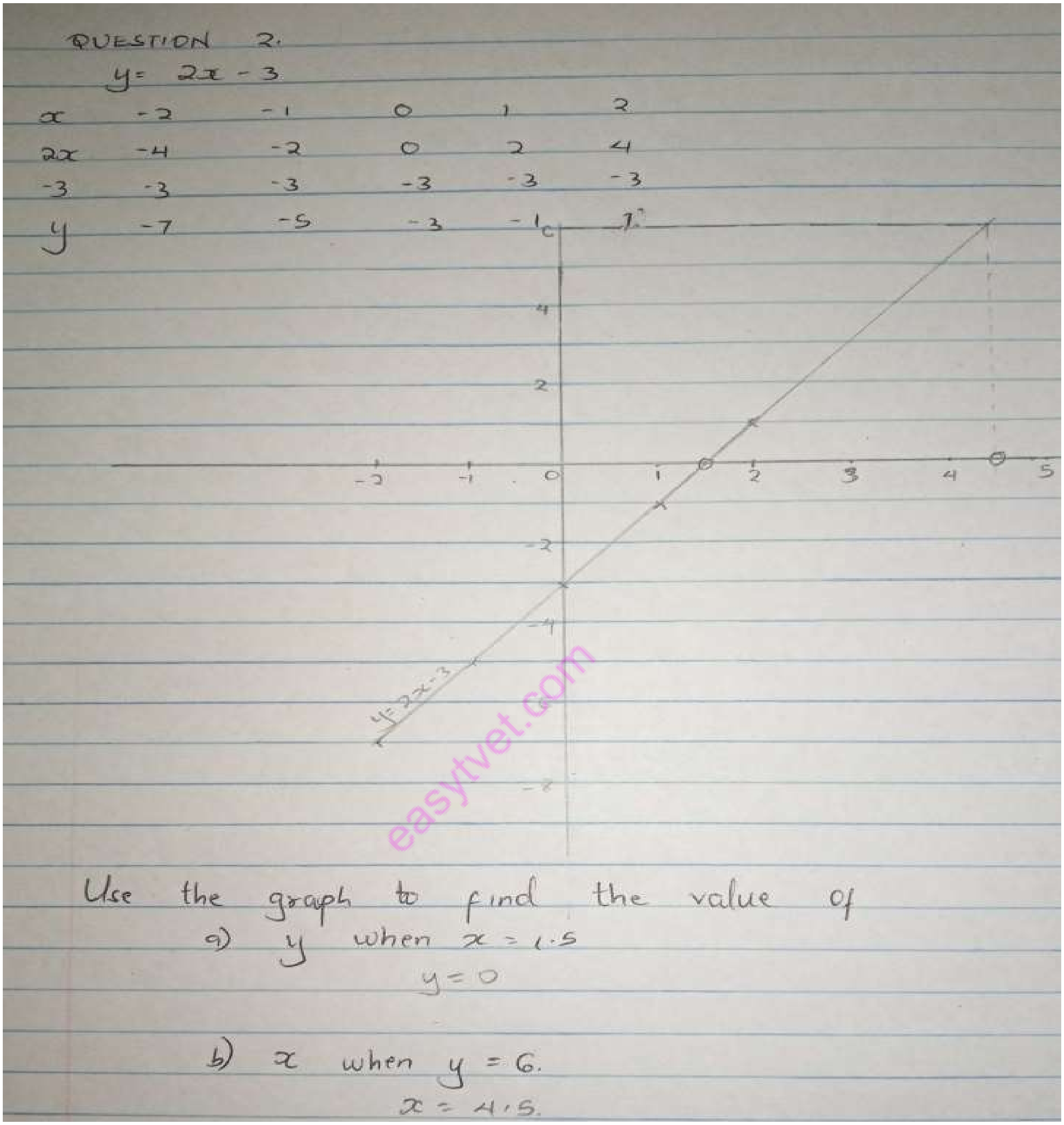
1.2.6.8 Model Answers

QUESTION ONE $y = 2x + 5$

x	-2	-1	0	1	2
$2x$	-4	-2	0	2	4
$+5$	5	5	5	5	5
y	1	3	5	7	9





1.2.7 Learning Outcome 7: Apply Indices and Logarithms

1.2.7.1 Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics on indices, logarithms and ratio.

1.2.7.2 Performance Standard

1. Converted numbers from one base to another
2. Applied the laws of indices in solving exponential equations
3. Applied the laws of logarithms in solving logarithmic equations

1.2.7.3 Information Sheet

Laws of indices

1. $\boldsymbol{Law\ of\ Multiplication\ a^n x a^m = a^{n+m}}$
2. $\boldsymbol{Law\ of\ division\ a^n \div a^m = a^{n-m}}$
3. $\boldsymbol{Law\ of\ Power\ to\ Power\ (a^n)^m = a^{nm}}$

Examples

- $2^4 \times 2^8 = 2^{4+8} = 2^{12}$
- $5^4 \times 5^{-2} = 5^{4+-2} = 5^2$
- $3^9 \div 3^4 = 3^{9-4} = 3^5$
- $7^2 \div 7^5 = 7^{-3}$
- $2^{-3} = \frac{1}{2^{-3}} = \frac{1}{8}$
- $16^{1/2} = \sqrt{16} = 4$
- $8^{2/3} = (\sqrt[3]{8})^2 = 4$
- $5^0 = 1$

Laws of logarithms

I. $\boldsymbol{\log (A \times B) = \log A + \log B}$

II. $\boldsymbol{\log \left(\frac{A}{B}\right) = \log A - \log B}$

III. $\boldsymbol{\log A^n = n\log A}$

Examples

1. **Simplify**; log 64 − log 128 + log 32

$64 = 2^6$, $128 = 2^7$, and $32 = 2^5$,

Hence log 64 − log 128 + log 32

$= \log 2^6, \ -\log 2^7 + \log 2^5,$

$= 6 \log 2 - 7 \log 2 + 5 \log 2$

by the third law of logarithms

$= 4 \log 2$

2. **Evaluate** $\frac{\log 25 - \log 125 + \frac{1}{2}\log 625}{3 \log 5}$

$\frac{\log 5^2 - \log 5^3 + \frac{1}{2}\log 5^4}{3 \log 5}$

$\frac{2\log 5 - 3\log 5 + 2\log 5}{3 \log 5}$

$\frac{1 \log 5}{3 \log 5} = \frac{1}{3}$

3. **Solve the equation**:

$\log(x - 1) + \log(x + 1) = 2\log(x + 2)$

$\log(x - 1) + \log(x + 1) = \log(x - 1)(x + 1)$

from the first law of logarithms

$= \log(x^2 - 1)$

$2\log(x + 2) = \log(x + 2)^2 = \log(x^2 + 4x + 4)$

Hence if $\log(x^2 - 1) = \log(x^2 + 4x + 4)$

then $x^2 - 1 = x^2 + 4x + 4$

$-1 = 4x + 4$

$-5 = 4x$

$x = -\frac{5}{4}$

Examples on Logarithms

1. **Express $5^3 = 125$ in logarithm form.**

Solution:

$5^3 = 125$

As we know,

$a^b = c \Rightarrow \log_a c = b$

Therefore;

$\text{Log}_5 125 = 3$

2. **Express $\log_{10} 1 = 0$ in exponential form.**

Solution:

Given, $\log_{10} 1 = 0$

By the rule, we know;

$\log_a c = b \Rightarrow a^b = c$

Hence,

$10^0 = 1$

3. **Find the log of 32 to the base 4.**

Solution: $\log_4 32 = x$

$4^x = 32$

$(2^2)^x = 2x2x2x2x2$

$2^{2x} = 2^5$

$2x=5$

$x=5/2=2.5$

4. **Find x if $\log_5(x-7)=1$.**

Solution: Given,

$\log_5(x-5) = 1$

Using logarithm rules, we can write;

$5^1 = x-7$

$5 = x-7$

$x=5+7$

$x=12$

5. **Solve for x if $\log(x-1)+\log(x+1)=\log_2 1$**

Solution: $\log(x-1)+\log(x+1)=\log_2 1$

$\log(x-1)+\log(x+1)=0$

$\log[(x-1)(x+1)]=0$

Since, $\log 1 = 0$

$(x-1)(x+1) = 1$

$x^2-1=1$

$x^2=2$

$x=\pm \sqrt{2}$

Since, log of negative number is not defined.

Therefore, $x=\sqrt{2}$

3. **Find the value of x, if $\log_{10}(x-10)=1$.**

Solution: Given, $\log_{10}(x-10)=1$.

$\log_{10}(x-10) = \log_{10}10$

$x-10 = 10$

$x=10+10$

$x=20$

1.2.7.4 Learning Activities

In your groups, perform the following;

In Problems 1 to 11, evaluate the given expression:

1. $\log_{10} 10\,000$
2. $\log_2 16$
3. $\log_5 125$
4. $\log_2 \frac{1}{8}$
5. $\log_8 2$
6. $\log_7 343$
7. $\lg 100$
8. $\lg 0.01$
9. $\log_4 8$
10. $\log_{27} 3$
11. $\ln e^2$

In Problems 12 to 18 solve the equations:

12. $\log_{10} x = 4$
13. $\log x = 5$
14. $\log_3 x = 2$
15. $\log_4 x = -2\frac{1}{2}$
16. $\lg x = -2$
17. $\log_8 x = -\frac{4}{3}$
18. $\ln x = 3$

In Problems 19 to 22 write the given expressions in terms of log 2, log 3 and log 5 to any base:

19. $\log 60$
20. $\log 300$
21. $\log\left(\frac{16 \times \sqrt[4]{5}}{27}\right)$
22. $\log\left(\frac{125 \times \sqrt[4]{16}}{\sqrt[4]{81^3}}\right)$

Simplify the expressions given in Problems 23 to 25:

23. $\log 27 - \log 9 + \log 81$
24. $\log 64 + \log 32 - \log 128$
25. $\log 8 - \log 4 + \log 32$

Evaluate the expressions given in Problems 26 and 27:

26. $\dfrac{\frac{1}{2}\log 16 - \frac{1}{3}\log 8}{\log 4}$
27. $\dfrac{\log 9 - \log 3 + \frac{1}{2}\log 81}{2\log 3}$

Solve the equations given in Problems 28 to 30:

28. $\log x^4 - \log x^3 = \log 5x - \log 2x$
29. $\log 2t^3 - \log t = \log 16 + \log t$
30. $2\log b^2 - 3\log b = \log 8b - \log 4b$

1.2.7.5 Self-Assessment

1. $\text{Log}_6(216)$ + [log(42) - log(6)] / log(49)
2. $(3^{-1} - 9^{-1}) / 6)^{1/3}$
3. $(\log_x a)(\log_a b)$

4. $2 = \log_a e$

1.2.7.6 Tools, Equipment, Supplies and Materials

Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection	• Charts with presentations of data • Graph books • Text books

1.2.7.7 References

Ministry of Education (2003). *Secondary Mathematics Students' Book One (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Two (3rd ed)*. Nairobi: Kenya Literature Bureau

Ministry of Education (2003). *Secondary Mathematics Students' Book Three (3rd ed)*. Nairobi: Kenya Literature Bureau

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1.2.7.8 Model Answers

1.

a. $= \log_6(6^3) + \log(42/6) / \log(7^2)$
$= 3 + \log(7) /2 \log(7) = 3 + 1/2 = 7/2$

b. $= ((1/3 - 1/9) / 6)^{1/3}$
$= ((6 / 27) / 6)^{1/3} = 1/3$

c. $= \log_x a\ (\log_x b / \log_x a) = \log_x b$

2. $a^2 = e$

$\ln(a^2) = \ln e$

$2 \ln a = 1$

$a = e^{1/2}$

1.2.8 Learning Outcome 8: Perform business calculations

1.2.8.1 Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics on business calculations.

1.2.8.2 Performance Standard

1. Converted one currency to another
2. Calculated exchange rates
3. Calculated income
4. Calculated of taxes
5. Calculated average sales

1.2.8.3 Information Sheet

Business calculations refers to calculations and estimations related to transactions done in a Business. The medium of a Business Transaction is " The Currency". A countrys currency cannot be used to transact in another country. For international trading, currencies will have different values in relation to each other. These rates are not fixed and will fluctuate. When changing the Kenyan currency to a foreign currency, the bank sells to us and when changing a foreign currency to a Kenyan currency, the bank buys from us.

Use the table to answer the questions that follows;

Currency	Buying	Selling
1 US Dollar **$**	**78.4133**	78.4744
1 Sterling Pound **£**	**114.1616**	114.3034
1 Euro **€**	**73.4226**	73.52953
1 South African Rand	**7.8842**	7.9141
1 UAE Dirham	**21.3480**	21.3670
1 Indian Rupee	**1.5986**	1.5999

1. A tourist visited Kenya and exchanged **500** Euros for his use while in the country how much Kenya shillings did he get.

Solution

1 € = 73.4226 Ksh

500 **€ =?**

500 × 73.4226 = 36,711.30

2. An exporter bought sterling pounds equivalent to **ksh 500,000.** After settling bills worth **1000** Sterling Pound **£** He exchanged the balance for Euros. If he purchased goods worth **100** Euros, calculate his balance in Kenya shillings.

Ksh 114.3034 = 1 **€ hence**

Ksh 500,000 ÷114.3034= £ 4374.3230

£ 4374.3230- £ 1000 = £ 3374.3230

1**£** = 114.1616

3374.3230 = ?

3374.3230× 114.1616 = **ksh** 385218.1126

To Euros

ksh 73.52953 = 1 **€**

385,218.1126 **= ?**

(385,218.1126× 1) / 73.52953 = **€** 5238.9579

5238.9579 – 100 = 5138.9579

1 **€ = ksh** 73.4226

5138.9579 = ?

5138.9579 ×73.4226 = Ksh 384,657.9108

INCOME TAX

Tax on personal income is known as income tax. **Taxable income** is the amount on which tax is levied and includes salary plus allowances. Every employee in Kenya is entitled to an automatic personal relief of **ksh 1056** per month.

To find the tax payable by an individual we subdivide the income into tax brackets /slabs corresponding to the table of taxation in use such as

K**£** per annum	Rate in ksh / £
1 – 5808	2
5809 – 11280	3
11281 – 16572	4
16573 – 22224	5
Excess over 22224	6

Example

Alison has a taxable income of k£ **18460** p.a. calculate how much **tax** she should pay per month if she claims personal relief.

Solution

Divide the income into tax slabs as follows

18460-(It's between 16573 – 22224)

1st 5808$\times$ 2 = Ksh11616

(11280-5808=5472)

2nd 5472 $\times$3 = Ksh 16416

(16572-11280=5472)

3rd 5472 × 4 = Ksh 21888

Remaining

18460-16572=1888

1888 ×5 = Ksh 9440

Gross tax per year **Ksh59,360 -**

Less personal relief 1056 × 12 = Ksh 12672

Net tax per year **Ksh46688**

Per month

46688÷12= Ksh 3890.67

Example 1

Mrs. Otieno earns a monthly salary of ksh **12,400**, a house allowance of ksh **8000** per month and a medical allowance of ksh **2,400** per month she claims a personal relief and contributes ksh **1000** towards a pension scheme. Calculate her net income.

Solution

Taxable income = salary plus allowances = 12,400 +8,000+2,400 = **22,800.**

(22,800×12) ÷20 = £13,680p.a.

Divide it into slabs

13680---

1st 5808 ×2 = ksh11,616

7872-

2nd 5472×3 = ksh16,414

Remainder 2400×4 = ksh 9,600

Gross tax…………………….... ksh 37,630

Less personal **relief ……………(1056$\times$ 12)=**ksh12,672

Net tax ………………………...ksh 24,958

Per month=24958$\div$ 12 = 2080

P.A.Y.E

Total deductions are ksh2080 (P.A.Y.E) + ksh1000 (pension scheme) = ksh3080

Net income = ksh22,800 – ksh3,080 = ksh19,720

Housing

If an employee is provided with a house by the employer (either freely or for nominal rent) then **15% of his salary is added** to his salary (less rent paid) for purposes of tax calculated.

Example 2

John earns k£ **13636** p.a. and is housed by his employer; calculate his P.A.Y.E and his net income.

Solution

Taxable income = $13636+(13636 \times 15\%)$ =15681.4

Tax brackets

15681.4 –

1st slab 5808 $\times$2 = Ksh11,616

9873-

2nd slab 5472 $\times$3 = Ksh16,416

remainder 4401.4 $\times$4= Ksh17,605.6

Gross tax Ksh 45,637.6

Less relief Ksh 12,672

Net tax Ksh 32,965.60

P.A.Y.E =(per month)32965.6÷12=2747

Net income = (13,636×20÷12) – 2747 = **19,980**

1.2.8.4 Learning Activities

In groups of three practice the following

Use the table of taxation below in this exercise

Income in £ /month	Rate %
1 – 484	10
485- 940	15
941- 1396	20
1397-1852	25
Excess over 1852	30

1. Mr Kenneth earns £ **40000** p.a. he is housed by the employer and pays a nominal rent of ksh **1000** . Calculate his **P.A.Y.E** and his **net income** .

2. Mrs Naliaka earns a monthly salary of **Ksh 14,800** a medical allowance of ksh**1200** per month and a travelling allowance of ksh**12,000** per month. She is housed and pays a nominal rent of ksh**700** per month, she contributes towards a retirement scheme towards which she pays k£**240** per annum. Calculate her P.A.YE. hence her net income.

1.2.8.5 Self-Assessment

Use the table below to answer the questions that follows;

Currency	Buying	Selling
1 US Dollar **$**	**78.4133**	78.4744
1 Sterling Pound **£**	**114.1616**	114.3034
1 Euro **€**	**73.4226**	73.52953
1 South African Rand	**7.8842**	7.9141

1 UAE Dirham	**21.3480**	21.3670
1 Indian Rupee	**1.5986**	1.5999

1.A Kenyan businessman purchased a commodity worthy US$100 to a company in the United States of America. The Kenyan can either pay through his account in Kenya or through his account in the United Kingdom. Which method is cheaper and by how much? Give your answer in Kenya shillings given that;(United Kingdom use Sterling Pound)

2.A tourist came to Kenya from London with 6000 Euros which he converted to Kenya shillings at a bank. While in Kenya he spent a total of Kshs.300,000 then converted the balance into sterling pounds at the Same bank. Calculate the amount in sterling pounds he received.

3. John intended to import a car worth € **15,000** from France. How much did he pay in **ksh** to acquire the Euros?

4. If he later changed his mind and instead re-converted the money to **ksh** , how much did he end up with ?

5. Mary raised **ksh** 500,000 for a study course in Britain. She bought an air ticket for **ksh** 80,000 and converted the balance to sterling pounds. Once in Britain she bought winter clothes worth £ 250 and paid **£2060** as tuition fees. How much in **ksh** did she end up with?

1.2.8.6 Tools, Equipment, Supplies and Materials

Tools/Equipment:	Materials:
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection	• Charts with presentations of data • Graph books • Text books

1.2.8.7 References

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Question 1

Purchase Price = US$ 100

1 US$ = 78·4133 ksh

100$ =

100 × 78·4133

= Ksh 7841·33

If he pays via account in the UK.

1 £ = 114·16 ksh

? = 7841·33 ksh

= 68·69 £

1 £ = Ksh 114·3034

68·69 £ = ?

$$\frac{68{\cdot}69\,\text{£} \times 114{\cdot}3034}{1\,\text{£}} = \text{Ksh } 7830{\cdot}34$$

Paying via his account in the UK is cheaper by 11 shillings.

Question 2

1 Euro = Ksh 73·52953

6000 Euros = ?

= sh 441179·8

less Spent sh 300000·0

141,175·80 Ksh

Converted to pounds

1 £ = Ksh 114·1616

? = Ksh 141175·80

$$= \frac{141175{\cdot}80 \times 1\text{£}}{114{\cdot}1616}$$

= £1236·6

Question 3

	Cash raised =	Sh 500000
less	Air ticket	80,000
		420,000

Balance converted to sterling pounds

1 £ = Ksh 114.1616

? = Sh 420,000

$= \frac{420000}{114.1616}$

= £ 3678.99

less clothes	250
	3428.99
Tuition fee	2060
	1368.99

How much in Ksh

1 £ = Ksh 114.3034

1368.99£ = ?

= 1368.99 x 114.3034

= Sh 156480.20

1.2.9 Learning Outcome 9: Apply Ratios

1.2.9.1. Introduction to the learning outcome

This unit describes the competencies required in applying basic mathematics on numbers and ratio.

1.2.9.2. Performance Standard

1. Differentiated between rational and irrational numbers
2. Expressed ratios as percentages

3. Solved problems involving direct and inverse proportions

1.2.9.3. Information Sheet

Rational numbers refer to a number that can be expressed in a ratio of two integers. An irrational number is one which can't be written as a ratio of two integers. Expressed in fraction, where denominator ≠ 0. Cannot be expressed in fraction.

Problems and Solution

Question 1: **Which of the following are Rational Numbers or Irrational Numbers?**

2, -0.45678…, 6.5, √ 3, √ 2

Solution: Rational Numbers – 2, 6.5 as these have terminating decimals.

Irrational Numbers; – -0.45678…, √ 3, √ 2 as these have a non-terminating non-repeating decimal expansion.

Question 2: Check if below numbers are rational or irrational.

2, 5/11, -5.12, 0.31

Solution: Since the decimal expansion of a rational number either terminates or repeats. So, 2, 5/11, -5.12, 0.31 are all rational numbers.

Rationalization of denominators in working

1. $\frac{7\sqrt{10}}{\sqrt{2}}$

$$
\begin{aligned}
\frac{7\sqrt{10}}{\sqrt{2}} \cdot \frac{\sqrt{2}}{\sqrt{2}} &= \frac{7\sqrt{20}}{\sqrt{4}} \\
&= \frac{7\sqrt{20}}{2} \\
&= \frac{7\sqrt{4 \cdot 5}}{2} \\
&= \frac{7\sqrt{4}\sqrt{5}}{2} \\
&= \frac{7 \cdot 2\sqrt{5}}{2} \\
&= \frac{{}^{7}\cancel{14}\sqrt{5}}{\cancel{2}\ {}_{1}} \\
&= 7\sqrt{5}
\end{aligned}
$$

Incase the denominator contains a sum of two numbers either both rational and irrational or all irrational, we use a conjugate;

2. $\frac{2}{3+\sqrt{3}}$

$$\frac{2}{3+\sqrt{3}}\cdot\frac{3-\sqrt{3}}{3-\sqrt{3}}=\frac{2\left(3-\sqrt{3}\right)}{\left(3+\sqrt{3}\right)\left(3-\sqrt{3}\right)}$$

$$=\frac{6-2\sqrt{3}}{9-3\sqrt{3}+3\sqrt{3}-\sqrt{9}}$$

$$=\frac{6-2\sqrt{3}}{9-\cancel{3\sqrt{3}}+\cancel{3\sqrt{3}}-\sqrt{9}}$$

$$=\frac{6-2\sqrt{3}}{9-3}$$

$$=\frac{6-2\sqrt{3}}{6}$$

$$=\frac{2\left(3-\sqrt{3}\right)}{6}$$

$$=\frac{\overset{1}{\cancel{2}}\left(3-\sqrt{3}\right)}{\cancel{6}\,3}$$

$$=\frac{3-\sqrt{3}}{3}$$

3. $\frac{3}{2-\sqrt{2}}$

$$\frac{3}{2-\sqrt{2}}\cdot\frac{2+\sqrt{2}}{2+\sqrt{2}}=\frac{3\left(2+\sqrt{2}\right)}{\left(2-\sqrt{2}\right)\left(2+\sqrt{2}\right)}$$

$$=\frac{6+3\sqrt{2}}{4+\cancel{2\sqrt{2}}-\cancel{2\sqrt{2}}-\sqrt{4}}$$

$$=\frac{6+3\sqrt{2}}{4-\sqrt{4}}$$

$$=\frac{6+3\sqrt{2}}{4-2}$$

$$=\frac{6+3\sqrt{2}}{2}$$

Expressing ratios as percentages ang vice versa

1. For example, If the ratio is 12:4, convert it to the form $\frac{12}{4}$, which is an equation we can solve. After that, multiply the result by 100 to get the percentage.

12 ÷ 4 = 3

3 × 100 = 300%

Equation to solve the percentage for a ratio

If given a percentage, you can be converted back into a ratio using very simple steps

Examples

a. 75%

Step One: Convert the percentage to a decimal

75%=0.75

Step Two: Convert from decimal form to fraction

0.75= $\frac{3}{4}$

Step Three: Rewrite as a ratio

$\frac{3}{4}$=3:4

b. 300%

Step One: Convert the percentage to a decimal

300%=3

Step Two: Convert from decimal form to fraction

3= $\frac{3}{1}$

Step Three: Rewrite as a ratio

$\frac{3}{1}$=3:1

Direct and inverse proportion

Direct proportion

There is a direct proportion between two values when one is a multiple of the other. For example,**1cm=10 mm** . To convert cm to mm, the multiplier is always 10. Direct proportion is used to calculate the cost of petrol or exchange rates of foreign money.

The symbol for direct proportion is α.

The statement 't is directly proportional to r' can be written using the proportionality symbol:

t αr

if y=2p then y is proportional to p and y can be calculated for p=7;

y=2x7=14

similarly, if y=60 then p can be calculated; 60=2p

to find p, divide 60 by 2:

60÷2=30

Finding the equation in direct proportion

Proportionality can be used to set up an equation.

There are four steps to do this:

1. write the proportional relationship
2. convert to an equation using a constant of proportionality
3. use given information to find the constant of proportionality
4. substitute the constant of proportionality into the equation

Example

The value e is directly proportional to p. When e=20, p=10. Find an equation relating e and p.

1. e ∝ p
2. e=k p

3. 20=10k so k= 20÷10 =2
4. e=2p

This equation can now be used to calculate other values of e and p.

If p=6 then, e=2×6=12.

Inverse proportion

It occurs when one value increases and the other decreases. For example, more workers on a job would reduce the time to complete the task. They are inversely proportional.

he statements ‘b is inversely proportional to m’ is written:

$b\propto\frac{1}{m}$

Equations involving inverse proportions can be used to calculate other values.

Using: $g=\frac{36}{w}$ (so g is inversely proportional to w).

If g=8 then find w.

$8=\frac{36}{w}$

$w=\frac{36}{8}$

Similarly, if w=6, find g.

$g=\frac{36}{6}$

g=6

Finding the equation in inverse proportion

Proportionality can be used to set up an equation.

There are four steps to do this:

1. write the proportional relationship
2. convert to an equation using a constant of proportionality
3. use given information to find the constant of proportionality
4. substitute the constant of proportionality into the equation

Example

If g is inversely proportional to w and when g=4, w=9, then form an equation relating g to w.

1. $g\propto\frac{1}{w}$

2. $g=k\times\frac{1}{w}=\frac{k}{w}$

3. $4=\frac{k}{9}$ so $k=4\times9=36$

4. $g=\frac{36}{w}$

This equation can be used to calculate new values of g and w.

If g=8 then find w.

$8=\frac{36}{w}$

$w=\frac{36}{8}=4.5$

Similarly, if w=6, find g.

$g=\frac{36}{6}$

$g=6$

1.2.9.4. Learning Activities

Practice the following assessment

1. A student pays 20% more for his bus fare from home to school than he used to pay two years ago. If he pays sh. 30, how much was he paying then?
2. A hawker bought a glass for sh 24 and later sold it latter for sh.36. what was his percentage gain?
3. In an analysis, 3.5% of all parts of a machine were declared substandard. If there were 72 substandard parts, how many parts were analyzed?
4. What percentage is 0.002cm of 4cm?
5. Four men can build 32m long in 12 days. what length of wall can eight men working in the same rate build in eight days?
6. Three tractors, each working eight hours a day, can plough a field in five days. How many days would two such tractors, working 10 hours a day take to plough the same field?

1.2.9.5. Self-Assessment

1. Convert each of the following decimals into a percentage;

a) 0.32
b) 0.88
c) 0.02
d) 3.2

2. Convert the following percentages into decimal;
   a) 120%
   b) 200%
   c) 40%
   d) 25%

1.2.9.6. Tools, Equipment, Supplies and Materials

Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Scientific Calculators • Rulers • Pencils • Erasers • Computers with internet connection	• Charts with presentations of data • Graph books • Text books

1.2.9.7. References

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1.2.9.8. Model Answers

QUESTION 1

Convert the following decimals to percentages.

a) 0.32

$= \frac{32}{100} \times 100 = 32\%$

b) 0.88

$\frac{88}{100} \times 100 = 88\%$

c) 0.02

$\frac{02}{100} \times 100 = 2\%$

d) 3.2

$3\frac{2}{10} = \frac{32}{10} \times 100 = 320\%$

QUESTION 2

Convert the percentages to decimals.

a) 120%

$= \frac{120}{100} = 1.2$

b) 200%

$= \frac{200}{100} = 2.0$

c) 40%

$= \frac{40}{100} = 0.4$

d) 25%

$= \frac{25}{100} = 0.25$

CHAPTER 2: TECHNICAL DRAWING

Unit of learning code: CON/CU/PL/CC/02/5/A

Related Unit of Competency in Occupational Standard*: *Prepare and apply technical drawing

2.1 Introduction to the unit of learning

This unit covers the competencies required to prepare and apply technical drawing. It involves competencies in selecting, using and maintaining drawing equipment and materials. It also involves developing plane geometry drawings, solid geometry drawings, pictorial and orthographic drawings

2.2 Summary of Learning Outcomes

1. Select, use and maintain drawing equipment and materials
2. Develop plane geometry drawings
3. Develop solid geometry drawings
4. Develop pictorial and orthographic drawings
5. Apply Computer Aided Design

2.2.1 Learning Outcome 1: Select, use and maintain drawing equipment and materials

2.2.1.1. Introduction to the learning outcome

The focus of this specific learning outcome is to introduce the different working drawings and their purpose during the planning of plumbing works. This section will give an understanding of the different types of working drawings, building symbols and different representations of drawings.

2.2.1.2. Performance Standard

The following performance criteria will be required to be met by trainees to be considered competent

1. Drawing equipment are identified and gathered according to task requirements
2. Drawing materials are identified and gathered according to task requirements
3. Drawing equipment are used and maintained as per manufacturer's instructions
4. Drawing materials are used as per workplace procedures

2.2.1.3. Information Sheet

Specific materials and drawing instruments are required in order to undertake technical drawing. As technical drawing is now a universal language it is governed by rules regarding methods of drawing and the symbols used.

Terms and concepts

a) **Technical Drawing**

According to Autodesk a technical drawing, also known as an engineering drawing, is a detailed, precise diagram or plan that conveys information about how an object functions or is constructed. Engineers, electricians, and contractors all use these drawings as guides when constructing or repairing objects and buildings

b) **Importance of Technical Drawing**

Technical drawings bridge the communication between designers, the people who come up with ideas, and producers, the people who put those ideas into practice. They are designed as a universal language to be understood by engineers, contractors, and architects.

c) **Types of Technical Drawings:**

i. **Mechanical Engineering 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.

Mechanical drawings rely on precise mathematical equations to accurately depict the mechanism and it component parts.

ii. **Electrical Drawing**

Electrical drawings are technical documents that depict and notate designs for electrical systems. They convey relevant information about lighting, wiring, and power sources, as well as information about voltage and capacity. Technicians rely on electrical drawings during a building's construction or when repairing a building's electrical system.

iii. **Architectural Drawing**

Architectural drawings are detailed, precise depictions of every aspect of the construction being proposed. Architects use the drawings to visualize ideas and concepts, turn a design idea into a coherent plan for a building, and decide the type of supplies and labor that is needed for the project.

Classification of drawings

a) Part drawing

Component or part drawing is a detailed drawing of a component to facilitate its manufacture. All the principles of orthographic projection and the technique of graphic representation must be followed to communicate the details in a part drawing. A part drawing with production details is rightly called as a production drawing or working drawing.

b) Assembly drawing

A drawing that shows the various parts of a machine in their correct working locations is an assembly drawing. There are several types of assembly drawing namely;

i. Design Assembly Drawing

When a machine is designed, an assembly drawing or a design layout is first drawn to clearly visualize the performance, shape and clearances of various parts comprising the machine.

ii. 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.

iii. Sub-assembly drawing

A sub-assembly drawing is an assembly drawing of a group of related parts, that form a part in a more complicated machine.

iv. 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.

v. Assembly drawing 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.

vi. 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.

d) **Drawing Office**

A drawing office is a room or set of rooms where designs and drawings are done and Drawing materials are stored.

A typical layout consists of drawing instruments and equipment, storage for these items, office for the drawing staff, drawing tables spread out in a spacious area for users.

e) **Drafting/Draughting**

This the ability to compose drawings that communicate how an object functions or is constructed

f) **Draughtsman**

This is the person who interprets and draws to scale the engineer's design.

g) **Drawing Instruments and Equipment**

Engineering drawing involves sketching with drawing instruments and the ability to:

i. To produce clean accurate lines of the desired thickness.
ii. To print clear alphabetical letters and numerals in dimensions or written Communications.
iii. To understand and apply the necessary drawing conventions as used in engineering drawing.
iv. Think in three dimensions
v. Master the techniques of projecting drawing views from one another.
vi. To practice the skills developed to enable production of professional drawings

h) **Drawing equipment**

Some of the drawing instruments and equipment are:

i. Tee or T-square

A Tee or T-square is a wooden or plastic ruler having a short, sometimes sliding Perpendicular cross piece at the end.

It is used to draw parallel lines. It is also used with other drawing instruments for Drawing lines at different angles.

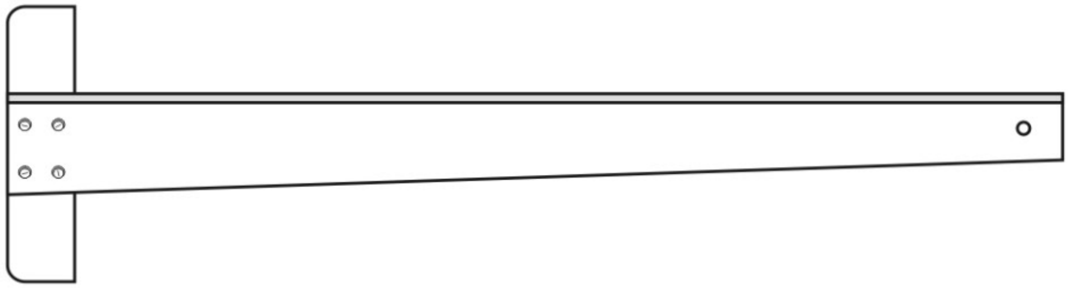

Figure 2: **T-Square**

ii. Set squares

These are thin flat pieces of plastic, metallic or wooden shaped in right angled triangles. They are available in various sizes such as 30°-60°, 45° and the adjustable set square which can be adjusted to accommodate different angles.

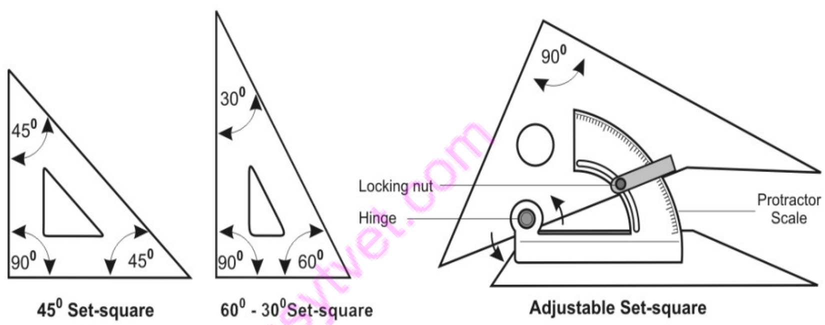

Figure 3 Set Squares

iii. Protractors

It is a thin flat piece of plastics, metallic or wooden semi-circular instrument with a straight edge. The semi-circular part is graduated to measure angles while the straight edge is graduated to take straight measurements. Protractors are used to mark out angles on drawing.

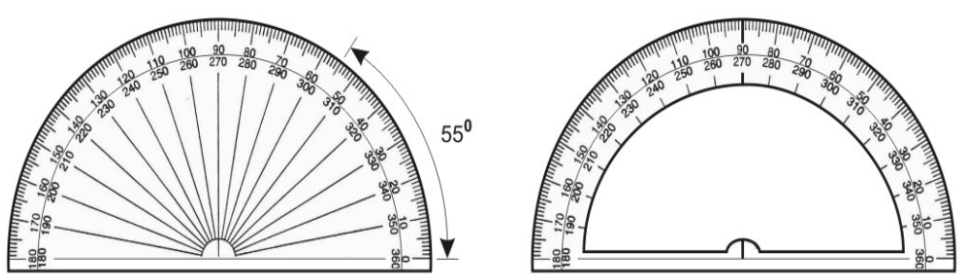

Figure 4 Protractors

iv. Compasses

It is an instrument with two arms joined together at the top; one has a sharp point that acts the pivot while other arm has a provision for holding a pencil or a marker.

It is used for drawing circles and arcs and for taking

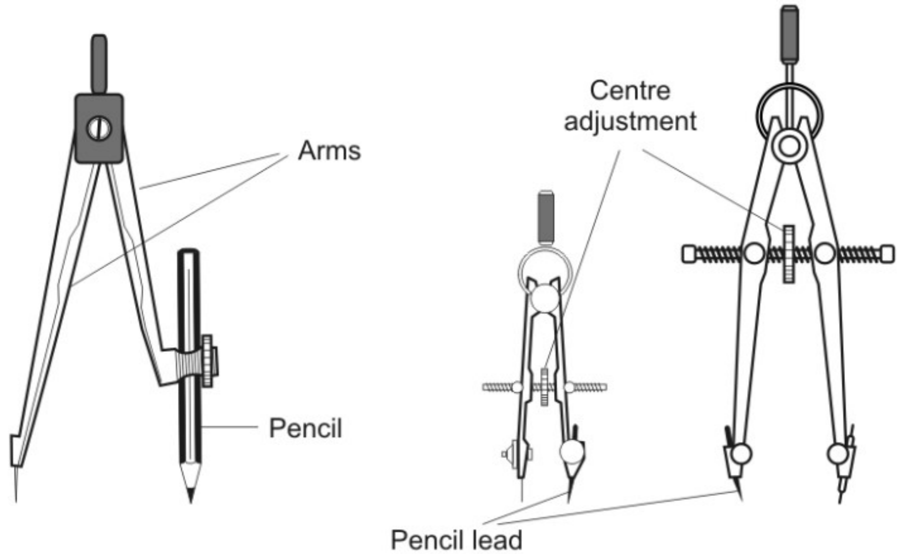

Figure 5 Compasses

v. Triangular Scale

Drafters use two types of triangular scales in combination with the T-square to draw lines at various angles. These acts as guides for horizontal, vertical, and diagonal lines. They are also used to map out scales.

Figure 6 Triangular scales

vi. Drawing board

This is a flat smooth rectangular surface made of either wood, plastic, or metal. It is used for drawing purposes. Drawing board is either fixed or portable.

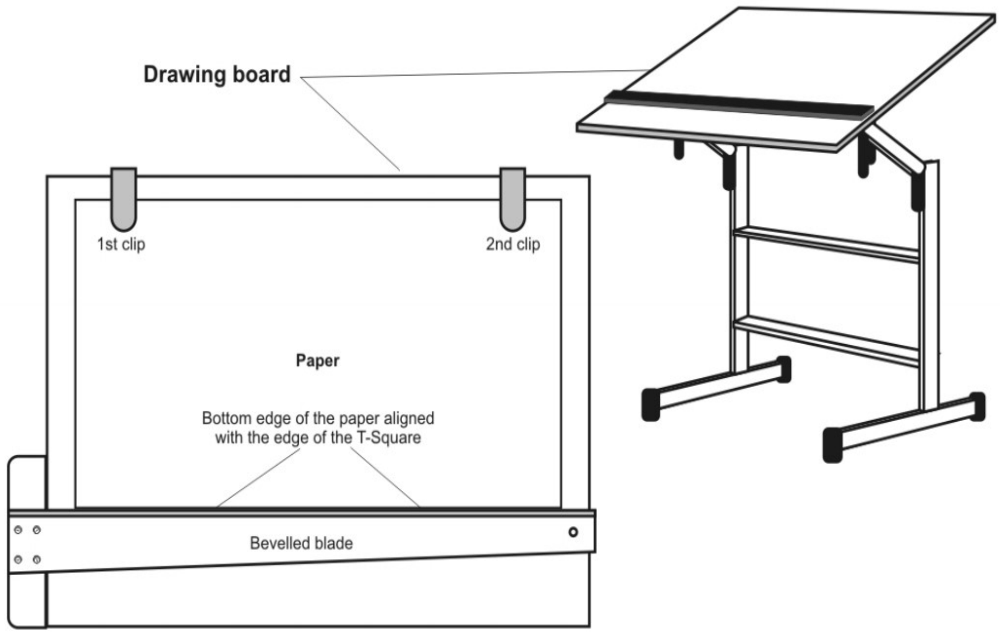

Figure 7 Drawing Boards

vii. Clips and marking tapes

A clip is a small metal or plastic object used for holding a drawing paper onto the drawing board.

A masking tape is a long narrow strip of material with a sticky substance on one side that is used to attach the drawing paper onto the drawing board

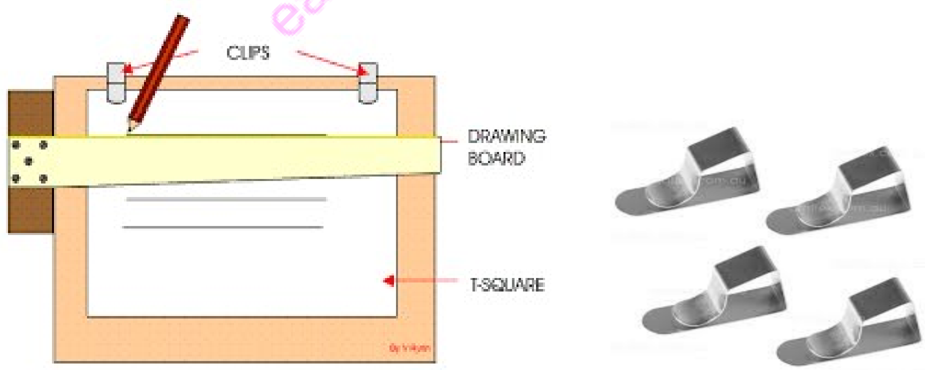

Figure 8 Clips

Figure 9 Masking Tape

viii. Pencils and pencil sharpeners

A pencil is a narrow cylindrical device for writing, drawing, or marking. It consists of a thin rod of graphite, coloured works or similar substance encased (covered) in wood or held in mechanical holder. This is one of the most important tools in drawing. It comes in various grades. The grade of pencil to be used depends on the quality of paper to be used. You must take into consideration also the type of line work required.

Pencils can be categorized in three classes, namely:

a) The **soft range pencils** such as 2B, 3B, 4B, 5B, 6B, 7B. The 7B being the softest. These pencils are mostly used in artwork.

b) The **medium range pencils** such as B, HB, BH, 2H, 3H; these are used for general drawing and sketching.

- HB grade is recommended for lettering and dimensioning.
- H Medium grade for Visible outlines, visible edges and boundary lines
- 2H Hard grade for construction lines, Dimension lines, Leader lines, Extension lines, Centre lines, Hatching lines and Hidden lines.

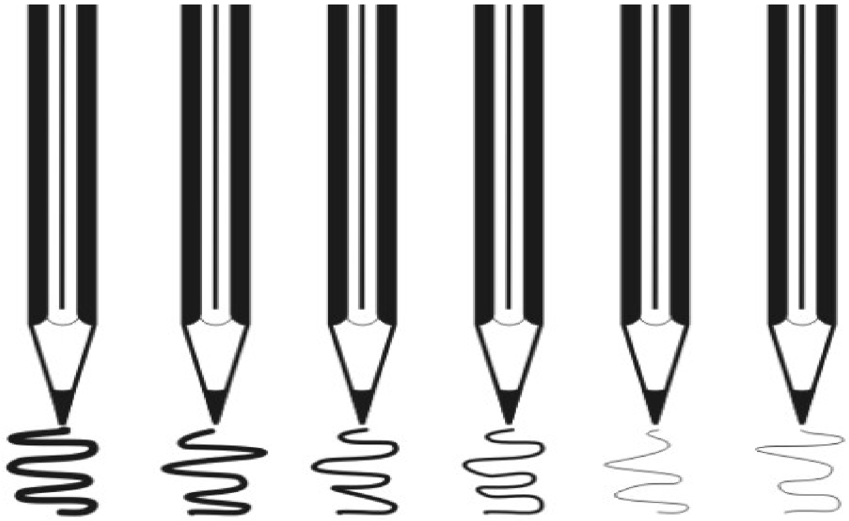

Figure 10 Wooden pencils-has graphite lead

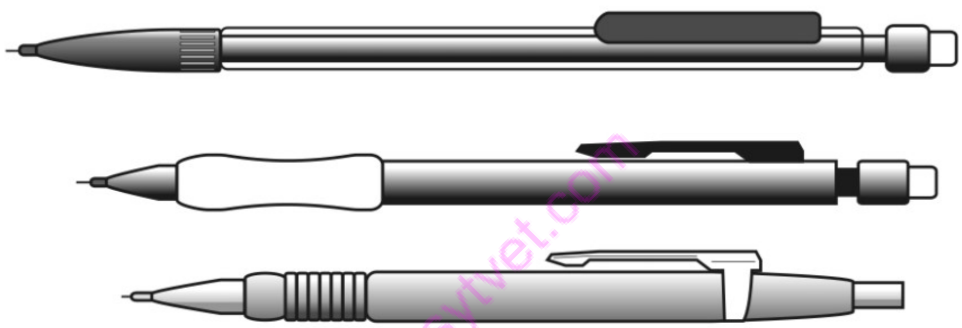

Figure 11 Mechanical/Clutch pencils-uses replace lead

The choice of which pencil to use is determined by the type of line desired.

c) The **hard range pencils** such as 4H, 5H, 6H, 7H, 8H, 9H. The 9H being hardest.

These pencils are used for accurate layout work.

Sharpening of pencils

This can be done using a razor blade, a mechanical sharpener, or a knife. The procedure involves:

a) Cutting the wood at about 20mm of the front part of the pencil.
b) Shaping the internal lead into a conical shape using a sandpaper pad or a fine file while revolving the pencil, or shaping the lead to a flat or chisel edge by rubbing on two opposite's side of the lead. A long, tapering point produces clean sharp lines while a dull point produces poor line works.

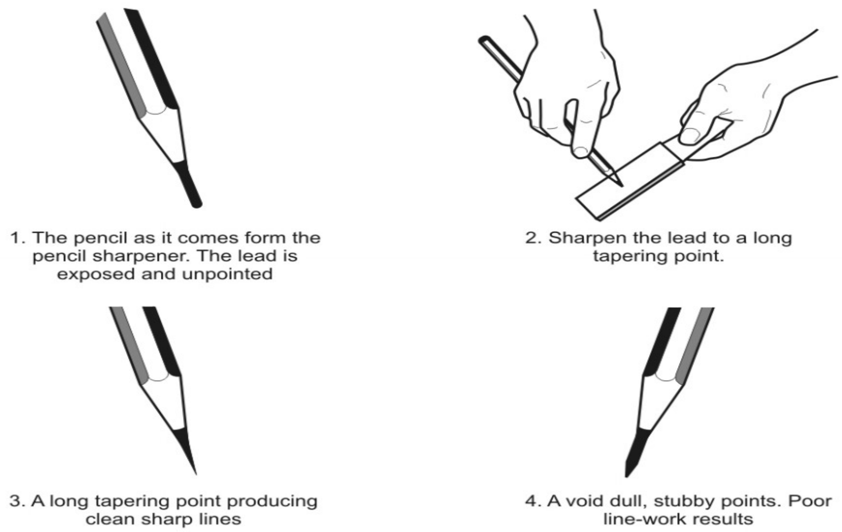

Figure 12 Sharpening a Pencil Procedure

The sharpening of the pencil should be done away from the drawing paper and board. The pencils used should be of reasonable length and of the expected hardness to get the desired line result.

ix. Geometrical sets

This consists of compasses, dividers, erasers, protractors, sharpener and other Accessories.

Divider

A tool with two metal legs used to lay-out an arc circle or step off division on a line. Is like the compass in construction. As the name implies, divider is used for dividing distances into several equal parts by the trial-and-error method.

Figure 13 Dividers

Steps in Using a Divider

a) Align each arm of the dividers so that one point is laying on the start point of the measurement you want to transfer and the other divider point is laying on the endpoint of that same measurement.

b) Lift the dividers off the measurement you intend to transfer, being careful not to change their alignment.

c) Place the dividers over the location you'd like to transfer the measurement to, and make a pencil mark to indicate where each of the dividers' pointers sits. This duplicates the measurement.

Erasers

These are used to rub off the pencil works that need correction or removing untidy patches from drawing paper. Erasers are used to remove pencil works though care must be taken to avoid damaging the drawing.

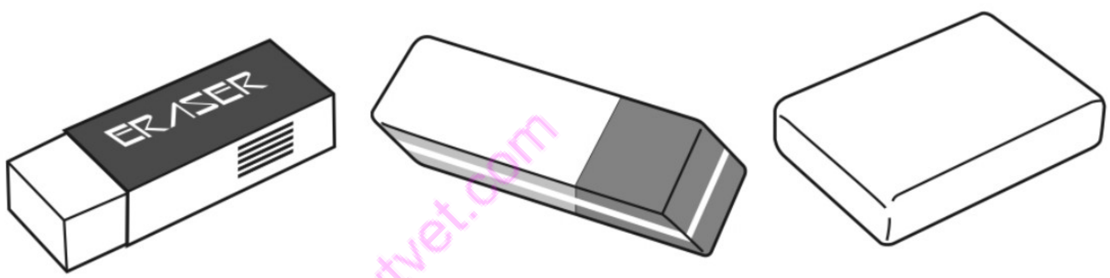

Figure 14 Erasers

Eraser shields

These can be made of metallic or plastic materials and are used for protecting line works that should not be erased. The shields have opening of various shapes that are placed on the area required to be rubbed and then the eraser is insert through these openings, shielding the blocked areas.

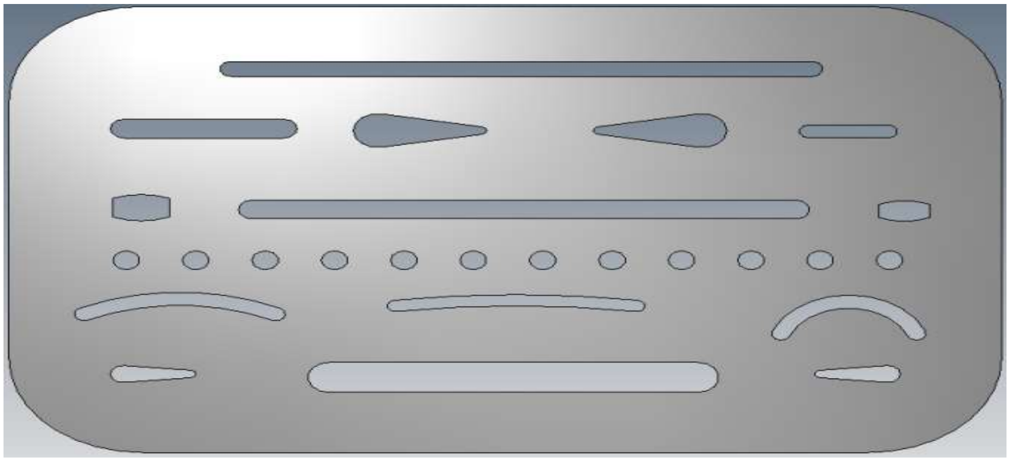

Figure 15 Eraser Shield

x. Drawing template curves

Drawing templates and lettering guides are precision drafting templates covering a wide variety of applications. They are used in architecture, interior design, landscaping, engineering, and map making are included;

a) Lettering guides conforming to ISO 3098 standards.
b) Line guides for establishing a set of hand lettering parameters.
c) French curves and flexible curves which enable varieties of curved shapes to be drawn with minimal effort.

Figure 16 French Curves

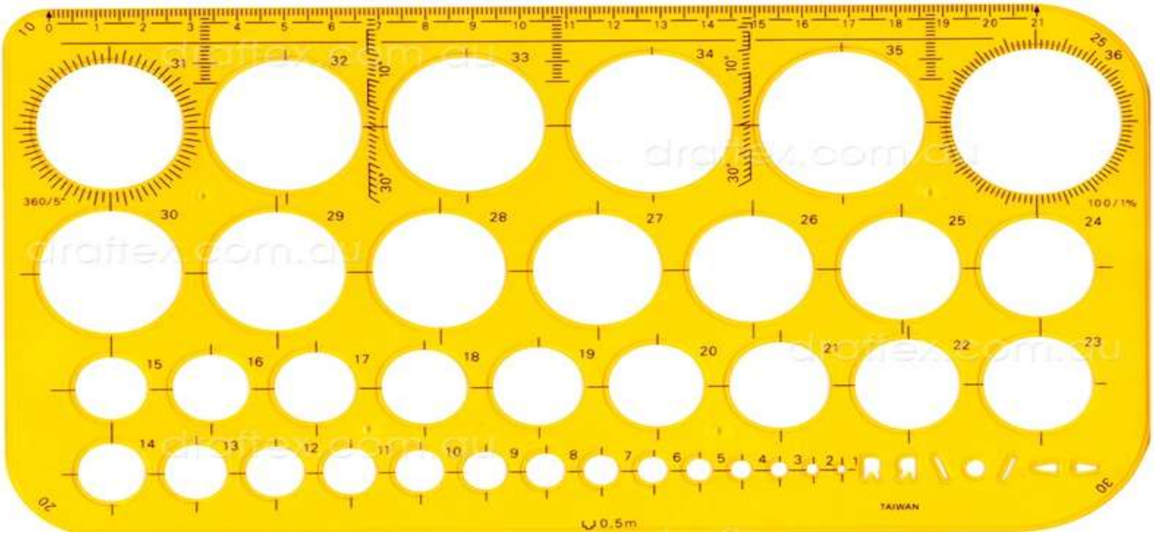

Figure 17 Circle template

xi. Draughting equipment

"A draughting machine is a tool used in technical drawing, consisting of a pair of scales mounted to form a right angle on an articulated protractor head that allows an angular rotation. Draughting tools are instruments that can be used for measurement and layout of drawings or to improve consistency and the speed for creating standard drawing elements".

Drafting machines combine the functions of the T-square, triangles, scales, and protractor. Allowing you to draw more quickly and with less work.

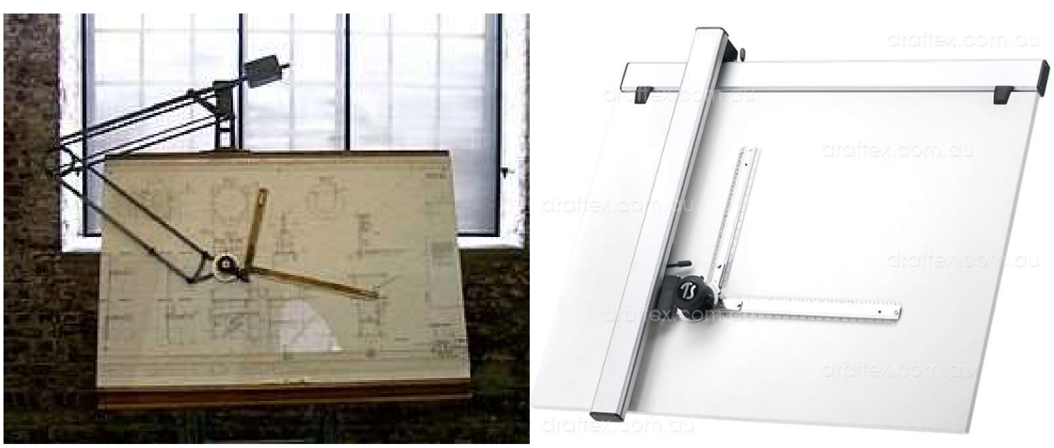

Figure 18 Draughting Equipment

xii. Computer-aided design (CAD)

"Computer-aided design (CAD) is the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design. ... The term CADD (for computer aided design and drafting) is also used."

xiii. Engineering drawing software's

These are various software's used by engineers, architects, draughtsman, and construction managers among others to replace manual drafting. They help users to create designs in either two dimensions (2D) or three dimensions (3D) enabling the user to visualize the object in different perspectives. CAD enables the development, modification, and optimization of the design process

i) Drawing materials

i. Drawing paper

Paper layout on the drawing board. Paper layout is the process of defining the workspace and orientation of the drawing paper. The following steps are involved in paper layout:

1. Paper sizing

Drawing papers used in technical drawing are rectangular in shape.

The papers are serialized according to the sizes.

The table below shows the different paper sizes.

Series	Paper size in (mm)
A0	1189×841
A1	841×594
A2	594×420
A3	420×297
A4	297×210
A5	210×148
A6	148×105

Figure 19 Paper sizes

2. Setting of the drawing papers

The drawing paper is placed on the drawing paper according to the desired orientation. A T-square is then held firmly on the drawing board with the horizontal edge aligned to lower edge of the paper.

The paper is finally fixed in position with either clips or masking tape.

3. Drawing of boundary lines.

Boundary line is a line that defines the working space of the drawing paper. It is always equidistant from all the edges of the paper and at least 10 mm from edge.

The figure below shows the drawing paper boundary.

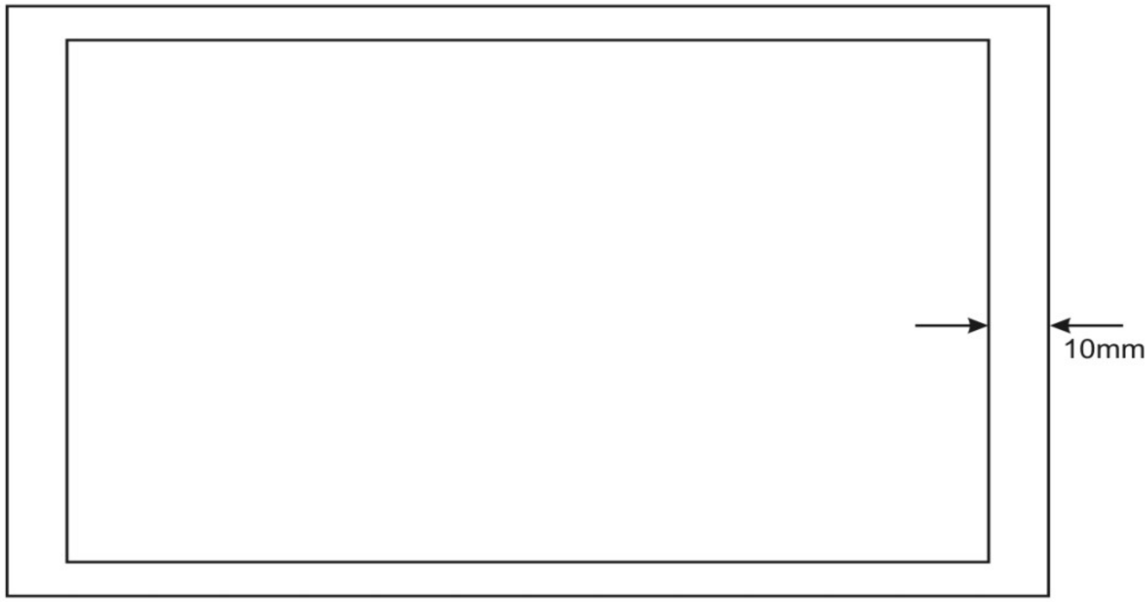

Figure 20 Drawing Paper Layout

4. **Drawing the title block**

   A title block is a designated area where the parameters for defining the drawing are stated. These parameters include details such as; name of the person drawing, scale and the institution. It is usually drawn at the bottom of the right-hand corner within the working area of the drawing paper.

   The figure below is a sample of title block.

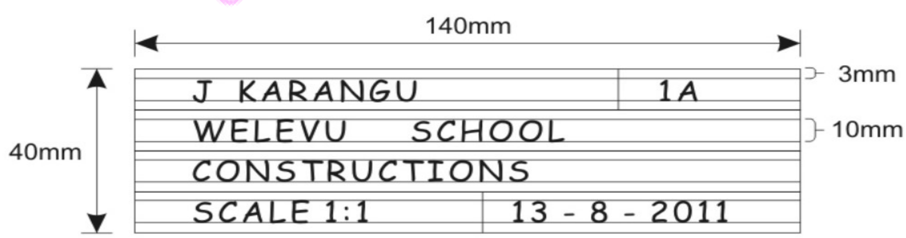

Figure 21 Sample title block

ii. **Pencils-**covered above

iii. **Erasers-** covered above

iv. **Masking Tapes-** covered above

v. **Paper Clips-** covered above

j) Use, care and maintenance of drawing equipment's

Draughting tools, materials, and equipment are delicate and need good care for their applications to remain at its best. Keeping your drafting tools clean, well maintained, and properly stored will result in better performance and longer service life. Below are some tips to properly use and take care of them.

a) The performance of simple cleaning, maintenance, and storage procedures help a lot in keeping the efficiency of every drafting instrument. The early detection and reparation of any signs of deterioration will enable the drafter to save time and resources in the future.
b) Perform safety procedures in maintaining drawing tools, drawing instruments, equipment, and other related accessories.
c) Follow procedures in cleaning, tightening and simple repair of drawing tools, drawing instruments, equipment, and accessories.
d) Identify common malfunction (unplanned or unusual events) when using tools, drawing instruments, equipment, and accessories. Always ensure you inspect tools before use, this is to check if they are in working condition.
e) After using a tool, clean it thoroughly with a damp cloth. Wipe it dry with another piece of cloth before keeping it.
f) The following are common good practices in handling and caring for your drafting tools and equipment.

i. Pencils

- Use soft cloth or tissue to clean the pencil to get rid of particles that may ruin your work.
- Sharpen your wooden pencil with a quality sharpener.
- Keep your pencils in a secure case or tie them together with rubber band to avoid breakage when transporting them.
- Never sharpen the pencil over the drawing or close to any of your equipment.
- Keep the pencil lead sharp and pointed when drawing.
- Avoid using solvents or other strong chemicals when cleaning your mechanical pencil. Such chemicals may corrode the material your pen is made of.
- Use only the lead designed for your mechanical pencil to avoid mechanical jam and clogging.
- Load your mechanical pencil with the recommended amount of lead.
- Observe correct refilling procedure.

ii. T-square, triangles, and French curves

- Do not use the T-square for any rough purposes.

- Never cut paper along its working edge, since the plastics can easily be damaged. Even light nick can ruin the T-square.
- When not in use, the T-square, triangles, or French curves is preferably hung by inserting the hole to a nail on a surface i.e a wall.
- Apply oil on all the movable parts of the measuring tools such as zigzag rules, calipers, dividers, and compasses to avoid rusting.
- Avoid unnecessary sliding of T-square or triangles protect the drawing. Pick up the triangle by its tip and tilt the T-square blade upward slightly before moving.

iii. **Ruler or scale**

- Scales should not be pricked with needle points of either the divider or compass when measurements are taken.
- Do not use scale as a ruler.

iv. **Dividers and compasses**

- Do not oil the joints of the legs of the dividers.
- Do not use the divider as substitute for clips in fastening the drawing paper on the drawing board or tabletop.
- The needle points must be sharp and of equal length.

v. **Drawing paper**

- It should be stored in rolled form.
- It should not be crumpled or wet or kept in a moist or cold place.

vi. **Masking tape, eraser and erasing shield**

- Should be kept together with other supplies to avoid losing it.

vii. **Drawing board or drawing tape**

- It should always be in good (drawing) working condition.
- It must always be clean on or before using.
- Do not leave any kind of marks on your board to retain its smoothness.

g) Avoid dropping your tools and equipment by keeping them far from the edges of the board.
h) Report defective measuring tools and any hazard to instructor immediately
i) Never use measuring tools in cutting paper.
j) Ensure measuring tools are protected and stored well
k) Have a separate container for marking tools.
l) Keep your drawing sheets in a plastic tube to protect them from a dust and dirt.

m) Never borrow drafting tools and materials if you do not know how to use and store them.

Check out the lesson online on introduction to technical drawing for further explanation
https://www.youtube.com/watch?v=YE0oZZO7vbk
https://www.youtube.com/watch?v=0Q6QwvtjVm8
http://www.depedbataan.com/resources/9/k_to_12_mechanical_drafting_learning_module.pdf

2.2.1.4. Learning Activities

Below is a wash hand basin drawn in isometric view? As a trainee you are required to;

i. Identify and gather drawing equipment's according to the below task
ii. Identify and gather drawing materials according to the task

2.2.1.5. Self-Assessment

Exercise 1

Select the drafting material and tool/drawing applicable to a specific job.

1. A drafting tool used for drawing horizontal lines
   a) Compass
   b) Triangle
   c) T-square
   d) Triangular Scales
2. Drafting material used for fastening the drawing paper on the drawing table
   a) Compass
   b) Divider

c) Masking Tape
d) Triangle

3. The main function of this tool is to reproduce the measurements of an object to any size.
   a) Compass
   b) Protractor
   c) Triangle
   d) Triangular Scales
4. This drafting tool is used to protect the rest of the drawing when removing unnecessary lines.
   a) Erasing Shield
   b) Eraser
   c) Masking Tape
   d) Pencil Sharpener
5. This drafting tool is used when drawing vertical lines.

a) Compass
b) Triangle
c) Triangular Scales
d) Ruler

2.2.1.6. Tools, Equipment, Supplies and Materials

i. Drawing boards
ii. T squares
iii. Set squares
iv. Drawing sets
v. Drawing paper
vi. Protractors
vii. Eraser Shield
viii. Pencils
ix. Erasers
x. Masking tapes
xi. Paper clips
xii. Drawing curves
xiii. Technical drawing software'

2.2.1.7. References

1. Bhatt, N. D. (2011). *Engineering Drawing.* Gujarat: Charotar Publishing house.
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3. Morling, K. (2010). *Geometric and Engineering drawing.* London: Elsevier.
4. https://www.youtube.com/watch?v=lk-FBgadTyA
5. K.L Narayana, P.Kannaiah and K.venkata Reddy .(Third edition) Machine Drawing :New Age International (P) Limited, Publishers.

Model answers.

1. A drafting tool used for drawing horizontal lines

   C. T-square

2. Drafting material used for fastening the drawing paper on the drawing table

   C.Masking Tape

3. The main function of this tool is to reproduce the measurements of an object to any size.

   D.Triangular Scales

4. This drafting tool is used to protect the rest of the drawing when removing unnecessary lines

   D. Erasing Shield

5. This drafting tool is used when drawing vertical lines.

   B. Triangle

2.2.2 Learning outcome 2:Develop plane geometry drawings

2.2.2.1. Introduction to the learning outcome

The focus of this specific learning outcome is to introduce the different working drawings and their purpose during the planning of plumbing works. This section will give an understanding of the different types of working drawings, building symbols and different representations of drawings.

2.2.2.2. Performance Standard

The following performance criteria will be required to be met by trainees to be considered competent:

1. Freehand sketching of different types of geometric forms and diagrams is conducted.
2. Different types of lines used in drawing and their meanings are identified according to standard.
3. Drawing conventions.
4. Different types of geometric forms are constructed according to standard conventions.
5. Different types of angles are constructed, measured, and bisected according to principles of trigonometry.

2.2.2.3. Information Sheet

a) Terms and concepts

i. Freehand Sketching

Sketching or freehand is a first step to the preparation of a scale-drawing, i.e., a drawing drawn with the aid of instruments. A designer records his ideas initially in the form of sketches which are later converted into drawings. Similarly, views of actual objects are in the first instance, sketched freehand.

Scale-drawings are then prepared from these sketches. Ideas and objects can be described in words, but the description is made more expressive with the aid of sketches. Thus sketching is of great importance in engineering practice.

Sketching is always done freehand. It is in fact a freehand drawing made in Correct proportions, but not to scale. A sketch should be so prepared as to give to others a clear idea, complete information, and true impression of the object to be constructed. It should never be drawn too small. The size of a sketch should be such that all the features of the object, together with their dimensions, explanatory notes etc. are clearly incorporated in it. Proficiency in sketching can be achieved with constant practice only.

ii. **Axonometric**
Method of projection in which an object is drawn with its horizontal and Vertical axes to scale but with its curved lines and diagonals distorted

iii. **Detailed drawing**
Drawing of a detail part usually in orthographic projection

iv. **Detail dimension**
Measurements of the detail part or parts of the object

v. **Dimensioning**
Process of placing measurements in a drawing in the metric or English System

vi. **Isometric axes**
Light lines used as bases in constructing an isometric view of an object

vii. **Isometric drawing**
Pictorial drawing showing the three views of the object tilted 30 degrees in front of the observer.

viii. **Multi-view drawing**
Drawing that shows more than one view of an object

ix. **Notation**
All lettering and other dimension found in a drawing or working sketch

x. **Oblique drawing**
Kind of pictorial drawing of an object one surface of which is shown parallel to the frontal plane and the other is inclined to it.

xi. **Orthographic projection**
Presentation of an object in two or more views by projecting the outline of the object to the plane of projection perpendicular to each other

xii. **Overall dimension**
The total width, height, and depth of the object

xiii. **Perspective drawing**

A drawing which shows an object as it appears to our eyes

xiv. **Pictorial view**

The presentation of an object where it is viewed showing the three faces of an object

xv. **Working plan**

A freehand drawing showing all the information needed to construct an object.

xvi. **Types of drawings**

There are various drawings used in the construction sector, some of these are list below:

Production drawing:

A production drawing is legal document of a manufacturer. It is used by the technicians on the shopfloor for manufacturing the parts. It should provide information about part number, dimensions, tolerance, surface finish, material and stock size, manufacturing process, special finishing process if required, and no. off required for each assembly. It is further sub-classified as:

- Part drawing or detailed drawing
- Assembly drawing.

Exploded Assembly Drawing

It represents the details of machine in a pictorial form as it is assembled. It helps the plumber to dismantling machine for repairing purpose.

Schematic assembly drawing

This type of assembly drawing is used for explaining working principle of any machine

Drawing for instructional manual

This is assembly drawing without dimensions. Each part of machine is numbered so that it can be easily dismantled or assembled if required. This is also used for explaining working principle of each part.

Drawing for installation

This is assembly drawing with overall dimensions. It is used for the preparation of foundation for installing machine.

b) **Types of lines in drawings**

There are many lines used in technical drawing, the table below illustrates some of them;

i. **Visible line** – a thick line that represents the visible edges or outline of the object; also known as the object line
ii. **Hidden line** – a medium thick line composed of short dashes about 2-3 millimeters long with space between dashes about 1-2 millimeters wide; it represents the surface or edges that cannot be seen
iii. **Center line** – a thin line consisting of two long dashes and short dash drawn alternately with a gap of at least 2 millimeters in between; it represents the axis or center of symmetrical shapes like a ball, washer, rectangular block, cube.
iv. **Section line** – a thin lines to show the surface that has been cut; they are spaced evenly at 45 degrees with the horizontal to make shaded effect
v. **Extension line** – a thin line that extends from the object to show dimension limits
vi. **Dimension line** – a thin line with an arrowhead in one end used to indicate the Measurements of the object
vii. **Long-break line** – a medium thick line consisting of broken and straight lines drawn alternately. This is also known as the limiting line. This limits the length of an elongated object without changing the size of its view.
viii. **Short-break line** – thick line drawn in freehand to show details that a part has been cut off or broken out.
ix. **Leader line** – a short inclined thin line with an arrowhead at the end and short horizontal line on the other end.
x. **Phantom line** – a thin line that shows position(s) of part of an object that moves drawn by two short dashes and one long dash.
xi. **Cutting-plane line** –thick lines used to indicate an imaginary cut through an object along the line. Made up of two long dashes broken in one end with an arrowhead and two short dashes drawn in between the long dashes.

Type of line	Used for drawing	Pencil Grade	Sample Drawing
Continuous thick	Visible outlines	H	
Continuous thin	Dimension line,leader line,extension, construction lines and hatching lines	2H	
Continuous thin (drawn free hand)	Irregular boundary line,short break line	2H	
Continuous thin with zigzag	Long break line	2H	
Short dashes (Hidden line)	Invisible edges	H	
Long chain (thin)	Center lines	2H	
Long chain (thick at ends and thin else where)	Cutting plane	H&2H	

Figure 22 Types of lines and their applications

c) Freehand sketching

A freehand sketch is a drawing in which all proportions and lengths are judged by eyes and all lines are drawn without the use of drawing instruments. Comparing with mechanical drawing, the use of freehand sketching in engineering Communication provides the following advantages:

i. A better means of visualizing problems
ii. Organizing ideas more quickly
iii. Avoiding wasting of time on formal drawing methods

The following requirements are necessary for sketching materials in plumbing,

Sketching tools:

A sketch communicates information and does not have to be an exact drawing. Many designs were visualized on just a piece of paper or whatever is available. The tools that are used in freehand sketching are:

i. Sketching paper cross-section paper or grid paper, help secure good proportions and serve as guides in sketching lines

ii. Pencil medium lead (B) or soft lead (HB) type
iii. Eraser soft type

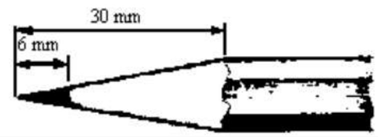
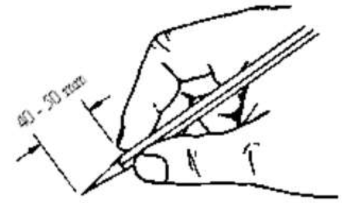
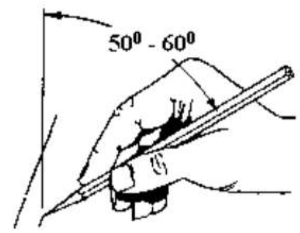
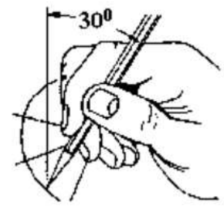
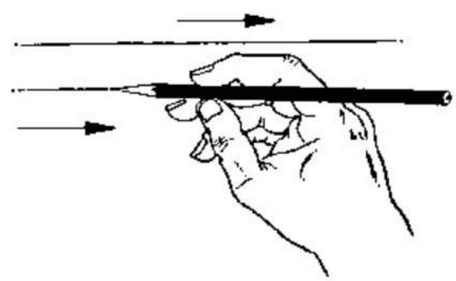
Above the three things are essential for sketching. Sometimes, cross-sectioned graph paper ruled with light lines is also used instead of a plain paper. These lines and squares help in drawing straight lines and maintaining proportions.

As such papers may not always be readily available, it is advisable to learn sketching without their aid.

Freehand drawing is known as sketching. This technique is necessary in any area of drafting and an important skill for everyone. Skills in freehand drawing can be achieved through constant training and correct practice.

Use of pencils

Although freehand lines will never be perfectly straight and absolutely uniform along their lengths, effort should be made to sketch distinct, black and uniform lines. Hints of using pencils that help sketching to be made to approach exacting uniformity are as follows:

i)	Sharpen the pencil to obtain a proper point	
ii)	Hold the pencil loosely, approximately 40 - 50 mm from the point	
iii)	Slant the pencil at an angle of 50 - 60 degrees from the vertical for sketching straight lines	
iv)	Slant the pencil at an angle of 30 degrees from the vertical for sketching circles	
v)	Pull the pencil when sketching straight lines or curves	

Line Sketching

One advantage of freehand sketching is that it needs only patience and continuous Practice. Practice on a drawing paper the construction of following line without use of instruments. When drawing straight lines, as on the left, rest the weight of your hand on the backs of your fingers. When drawing curved lines, as on the right, rest the weight on that part of your hand between the knuckle of your little finger and your wrist. This provides a pivot about which to swing your pencil. Always keep your hand on the inside of the curve, even if it means moving the paper around.

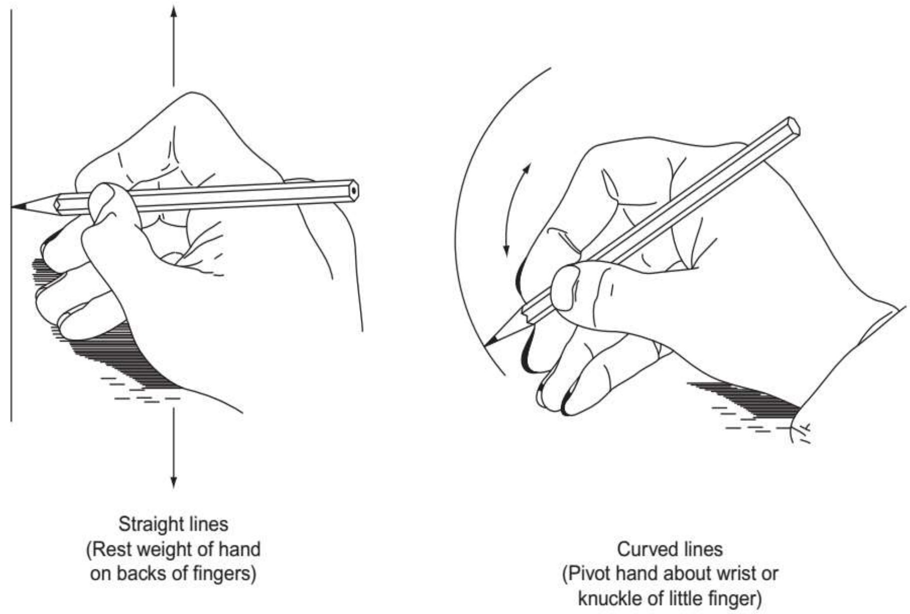


Figure 23 Freehand sketching technique (Source: H Morling)

Basic Line Sketching

Kind of lines	Direction of strokes
For right-handed For left-handed **Horizontal lines**	Strokes are drawn from left to right for right-handed and from right to left for left-handed individuals.
Vertical lines	Strokes are drawn downward.

Figure 24 Exercise 1 on drawing various lines in freehand

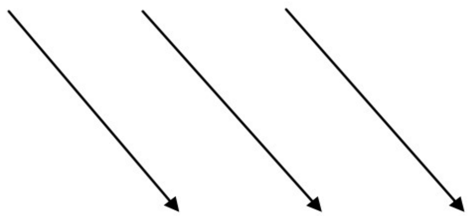
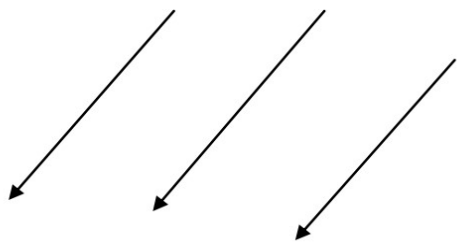
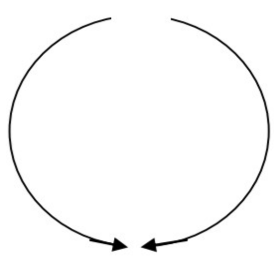
 **Inclined to the right**  **Inclined to the left**	Inclined strokes (diagonal) are drawn downward
 **Curved line**	Curved strokes are drawn downward for either right-handed or left-handed

Figure 25 Exercise 2 on freehand sketching

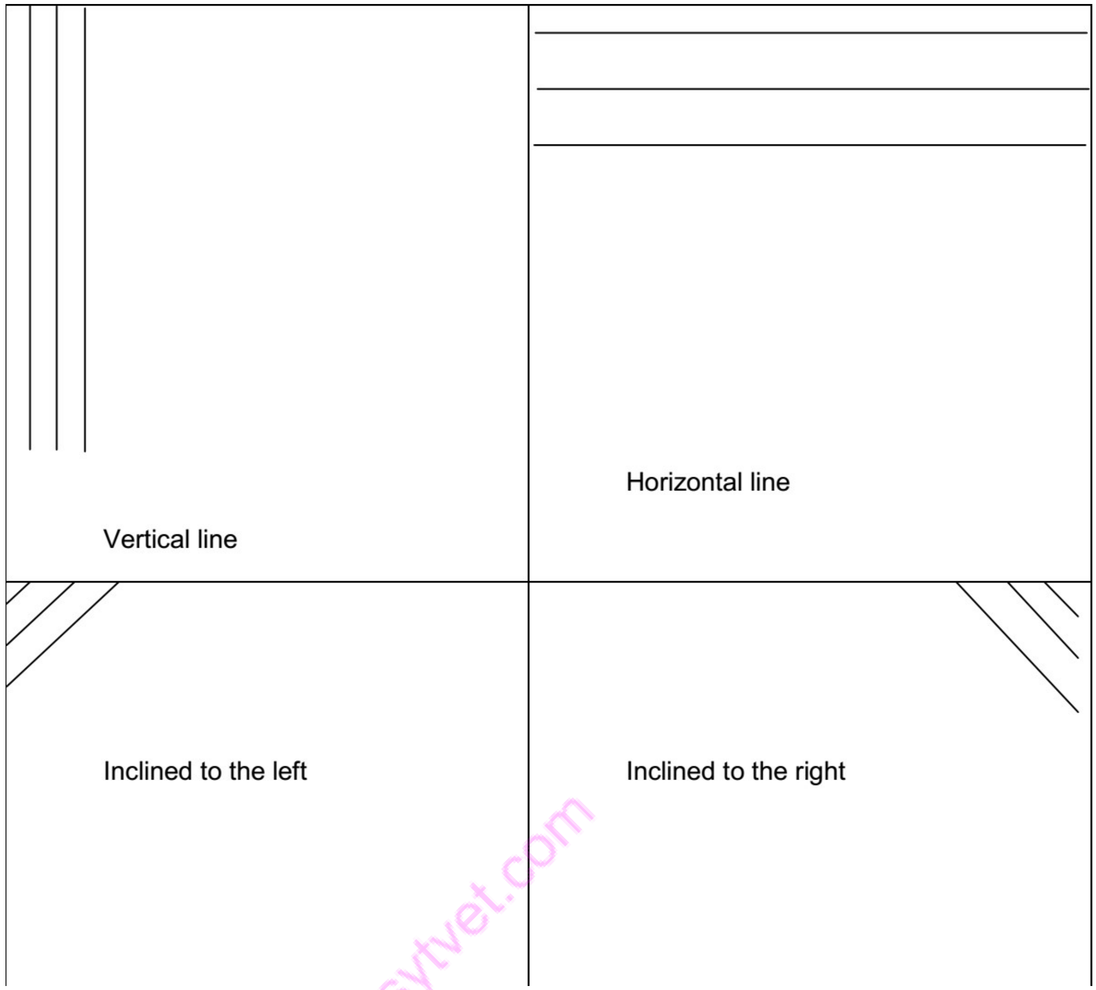


Figure 26 Exercise 3

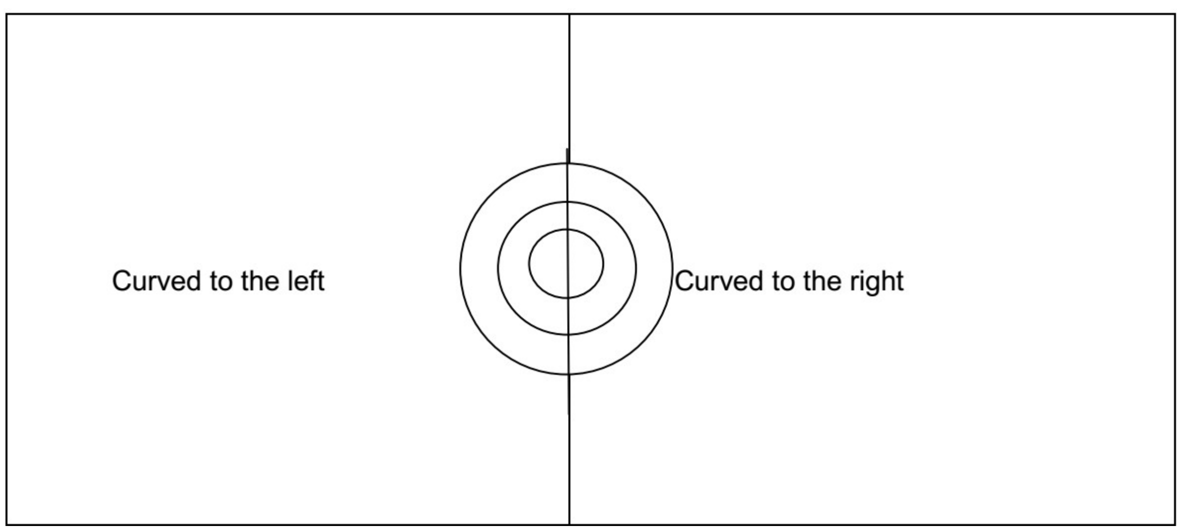


Figure 27 Exercise 4

Pictorial Sketching

Freehand pictorial sketching looks very much like isometric drawing. Circles appear as ellipses and lines are drawn at approximately 30 °. Circles have been sketched onto an isometric cube in figure below. You can see how these same ellipses appear on sketches of a round bar material.

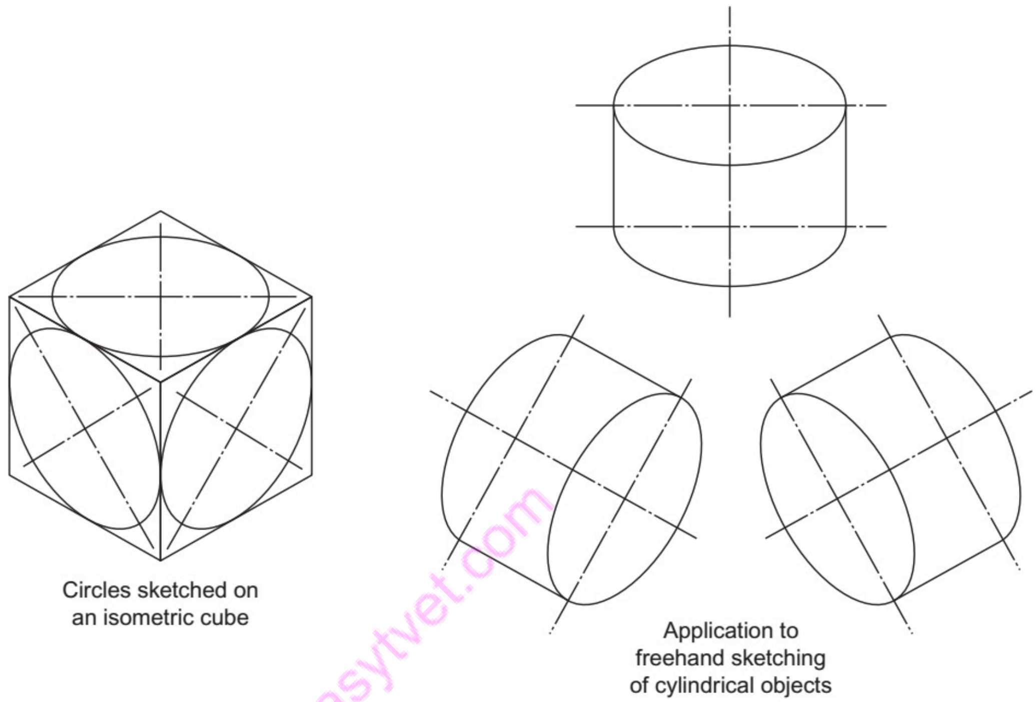


Figure 28 Pictorial exercises

When sketching, you may find it an advantage to draw a faint 'box' first and draw in the ellipses afterwards. With practice you should find that you can draw quite a good ellipse if you mark out its centre lines and the major and minor axes. Although drawing is a continuous process, the work can be divided into three basic stages.

Stage 1: Construction

This should be done with a hard pencil (3H), used lightly, and the strokes with the pencil should be rapid. Slow movements produce wavy, uncertain lines. Since these constructed lines are very faint, errors can easily be erased.

Stage 2: Lining in

Carefully line in with a soft pencil (HB), following the construction lines drawn in stage 1. The completion of stage 2 should give a drawing that shows all the details and you may decide, particularly in an examination, not to proceed to stage 3

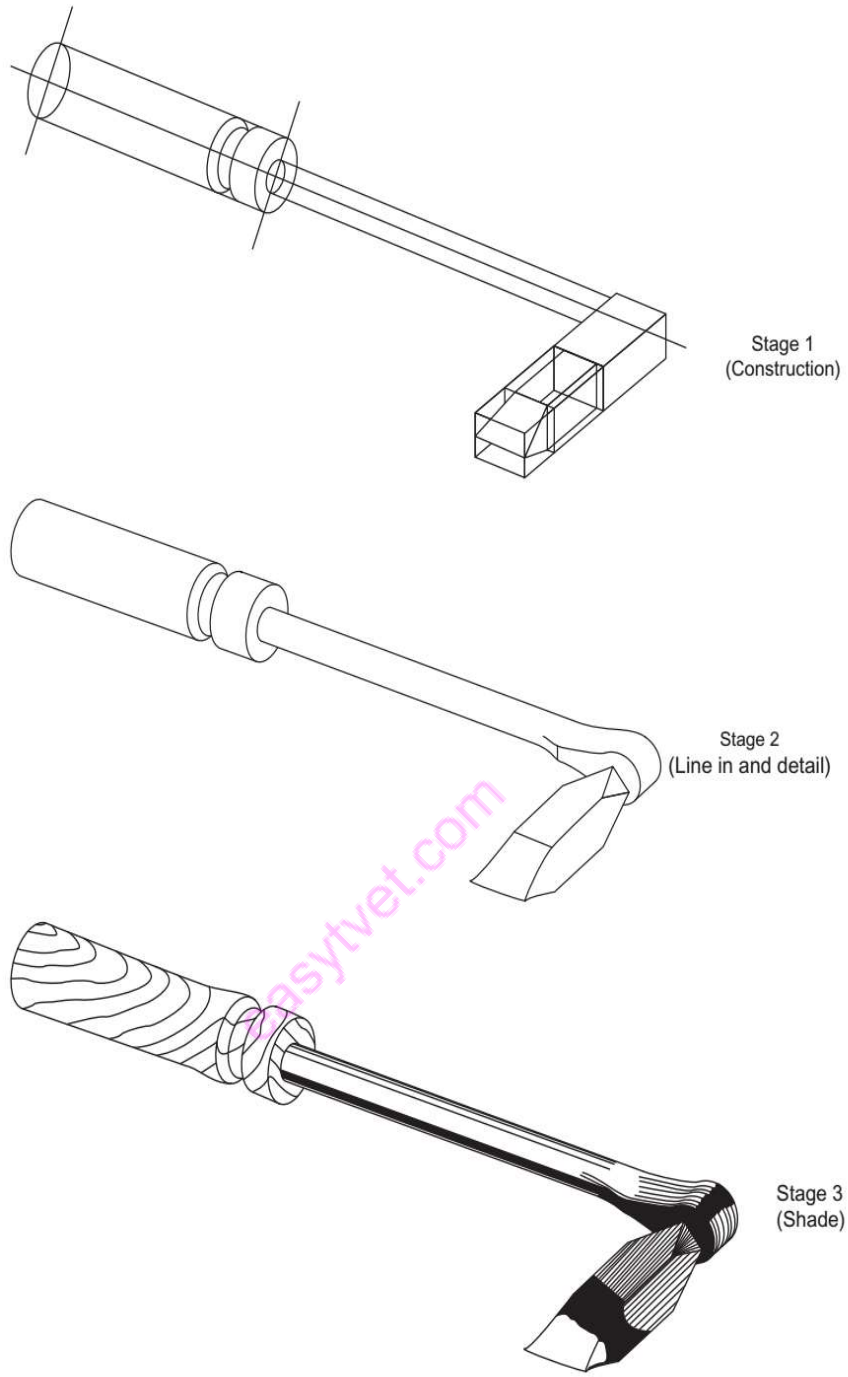


Figure 29 3 stages of freehand sketching

Stage 3: Shading

Shading brings a drawing to life. It is not necessary on most sketches, and in some cases it may tend to hide details that need to be seen. If the drawings are to be displayed, however, some shading should certainly be done.

Shading is done with a soft pencil (HB). It is very easy to overshade, so be careful. For the smooth merging of shading, the dry tip of a finger can be gently rubbed over the area.

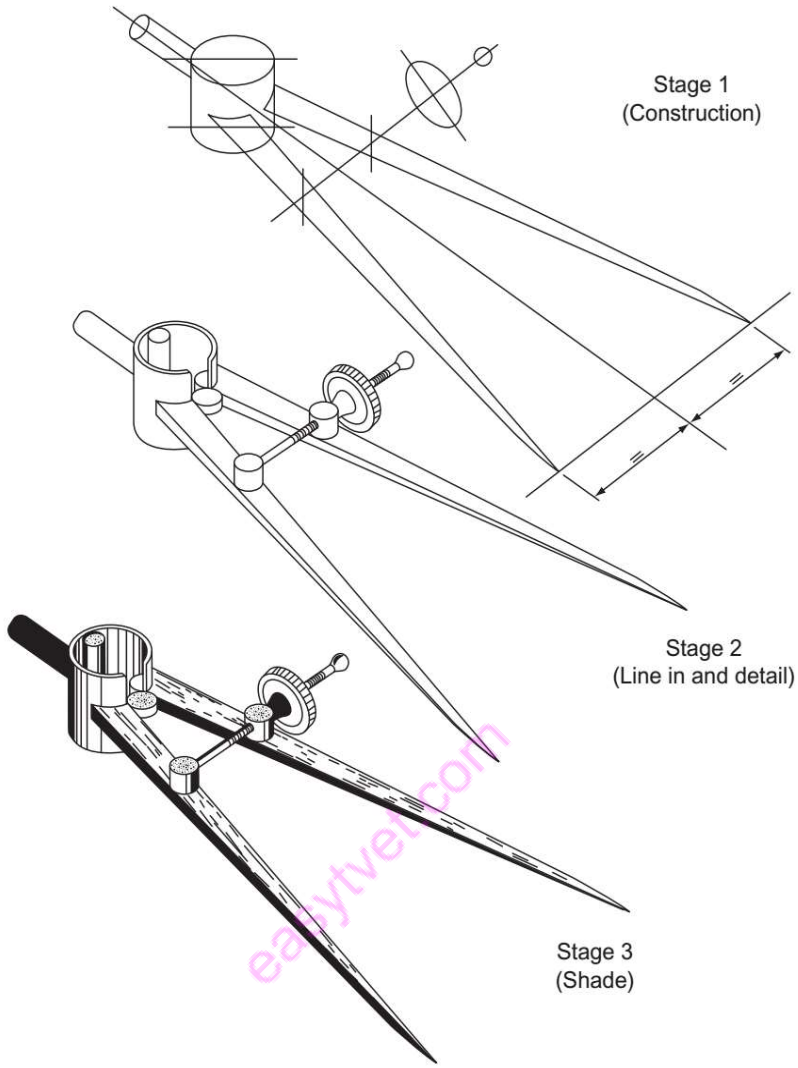


Figure 30 Divider Exercise

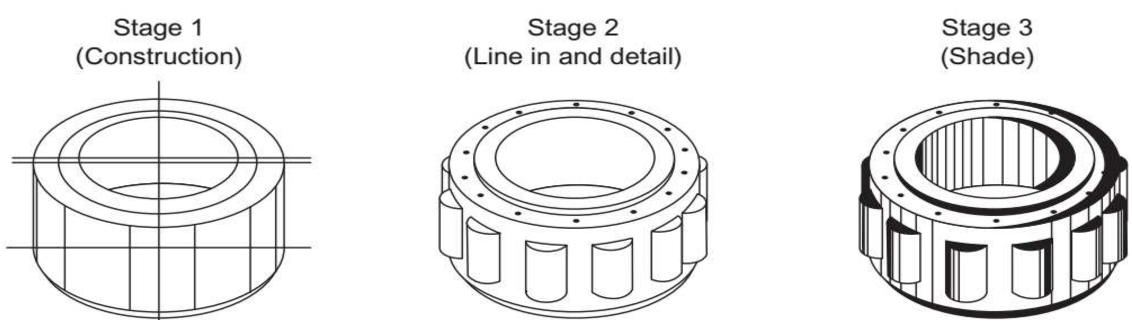


Figure 31 Bearing exercise

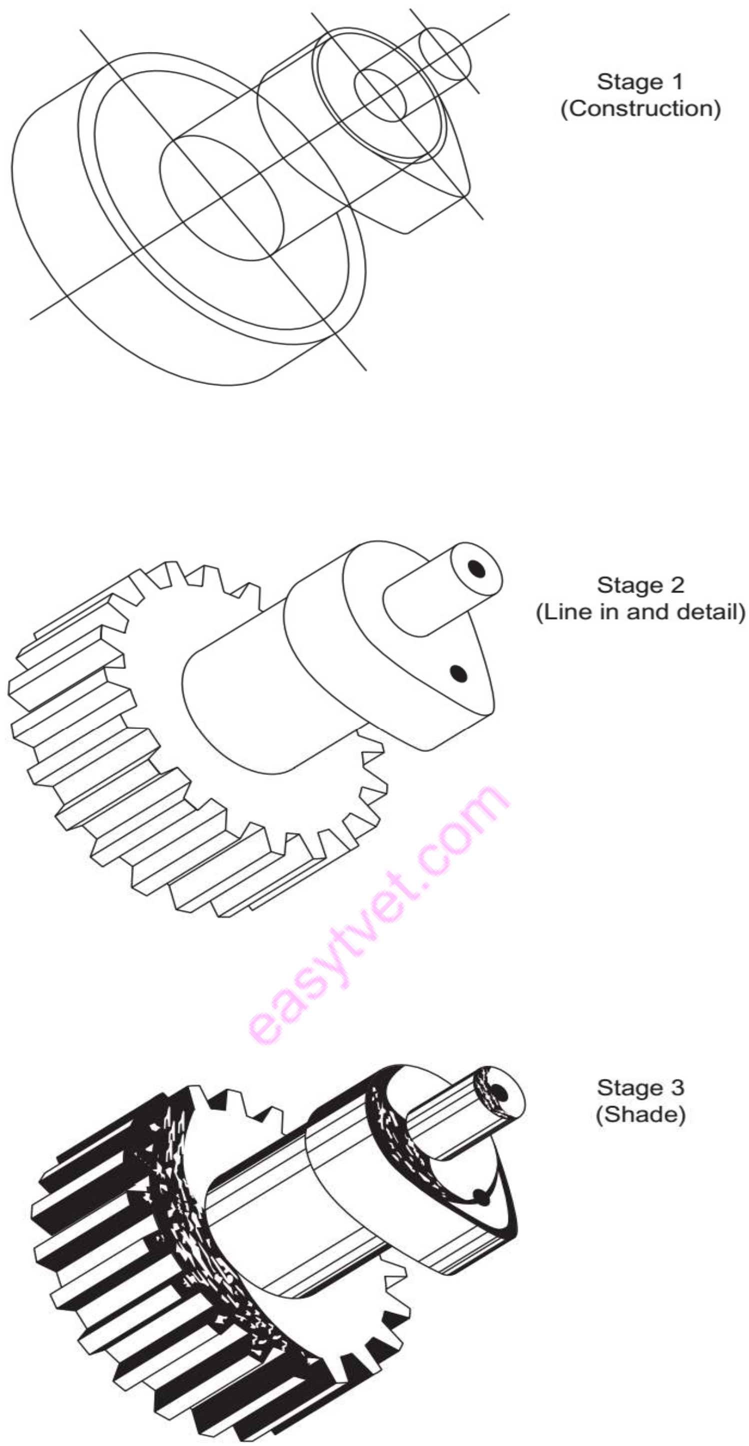


Figure 32 Gear Exercise

Sketching in Orthographic Projection

More detail can be seen on an orthographic drawing than on an isometric, mainly because more than one view is drawn. For this reason it is often advantageous for a draughts person to make an orthographic sketch. This will be undertaken below Circles are difficult to draw freehand but you can use your hand as a compass. Hold your pencil upright and, using your little finger as a compass 'point', revolve the paper keeping your hand quite still.

d) Construction, measurement, and bisection of angles

The following constructions are important in preparation of drawing various objects:

i. Construction of a parallel line parallel to another using compasses and T-square

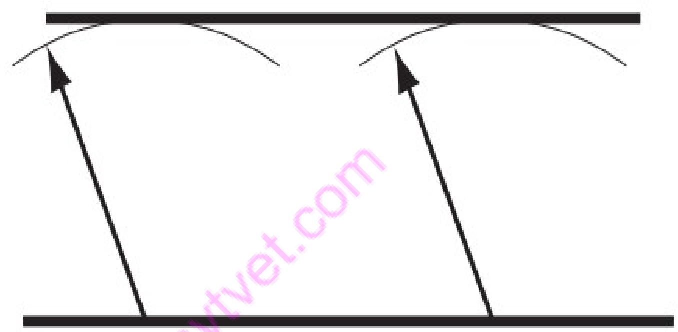


Figure 33 Construction of parallel lines

- Construct the given line,
- using compasses set to wanted distance apart,
- make two arcs at different point on the lines
- Join the want line by T-square at the top of the two arcs

ii. Bisection of a given line

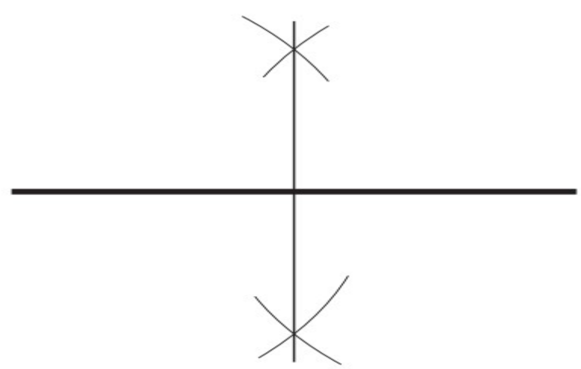


Figure 34 Bisection of a line

- Draw the given line using a T-square
- At each end of the line open the compasses approximately more than half and strike two arcs that meet as shown
- Join the meeting arc points as shown
- Where the line is cut by the bisector is the middle point.

iii. To erect a perpendicular from a point on a line.

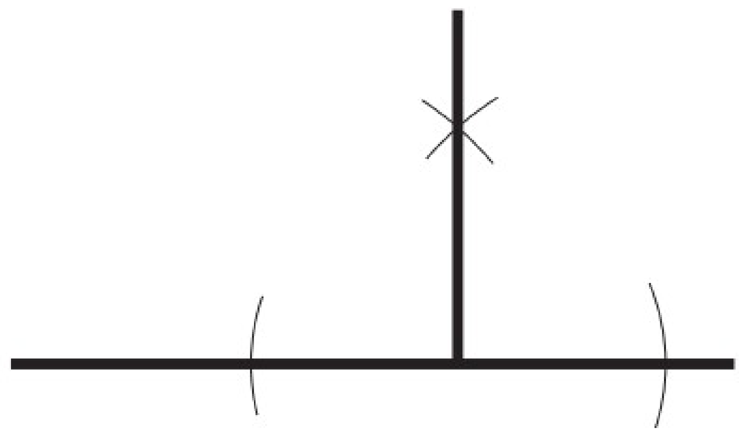


Figure 35 Construction of a perpendicular line

- Construct the given line using a T-square
- Using compasses with some distance from the line strike 2 arc on the line as shown
- Using the compasses at the 2 arc, strike arc to meet as shown
- Using T-square and a set square perpendicularly construct a line through the arc meeting point.

iv. To erect a perpendicular from a point to a line.

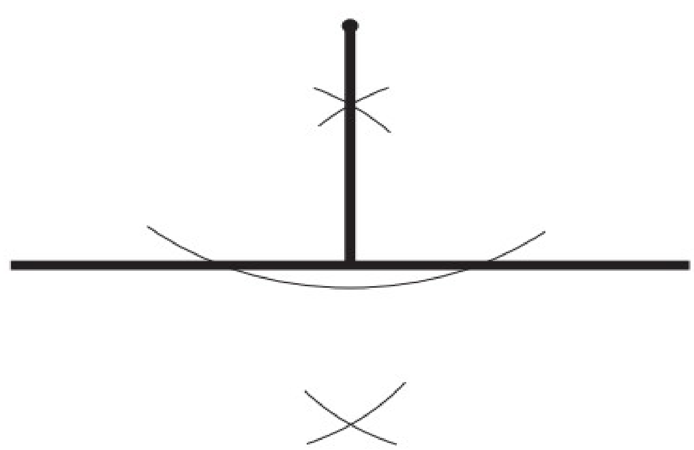


Figure 36 Electing a perpendicular line

- Construct the line using a T-square
- With the compass at the given point extend it to cut the line at 2 points as shown
- At the 2 points open compasses to strike 2 arcs that meet above and below the line
- Join the meeting points of the arcs as shown.

v. To bisect an angle.

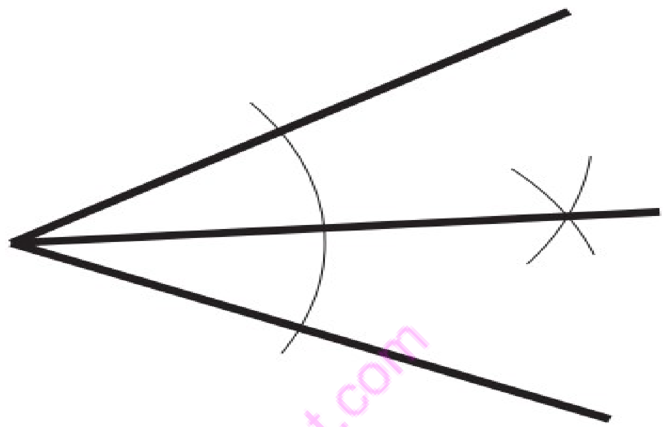


Figure 37 Bisecting an Angle

- Construct the angle as shown
- With a compass mark an arc from the apex of the angle as shown
- Using the points of the arc at both sides of the angle strike arc to meet as shown
- Draw the bisector from apex to arc meeting point

vi. To bisect the angle formed by two converging lines.

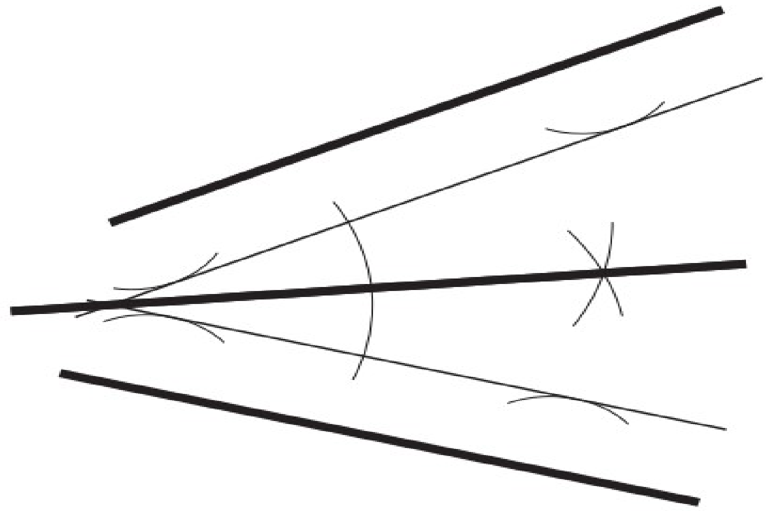


Figure 38 bisecting 2 converging angles

- Construct parallel lines to the two converging line as shown
- Bisect the angle as shown above

vii. To construct 60 °

- Construct a horizontal line as shown below using T-square
- Using compass strike an arc from a marked point on the line
- From the arc meeting point on the line strike an arc to cut the initial arc as shown.
- Draw a line from the marked point on line through the arcs meeting point to get 60^0 angle as shown

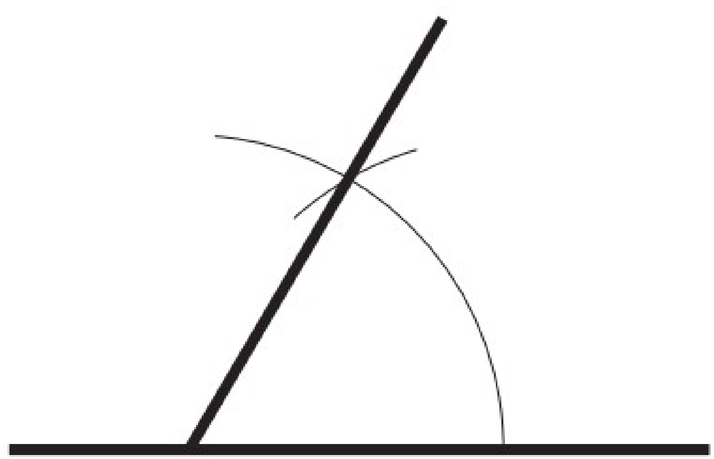


Figure 39 Constructing an angle of 60^0

viii. To construct an angle of 30^0

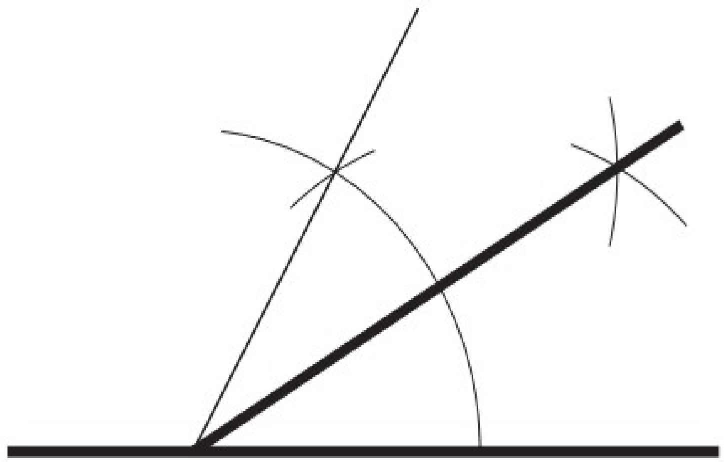


Figure 40 Construct an angle of 30^0

- This is done by constructing an angle of 60^0 and bisecting as shown

ix. **To construct 90 °**

- Construct a horizontal line as shown below
- With a compass mark a point on the line and draw a semi-circle on the line
- Mark from one end of semi-circle with same radius an arc which shows 60^0, then another arc of 60^0 as shown
- Bisect the second 60^0 to get 30^0 as shown below

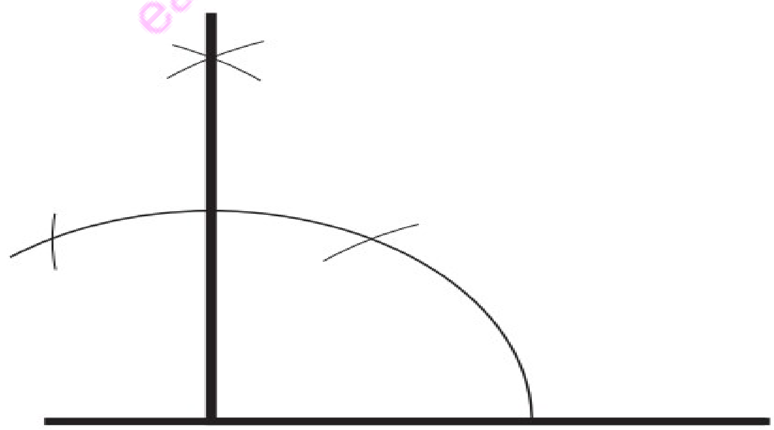


Figure 41 constructing an angle of 90^0

x. **To construct 45 °**

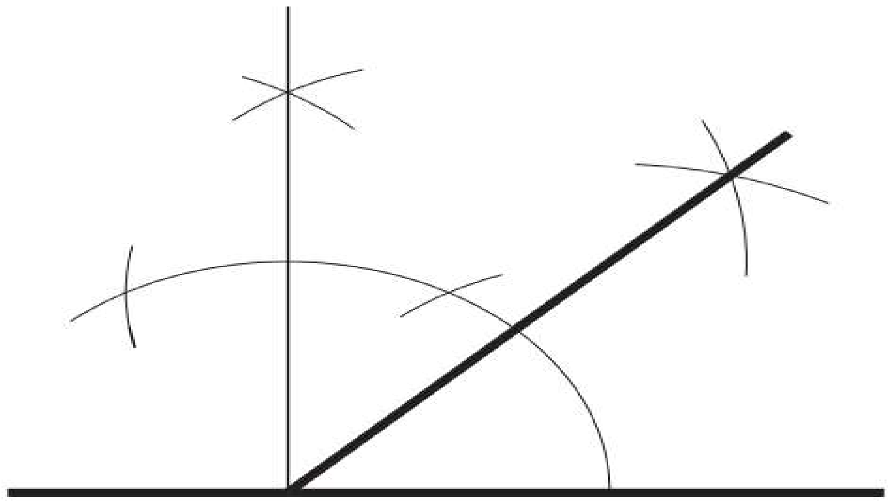


Figure 42 constructing an angle of 45^0

- Construct an angle of 90^0 and bisect as shown

xi. To divide a line into several equal parts (e.g. six).

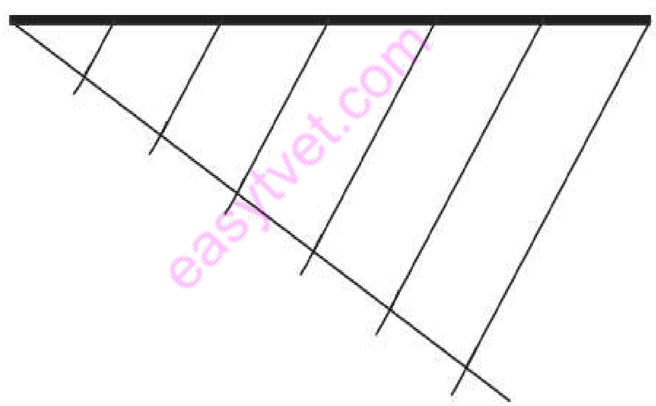


Figure 43 divide a line into equal parts

- Construct the line using a T-square
- Construct another line at an angle from the start of the line downwards
- Divide the inclined line to same number of lines as the wanted number using a compass
- Join the end point of inclined line to initial line
- Construct parallel lines from the marked inclined line to the original. This marks the wanted divisions

xii. To divide a line proportionally (e.g. 1:2:4).

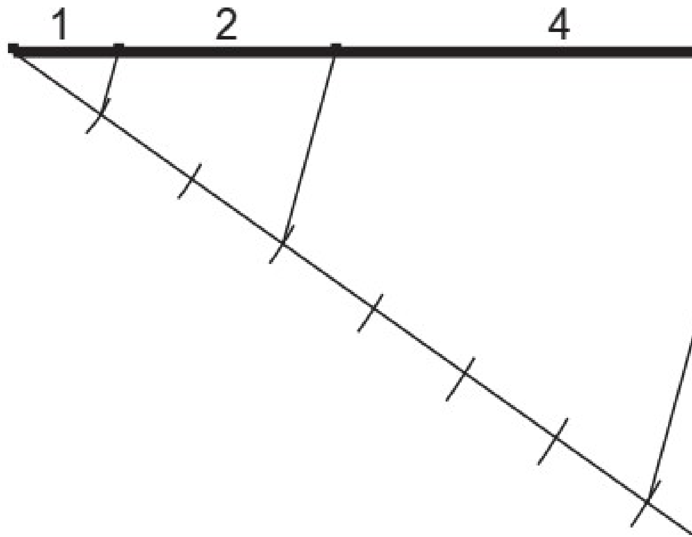


Figure 44 dividing a line proportionally

- Construct the given line using T-square
- Draw an inclined line and mark out the same number of equal arcs as the total wanted part i.e. 1+2+3=6 parts
- Join the end of the marked inclined line to the horizontal line and at the ratio point of point 1 and 2 construct parallel line to mark the ratio on the horizontal line.

Numbers and Alphabets

In professional drawing, numbers and alphabets are used to present certain information. They are written or drawn following some rules to ensure maximum legibility. Numbers and alphabets can be presented either as vertical or slanting. Alphabets can either be in upper case or in lower case.

The following are illustrations of presentation of numbers and letters of the alphabets.

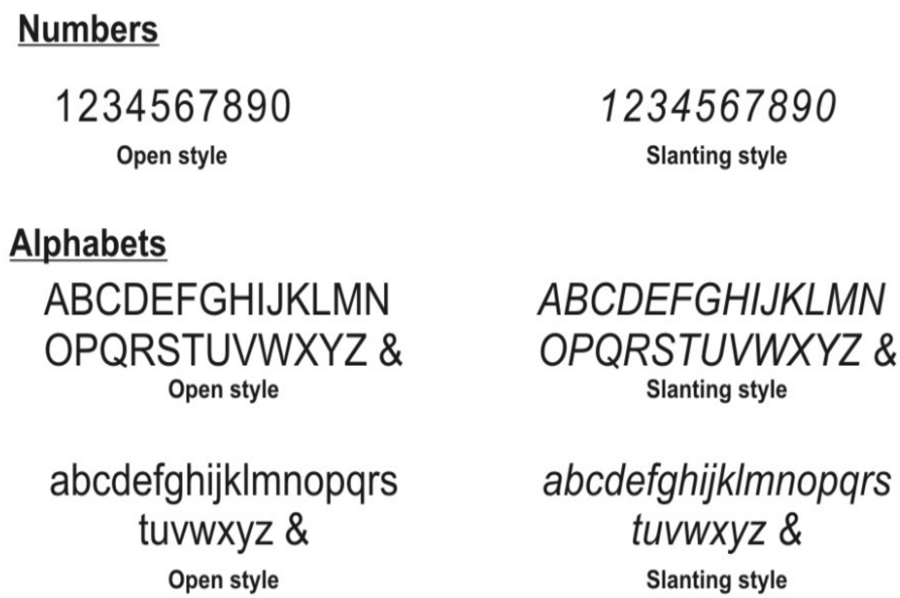


Figure 45 Alphabets and numbers

Lettering in drawing

Lettering plays major role in engineering. It indicates details like dimensioning, naming of the drawing, etc.The use of instruments for lettering is not advisable, as it will consume more time. Free hand sketching is used instead

Rules and Features:

- Lettering in drawing must be of standard height. The standard heights of letters used are 3.5mm, 5mm, 7mm and 10mm.

Features:

The essential features of lettering used in engineering drawing are:

• Legibility

• Uniformity

• Similarity

Single stroke letters are the simplest form of letters and are generally used in engineering drawing.

Vertical Lettering:

Vertical lettering is upright, i.e. 90 (to the horizontal.

Both uppercase or large and lowercase or small letters are used.

Inclined Lettering:

Inclined lettering has letters inclined at 75° to the horizontal and as for vertical lettering both uppercase and lowercase letters are used.

The following are some of the rules to be observed in writing numbers and alphabets:

a) Avoid unnecessary details in writing numbers and alphabets.

b) Ensure that numbers and alphabets are properly spaced.

c) Ensure that the numbers and alphabets ft into the printing guidelines.

d) Use the right eraser or rubber when erasing.

e) Use the same alphabet style and casing on the same drawing.

f) Never use vertical and sloping numbers on the same drawing.

Dimensioning

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.
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

e) Construction of geometric forms e.g. squares, circles

Two dimensional representations

These are representations which describe the length and area of an object. They are created from orthographic projections. Examples of some of the two dimensional representation are:

a) Square. b) Triangle. c) Parallelogram. d) Circle.

The construction of some of the two –dimensional figures are illustrated below

The Quadrilateral

Definitions

The quadrilateral is a plane figure bounded by four straight sides.

Types of quadrilaterals

i. **A square** is a quadrilateral with all four sides of equal length and one of its angles (and hence the other three) a right angle.

ii. **A rectangle** is a quadrilateral with its opposite sides of equal length and one of its angles (and hence the other three) a right angle.

iii. **A parallelogram** is a quadrilateral with opposite sides equal and therefore parallel.

iv. **A rhombus** is a quadrilateral with all four sides equal.

v. **A trapezium** is a quadrilateral with one pair of opposite sides parallel.

vi. **A trapezoid** is a quadrilateral with all four sides and angles unequal.

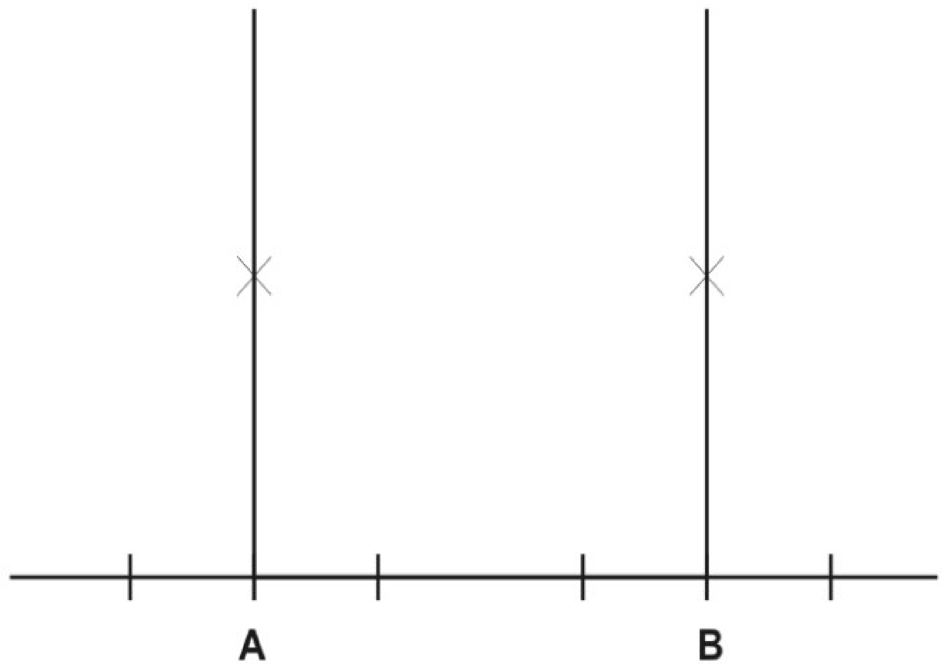
Square

A square is a figure with four straight equal sides and four angles of 90°. The following is a procedure for constructing a square:

Procedure:

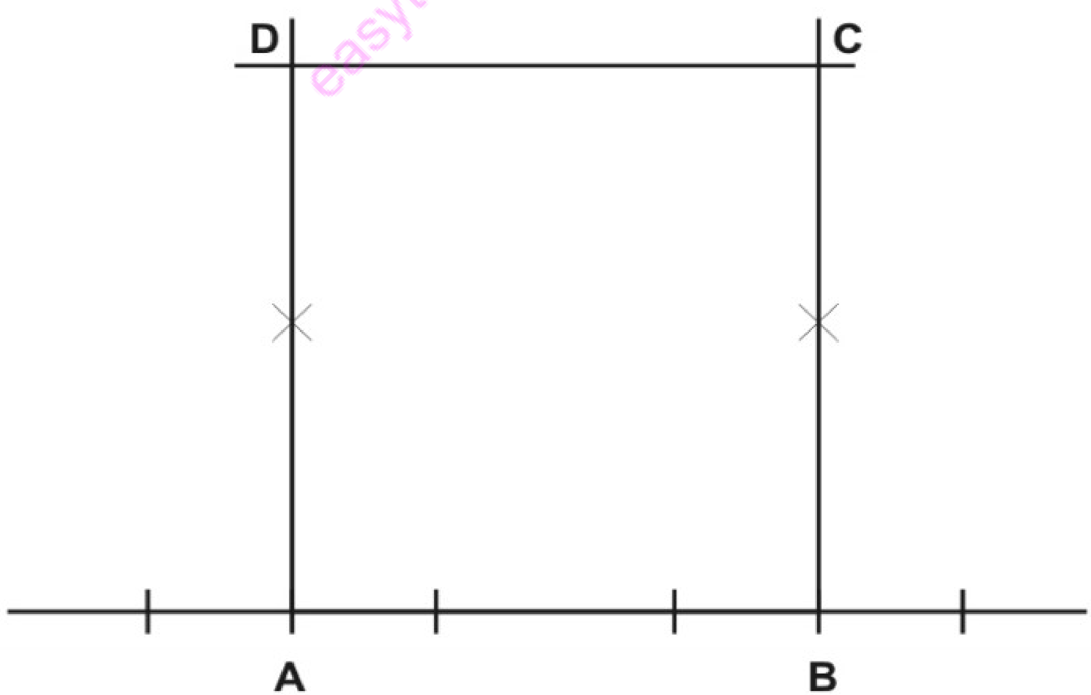
i. Draw a line AB to a given length and extend it past the point A and B,

ii. Construct perpendicular lines from points A and B.



iii. Using a pair of compasses mark lengths equal to length AB on the perpendicular lines from A and B and mark the new points C and D.

iv. Join points C to D.



To construct a square given the diagonal

i. Draw the diagonal AC.
ii. Bisect AC.
iii. With centre O and radius OA (OC), draw a circle to cut the bisecting line in B and D.

ABCD is the required square.

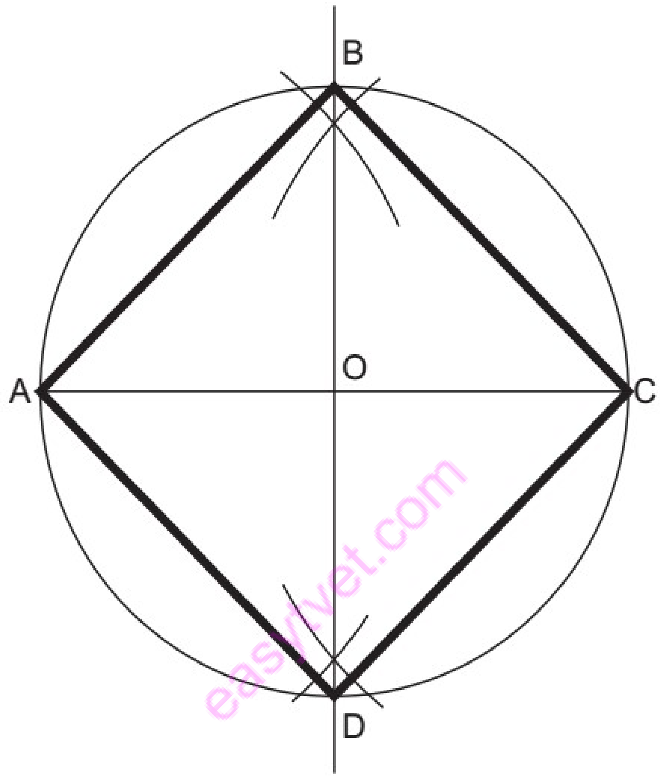


Figure 46 Construction of a square given diagonal

To construct a rectangle given the length of the diagonal and one of the sides

i. Draw the diagonal BD.
ii. Bisect BD.
iii. With centre O and radius OB (OD), draw a circle.
iv. With centre B and radius equal to the length of the known side, draw an arc to cut the circle in C.
v. Repeat step 4 with centre D to cut at A.

ABCD is the required rectangle

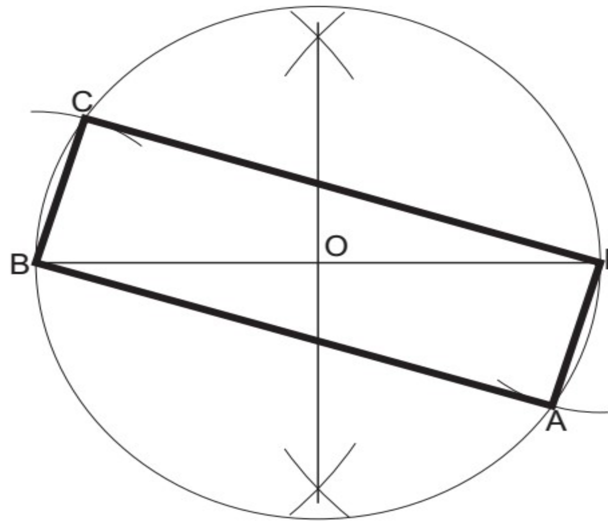


Figure 47 Construction of a rectangle

To construct a parallelogram given two sides and an angle

i. Draw AD equal to the length of one of the sides.
ii. From A construct the known angle.
iii. Mark off AB equal in length to the other known side.
iv. With compass point at B, draw an arc equal in radius to AD.
v. With compass point at D, draw an arc equal in radius to AB.

ABCD is the required parallelogram.

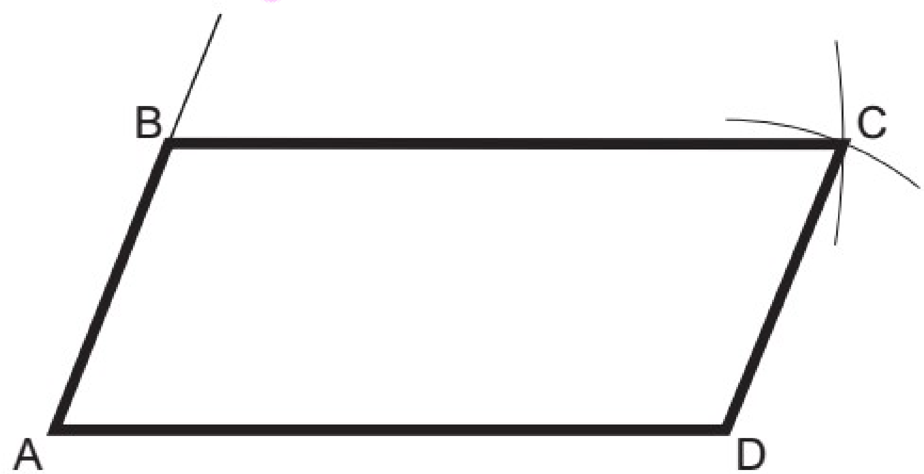


Figure 48 Construction of a parallelogram

Circle

A circle is a path of points equidistant from a fixed point. A circle is the locus of a point which moves so that it is always a fixed distance from another stationary point. A circle is constructed as illustrated below:

Procedure

i. Mark a point ‘C’, the centre of the circle by bisecting the given diameter.
ii. Open the compass to radius =AC=CB.
iii. Fix the pinned of the pair of compasses at the point ‘C’
iv. Rotate the penciled end of the pair of compasses through an angle of 360°, about point C

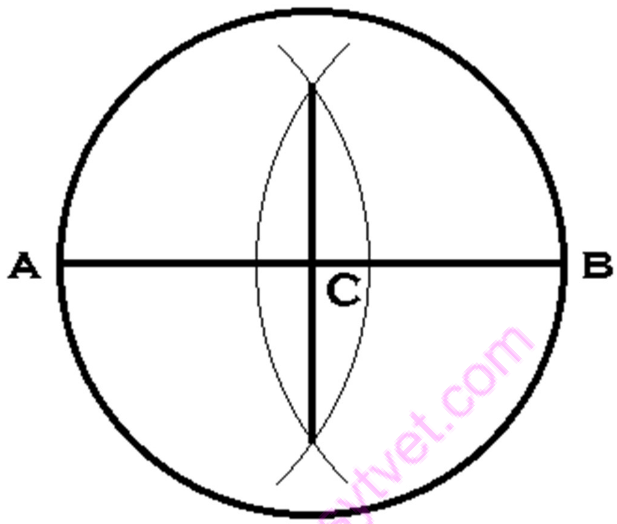


Figure 49 Construction of a circle

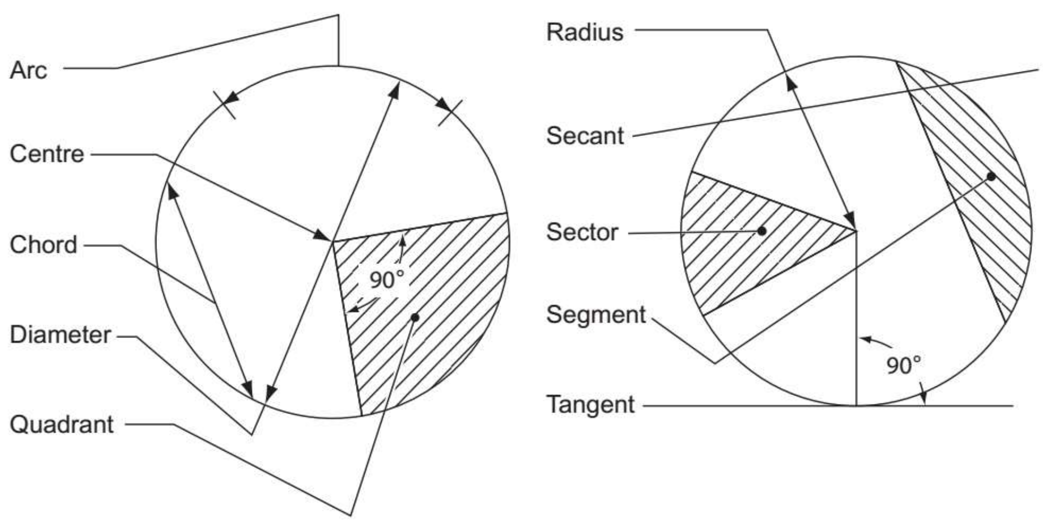


Figure 50 Parts of a circle

Construction of a triangle

Definitions

The triangle is a plane figure bounded by three straight sides.

Types of triangles

i. A **scalene triangle** is a triangle with three unequal sides and three unequal angles.

ii. An **isosceles triangle** is a triangle with two sides, and hence two angles, equal.

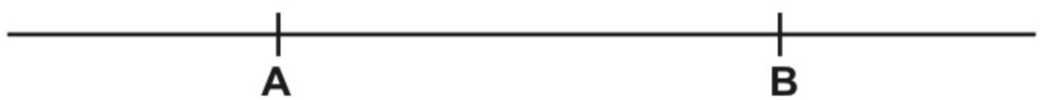
iii. An **equilateral triangle** is a triangle with all the sides, and hence all the angles, equal.

iv. A **right-angled triangle** is a triangle containing one right angle. The side opposite the right angle is called the 'hypotenuse'.

Construction of an equilateral triangle

The following is a procedure for constructing an equilateral triangle.

i. Draw a line AB of a given length.



ii. With a pair of compasses mark an arc of length equal to AB, from point A and B to meet at point C.

iii. Join points A to C and B to C.

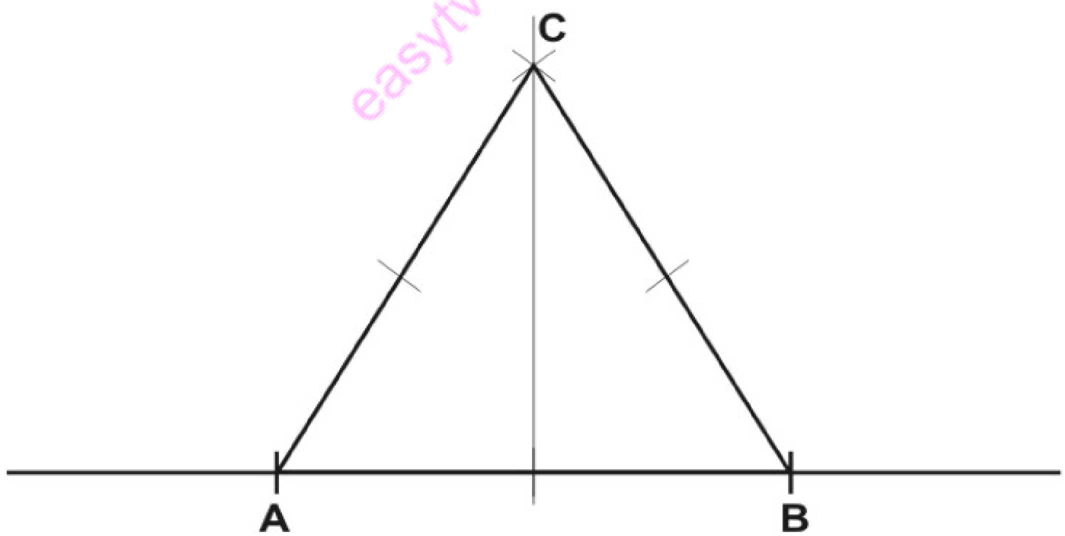


Figure 51 Construction of an Isosceles triangle

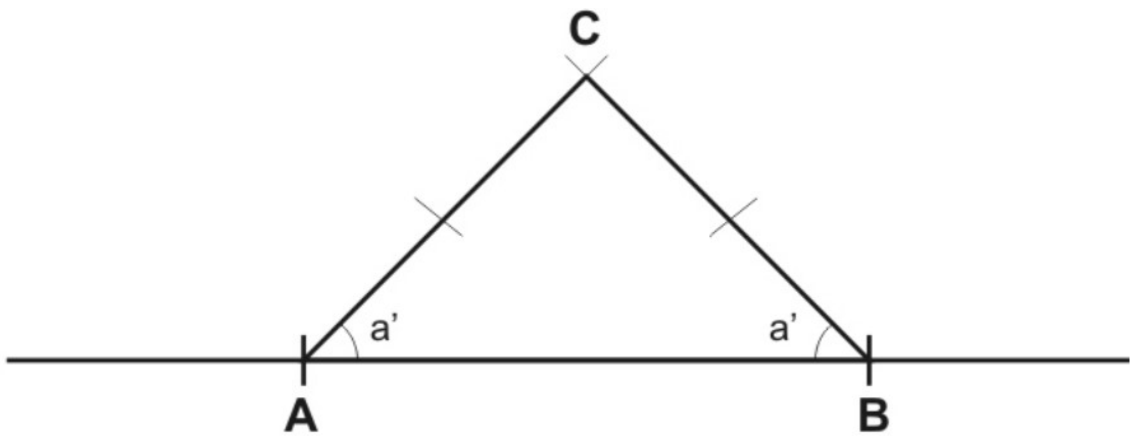
Construction of an isosceles triangle

The following is a procedure for constructing an isosceles triangle.

i. Draw a line AB.

ii. From point A, draw a line inclined at a specified angle.

iii. From point B, draw a line BC inclined at an angle equal to that of AC.



Construction of a right-angled triangle.

The following is the procedure for construction a right-angled triangle:

i. Draw a line AB

ii. From A, draw a perpendicular line AC of a specified length.

iii. Join B to C

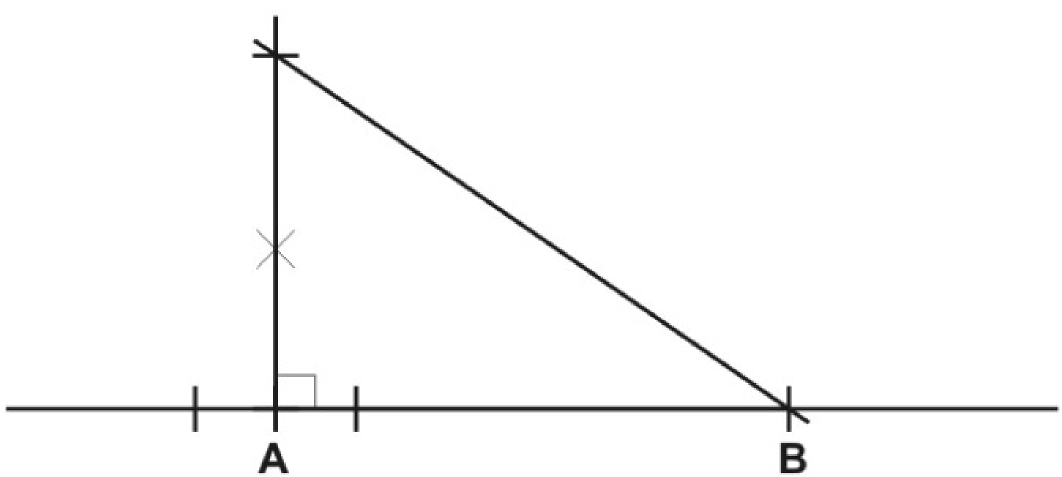


Figure 52 Construction of a right-angled triangle

To construct an isosceles triangle given the perimeter and the altitude;

i. Draw line AB equal to half the perimeter.
ii. From B erect a perpendicular and make BC equal to the altitude.
iii. Join AC and bisect it to cut AB in D.
iv. Produce DB so that BE = BD. CDE is the required triangle.

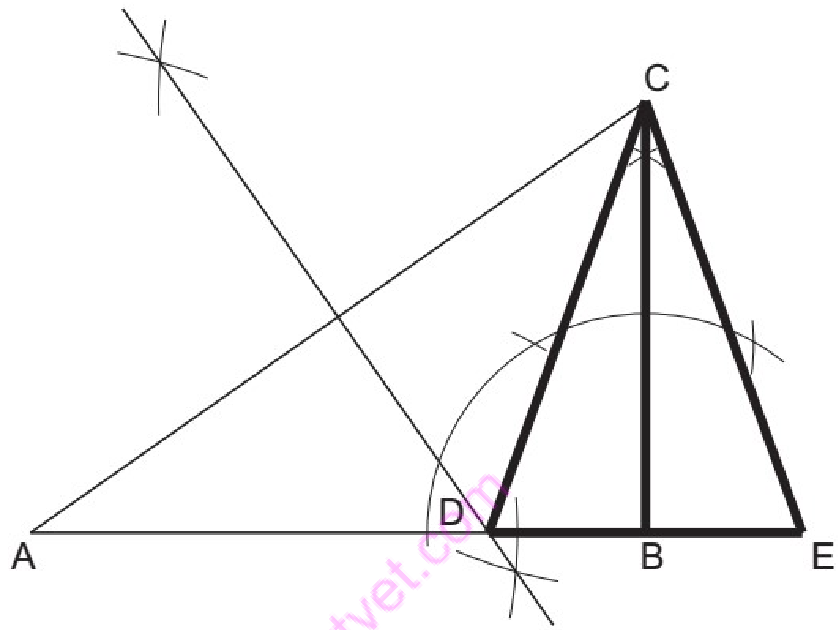


Figure 53 Construction of an Isosceles tringle given perimeter

To construct a triangle, given the base angles and the altitude

i. Draw a line AB.
ii. Construct CD parallel to AB so that the distance between them is equal to the altitude.
iii. From any point E, on CD, draw C Ê F and D Ê G so that they cut AB in F and G, respectively.

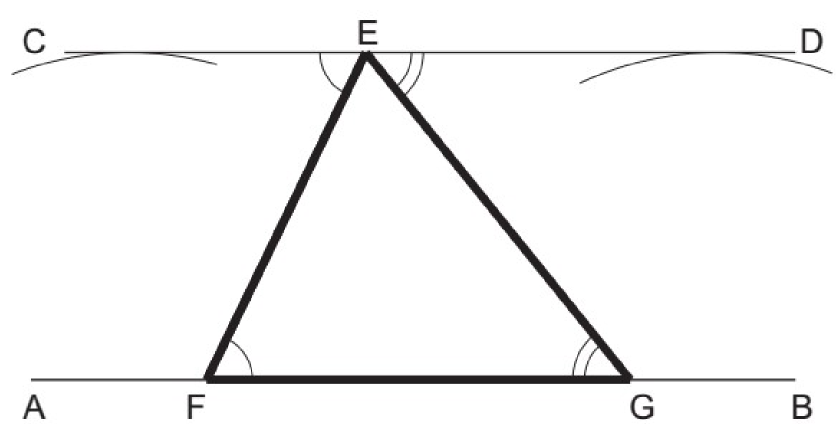


Figure 54 Construction of a tringle given angles and height

Polygons

Definitions

A polygon is a plane figure bounded by more than four straight sides. Polygons that are frequently referred to have names. Some of these are listed below.

A pentagon is a plane figure bounded by five sides.

A hexagon is a plane figure bounded by six sides.

A heptagon is a plane figure bounded by seven sides.

An octagon is a plane figure bounded by eight sides.

A nonagon is a plane figure bounded by nine sides.

A decagon is a plane figure bounded by ten sides.

A regular polygon is one that has all its sides equal and therefore all its exterior angles equal and all its interior angles equal.

It is possible to construct a circle within a regular polygon so that all the sides of the polygon are tangential to that circle. The diameter of that circle is called the '**diameter of the polygon'**. If the polygon has an even number of sides, the diameter is the distance between two diametrically opposed faces. This dimension is often called the 'across-flats' dimension.

The diagonal of a polygon is the distance from one corner to the corner furthest away from it. If the polygon has an even number of sides, then this distance is the dimension between two diametrically opposed corners.

Constructions

i. To construct a regular hexagon given the length of the sides

a) Draw a circle, radius equal to the length of the side.
b) From any point on the circumference, step the radius around the circle six times. If your construction is accurate, you will finish at the same place that you started.
c) Connect the six points to form a regular hexagon.

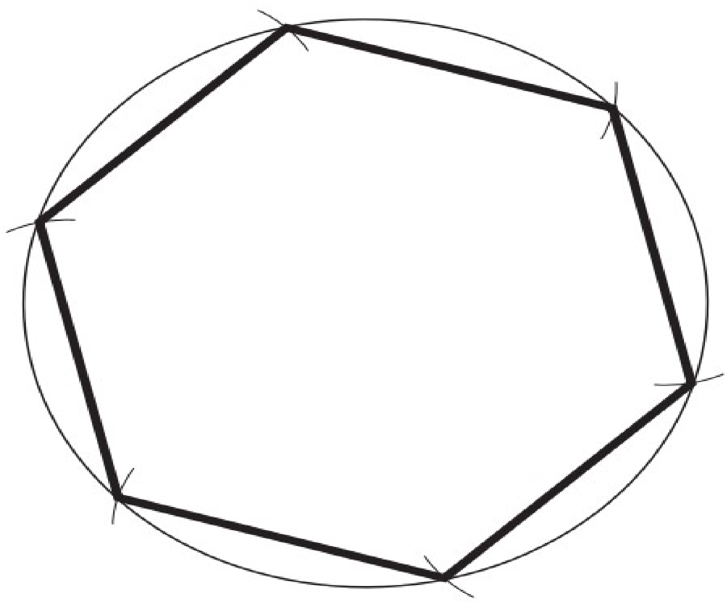


Figure 55 General Construction of a regular polygon given the side

ii. To construct a regular hexagon given the diameter

This construction, using compasses and straight edge only, is quite feasible but Is relatively unimportant. What is important is to recognize that a hexagon can be Constructed, given the diameter or across-flats dimension, by drawing tangents to the Circle with a 60° set square. This is very important when drawing hexagonal-headed Nuts and bolts.

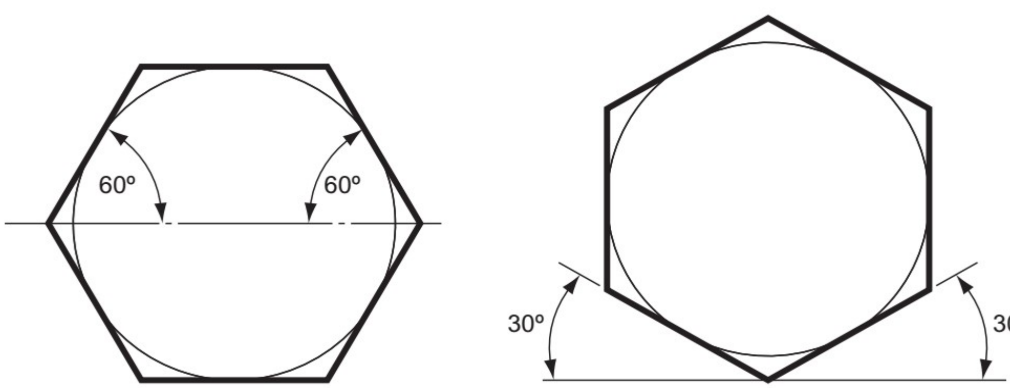


Figure 56 Construction of a hexagon

iii. To construct a regular octagon given the diameter, i.e. within a given square

a. Construct a square PQRS, length of side equal to the diameter.

b. Draw the diagonals SQ and PR to intersect in T.

c. 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.

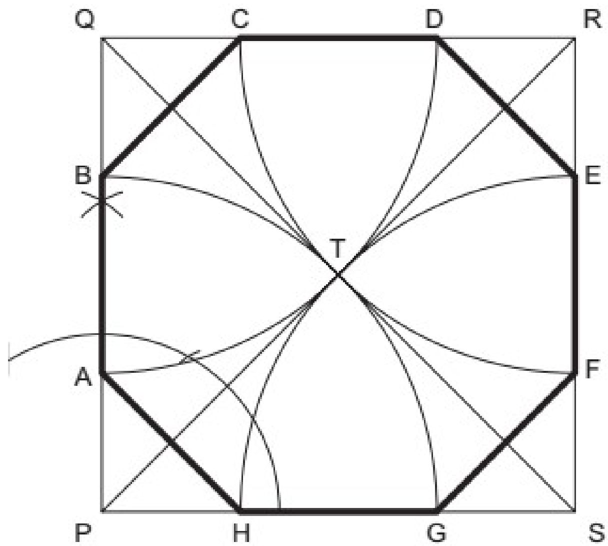


Figure 57 Inserting Octagon in a square

ABCDEFGH is the required octagon

The following methods can be used to construct any polygon

To construct any given polygon, given the length of a side.

Procedure

i. Draw a line GA equal in length to one of the sides.

ii. Bisect GA.

iii. From A construct an angle of 45 ° to intersect the bisector at point 4.

iv. From G construct an angle of 60 ° to intersect the bisector at point 6.

v. Bisect between points 4 and 6 to give point 5.

vi. Point 4 is the centre of a circle containing a square. Point 5 is the centre of a circle containing a pentagon. Point 6 is the centre of a circle containing a hexagon. By marking off points at similar distances the centres of circles containing any regular polygon can be obtained.

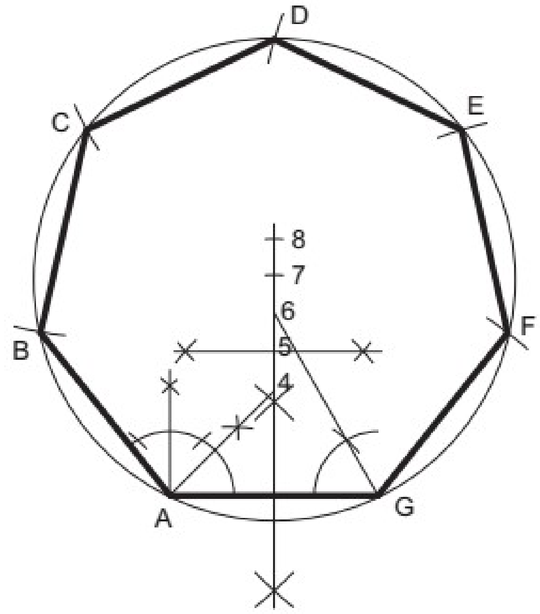


Figure 58 General construction of a polygon given a side

vii. Mark off point 7 so that 6 to 7 = 5 to 6 (= 4 to 5).

viii. With centre at point 7 draw a circle, radius 7 to A (= 7 to G).

ix. Step off the sides of the figure from A to B, B to C, etc.

ABCDEFG is the required heptagon.

To construct a regular polygon given a diagonal, i.e. within a given circle

i. Draw the given circle and insert a diameter AM.

ii. Divide the diameter into the same number of divisions as the polygon has sides.

iii. With centre M draw an arc, radius MA. With centre A draw another arc of the same radius to intersect the first arc in N.

iv. Draw N2 and produce to intersect the circle in B (for any polygon).

v. AB is the first side of the polygon. Step out the other sides BC, CD, etc.

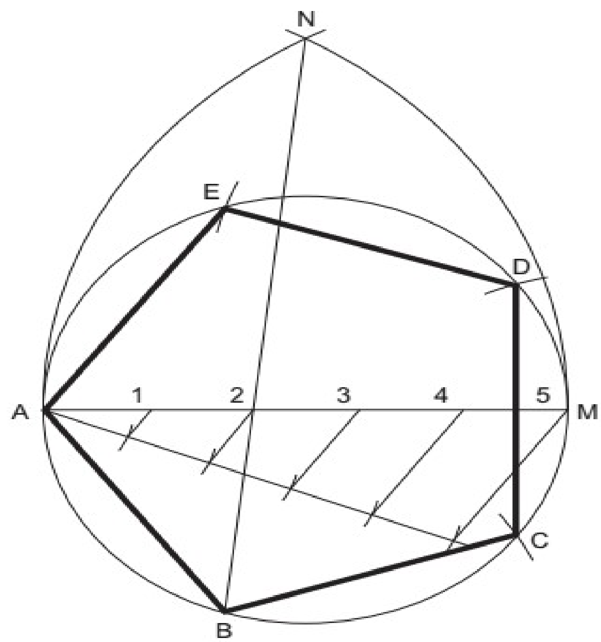


Figure 59 Construction of a polygon given diagonal

ABCDE is the required polygon.

f) Standards drawing conventions

Conventions are a widely used practices or procedure in engineering drawing, they are a set of rules for drawing. Because drawings contain a lot of information, they can easily become cluttered and not easily understood by all working with them. One way to keep them tidy and consistent is to use standards and conventions.

Some of the conventions are:

i. **Scaling**

Sometimes we need to scale down some larger parts in order to see the whole object on a single sheet and for detailed parts we may need to scale them up in size in order to see the finer details.

ii. **Dimensioning**

Dimensioning is the convention used for adding measurement notes, such as the length and breadth of the object, to a drawing. Dimensions include text, lines, extension lines and arrowheads.

When an engineering drawing is made, dimensioning is of vital importance. All the dimensions necessary to make the articles drawn must be on the drawing and they must be presented so that they can be easily read, easily found, and not open to misinterpretation. A neat drawing can be spoilt by bad dimensioning.

The conventions for drawing dimension lines are described below.

a) Projection lines should be thin lines and should extend from about 1 mm from the outline to 3 mm to 6 mm past the dimension line.
b) The dimension line should be a thin line and terminate with arrowheads at least 3mm long and these arrowheads must touch the projection lines.
c) The dimension may be inserted within a break in the dimension line or be placed on top of the dimension line.
d) The dimensions should be placed so that they are read from the bottom of the paper or from the right-hand side of the paper.
e) Dimension lines should be drawn outside the outline, whenever possible, and should be kept well clear of the outline.
f) Overall dimensions should be placed outside the intermediate dimensions.
g) Centre lines must never be used as dimension lines. They may be used as projection lines
h) Diameters may be dimensioned in one of two ways. Either dimension directly across the circle (not on a centre line) or project the diameter to outside the outline. 'Diameter' is denoted by the symbol φ placed in front of the dimension.
i) When dimensioning a radius, you must, if possible, show the centre of the radius. The actual dimension for the radius may be shown either side of the outline but should, of course, be kept outside if possible. The word radius must be abbreviated to R and placed in front of the dimension.
j) When a diameter or a radius is too small to be dimensioned by any of the above methods, a leader may be used. The leader line should be a thin line and should terminate on the detail that it is pointing to with an arrowhead or, within an outline, with a dot. Long leader lines should be avoided even if it means inserting another dimension. The leader line should always meet another line at an acute angle.
k) Dimensions should not be repeated on a drawing. It is necessary to put a dimension on only once, however many views are drawn. There is one exception to this rule. If, by inserting one dimension, it saves adding up lots of small dimensions then this is allowed.
l) These types of dimensions are called 'auxiliary dimensions' and are shown to be so either by underlining the dimensions or putting it in brackets.

m) Unless unavoidable, do not dimension hidden detail. It is usually possible to dimension the same detail on another view.

n) When dimensioning angles, draw the dimension lines with a compass; the point of the compass should be on the point of the angle. The arrowheads may be drawn either side of the dimension lines, and the dimension may be inserted between the dimension lines or outside them. Whatever the angle, the dimension must be placed so that it can be read from either the bottom of the paper or from the right-hand side.

o) If a lot of parallel dimensions are given, it avoids confusion if the dimensions are staggered so that they are all easier to read.

p) If a lot of dimensions are to be shown from one projection line (often referred to as a datum line), either of the methods shown in Fig. 18.20 may be used. Note that in both methods, the actual dimension is close to the arrowhead and not at the centre of the dimension line.

q) If most dimensions on a drawing are in one unit, it is not necessary to put on the abbreviation for the units used, i.e. cm or mm. In this case, the following note must be printed on your drawing.

UNLESS OTHERWISE STATED, DIMENSIONS ARE IN MILLIMETRES

r) If a very large radius is drawn, whose centre is off the drawing, the dimension line is drawn with a single zigzag in it.

s) Dimensioning small spaces raises its own problems and solutions. Some examples are shown in figure below. There are one or two more rules that do not require illustrating.

t) If the drawing is to scale, the dimensions put on the drawing are the actual dimensions of the component and not the size of the line on your drawing.

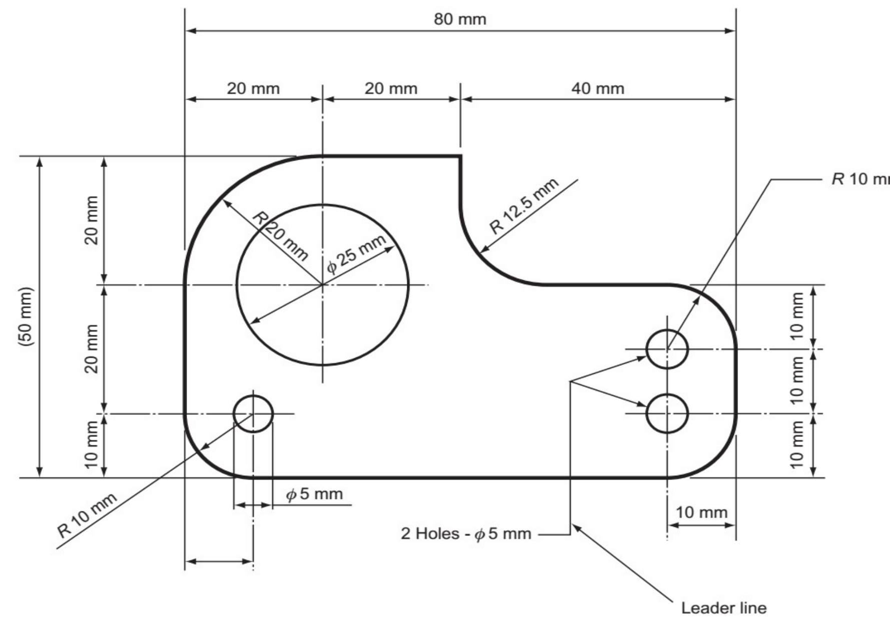


Figure 60 Sample dimensioning

iii. Title blocks

You need a title panel to identify the name of the person to whom the drawing belongs as well as the name of the drawing, the scale at which it is drawn, and the date that it was completed

Every drawing should include information which identifies the drawing. A title block is often used to do this. It will contain information that includes the:

a) name of the person the drawing belongs to
b) date the drawing was completed
c) number of the drawing
d) scale at which it was drawn.
e) Title of drawing

The title block is usually placed at the bottom right of the drawing. However, it may occupy the full width of the top or bottom of the paper to allow the drawing to fit within the size of the drawing paper.

iv. Margins

Margins define the space where the drawings are to be done.

Your drawing must also be enclosed within a frame called a margin.

Before starting the drawing, a manual drawing template should be drawn up. This will have the margins and the title block marked out and will allow you to see how much drawing space you have before you start.

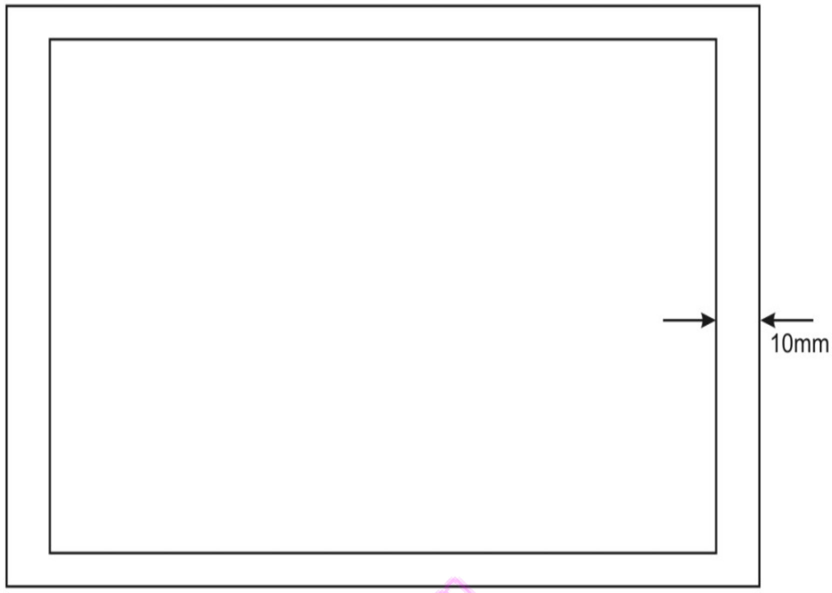


Figure 61 Paper Layout

v. Letters and Numbers

All drawings require some form of lettering and numbers. The principles to remember are:

a) They should be legible and clear – especially numbers, as they often must be read on their own.
b) They should be of a suitable size and not less than 3mm tall. Title blocks and relative information are usually larger.
c) 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 worlds it should not be necessary to turn a drawing on its side to read the information.
d) Notes should be grouped together and not spread over the drawing.
e) Underlining is not recommended.

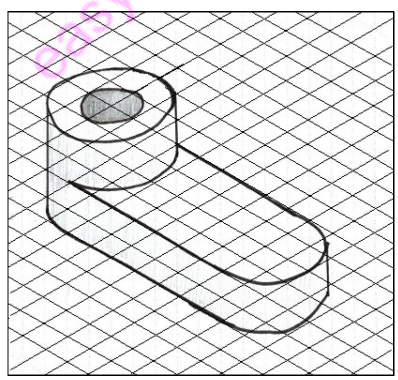
vi. Abbreviations

A list of the standard abbreviations for some general engineering terms is shown below. These abbreviations are used to save time, and space on drawings. Although the abbreviations are shown in block capital letters, small letters may be used. For unit abbreviations always use small letters.

To read a drawing properly, and to understand what is happening, an agreed set of graphical symbols and abbreviations are used. All the different trades have a set of symbols pertaining to their respective works. The works of the plumber is often referred to as the "Mechanical Services".

2.2.2.4. Learning Activities

Study the isometric view below. Using the back side of grid paper, your engineering notebook, or graph paper (as indicated by your instructor) recreate the isometric view for practice. Be sure to use the techniques you have learned for sketching isometric circles to sketch the arcs and circles in this view.



2.2.2.5. Self-Assessment

1. State the use of the following line;
   i. Extension line
   ii. Dimension line
   iii. Long-break line
2. Construct the following angles;
   i. 30^0
   ii. 60^0

iii. 45^0

3. Explain the following types of triangles

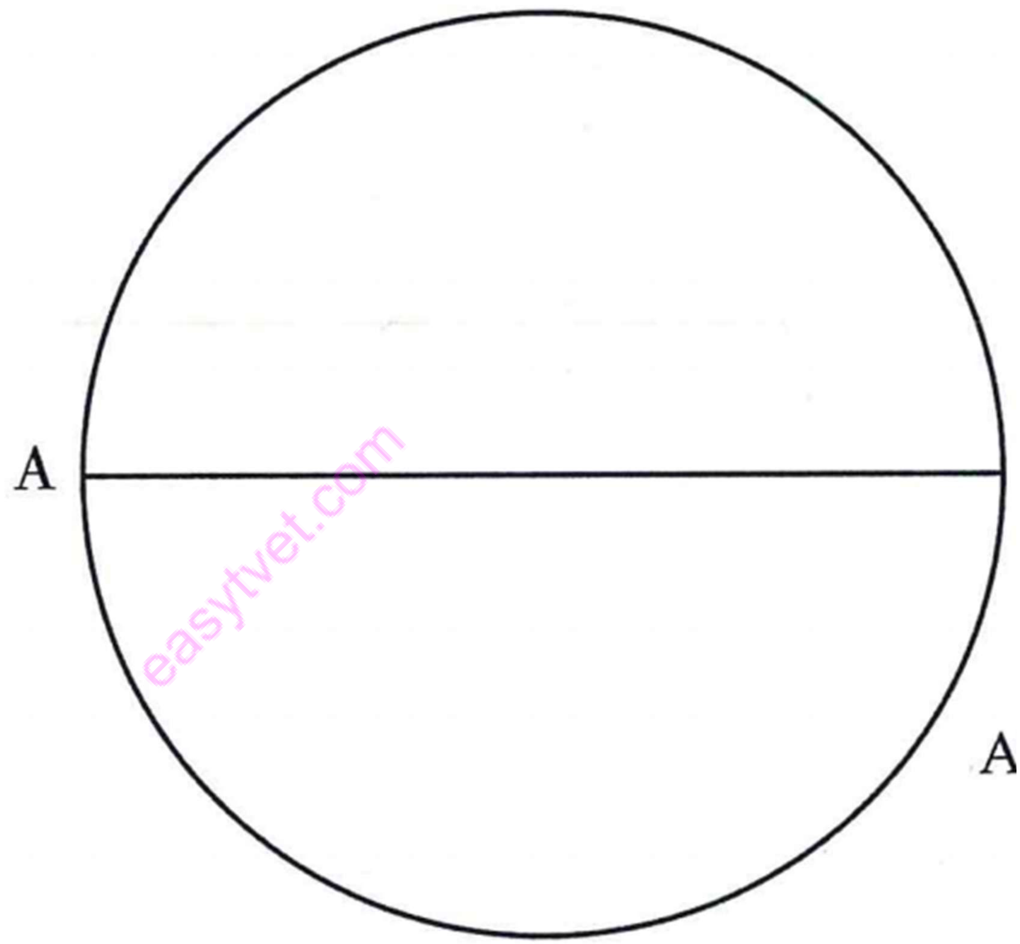
i. A **scalene triangle**

ii. An **isosceles triangle**

iii. An **equilateral triangle**

iv. A **right-angled triangle**

4. Figure below shows a circle of diameter 80mm.



Construct a pentagon circumscribed by the circle.

5. Explain the following terms as used in polygons;

a) Pentagon

b) **A hexago**n

c) A heptagon

d) An octagon

e) **A nonagon**

f) **A decagon**

2.2.2.6. Tools, Equipment, Supplies and Materials

i. Drawing boards
ii. T squares
iii. Set squares
iv. Drawing sets
v. Drawing paper
vi. Protractors
vii. Eraser Shield
viii. Pencils
ix. Erasers
x. Masking tapes
xi. Paper clips
xii. Drawing curves
xiii. Technical drawing software'

2.2.2.7. References

Bhatt, N. D. (2011). *Engineering Drawing.* Gujarat: Charotar Publishing house.

Maguire, C. H. (2004). *Manual of Engineering drawing.* Oxford: Elsevier Newnes.

Morling, K. (2010). *Geometric and Engineering drawing.* London: Elsevier.

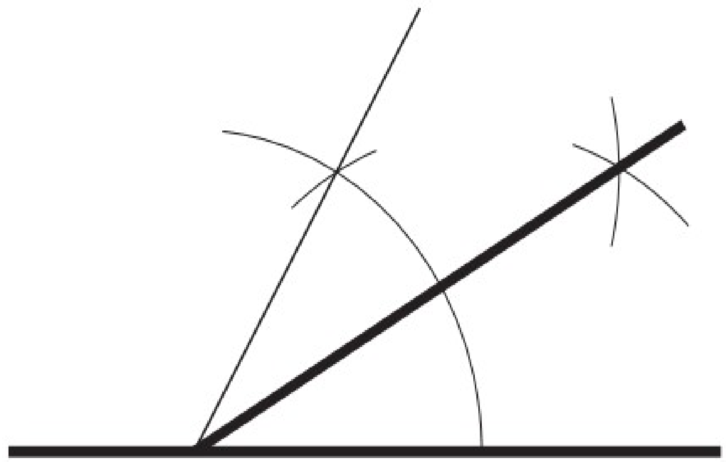
2.2.2.8. Model answers.

1. State the use of the following line;

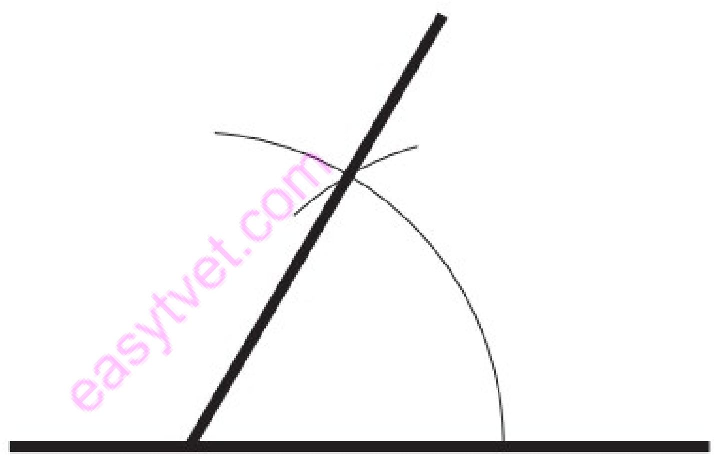
i. **Extension line** – a thin line that extends from the object to show dimension limits
ii. **Dimension line** – a thin line with an arrowhead in one end used to indicate the
iii. Measurements of the object
iv. **Long-break line** – a medium thick line consisting of broken and straight lines drawn

2. Construct the following angles;

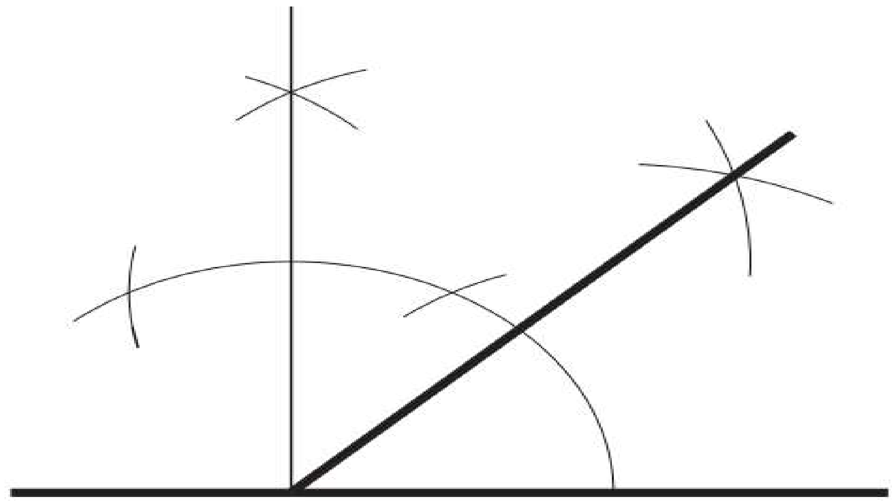
i. 30^0



ii. 60^0



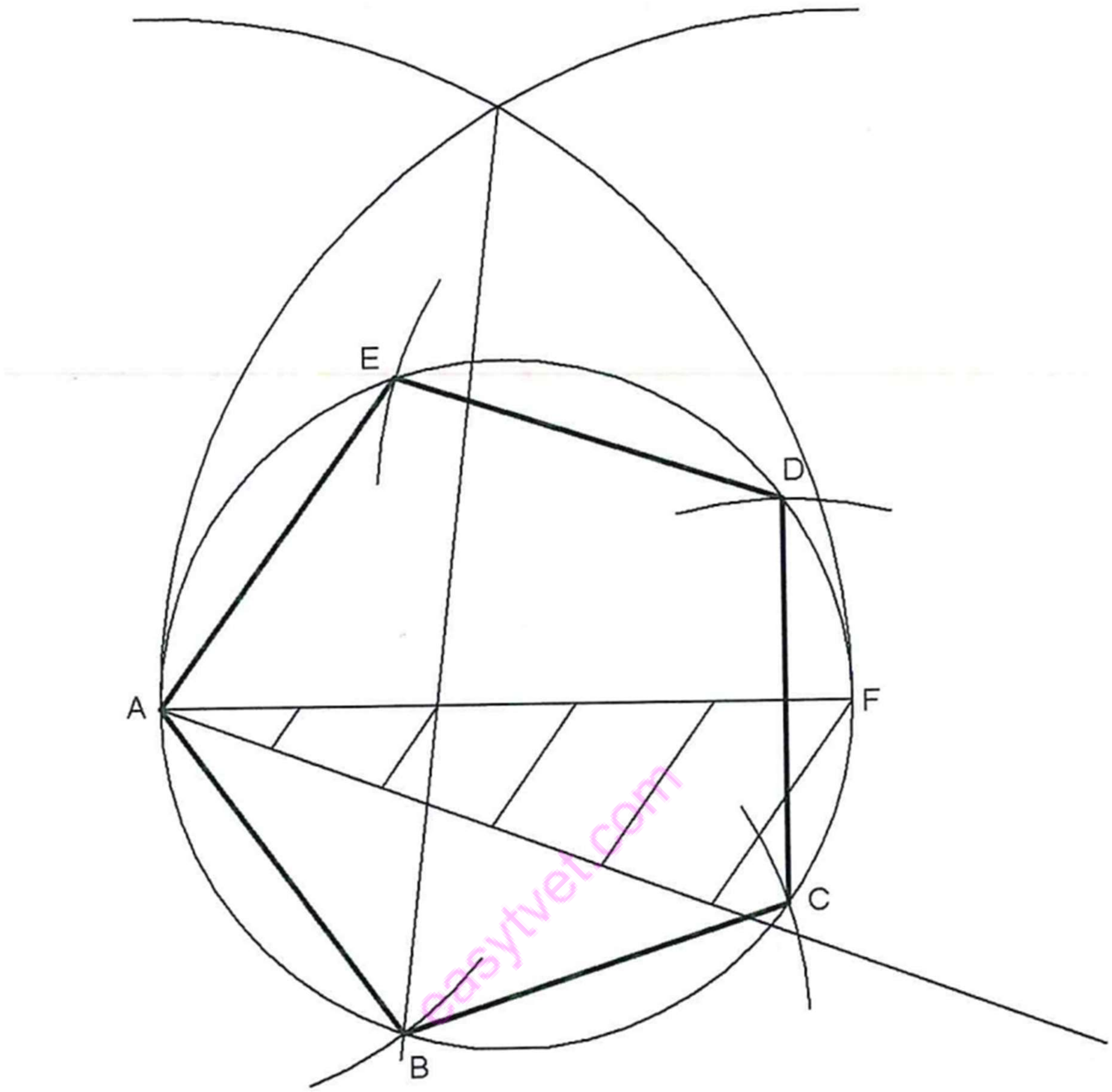
iii. 45^0



3. Explain the following types of triangles

i. A **scalene triangle** is a triangle with three unequal sides and three unequal angles.
ii. An **isosceles triangle** is a triangle with two sides, and hence two angles, equal.
iii. An **equilateral triangle** is a triangle with all the sides, and hence all the angles, equal.
iv. A **right-angled triangle** is a triangle containing one right angle. The side opposite the right angle is called the 'hypotenuse'.

4. Figure below shows a circle of diameter 80mm. Construct a pentagon circumscribed by the circle.



5. Explain the following terms as used in polygons;

i. **Pentagon** is a plane figure bounded by five sides.

ii. **A hexago**n is a plane figure bounded by six sides.

iii. **A heptagon** is a plane figure bounded by seven sides.

iv. **An octagon** is a plane figure bounded by eight sides.

v. **A nonagon** is a plane figure bounded by nine sides.

vi. **A decagon** is a plane figure bounded by ten sides.

2.2.3 Learning outcome 3: Develop solid geometry drawings

2.2.3.1. Introduction to the learning outcome

The focus of this specific learning outcome is to introduce the different working drawings and their purpose during the planning of plumbing works. This section will give an understanding of the different types of working drawings, building symbols and different representations of drawings.

2.2.3.2. Performance Standard

The following performance criteria will be required to be met by trainees to be considered competent:

1. Pattern drawings are interpreted according to standard conventions
2. Solid Geometry drawings are constructed according to given plane geometry

2.2.3.3. Information Sheet

a) Terms and concepts

i. Auxiliary view

This is when a view is projected on a plane that is parallel to the surface of the principal view. To see the true size of the surface the view must be shown at right angles to that surface. This is an Auxiliary view. Auxiliary views are often used to show the inclined surfaces true size

ii. Development

A layout of the complete surface of an object i.e it is the method of unfolding or unrolling a geometrical shape into a plane shape.

iii. Dimensioning

Process of placing measurements in a drawing in the metric or English System

iv. Isometric axes

Light lines used as bases in constructing an isometric view of an object

v. Isometric drawing

Pictorial drawing showing the three views of the object tilted 30 Degrees in front of the observer.

vi. Multi-view drawing

Drawing that shows more than one view of an object

vii. Notation

All lettering and other dimension found in a drawing or working sketch

viii. **Oblique drawing**

Kind of pictorial drawing of an object one surface of which is shown parallel to the frontal plane and the other is inclined to it.

ix. **Orthographic projection**

Presentation of an object in two or more views by projecting the outline of the object to the plane of projection perpendicular to each other

x. **Overall dimension**

The total width, height, and depth of the object

xi. **Perspective drawing**

A drawing which shows an object as it appears to our eyes

xii. **Pictorial view**

The presentation of an object where it is viewed showing the three faces of an object

xiii. **Truncated Object**

It is a geometrical object that has been cut

xiv. **Working plan**

A freehand drawing showing all the information needed to construct an Object.

b) Interpretation of sketches and drawings of patterns e.g. cylinders, prisms, and pyramids

Orthographic Projection

Orthographic Projection is a way of drawing an 3D object from different directions. Usually a front, side and plan view are drawn so that a person looking at the drawing can see all the important sides. Orthographic drawings are useful especially when a design has been developed to a stage whereby it is almost ready to manufacture.

There are two ways of drawing in orthographic - First Angle and Third Angle. They differ only in the position of the plan, front and side views. Below is an example of First Angle projection.

Opposite is a simple L-shape, drawn in three dimensions.

The front, side and plan views have drawn around the 3D shape. However this is not the correct way of drawing them as they are not in the right positions.

First angle orthographic

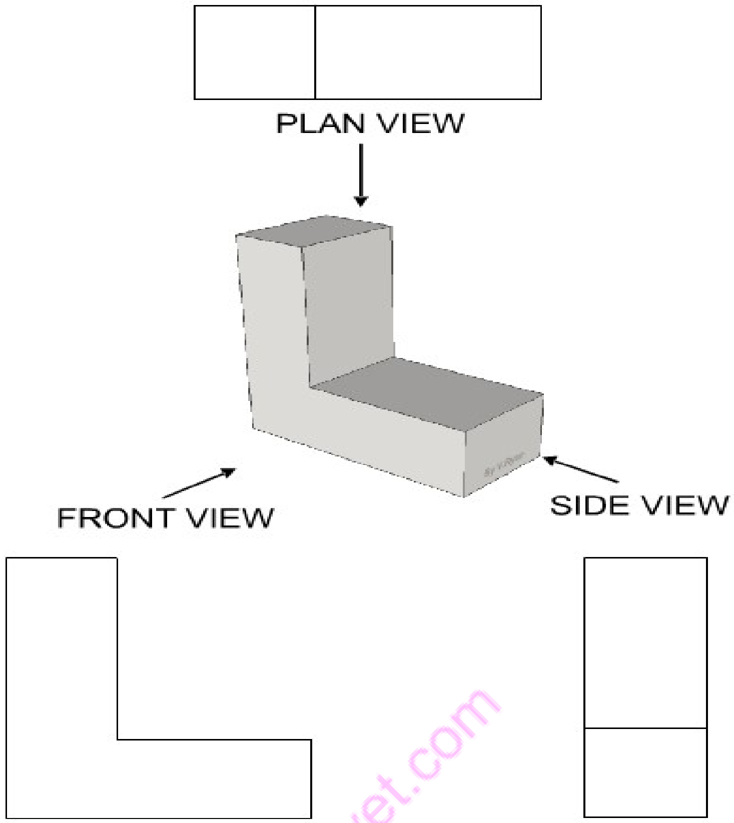
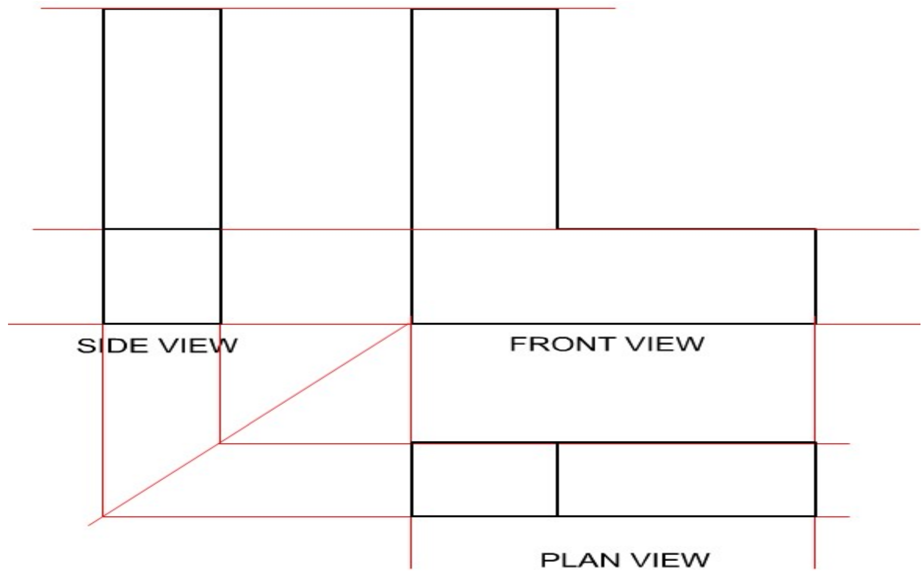
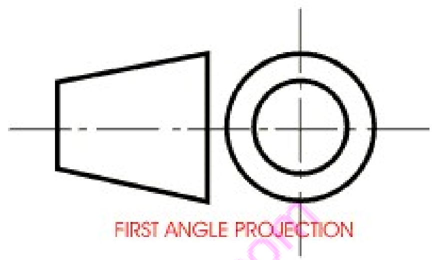


Figure 62 Example of orthographic views of an L shape figure

The correct method of presenting the three views, in first angle orthographic projection is shown below. The drawing is composed of a front, end, and plan view of the L-shaped object. The first drawing is the front view (drawn looking straight at the front of the L-shape), the second is a drawing of the L-shape seen from the side (known as side view) and last of all a drawing from above known as a plan view. The red lines are faint guidelines and they are drawn to help keep each view in line, level, and the same size.

The correct first angle projection of the L shape is shown below





First angle projection convention

Figure 63 First angle projection views of the L shape

The views are obtained as by imagining you are standing directly in front of the L-shape, the drawing below shows exactly what you would see.

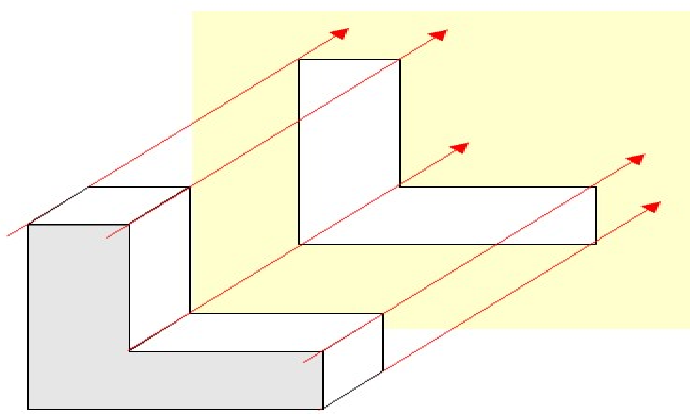


Figure 64 Front Elevation

The end elevation is obtained as shown below from a side view

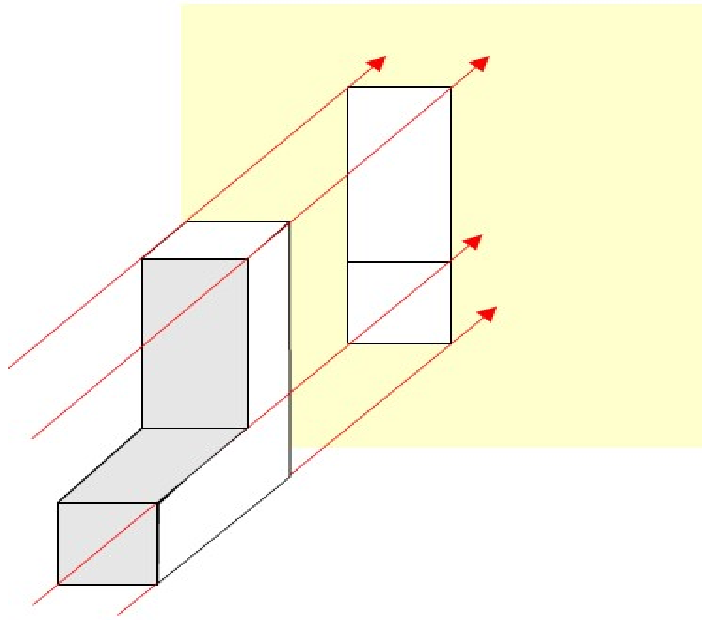


Figure 65 End Elevation obtained from the side view

The plan is obtained by viewing from the top as shown below

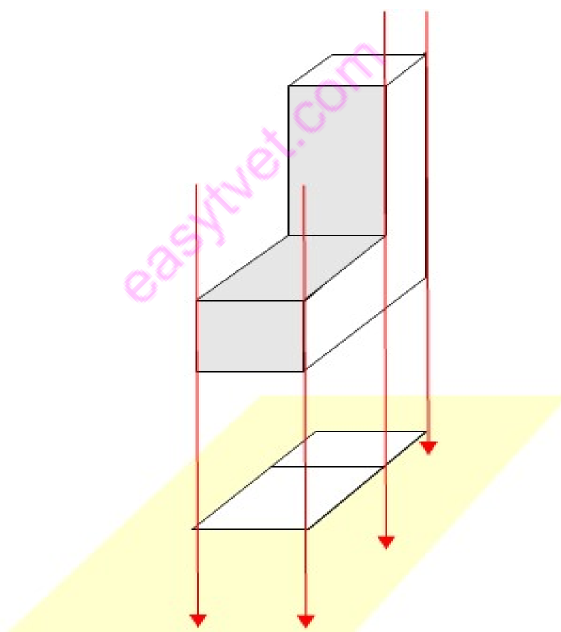


Figure 66 Plan view from the top

Third angle projection

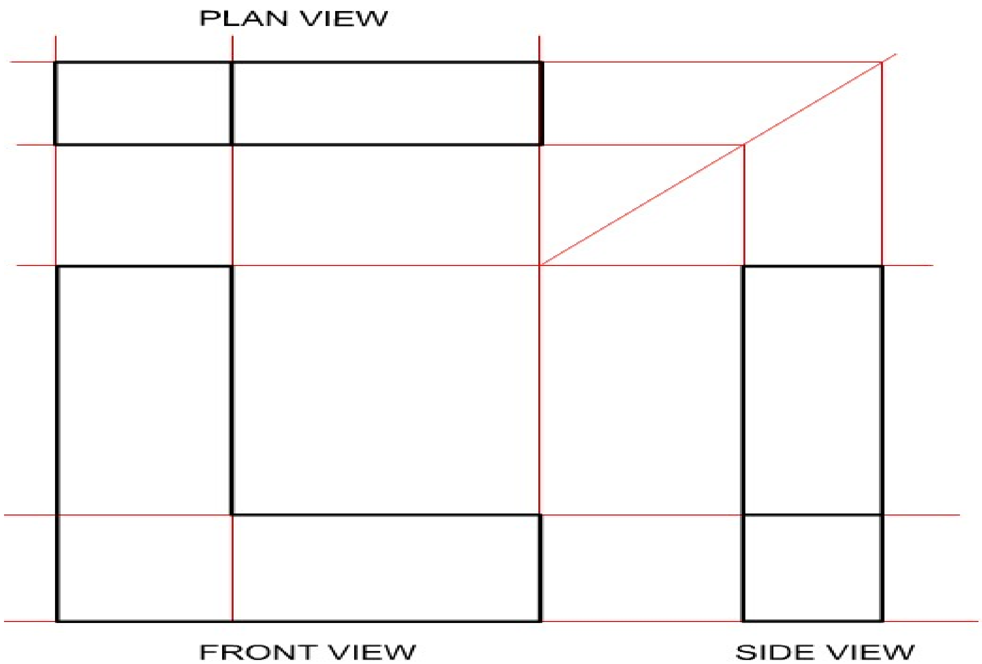
An L-shaped object.

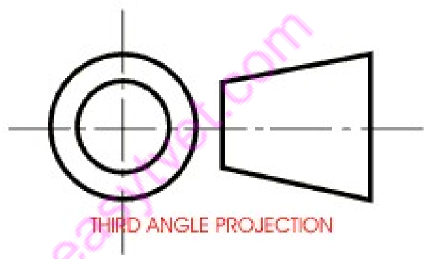
The Plan View of the L-shape is drawn as a 'birds eye' view, a view from above.

The Front View is drawn as if stood in front of the L-shape.

The Side View is drawn as if stood at the side.

The following figures show another metal block with the views in third angle and then first angle projection.





Third Angle projection convention symbol

Figure 67 Third angle orthographic projection of the L shape

The only difference is the positioning of the end elevation and plan views, the process of viewing is similar.

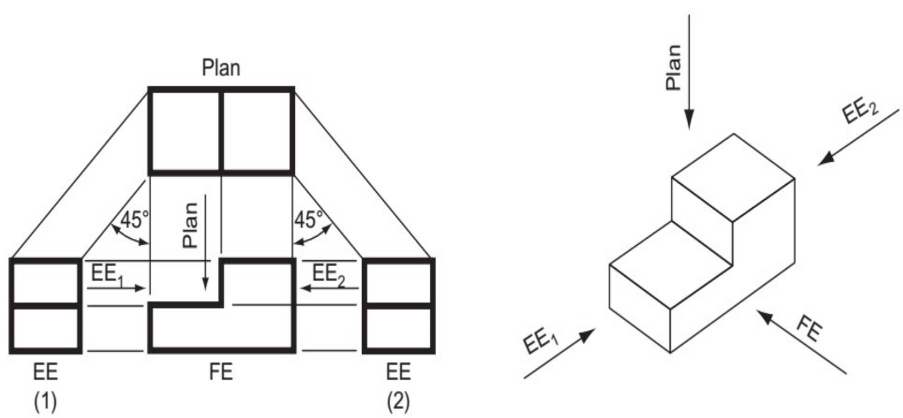


Figure 68 Third angle projection of a metal block

The figure above on the right shows a isometric view of a metal block where we are required to draw orthographic views of the front elevation (FE), 2 end elevations (EE) and plan from the top as indicated by the arrows.

The figure on the left shows the solution to the question and the views are projected by using the third angle projection

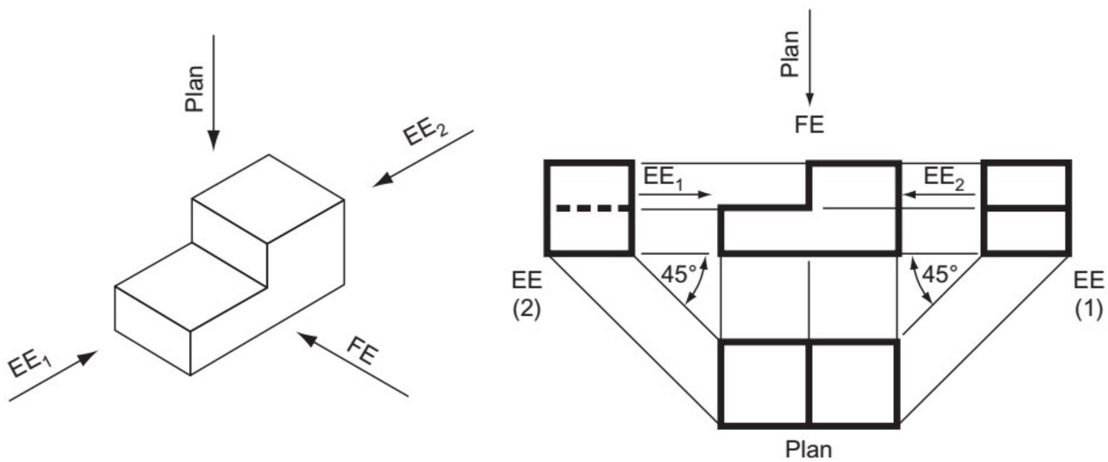


Figure 69 First angle orthographic projection

Figure above shows the same figure using first angle projection

c) Develop geometrical solid figures e.g. prisms, cones, surface development

Principle of Development

Every line on the development should show the true length of the corresponding line on the surface which is developed.

Methods of Development

i. Parallel-line development.

Used for developing prisms and cylinders.

ii. Radial-line development.

For developing pyramids and cones.

iii. Triangulation development.

For developing transition pieces.

iv. Approximate development.

For developing spheres.

Cylinder

Draw the development of the complete surface of a cylinder. Diameter is 40 mm and the height is 70 mm.

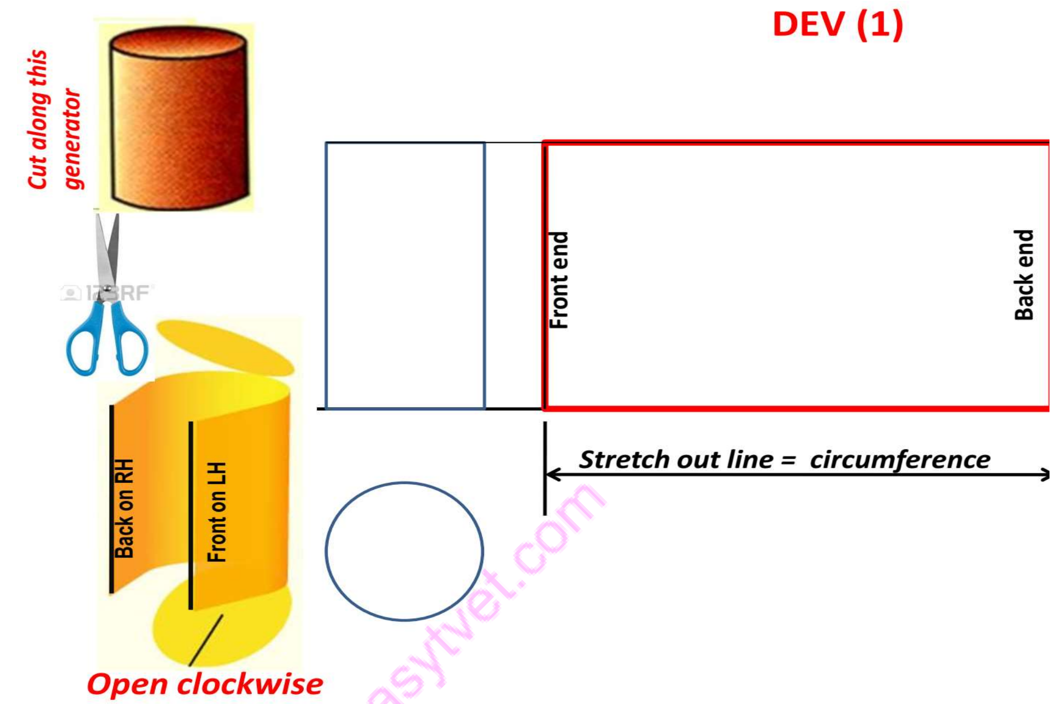


Figure 70 Development of a cylinder

Prism

Develop the complete surface of a square prism of side of base 40 mm and height 80 mm.

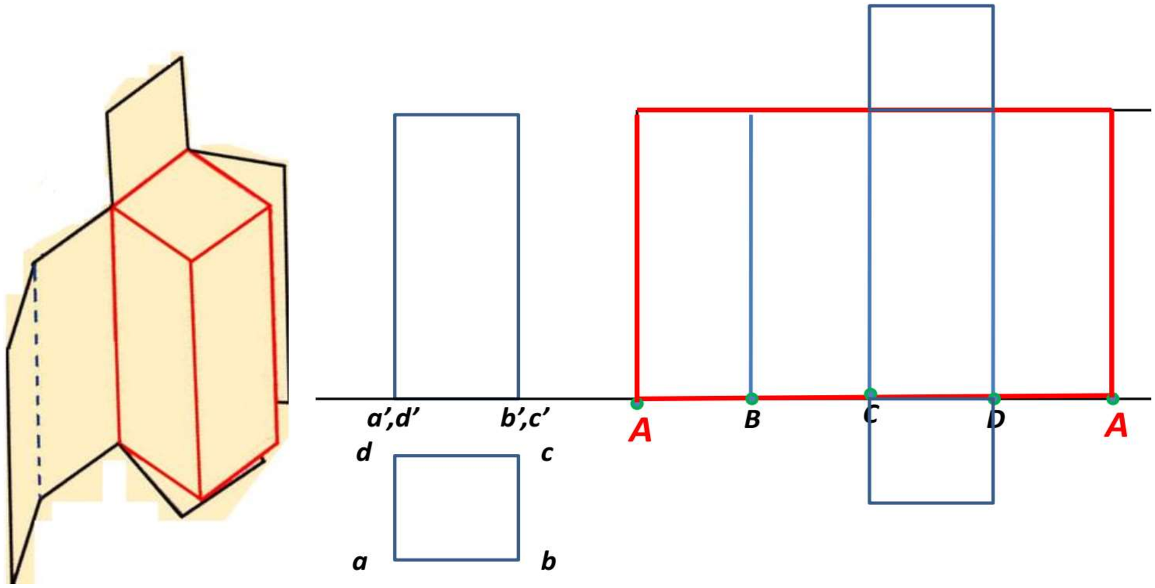


Figure 71 Square Prism development

Pyramid

Draw the development of the lateral surface of a square pyramid, side of base 30 mm and height 50 mm, resting with its base on H.P. All edge of the base are equally inclined to V.P.

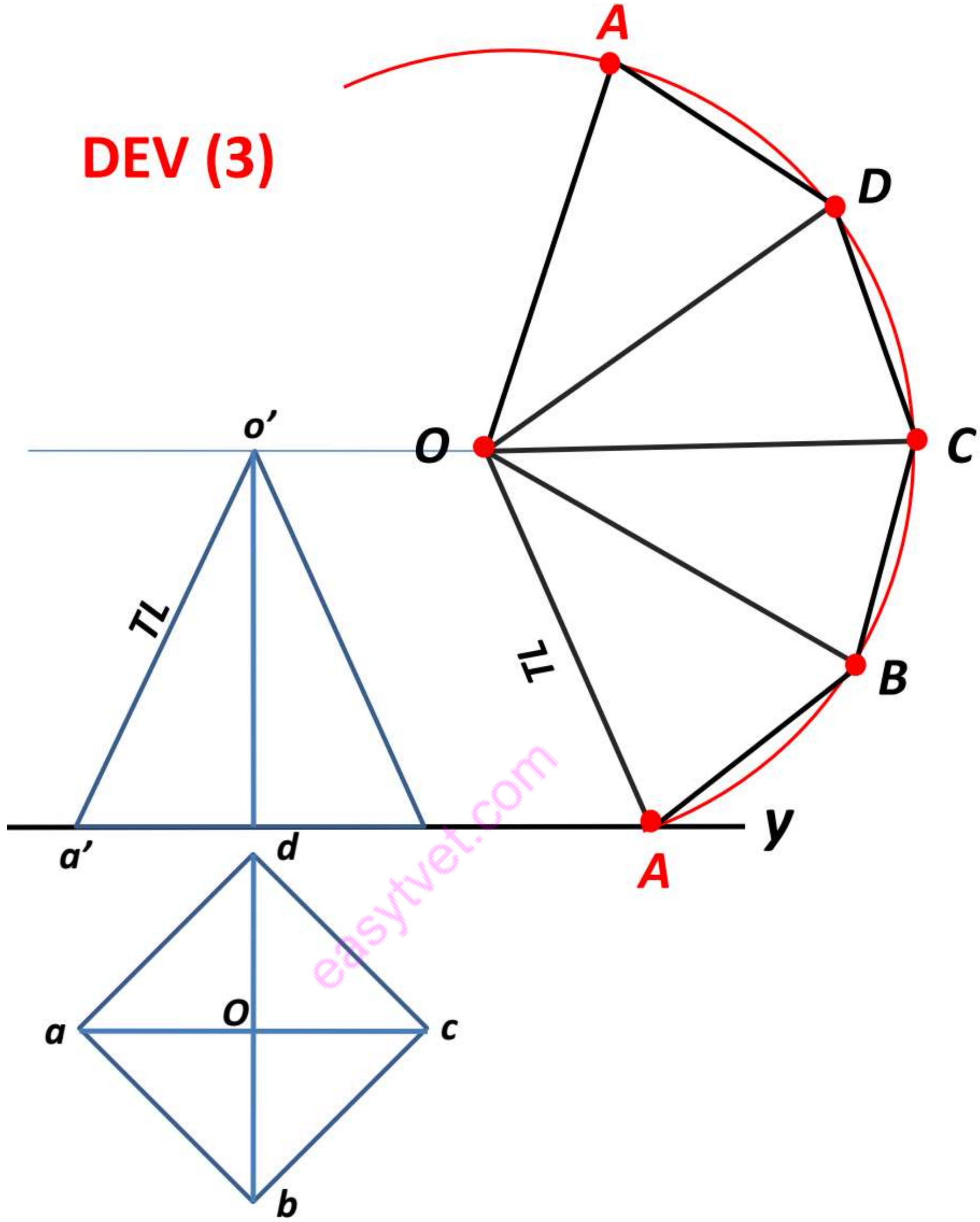


Figure 72 Pyramid development

Draw the development of the lateral surface of a square pyramid, side of base 30 mm and height 50 mm, resting with its base on H.P. Two of its base edge are equally parallel to V.P.

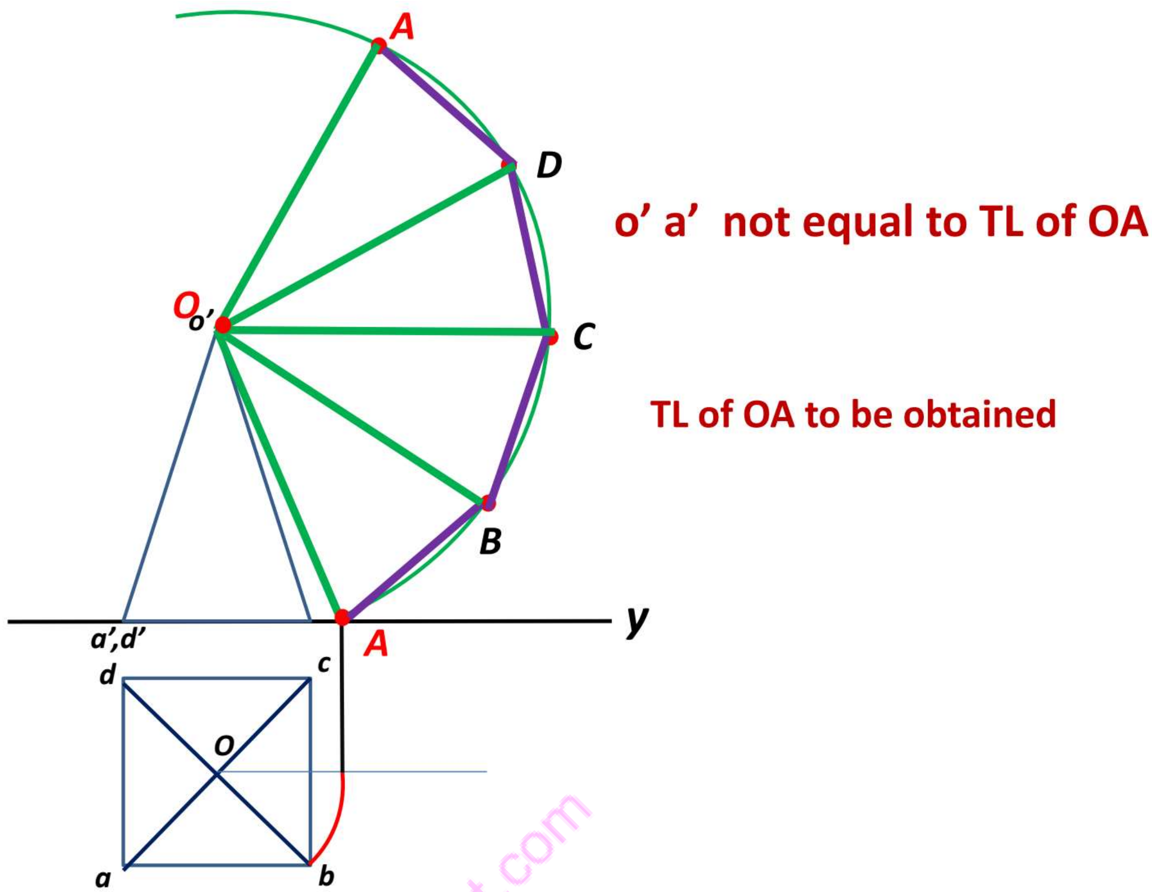


Figure 73 Square pyramid development 2

Cone

Draw the development of the lateral surface of a cone, base diameter 50 mm and height 70 mm, resting with its base on H.P.

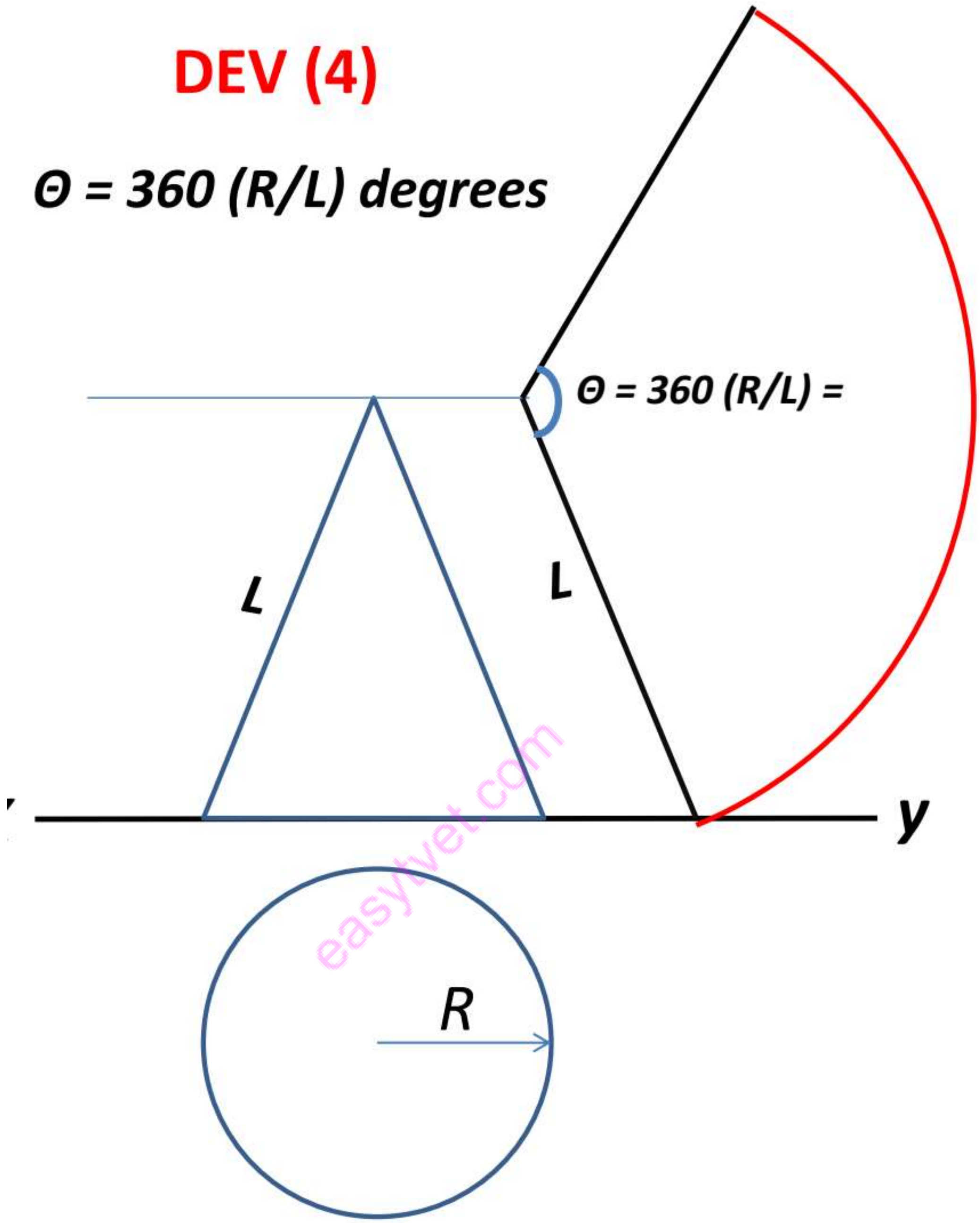


Figure 74 Cone development

Development of truncated cylinders, prisms, pyramids, and cones

Development of a truncated right circular cylinder

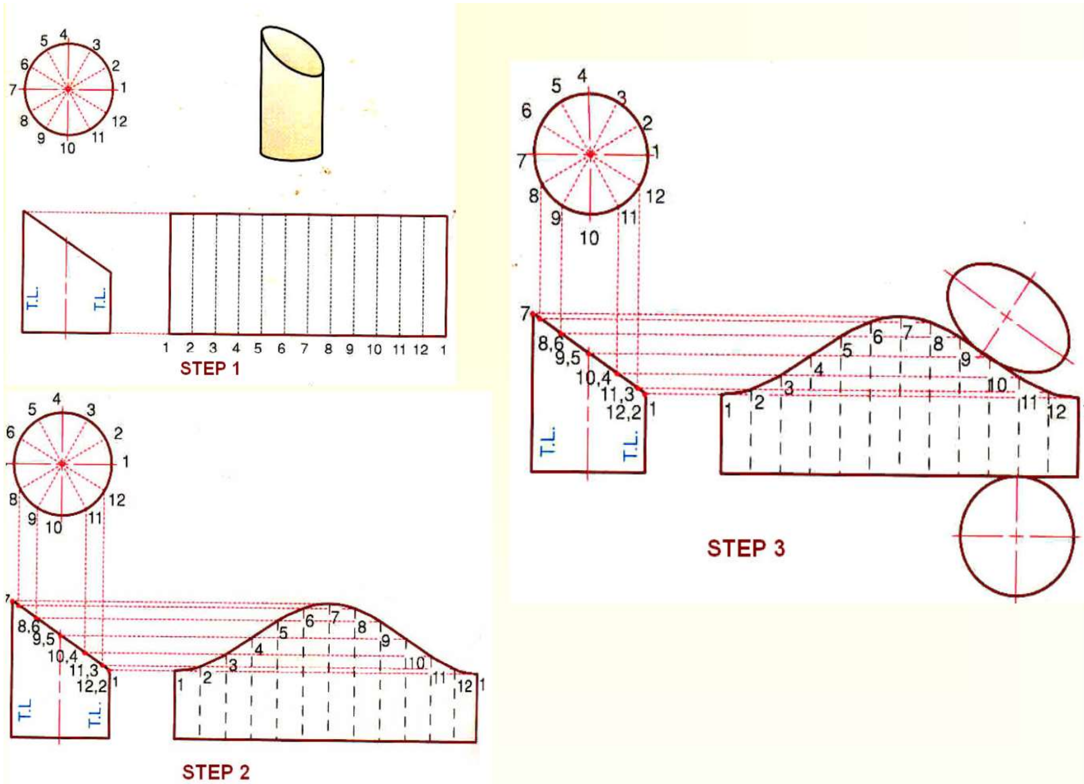


Figure 75 Truncated cylinder development

Development of a truncated prism

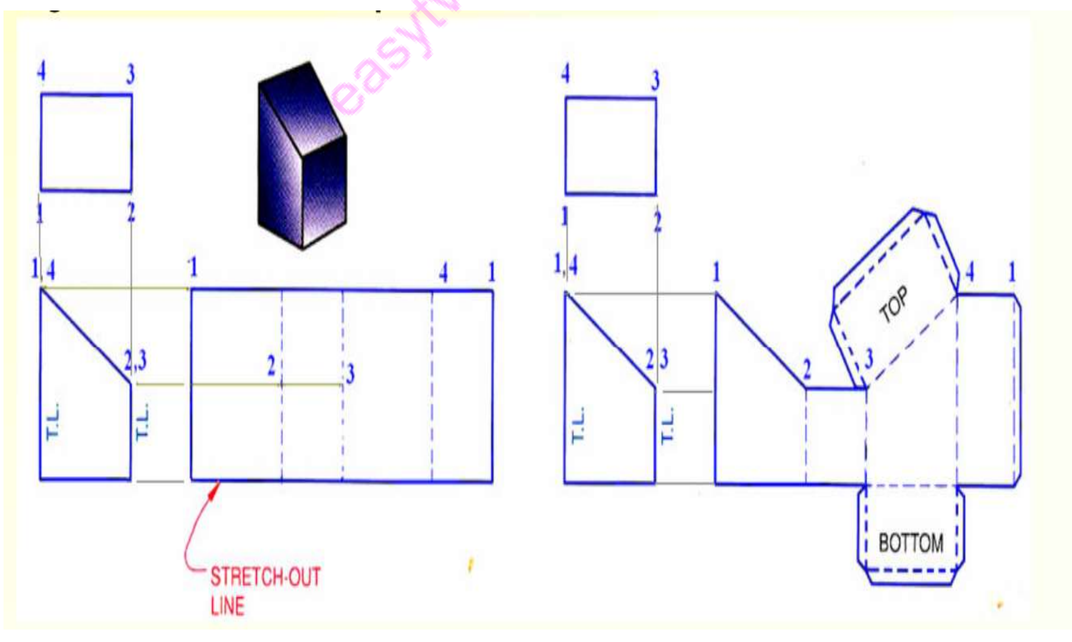


Figure 76 Truncated Prism Development

Development of truncated cone

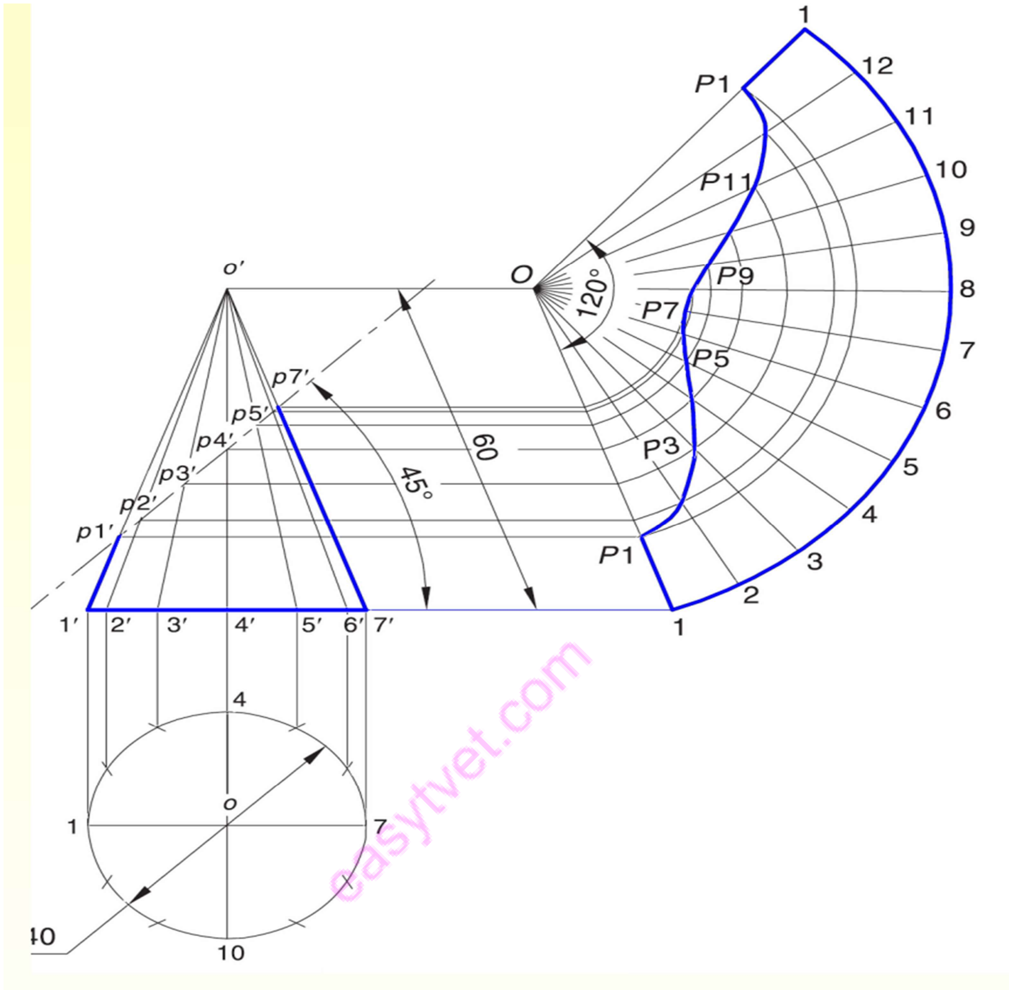


Figure 77 Truncated Cone development

Development of truncated pyramid

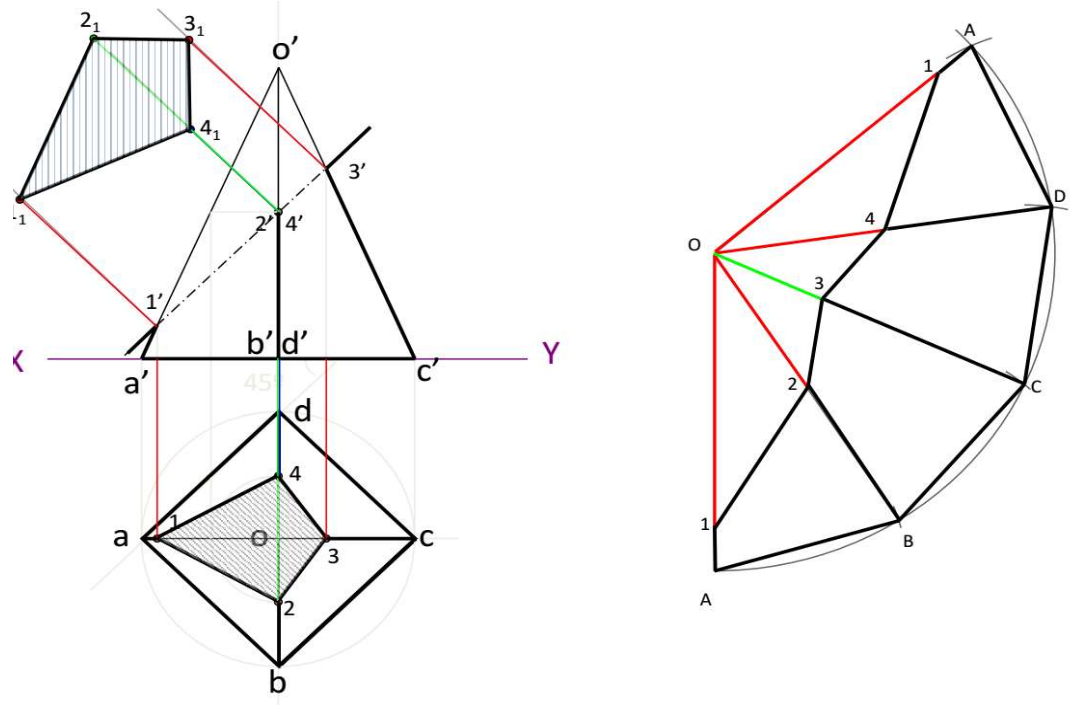
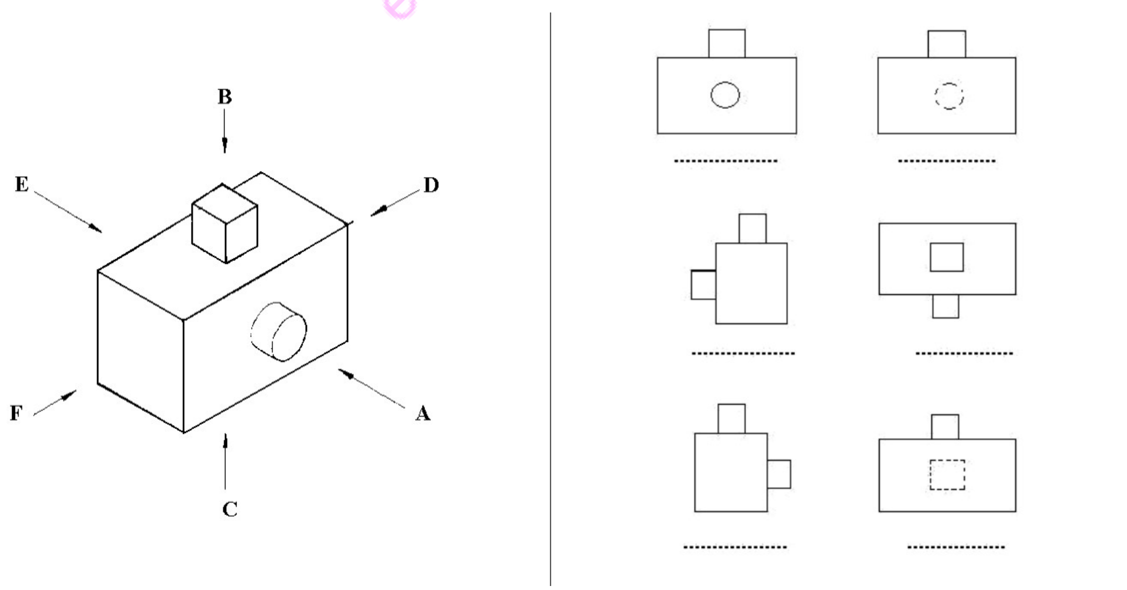


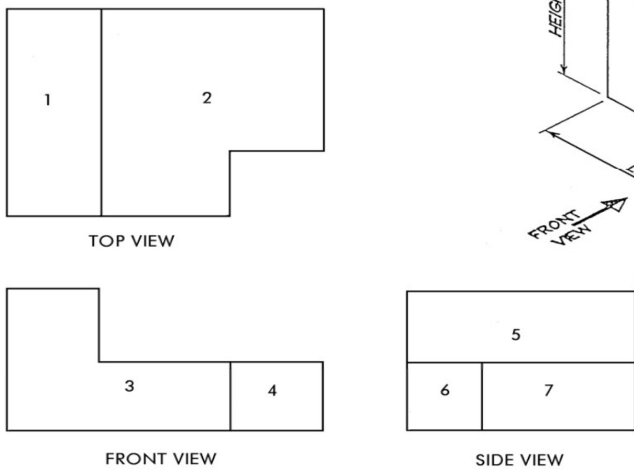
Figure 78 Truncated Pyramid development

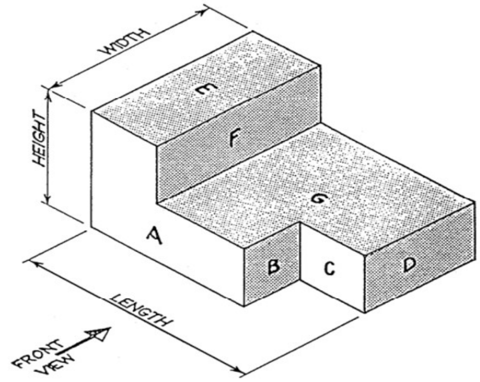
2.2.3.4. Learning Activities

i. In which direction must the object be viewed to produce the views shown opposite, taking 'A' as the FRONT VIEW. Put the appropriate letter under the view.



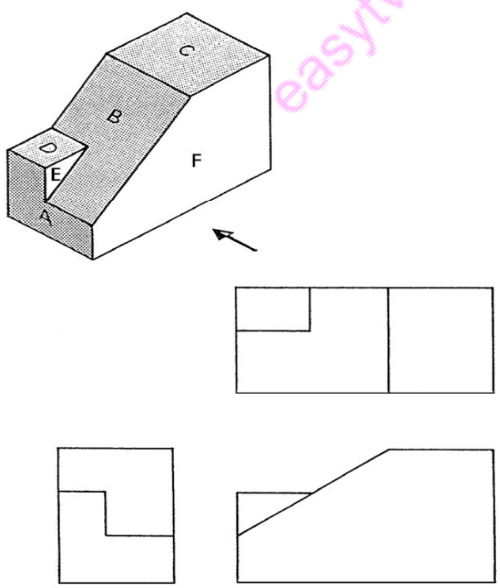
ii. Study the two drawings and complete the table by matching the numbered surfaces of the orthogonal drawing with the lettered surfaces of the isometric drawing.

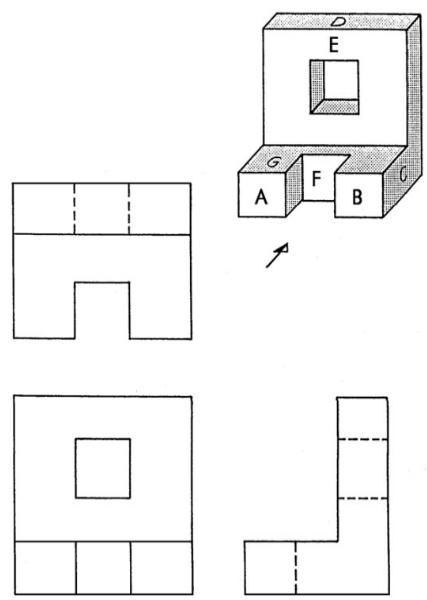




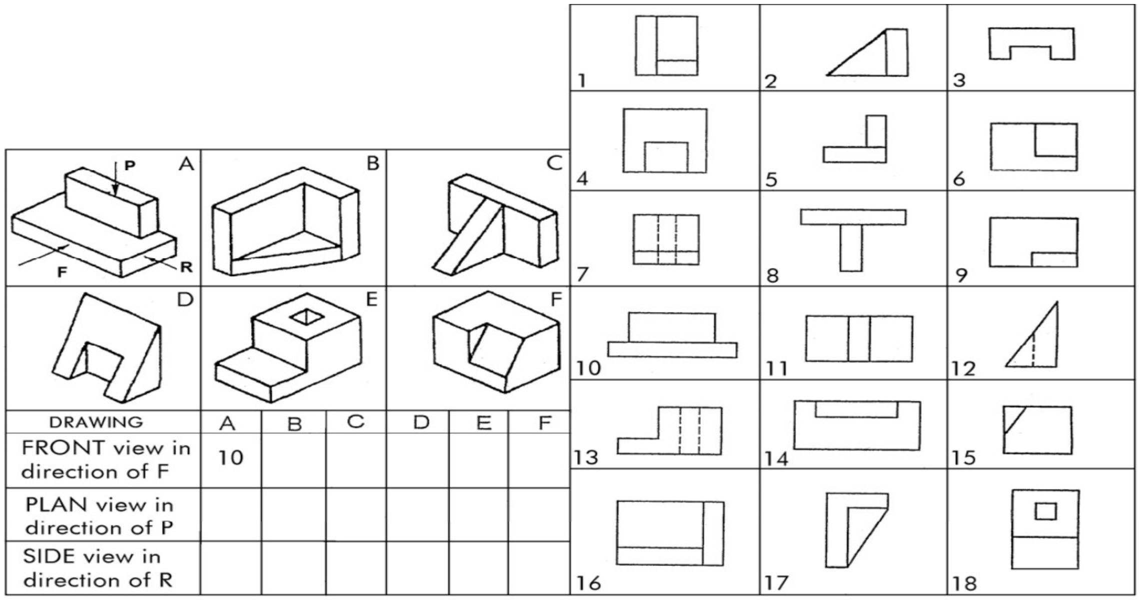
A	B	C	D	E	F	G

iii. Transfer the letters from the isometric drawing onto the same plane surfaces of the orthogonal drawing. Name each view.





iv. Select the view which is requested in the table below. Place the number of this view in the appropriate position in the table.



DRAWING	A	B	C	D	E	F
FRONT view in direction of F	10					
PLAN view in direction of P						
SIDE view in direction of R						

2.2.3.5. Self-Assessment

1. Explain the following terms;

   i. **Pictorial view**

   ii. **Truncated Object**

   iii. **Working plan**

2. Draw the third angle projection convention symbol.

3. Draw FULL SIZE in first angle projection the three orthographic views of the block.

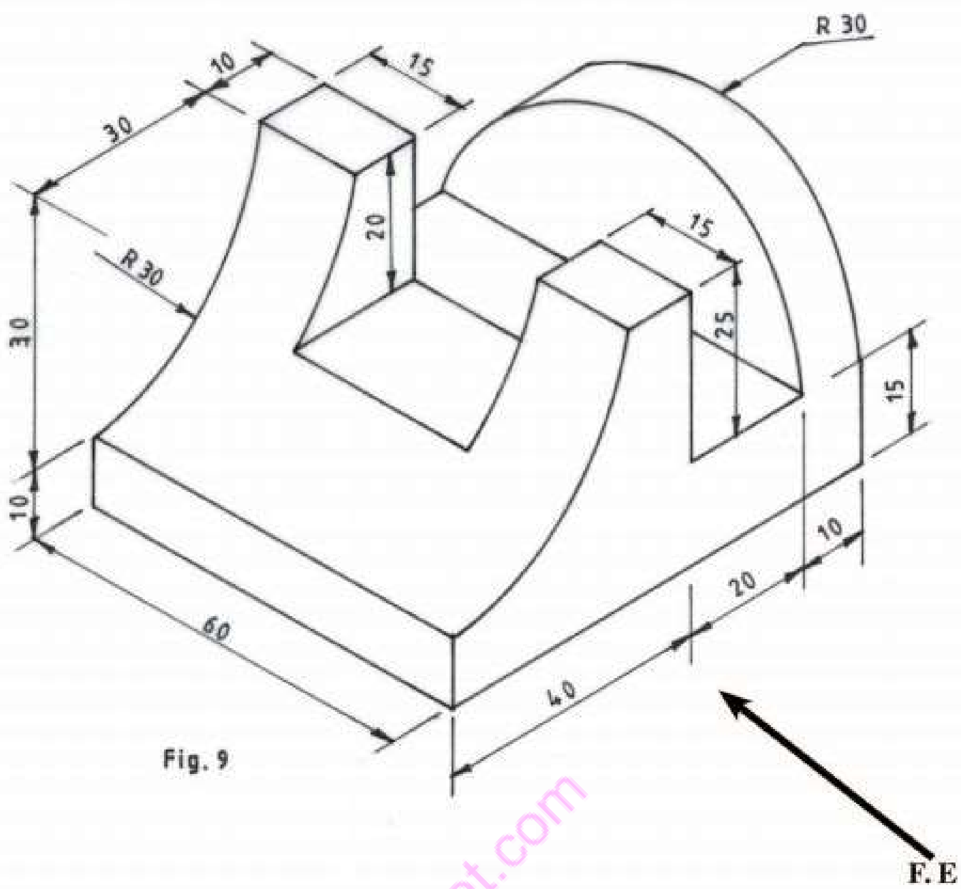


Fig. 9

2.2.3.6. Tools, Equipment, Supplies and Materials

i. Drawing boards
ii. T squares
iii. Set squares
iv. Drawing sets
v. Drawing paper
vi. Protractors
vii. Eraser Shield
viii. Pencils
ix. Erasers
x. Masking tapes
xi. Paper clips
xii. Drawing curves
xiii. Technical drawing software'

2.2.3.7. References

Bhatt, N. D. (2011). *Engineering Drawing.* Gujarat: Charotar Publishing house.
Morling, K. (2010). *Geometric and Engineering drawing.* London: Elsevier.

2.2.3.8. Model Answers

1. Explain the following terms;

i. **Pictorial view**

The presentation of an object where it is viewed showing the three faces of
an object

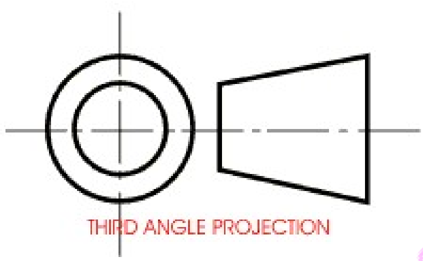
ii. **Truncated Object**

It is a geometrical object that has been cut

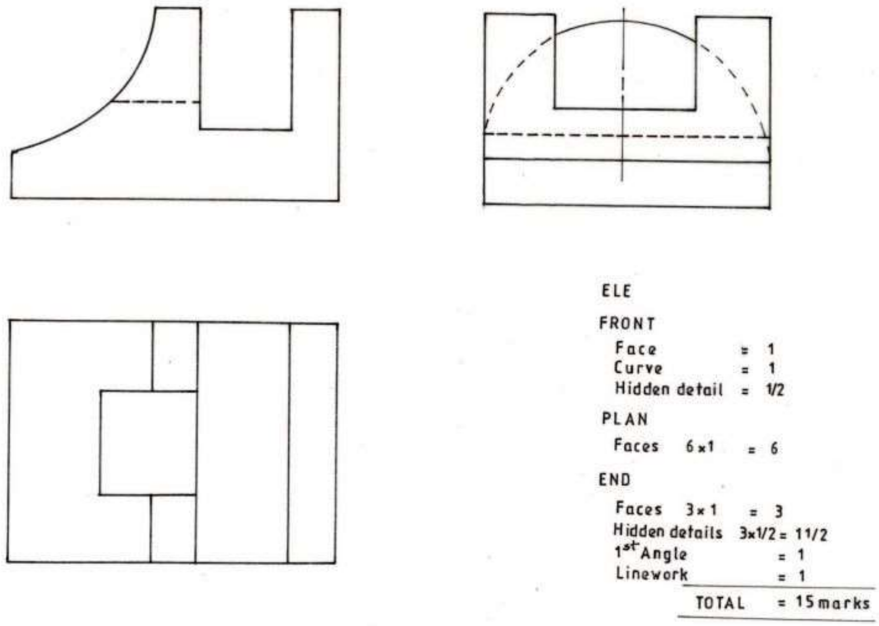
iii. **Working plan**

A freehand drawing showing all the information needed to construct an object.

2. Draw the third angle projection convention symbol.



3. Draw FULL SIZE in first angle projection the three orthographic views of the block.



2.2.4 Learning outcome 4: Develop orthographic and pictorial drawings

3.2.4.1. Introduction to the learning outcome

The focus of this specific learning outcome is to introduce the different working drawings and their purpose during the planning of plumbing works. This section will give an understanding of the different types of working drawings, building symbols and different representations of drawings.

3.2.4.2. Performance Standard

The following performance criteria will be required to be met by trainees to be considered competent:

1. Symbols and abbreviations are identified and interpreted according to standard drawing conventions
2. First and third angle orthographic drawings are interpreted and developed in accordance with the standard conventions
3. Orthographic elevations are dimensioned in accordance with standard conventions
4. Isometric drawings are interpreted and developed in accordance with standard conventions

5. Oblique drawings are interpreted and developed in accordance to standard conventions

3.2.4.3. Information Sheet

a) Terms and concepts

i. Plumbing drawing

Type of technical drawing used to visually represent and inform on a plumbing system conveying the engineering design to plumbers or other workers who install the plumbing system.

ii. Design drawing

Used to develop ideas about a new or developing design

iii. Concept drawings

These are sketches or drawings often freehand done, used by designers such as architects, engineers, and designers as a quick and simple way of exploring initial ideas for designs.

iv. Parallel Projection

These are projections where the line of sight or projectors are parallel and are perpendicular to the picture planes. It is subdivided in to the following three categories:

- Orthographic,
- Oblique and
- Axonometric Projections.

v. Orthographic projections

These are multi view drawings, which show flat representations of principal views of an object.

vi. Oblique Projections

"a projective drawing of which the frontal lines are given in true proportions and relations and all others at suitable angles other than 90 degrees without regard to the rules of linear perspective." According to Mirriam webster dictionary.

vii. **Axonometric Projections**:

Axonometric projection creates a true plan set at 45º, which retains the original orthogonal geometry of the plan. It is particularly suitable for representing interior designs, such as kitchen layouts. Planning drawings can also be effective represented as axonometric projections, showing the relationships between buildings and topography.

These are three-dimensional drawings that falls into three classifications:

- Isometric,
- Dimetric and

- Trimetric.

viii. Isometric drawing

The isometric was the standard view until the mid-20th century. Unlike the axonometric projection, the isometric plan view is slightly distorted, using a plan grid at 30º from the horizontal in both directions. It can be used to show the nature of the design and explain construction details more clearly than an orthographic projection. It is sometimes used during concept design to help the client grasp the mass of the proposal.

b) Free hand sketching

i. Purpose of Technical Drawings

To appreciate the need for technical drawings, one must understand the design process. The design process is an orderly, systematic procedure used in accomplishing a needed design.

Any product that is to be manufactured, fabricated, assembled, constructed, built, or subjected to any other types of conversion process must first be designed. For example, a house must be designed before it can be built.

ii. Application of Technical Drawing

Technical drawings are used in many different applications. They are needed in any setting, which involves design, and in any subsequent forms of conversion process. The most common applications of technical drawings can be found in the fields of manufacturing, engineering, and construction.

For instance, Surveyors, civil engineers, plumber use technical drawings to document such works as the layout of a new subdivisions, or the marking of the boundaries for a piece of property. Contractors and construction personnel use technical drawings as their blueprints in converting architectural and engineering designs into reality

c) Pictorial and orthographic drawings

d) Meaning of symbols and abbreviations

e) Drawing and interpretation of orthographic elevations

f) Dimensioning of orthographic elevations

g) Conversion of orthographic to pictorial

g) Freehand sketching

A freehand sketch is a drawing in which all proportions and lengths are judged by eyes and all lines are drawn without the use of drawing instruments. Comparing with mechanical drawing, the use of freehand sketching in engineering

Communication provides the following advantages:

iv. A better means of visualizing problems

v. Organizing ideas more quickly

vi. Avoiding wasting of time on formal drawing methods

The following requirements are necessary for sketching materials in plumbing,

Sketching tools:

A sketch communicates information and does not have to be an exact drawing. Many designs were visualized

on just a piece of paper or whatever is available. The tools that are used in freehand sketching are**:**

iv. Sketching paper cross-section paper or grid paper, help secure good proportions and serve as guides in sketching lines

v. Pencil medium lead (B) or soft lead (HB) type

vi. Eraser soft type

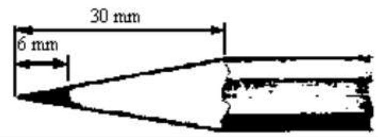
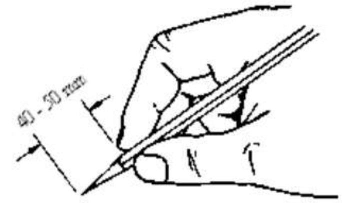
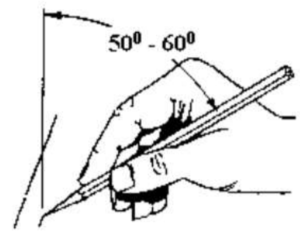
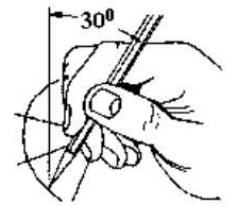
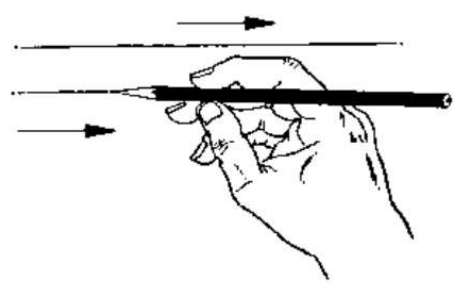
Above the three things are essential for sketching. Sometimes, cross-sectioned graph paper ruled with light lines is also used instead of a plain paper. These lines and squares help in drawing straight lines and maintaining proportions.

As such papers may not always be readily available, it is advisable to learn sketching without their aid.

Freehand drawing is known as sketching. This technique is necessary in any area of drafting and an important skill for everyone. Skills in freehand drawing can be achieved through constant training and correct practice.

Use of pencils

Although freehand lines will never be perfectly straight and absolutely uniform along their lengths, effort should be made to sketch distinct, black and uniform lines. Hints of using pencils that help sketching to be made to approach exacting uniformity are as follows:

i)	Sharpen the pencil to obtain a proper point	
ii)	Hold the pencil loosely, approximately 40 - 50 mm from the point	
iii)	Slant the pencil at an angle of 50 - 60 degrees from the vertical for sketching straight lines	
iv)	Slant the pencil at an angle of 30 degrees from the vertical for sketching circles	
v)	Pull the pencil when sketching straight lines or curves	

Line Sketching

One advantage of freehand sketching is that it needs only patience and continuous Practice. Practice on a drawing paper the construction of following line without use of instruments. When drawing straight lines, as on the left, rest the weight of your hand on the backs of your fingers. When drawing curved lines, as on the right, rest the weight on that part of your hand between the knuckle of your little finger and your wrist. This provides a pivot about which to swing your pencil. Always keep your hand on the inside of the curve, even if it means moving the paper around.\

Pictorial Sketching

Freehand pictorial sketching looks very much like isometric drawing. Circles appear as ellipses and lines are drawn at approximately 30 °. Circles have been sketched onto an isometric cube in figure below. You can see how these same ellipses appear on sketches of a round bar material.

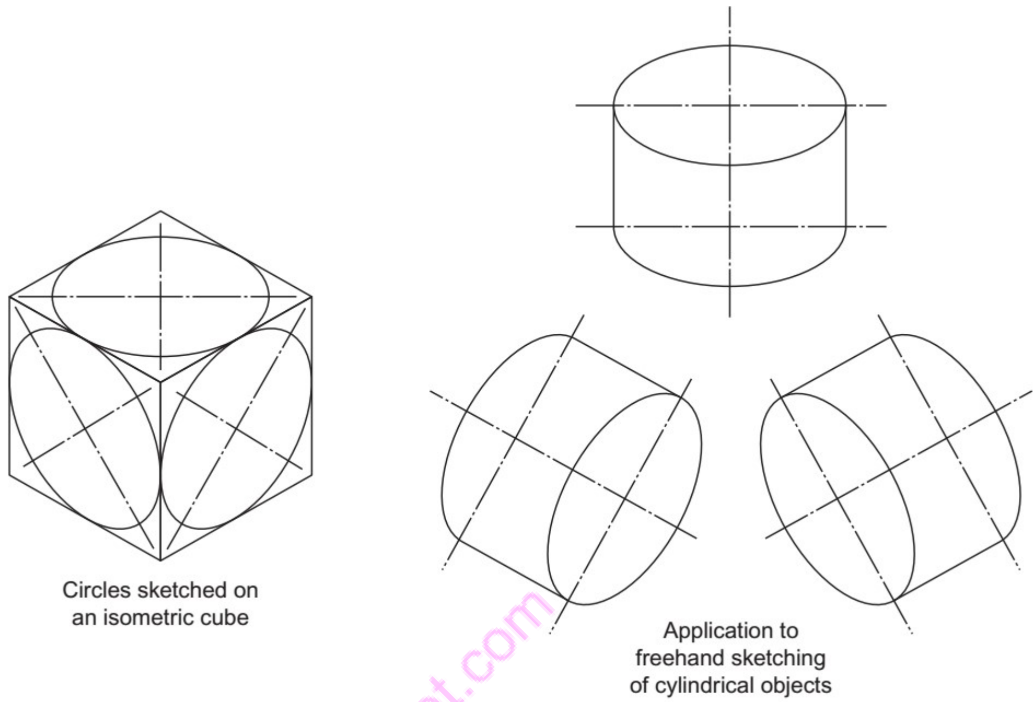


Figure 79 Pictorial exercises

When sketching, you may find it an advantage to draw a faint 'box' first and draw in the ellipses afterwards. With practice you should find that you can draw quite a good ellipse if you mark out its centre lines and the major and minor axes. Although drawing is a continuous process, the work can be divided into three basic stages.

Stage 1: Construction

This should be done with a hard pencil (3H), used lightly, and the strokes with the pencil should be rapid. Slow movements produce wavy, uncertain lines. Since these constructed lines are very faint, errors can easily be erased.

Stage 2: Lining in

Carefully line in with a soft pencil (HB), following the construction lines drawn in stage 1. The completion of stage 2 should give a drawing that shows all the details and you may decide, particularly in an examination, not to proceed to stage 3

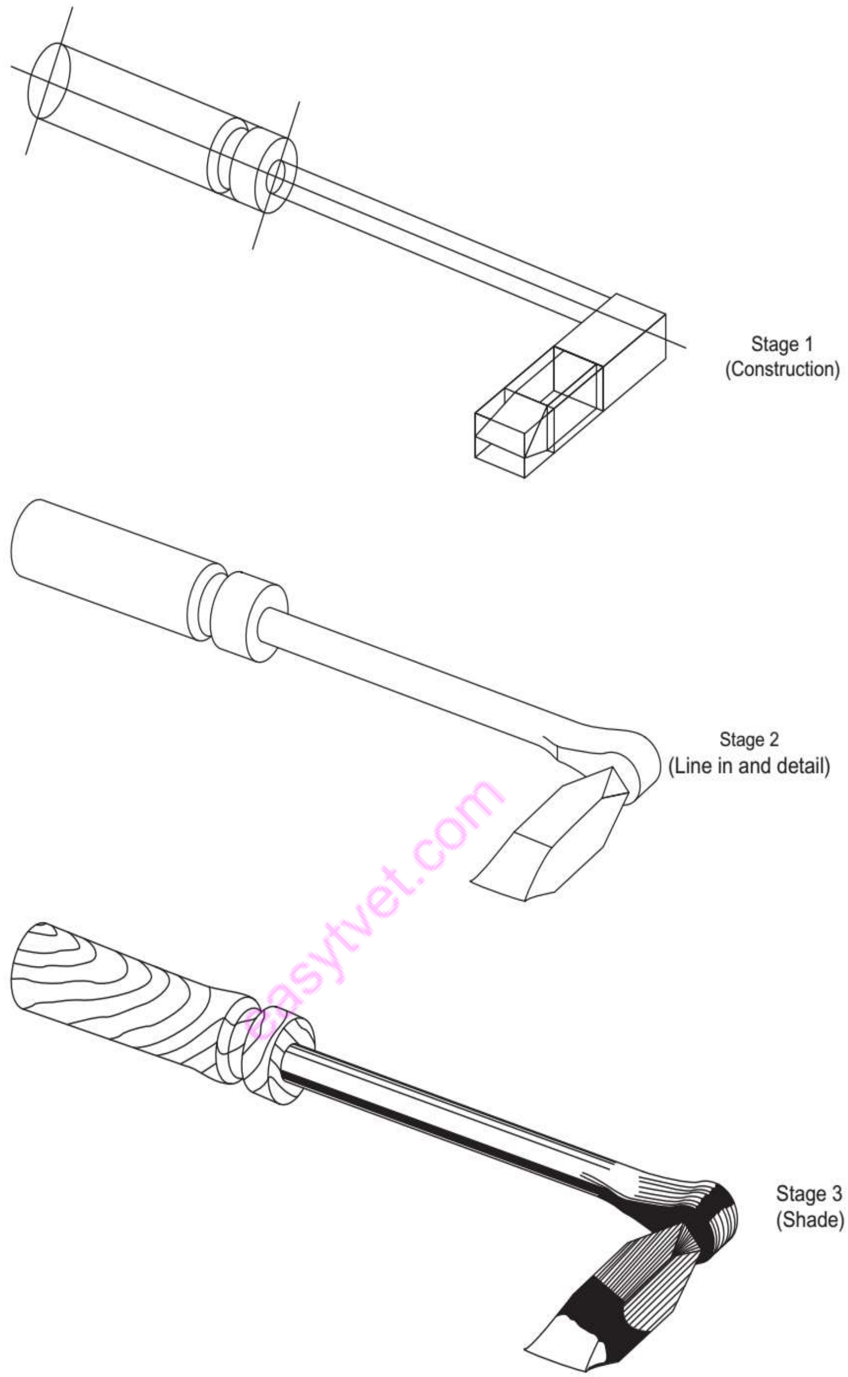


Figure 80 3 stages of freehand sketching

Stage 3: Shading

Shading brings a drawing to life. It is not necessary on most sketches, and in some cases it may tend to hide details that need to be seen. If the drawings are to be displayed, however, some shading should certainly be done.

Shading is done with a soft pencil (HB). It is very easy to overshade, so be careful. For the smooth merging of shading, the dry tip of a finger can be gently rubbed over the area.

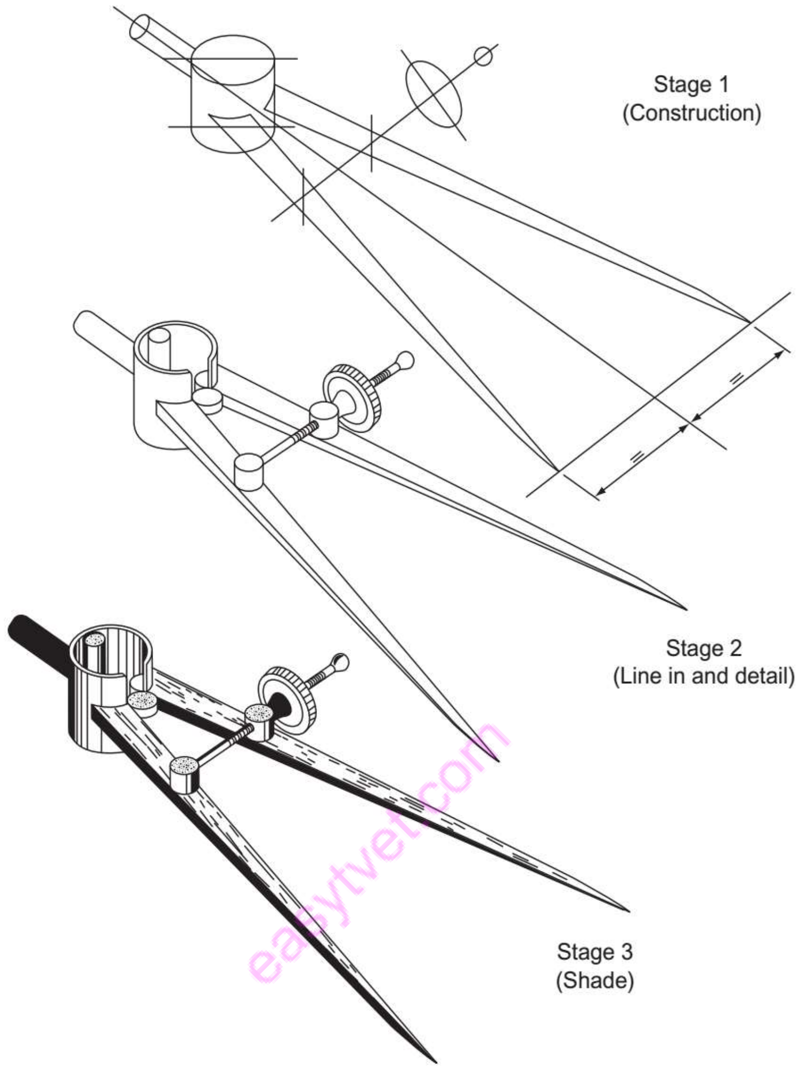


Figure 81 Divider Exercise

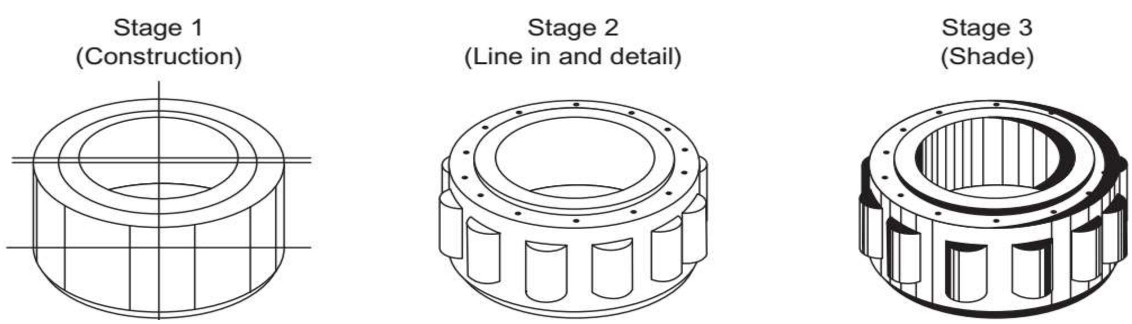


Figure 82 Bearing exercise

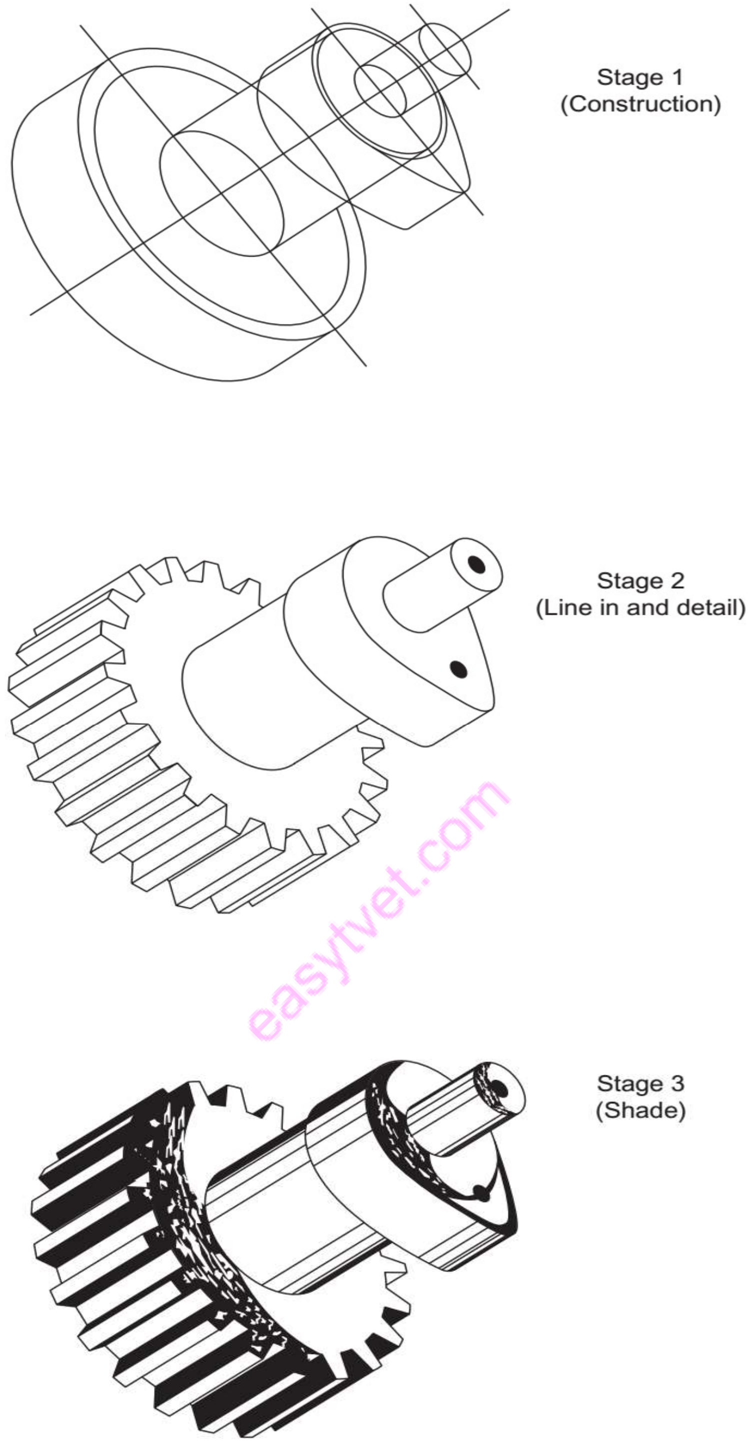


Figure 83 Gear Exercise

Sketching in Orthographic Projection

More detail can be seen on an orthographic drawing than on an isometric, mainly because more than one view is drawn. For this reason it is often advantageous for a draughts person to make an orthographic sketch. This will be undertaken below Circles are difficult to draw freehand but you can use your hand as a compass. Hold your pencil upright and, using your little finger as a compass 'point', revolve the paper keeping your hand quite still.

Orthographic projections

First and third angle projection

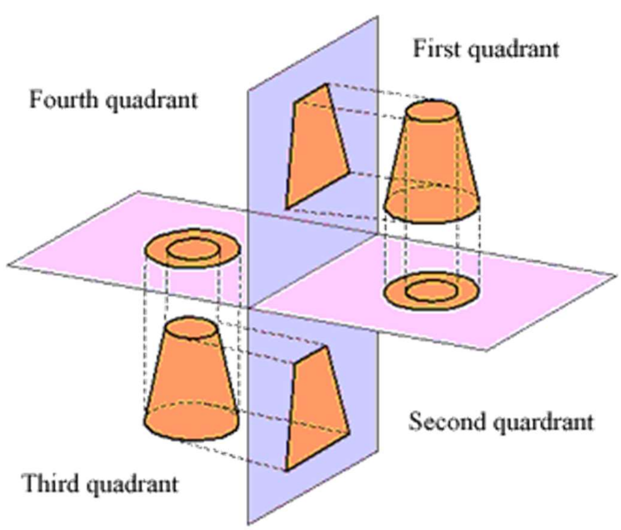
This is a graphical method used in engineering drawings. The word **orthographic** is derived from the Greek words **orthos**-*straight, rectangular* and **graphos**-*written, drawn*. A drawing of a structure or part thereof can be drawn using the following projection methods:

(a) orthogonal (b) oblique and/or (c) perspective

There are two methods of drawing **orthographic** projections:

1) first angle projection and 2) third angle projection

They are based on right angle planes with defined separate spaces , or quadrants. Each quadrant could obtain an object to be presented. However, only two are commonly used, the first and the third as shown .



Both systems of projection are approved internationally and the system used is clearly indicated on all engineering drawings with the following illustrations:

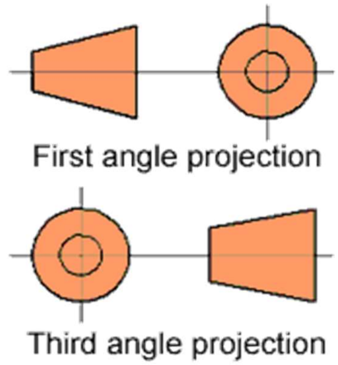
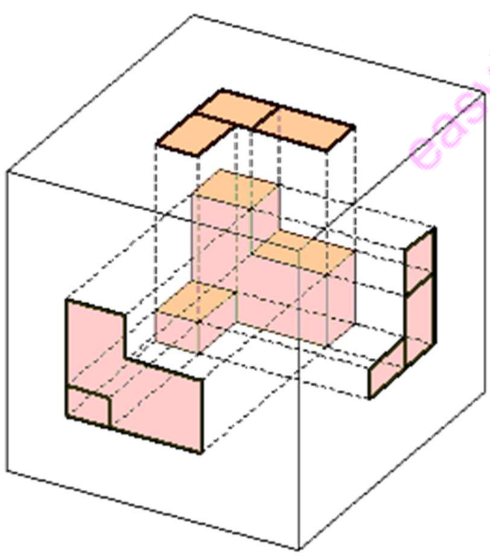


Figure 84: Orthographic Projection

In which projection architectural and builders working drawings are represented is generally insignificant. Nearly all of those drawings do not indicate in which projection they are drawn and it really does not matter. However, it is important that you understand the basic principles of orthographic projection and be able to construct orthographic views of objects.



The easiest way to explain the development of a orthographic drawing is to place an object in a glass cube as shown in the opposite figure. The object surfaces are then projected on the faces of the cube. The cube like any card box can be unfolded so that all six surface areas are shown as blow.

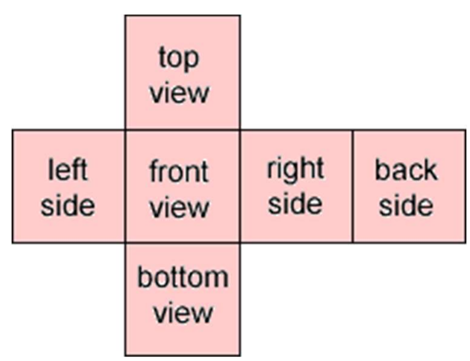


Figure 85: Views

The figure below shows the unfolded box with the same object as shown.

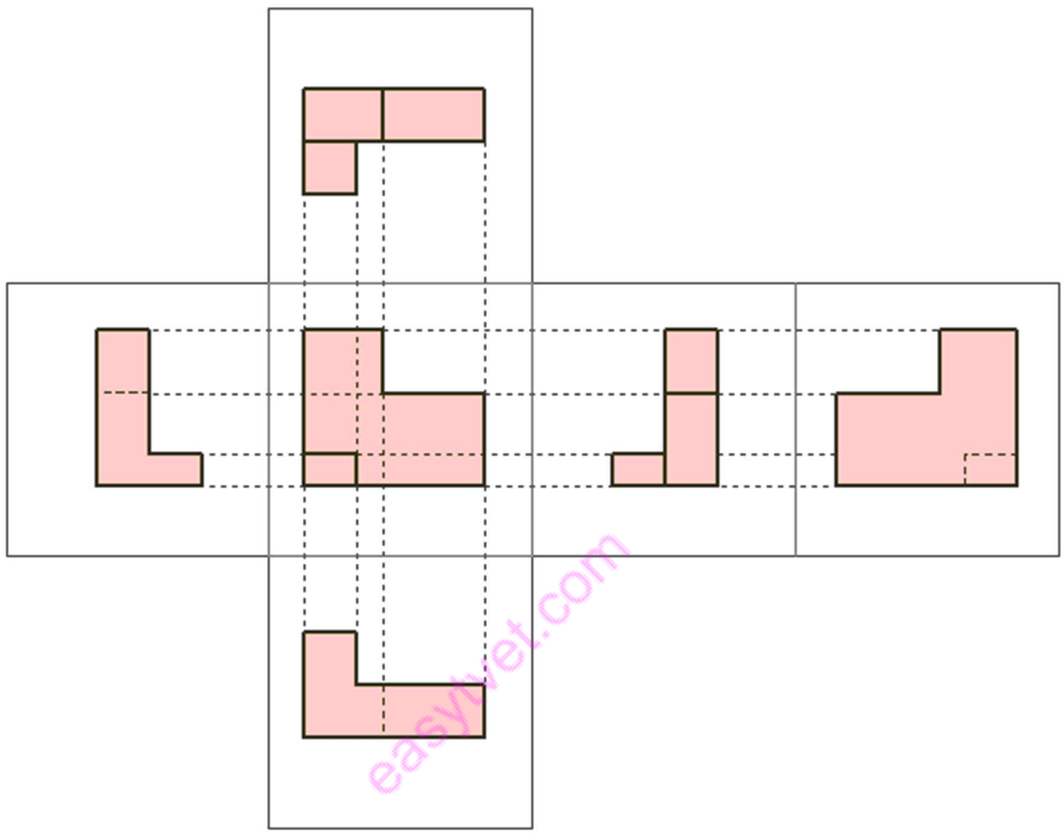


Figure 86: Unfolded Box

How to draw objects or components

Adopt the method below for drawing building objects or components.

Choose which view or direction or face will be used as the font view of the object or component.

The object or component you chose for the front view should have the longest straight edge..

From the bottom edge of the front view draw feint construction lines @ 45° as shown in Step 1

Carry on finishing the top view. Start a line below the front view with sufficient distance for dimensioning of the object or component.

Complete the top view

Use faint construction lines and draw the outline of the side views as shown in Step 2

Complete the side view with the aid of construction lines as shown in Step 3

Always use this method for drawing objects or components.

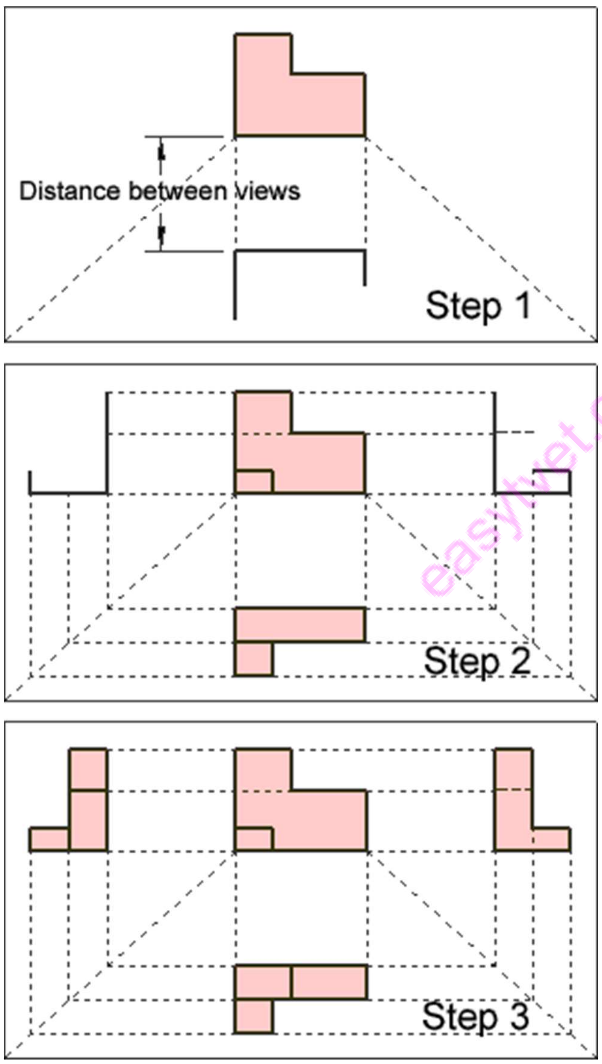


Figure 87: How to Draw objects/components

In Drawing 1 you will draw a number of different objects. The views should always be aligned with each other allowing sufficient space between the views for dimensions (see Step 1 - Figure 6). Lines that cannot be seen in a specific view are hidden and shown as dashed lines.

Orthographic Projection

Orthographic projection shows the views of an object in three different positions, namely:

PLAN – ELEVATION – END VIEW.

The plan is an outline of the object when viewed from above.

The elevation is what is seen when looking from the front.

The end view shows the view from one of the ends.

Orthographic projection is generally not used in the construction industry. It is more commonly found in the engineering sector where precise measurement is essential.

Try drawing the object below in orthographic projection i.e. draw a plan (z) an elevation (x) and an end view (y).

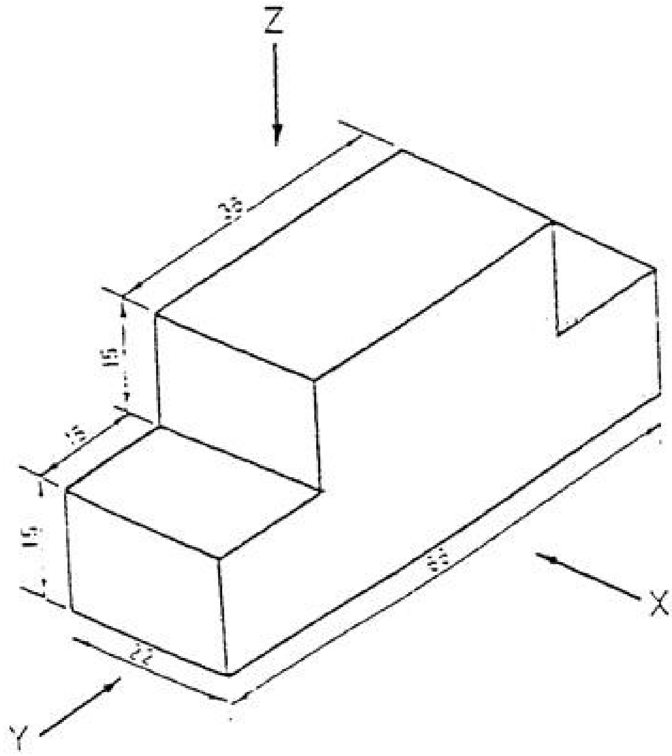


Figure 88 Orthographic views

Isometric Projection

In isometric projection all the horizontal lines are drawn at 30° to the horizontal plane while vertical lines are drawn vertical.

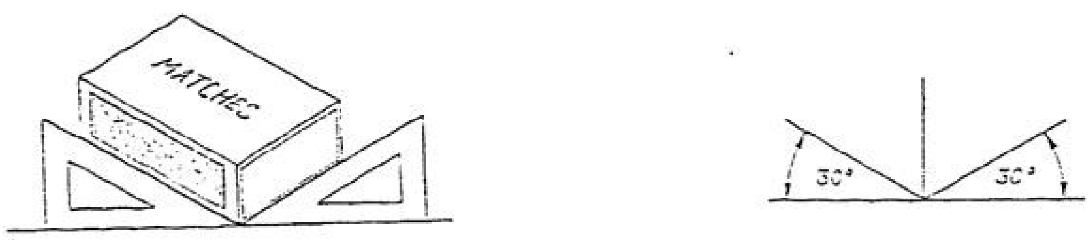


Figure 89 Isometric axis

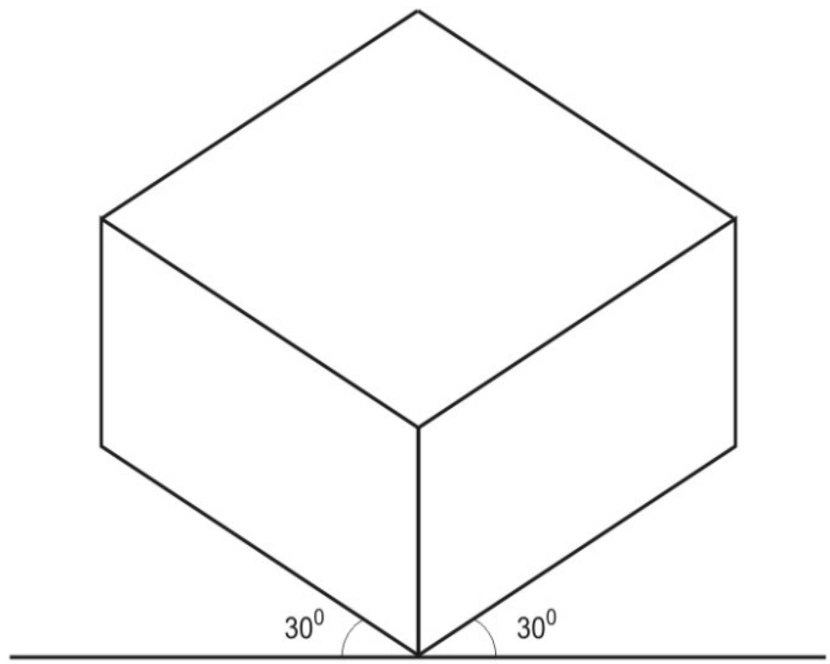


Figure 90 Isometric Box

Isometric projection embraces the three views from orthographic projection in the one drawing. In the drawing of the matchbox below you can see the plan, elevation, and end view.

Procedure for making an Isometric box

i. Draw a light horizontal baseline and a vertical line to represent the nearest corner.
‘A’ of the box.

Oblique drawing

This is a representation such that the edge of one face is parallel to the horizontal reference line and the other edges are elevated at an angle of 45°

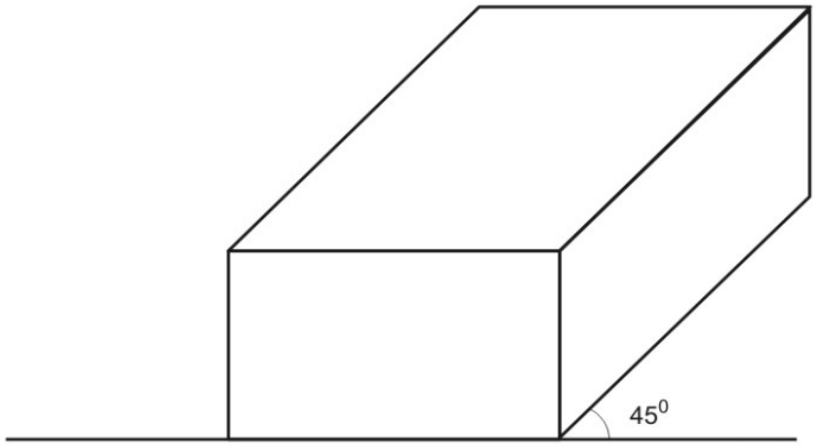


Figure 91 Oblique Box

Perspective drawing

Parallel – Parallel lines are lines that never touch… even if they are extended indefinitely.
Horizontal Lines – Lines drawn from side to side level with the horizon. Horizontal lines will be parallel the top and bottom edges of your paper.
Vertical Lines – Lines drawn up and down and perpendicular (right-angled) to the horizon. Vertical lines should be parallel to the sides of your paper.
Slanted Lines – Lines that are neither vertical nor horizontal; slanted lines are diagonal.
Horizon Line – The horizon line is a special horizontal line that represents eye level to the viewer.
Vanishing Point – A point on the horizon line where all perspective lines meet.
Perspective Lines (orthogonal lines) – The lines that meet at the vanishing point. Perspective lines are parallel in real life but converge in a one point perspective drawing.
One Point Perspective

One Point Perspective is a type of linear perspective that uses a single vanishing point to create the illusion of depth in a work of art.

Abbreviations

A list of the standard abbreviations for some general engineering terms is shown below. These abbreviations are used to save time, and space on drawings.

Although the abbreviations are shown in block capital letters, small letters may be used. For unit abbreviations always use small letters.

To read a drawing properly, and to understand what is happening, an agreed set of graphical symbols and abbreviations are used. All the different trades have a set of symbols pertaining to their respective works. The works of the plumber is often referred to as the "Mechanical Services".

Abbreviations for Pipe Rises/Drops

TA	*To Above*
FB	*From Below*
RTA	*Rise To Above*
DTB	*Drop To Below*

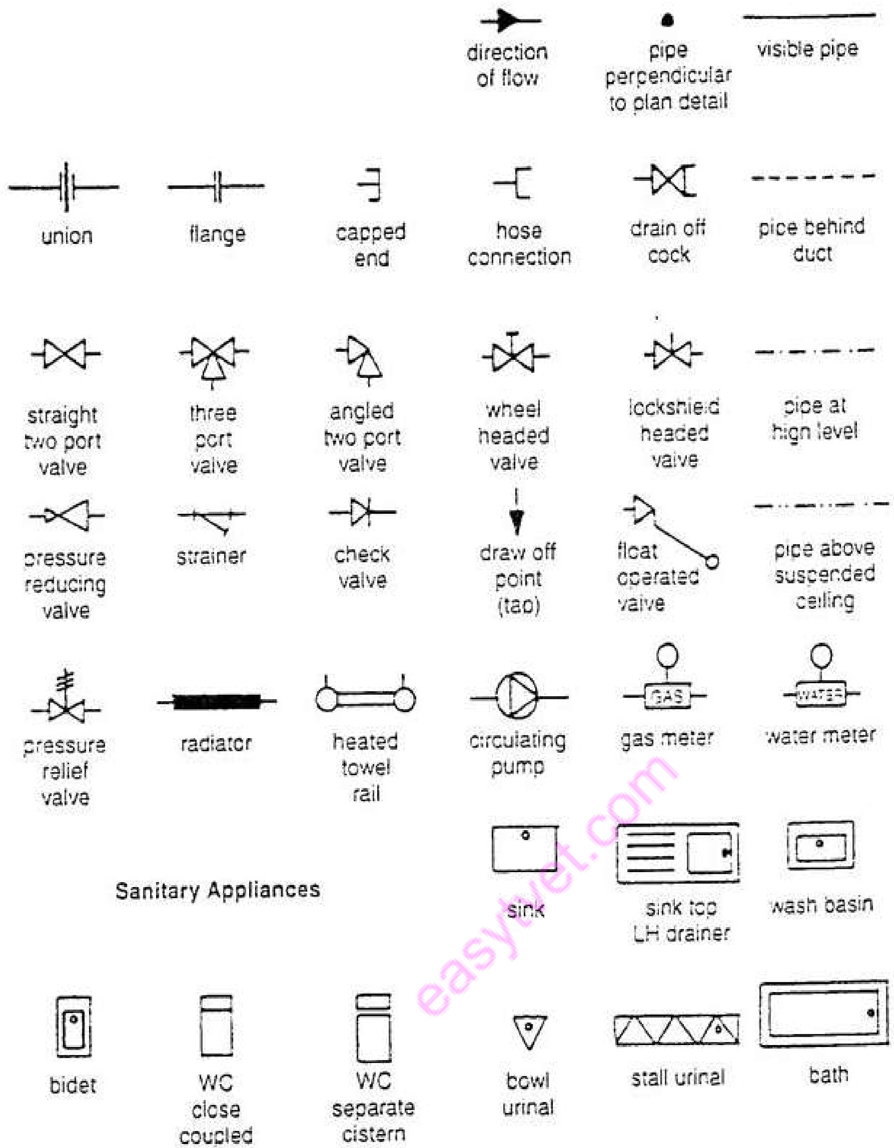
To identify individual services some of the following abbreviations may be used.

- Service Abbreviations

MWS	*Mains Water Services*
DW	*Drinking Water*
CWF	*Cold Water Flow*
CWS	*Cold Water Service*
HWSF	*Hot Water Service Flow*
HWSR	*Hot Water Service Return*
HWSVP	*Hot Water Service Vent Pipe*
FF	*Fire Fighting Services*
HRS	*Hose Reel Service*
CA	*Compressed Air*
F&R	*Flow and Return*

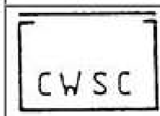
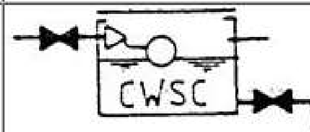
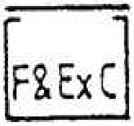
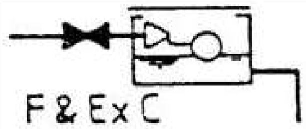
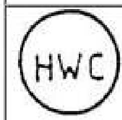
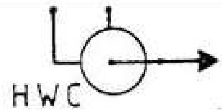
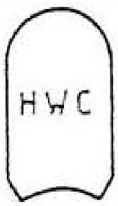
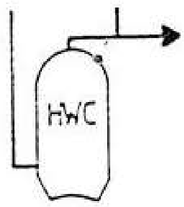
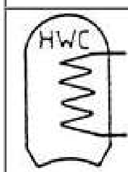
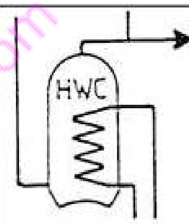
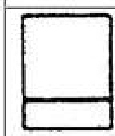
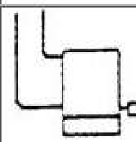
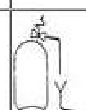
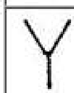
The symbols on the following pages are from the British Standards Institution and are used extensively in drawings relating to mechanical services.

Figure 92 Abbreviations for Pipe Rises/Drops



- British Standards Institution Symbols

- BSI Symbols

Symbol	Description	Application
	*Cold water storage cistern (Storage and feed cistern) (Feed Cistern)*	
	*Feed and expansion cistern*	
	*Hot water storage cylinder or tank (plan)*	
	*Hot water storage cylinder or hot store vessel (Direct types) (elevation)*	
	*Hot water storage cylinder or hot store vessel (indirect types) (elevation)*	
	*Boiler (elevation)*	
	*Temperature relief valve*	
	*Tundish*	

Dimensioning

By dimensions, the shape and size of an object are explained. A worker can complete the job according to the dimensioning.

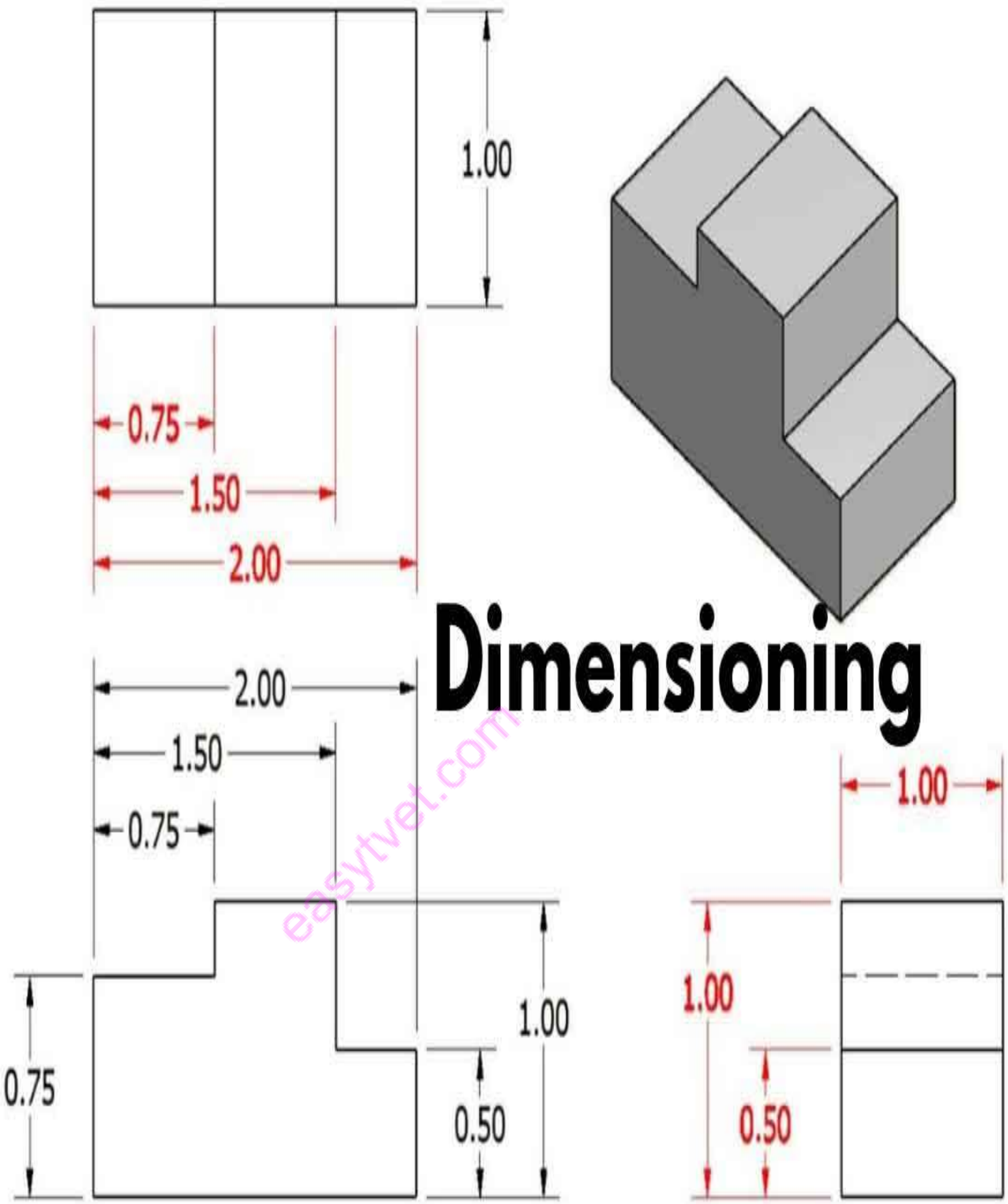
If the size of an object is represented then such a measurement is called **Size Dimension,** Similarly, if the place of an object is represented then such a measurement is called Location Dimension.

If the dimension is written in the same direction in the whole drawing, then such method is called **Unidirectional Method.**

If the dimension is written in two directions, then such method is called **Aligned Method.**

In addition to this, if dimension it is written parallel to the central line, then such method is called **Base Line Method.**

The beauty of a drawing depends on the beauty of dimensioning.



Types of Dimensioning.

There are two types of writing dimensions on a drawing.

1. Size Dimension.

2. Location Dimension.

1. **Size Dimension:**

In this type of dimension, the external size of an object is represented. Also, the sizes of different parts of a drawing are shown there.

This shows the length, breadth, and height.

Such a dimensioning is represented mostly by the front view.

2. Location Dimension:

In this type of dimensioning, the distances between different parts of the object and the distances between the centers of circles are shown.

In addition to this, the distance of the center of a circle or that of any other part from some particular point is represented.

Location dimension is divided into three different ways:

1. Center to Center Distance.

2. Center to Surface Distance.

3. Surface to Surface Distance.

Order of Dimensioning.

After completing a drawing, the following order is to be kept in mind.

This makes a drawing beautiful. It also saves time.

1. Drawing of Extension Line.

2. Drawing of Dimension Line.

3. Drawing of Arrow Heads.

4. Writing of Numerical Value.

5. Drawing of Cutting Plane Line.

6. Drawing of Leader Line.

7. Drawing of Center Line.

8. Writing of Notes and Specifications.

Systems of Dimensioning.

Following are the three systems of writing dimension.

1. Unidirectional Method.

2. Aligned Method.

3. Base Line Method.

1. Unidirectional Method:

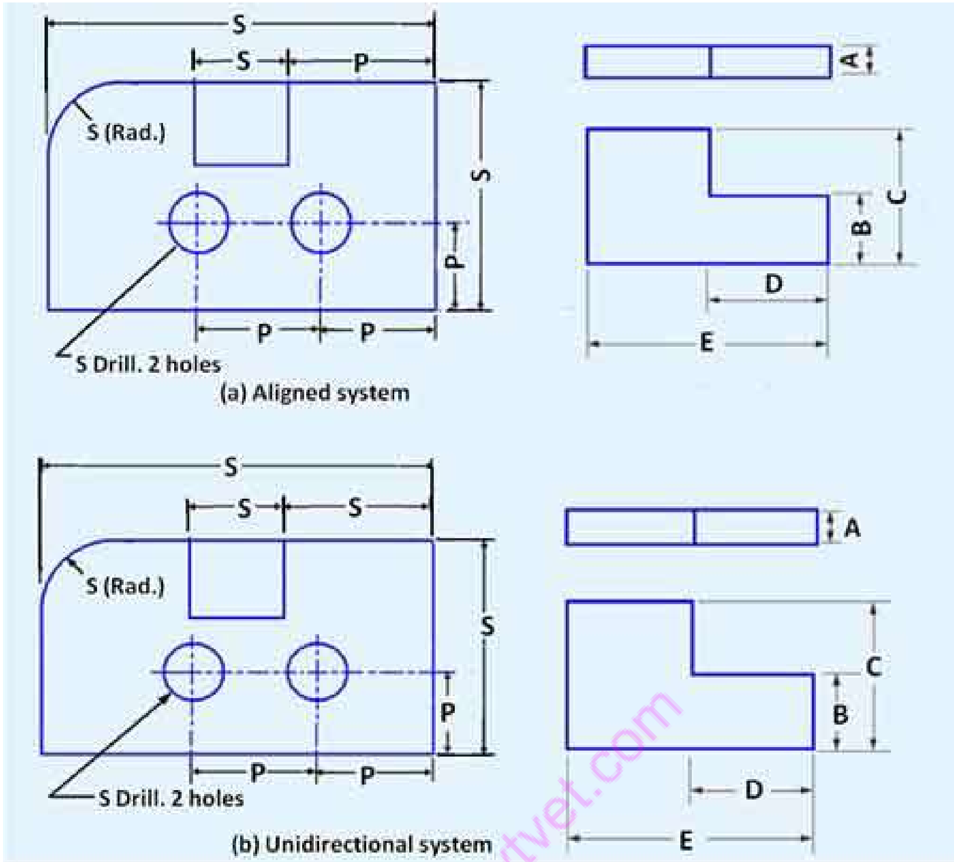
This method is mostly used in dimensioning. In this method, the whole dimension is written in the same direction in the whole drawing.

2. Aligned Method:

In this method of dimensioning, it is written in two directions in the whole drawing.

It is written upward and at the right side and is read from the bottom and right side of a drawing.

Its advantage is this that the dimensions can be written in the horizontal direction which is very easy to write.



(a) Aligned system

(b) Unidirectional system

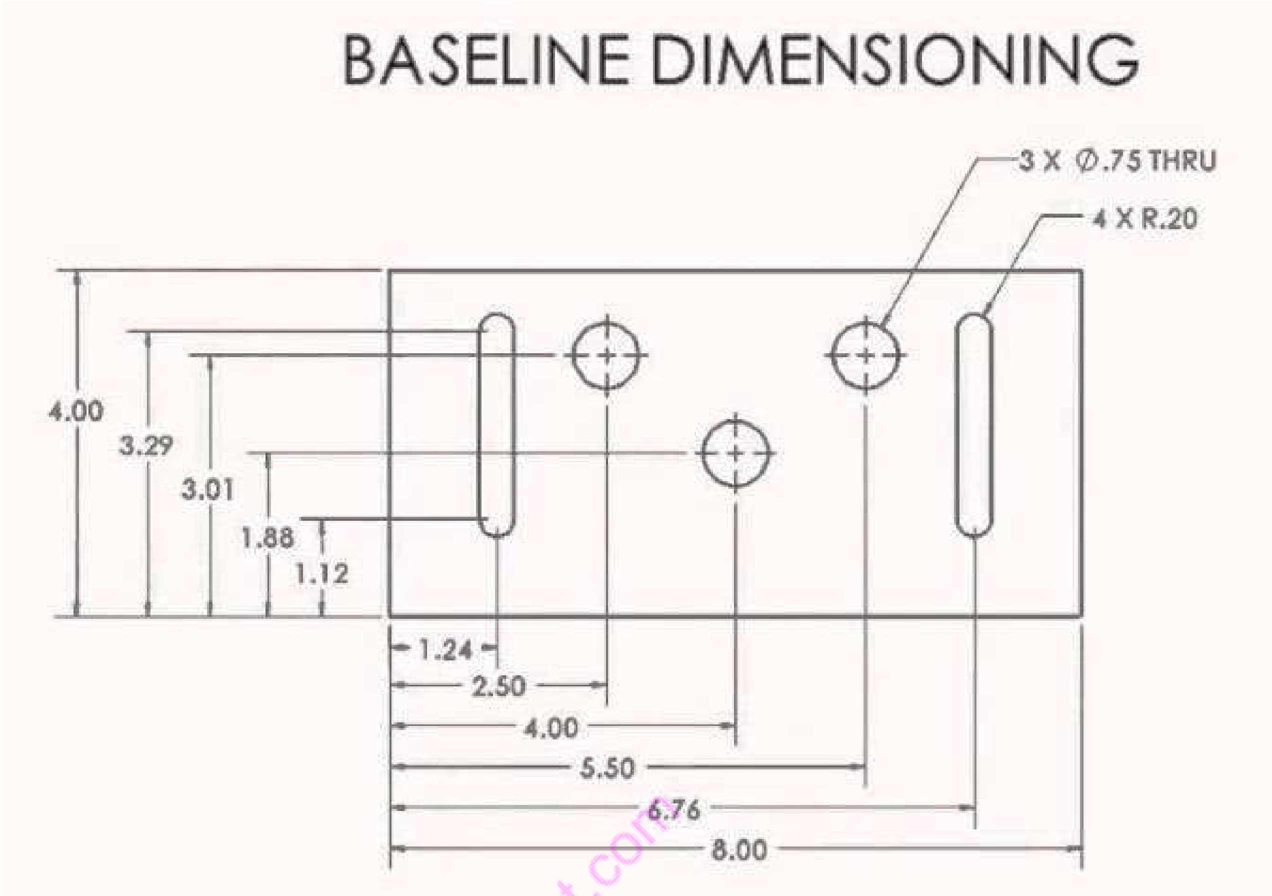
3. Base Line Method:

In this method of dimensioning, baseline is used to write the dimension of various parts of a drawing. Then all the dimensions are written parallel to the base line.

In writing dimension, the smallest one is written to the side of the object, and the biggest one is written on the external side of the object.

All other dimensions are written in between them.

In this system, the chances of mistake are very rare.



Elements of Dimensioning.

For any drawing to be workable, it is necessary that all the needful dimensions should be written on it, so that all information could be used properly.

For this purpose, the following elements are written down.

1. Dimension Line.

2. Extension Line.

3. Center Line.

4. Leader Line.

5. Arrow Head.

6. Numbers.

1. Dimension Line:

A Dimension Line is drawn for a given dimension of an object. This line should be at a distance from 10 mm to 15 mm from the object line.

For writing a dimension, this line is broken from the middle, and the dimension is written in the middle space. Alternatively, the dimension is written on it after its completion.

2H or 4H pencil is used for this purpose.

2. Extension Line:

Such lines which are drawn extending from the ends of a part of a drawing so that the dimension can be written in between them are called extension lines.

2H or 4H pencil is used for this purpose.

There should be a distance of 1 mm between them and the object line.

3. Center Line:

Such a line is used to represent the center of a cylindrical part of a drawing.

For example, a hole shaft, etc.

This should be extended up to 1 mm distance from the object line.

4. Leader Line:

Any note or specification is written on an object with the help of this line. This is drawn with 2H or 4H Pencil.

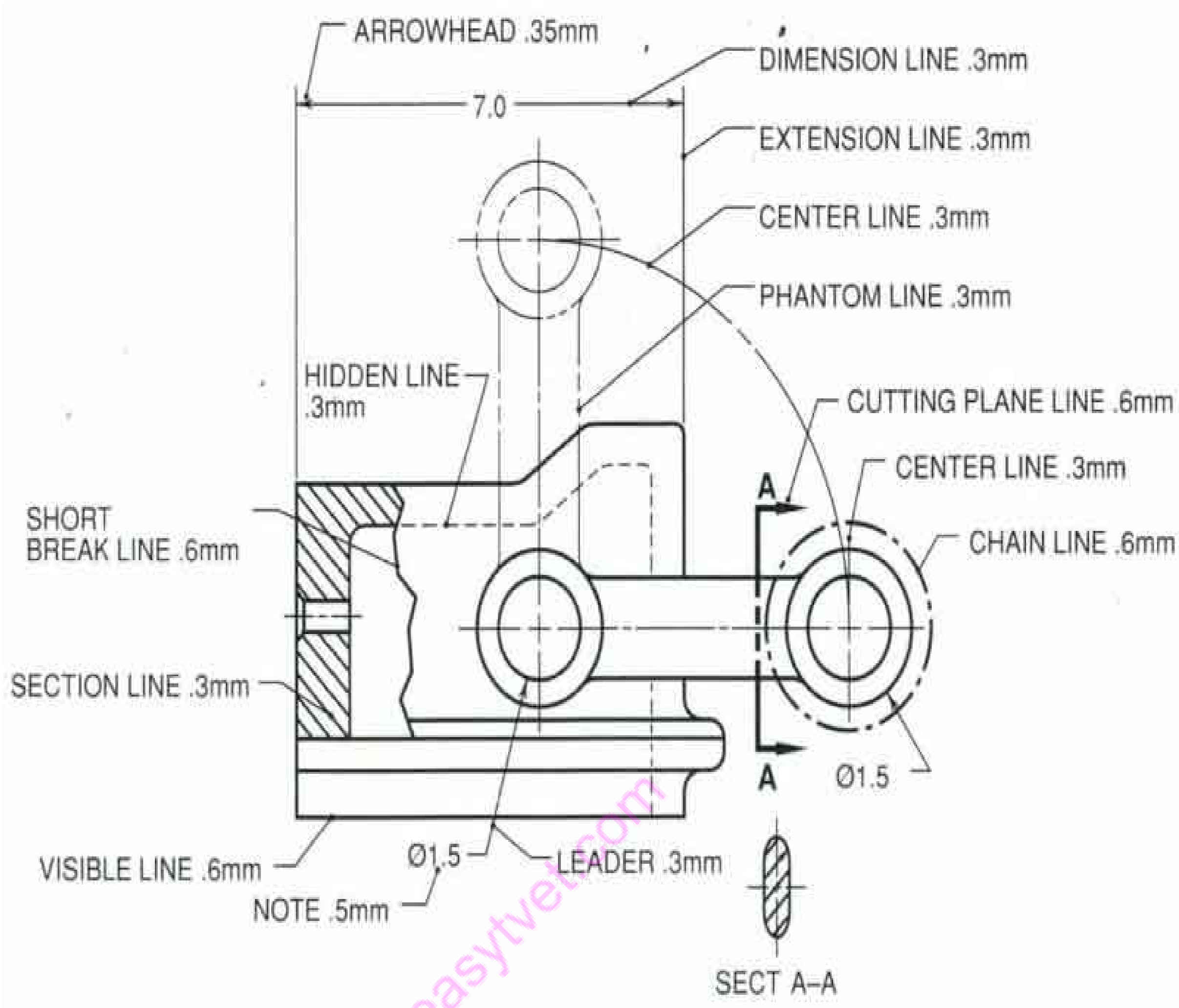
It consists of a circle and a leader.

5. Arrow Head:

This is used at the ends of a dimension and the end of a leader. The length of the arrow-head used in engineering drawing 3 mm.

6. Numbers:

After the completion of any geometric shape of an object, the writing of its size is desired. Numbers are used for this purpose. The height of the number is kept 3 mm.



Principles of Dimensioning.

After completing a drawing, it is necessary that its measurements and notes should be written in such a way that they can be read easily.

Follow are the Principles that have been devised for this purpose.

1. The dimensions should be given on such view which illustrates the true shape and size of an object.

2. As far as possible the dimensions should be given outside a view but can be given inside as well if unavoidable.

3. All the dimensions are given in group form. Scattering of these is not correct.

4. The dimensions should be intelligibly written.

5. All the dimensions should be written parallel to the object line and the numbers should be written such that they could be read easily.

6. The dimensions should not be repeated unless necessary.

7. The unnecessary dimensions should be avoided.

8. The extension and dimension lines should not intersect in any case.

9. While giving dimension after completing a drawing, it should be kept in mind that no unit should be written with any number.

3.2.4.4. Learning activities

Below is a single line pictorial view o a dwelling house. With the help of your trainer, you are required to develop it in third and first and label it using the dimensioning methods learned.

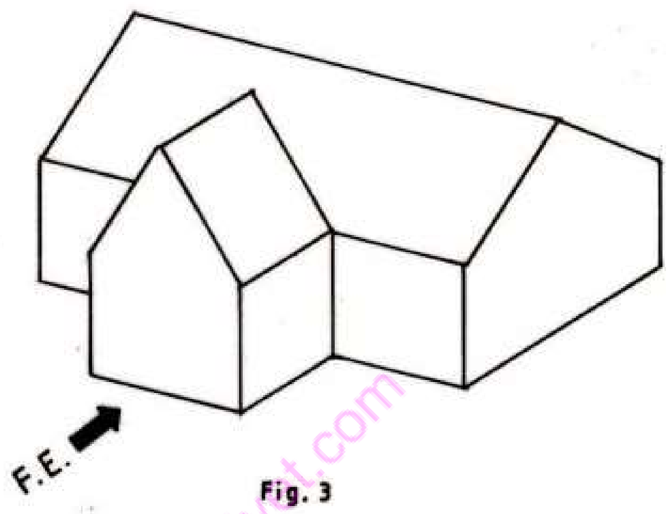


Fig. 3

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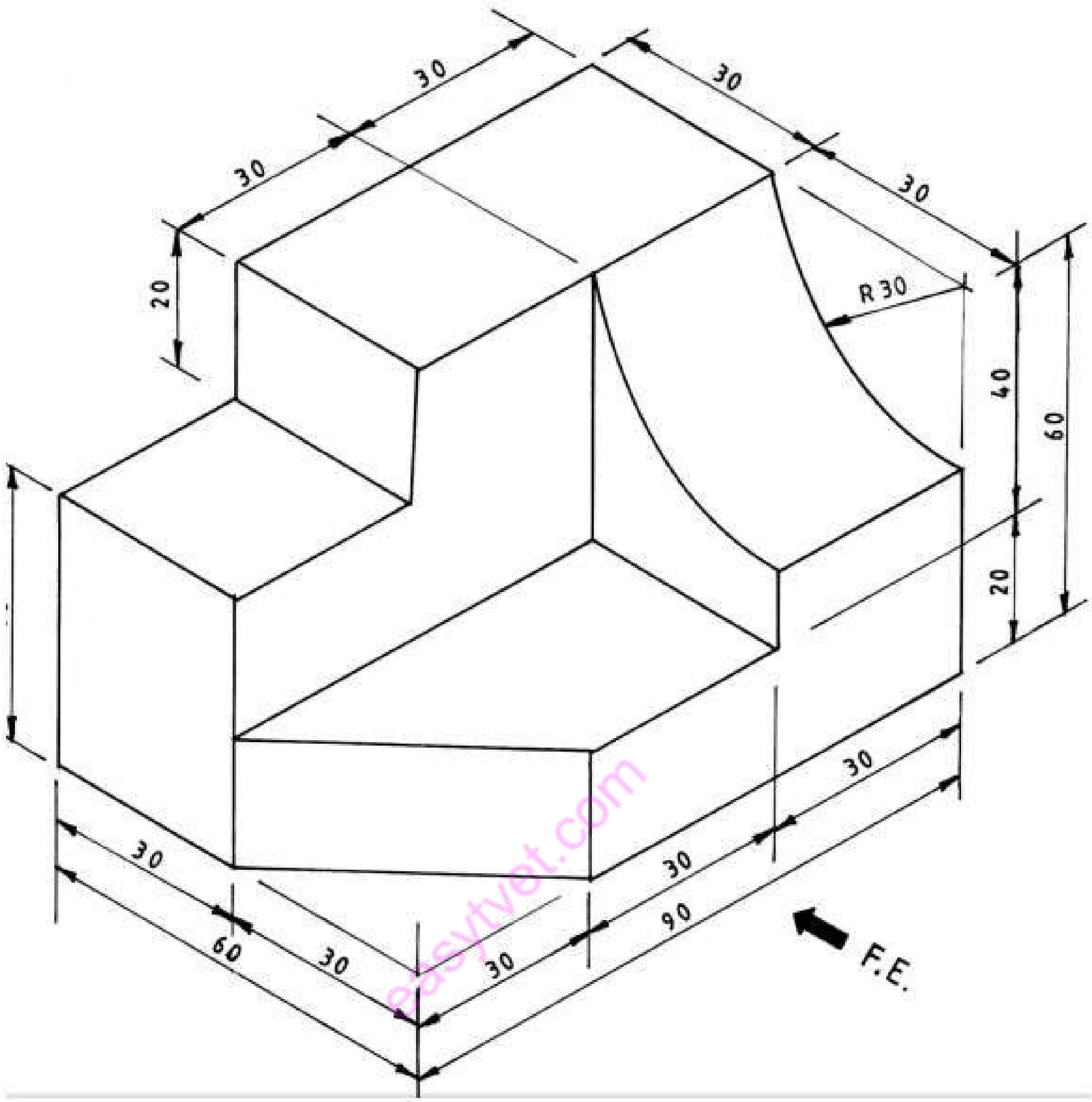
3.2.4.5. Self-Assessment

1. State any three elements of dimensioning.
2. State two types of writing dimensions

3. Figure below shows a pictorial drawing of a shaped block. To a scale of 1:1 , draw three orthographic views of the block in 3'd angle projection. Dimensions.



4. State any three principles of dimensioning.

3.2.4.6. Tools, Equipment, Supplies and Materials

i. Drawing boards
ii. T squares
iii. Set squares
iv. Drawing sets
v. Drawing paper
vi. Protractors
vii. Eraser Shield
viii. Pencils
ix. Erasers

x. Masking tapes
xi. Paper clips
xii. Drawing curves
xiii. Technical drawing software'

3.2.4.7. References

Bhatt, N. D. (2011). *Engineering Drawing.* Gujarat: Charotar Publishing house.
Morling, K. (2010). *Geometric and Engineering drawing.* London: Elsevier.

3.2.4.8. Model Answers.

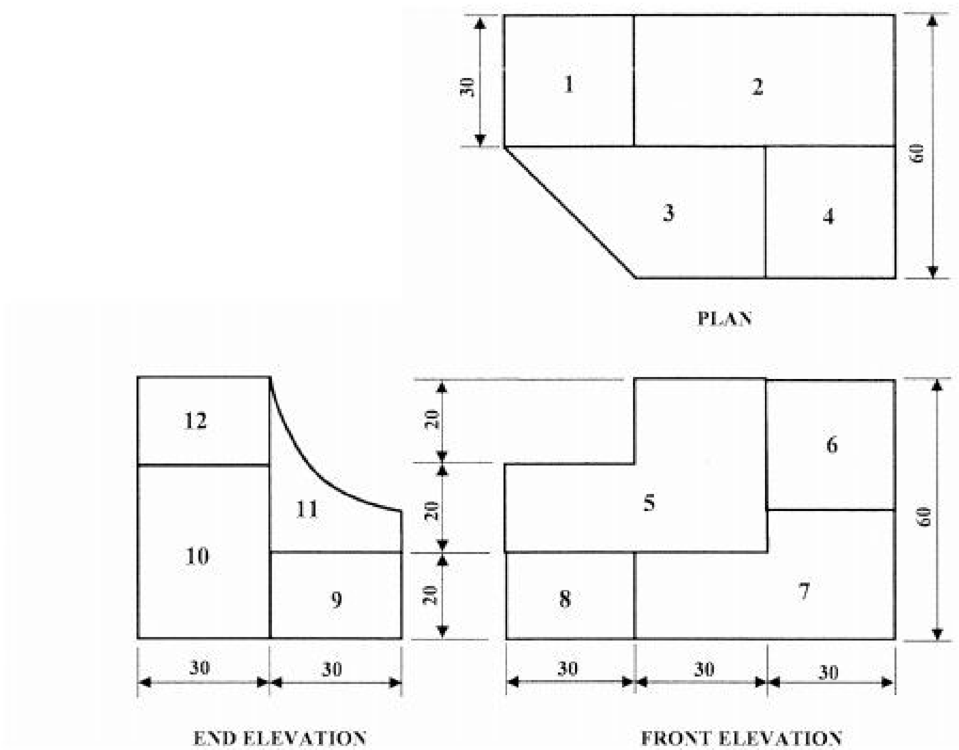
1. State any three elements of dimensioning.

- Dimension Line.
- Extension Line.
- Center Line.
- Leader Line.
- Arrow Head.
- Numbers.

2. State two types of writing dimensions

- Size Dimension.
- Location Dimension.

3. Figure below shows a pictorial drawing of a shaped block. To a scale of 1:1 , draw three orthographic views of the block in 3'd angle projection. Dimensions



3rd angle projection	=	1 mark
12 faces @ $\frac{1}{2}$	=	6 marks
6 dimensions @ $\frac{1}{2}$	=	3 marks
Naming the views	=	1 mark
Curve correctly drawn	=	1 mark
Lines drawn correctly	=	2 marks
Equal spacing of views	=	[illegible]

4. state any three principles of dimensioning.

- The dimensions should be given on such view which illustrates the true shape and size of an object.
- As far as possible the dimensions should be given outside a view but can be given inside as well if unavoidable.
- All the dimensions are given in group form. Scattering of these is not correct.
- The dimensions should be intelligibly written.
- All the dimensions should be written parallel to the object line and the numbers should be written such that they could be read easily.
- The dimensions should not be repeated unless necessary.
- The unnecessary dimensions should be avoided.

- The extension and dimension lines should not intersect in any case.

2.2.5 Learning outcome 5:Apply computer Aided design

3.2.5.1. Introduction to the learning outcome

The focus of this specific learning outcome is to introduce the different working drawings and their purpose during the planning of plumbing works by the use of computer software to design and document a products design process.

3.2.5.2. Performance Standard

The following performance criteria will be required to be met by trainees to be considered competent:

1. Plane geometry drawings are developed using CAD
2. Geometry drawings are developed using CAD
3. Orthographic drawings are developed using CAD

3.2.5.3. Information Sheet

CADD is an electronic tool that enables us to make quick and accurate drawings with the use of a computer. Drawings created with CADD have a number of advantages over drawings created on a drawing board. CADD drawings are neat, clean and highly presentable.

a) Terms and concepts

Chamfer Creates a chamfered corner at the intersection of two selected lines

Ortho mode

Is the mode which is used for vertical axis.

Orthographic Projection The method of showing 2 or more views of same part in drawing a term used is orthographic projection.

Pan-is terminology used to move around drawing by dragging drawing area around your screen.

Polar coordinates-to input point based on distance and angle in your drawing.

Snap-this is the drawing mode that allows you to snap your cursor to precise points laid out in a grid pattern.

CAD

Computer-Aided Design, a term usually applied to the software.

CADD

Computer-Aided Design and Drafting.

CAE

Computer-Aided Engineering.

Callout

An annotation typically comprised of a leader line and a balloon.

CAM

Type of gear used to achieve irregular motion.

Coordinates / Coordinate System

A set of magnitudes represented as x, y, and z, coordinates that determine the relative positioning of an object within the drawing space.

Coplanar surface

A given number of surfaces that follow the same planar path.

Cross Section

A 2D, cut-through view of a 3D object.

Draft

Typically used to describe the 2D and isometric line drawings created from 3D objects and engineering drawings.

Draftsman/Draftsperson

The person responsible for creating drafts.

Engineering Drawings

2D drawings generated for manufacturing.

Entity

A given single object in a drawing. Does not include things like text style or dictionary items.

Exploded view/Exploded drawing

A 2D visualization of a disassembled assembly.

Extrude

A technique of dragging a 2D dimensional boundary, face or polygon into a 3D object, either along a single axis or with a taper.

(Sourced from https://blog.bricsys.com/tuesday-tips-glossary-of-cad-terms/)

Introduction

The term computer aided design (CAD) refers to the use of computers to create graphical representations of physical objects to assist in the design process. It can also refer to the use of computers to prepare presentational images or to prepare production information enabling objects to be manufactured, although sometimes this is referred to as computer aided drafting as it does not necessarily involve designing. In combination, these processes may be referred to as computer-aided design and drafting (CADD).

CAD can be used to create 2D or 3D representations and can also be used to generate animations and other presentational material. It may allow the addition of supplementary information such as dimensions, descriptions of components, references to specifications and so on.

Specialist CAD software is available for specific purposes, and a wide range of software applications have been developed for use in the design and construction of built assists such as buildings.

Computer aided manufacturing

The combination of computer aided draughting and computer aided manufacturing (CAM) has allowed computer numerical control (CNC) of highly automated end-to-end component design and manufacture. Computers can produce files that translate design information into commands to operate machines, singularly or collectively, to perform pre-set sequences of tasks in the production of building components.

See Computer aided manufacturing for more information.

More recently, the range of possibilities has been increased further by the introduction of economically viable 3D printing.

BIM

The introduction of building information modelling (BIM) allows further reduction of errors and improvement to the quality of information and can enable the automatic generation of quantities, cost estimates, ordering and tracking information.

BIM is a very broad term that describes the process of creating and managing a digital model of a building or other facility (such as a bridge, highway, tunnel, and so on), which includes:

Level 0: Unmanaged CAD.

Level 1: Managed CAD in 2D or 3D.

Level 2: Managed 3D environment with data attached but created in separate discipline models.

Level 3: Single, online, project model with construction sequencing, cost and lifecycle management information.

See Building information modelling for more information.

Common standards and collaborative practices

Particularly important to the effective use of CAD is the ability to share and re-use information, and this requires the disciplined application of agreed standards of drawing preparation across project teams. This means that the effective use of CAD is as much about collaborative practices as it is about software.

Project standards can be formalised as standard methods and procedures (SMP's) which should be agreed as early in the project as possible and should describe how information is structured, how it will be produced and how it will be managed and exchanged.

The SMP might include agreed standards and procedures for:

- Software.
- Layering.
- Zoning.
- Co-ordination
- Origin.
- Orientation.
- Fonts, line types and weights.
- Dimensions, abbreviations and symbols.
- File structure and file naming.
- Standard templates (for example, drawing titles).

- Page sizes and scales.
- Permissions and change control procedures.

The great variety in the extent to which CAD and building information modelling can be used on a project means that it is important to clearly define what is expected and to set this out in tender documents and appointment documents.

b) Geometry drawings

c) Orthographic drawings

4.1 Plane geometry drawings are developed using CAD

Introduction to CAD

Computer Aided Drafting (CAD) is a process of preparing a drawing of an object on the screen of a computer. There are various types of drawings in different fields of engineering and sciences.

In the fields of mechanical or aeronautical engineering, the drawings of machine components and the layouts of them are prepared. In the field of civil engineering, plans and layouts of the buildings are prepared. In the field of electrical engineering, the layouts of power distribution systems are prepared. In all fields of engineering use of computer is made for drawing and drafting.

The use of CAD process provides enhanced graphics capabilities which allows any designer To:

- Conceptualize his ideas
- Modify the design very easily
- Perform animation
- Make design calculations
- Use colors, fonts and other aesthetic features.

Reasons for Implementing a CAD System

a) **Increases the productivity of the designer**: CAD improves the productivity of the designer to visualize the product and its component, parts and reduces the time required in synthesizing, analyzing and documenting the design

b) **Improves the quality of the design**: CAD system improves the quality of the design.

A CAD system permits a more detailed engineering analysis and a larger number of design alternatives can be investigated. The design errors are also reduced because of the greater accuracy provided by the system

c) **Improves communication**: It improves the communication in design. The use of a CAD system provides better engineering drawings, more standardization in the drawing, better documentation of the design, few drawing errors and legibility.

d) **Create data base for manufacturing**: In the process of creating the documentation for these products, much of the required data base to manufacture the products is also created.

e) **Improves the efficiency of the design**: It improves the efficiency of the design process and the wastage at the design stage can be reduced.

APPLICATION OF CAD:

There are various processes which can be performed by use of computer in the drafting process:

a) **Automated drafting**: This involves the creation of hard copy engineering drawings directly from CAD data base. Drafting also includes features like automatic dimensioning, generation of cross – hatched areas, scaling of the drawing and the capability to develop sectional views and enlarged views in detail. It has ability to perform transformations of images and prepare 3D drawings like isometric views, perspective views etc.,

b) **Geometric modeling**: concerned with the computer compatible mathematical Description of the geometry of an object. The mathematical description allows the image of an object to be displayed and manipulated on a graphics terminal through signals from the CPU of the CAD system. The software that provides geometric modeling capabilities must be designed for efficient use both by computer and the human designer.

BENEFITS OF CAD:

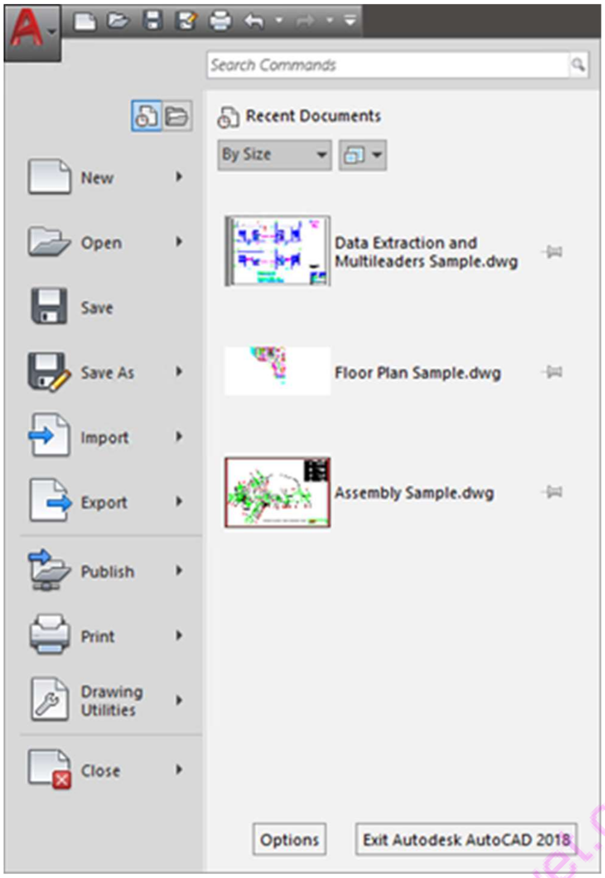
The implementation of the CAD system provides variety of benefits to the industries in design and production as given below:

- Improved productivity in drafting
- Shorter preparation time for drawing
- Reduced manpower requirement
- Customer modifications in drawing are easier
- More efficient operation in drafting
- Low wastage in drafting

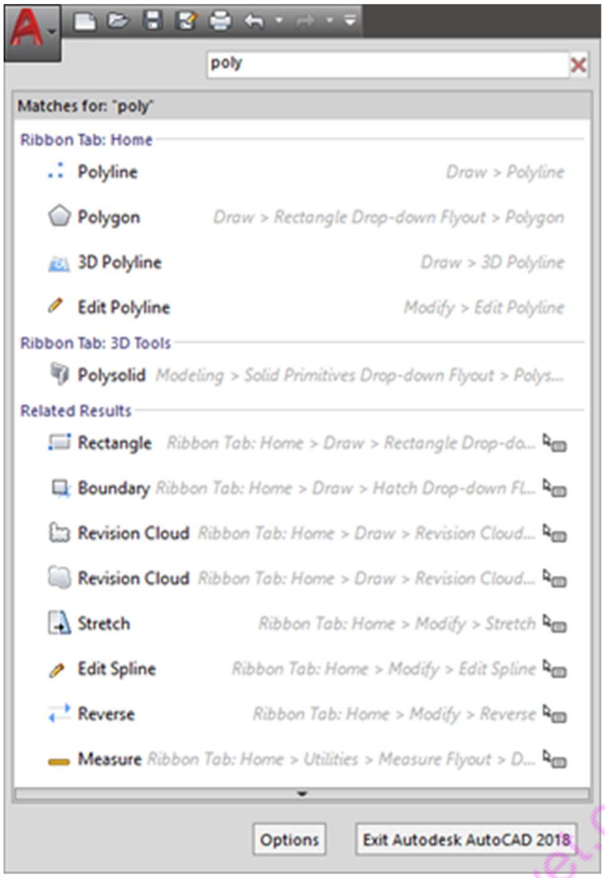
- Minimized transcription errors in drawing
- Improved accuracy of drawing
- Assistance in preparation of documentation
- Better designs can be evolved
- Revisions are possible
- Colours can be used to customize the product
- Production of orthographic projections with dimensions and tolerances
- Hatching of all sections with different filling patterns
- Preparation of assembly or sub assembly drawings
- Preparation of part list
- Machining and tolerance symbols at the required surfaces
- Hydraulic and pneumatic circuit diagrams with symbols
- Printing can be done to any scale

Application Menu

The first thing you might see after launching AutoCAD is the Application Menu, in the far upper left corner. In AutoCAD, it's generally contains a big red "A". (Other products generally have a different color and letter). When you single-click this button a menu drops down that contains some of the same items in the QAT, plus more. Probably more importantly, the application menu contains links to your most recently accessed drawings, and sheet sets. With the click of a button you can change this to a list of currently open drawings. *(Tip: Do not double-click on the Application Menu button, unless you want to shut-down AutoCAD)*

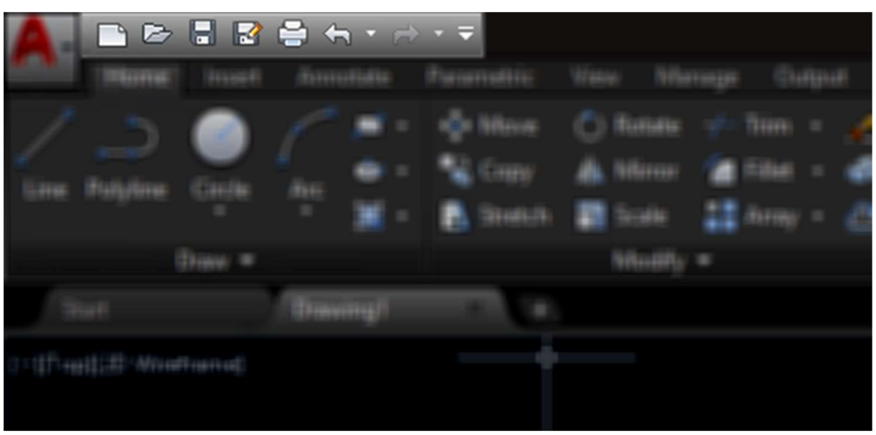


One feature of the Application Menu that many people overlook is the Search Commands portion. You can type in the full or partial name of any command and a search will be performed on the related commands in the menu. This can be helpful when you can't quite remember that command name or its location. In the image below, we have entered "poly" in the search box, and you can see the results.



Quick Access Toolbar (QAT)

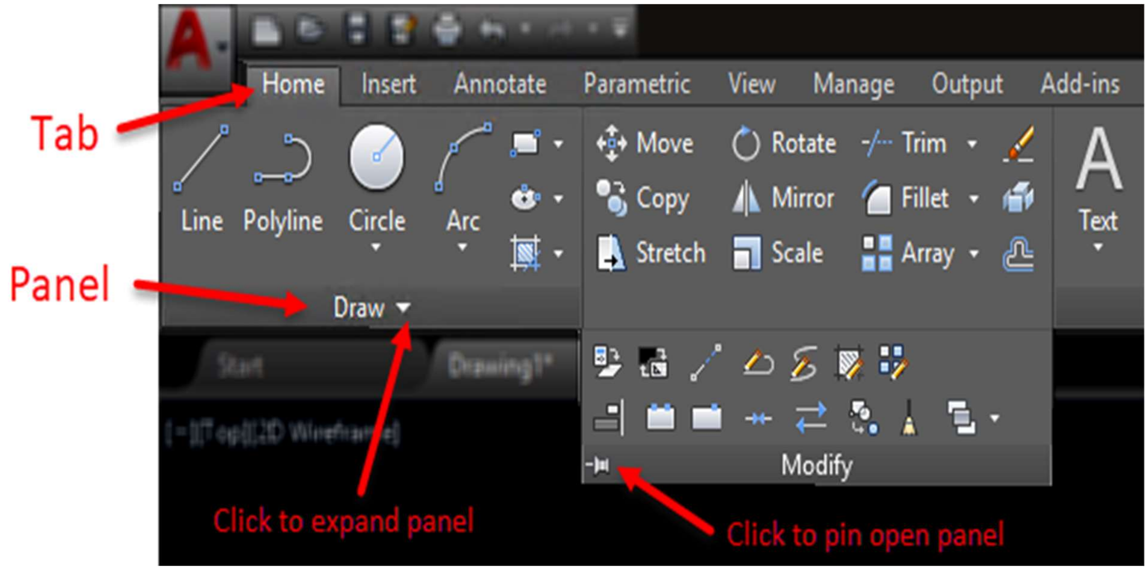
Right next to the At the top of the UI, in the title bar area, is the Quick Access Toolbar, or QAT. By default the QAT contains icons for the following commands: Qnew, Open, QSave, SaveAs, Plot, Undo, and Redo. But like most other UI elements, you can customize this to meet your desires. Below is the stock QAT, highlighted to show its position.



Ribbon

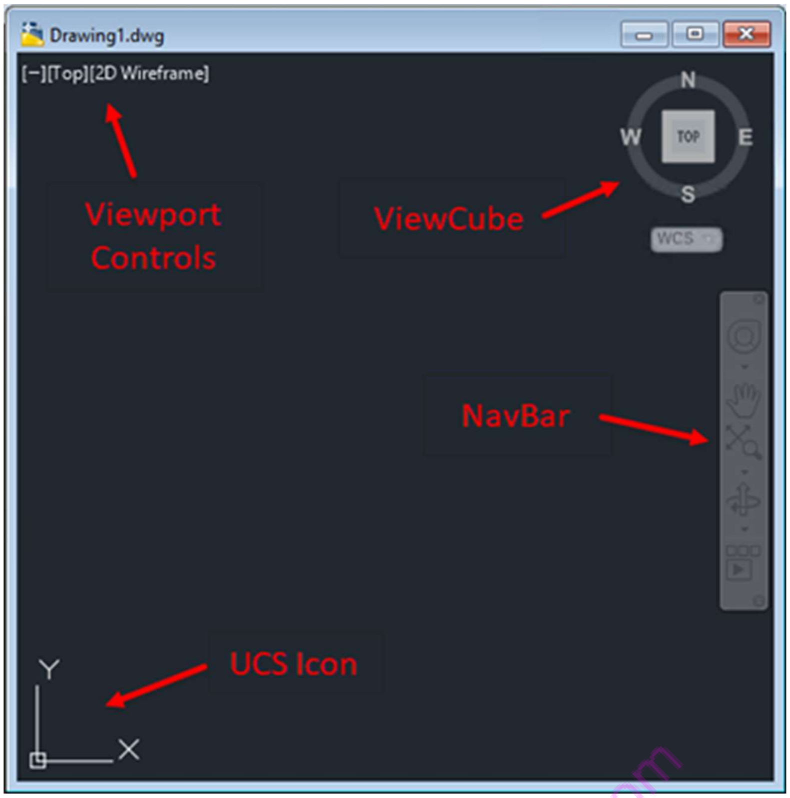
The ribbon is a UI tool that first appeared in AutoCAD 2009. It contains various commands organized into tabs and panels. It can be heavily customized by administrators and end users.

Contextual tabs are very powerful, they appear with panels of commands and options relating to whatever task is at hand and/or whatever entity type is selected. For example, if a HATCH object is selected, a contextual tab with hatch editing command appears automatically.



In-Editor elements

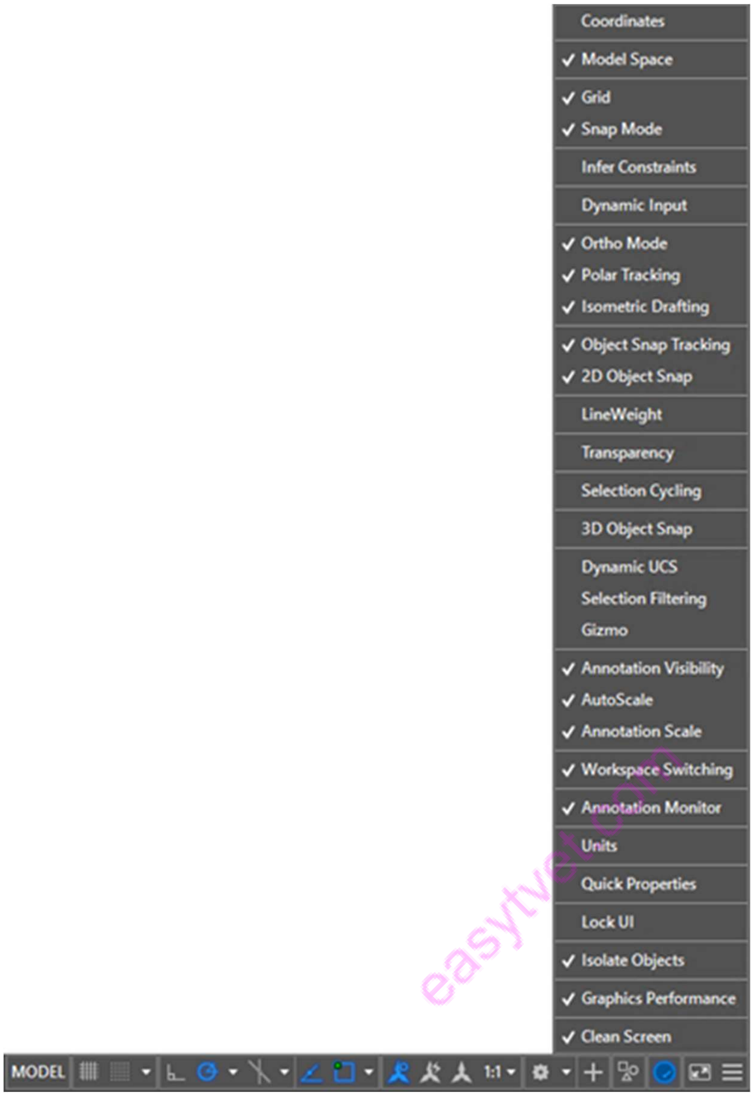
There are a few elements you may find inside the drawing editor, and are shown in their default location in the image below. The visibility of each of these can be controlled by the user. The viewport controls are in the upper left corner, and allow you to change the view and visual style. The Viewcube is in the upper right, from which you can change the view and UCS. Just below that is the NavBar, that gives you controls for zooming, panning, orbiting, and more. Lastly, in the lower left hand corner, is the UCS icon, which can tell you at a glance if you are in WCS, and/or the general orientation of the UCS.



Status Bar

Moving to the bottom of the application, you will find the Status Bar. Since AutoCAD 2015, the status bar contains icons only. By default several icons are not enabled, so you might want to turn them on. We believe Autodesk does this because on a small monitor, all of the icons may not fit across on one row. But the icons will wrap up to a second row if needed, and on any decent sized monitor these days, at 1920×1080 resolution, you can enable all of the status bar icons and they fit with ease.

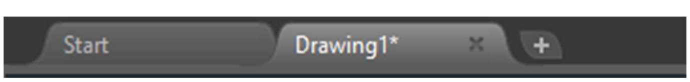
Below is a stock status bar, along with the control icon  on the far right, expanded to show you the other available icons (*Click on the image below for a full size version*)



You can hover your cursor over each icon to find its purpose. Generally speaking, gray means the toggle is off, and blue means the toggle it on.

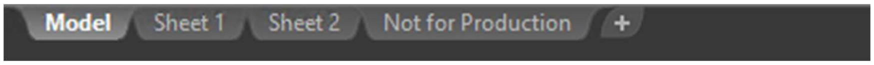
File Tabs

File tabs provide access to all open documents in a minimal amount of space. Each open document has its own tab. Left-click on a tab to make it current, and right-click on a tab to access more options, such as Save and Close. There is always a tab containing a plus sign to open a new document using the QNEW command. By default, File Tabs are oriented at the top of the documents, below the Ribbon.



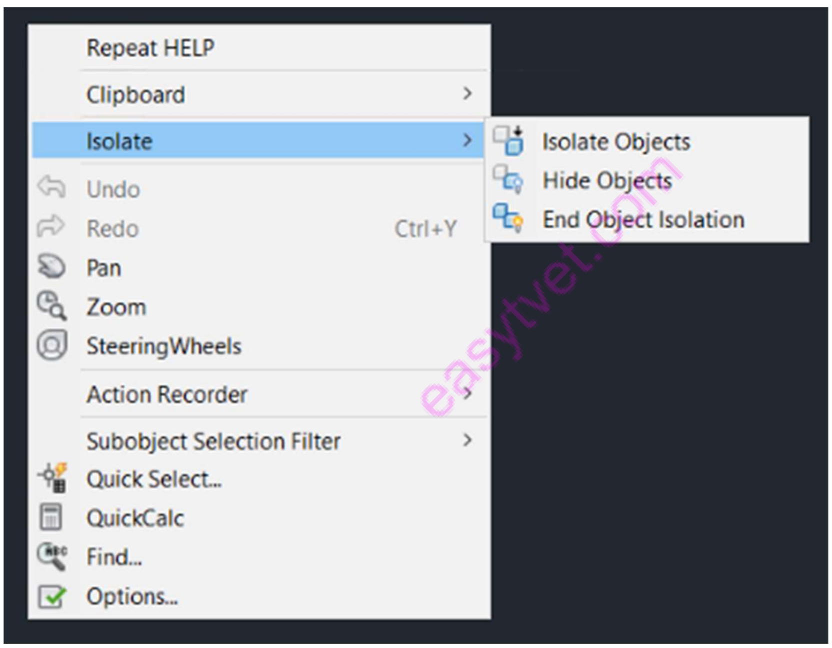
Layout Tabs

Layout tabs provide access to Model Space and each Layout in a given document. Left-click on a tab to make it current, and right-click on a tab to access more options such as Print, Move, or Rename. There is always a tab containing a plus sign for the creation of a new layout. By default, Layout Tabs are oriented at the bottom of the editor window and if the command line is docked, below that – in the status bar area.



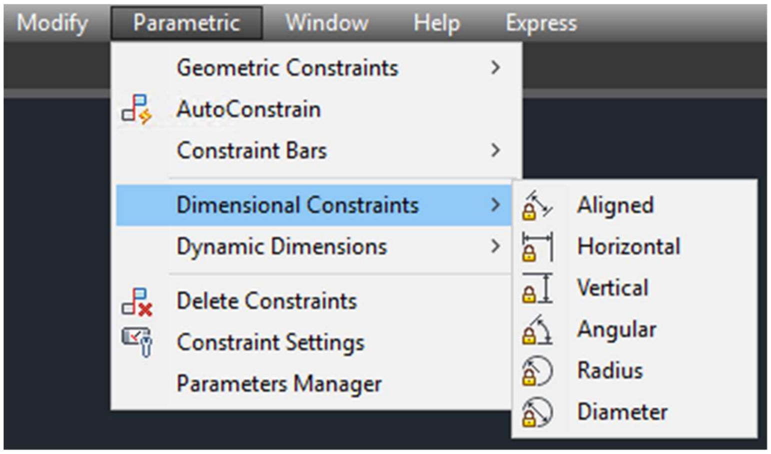
Shortcut Menu

By default, with no command active, if you right-click in the drawing editor, you will get the Shortcut Menu. This pop-up menu contains recent commands, and other common commands. You can customize this menu, like most other UI items. If there is a command active, a different menu may appear when you right-click. This behavior is controlled by the SHORTCUTMENU system variable.



Drop-Down Menus

Drop-down, or pull-down menus have been around since almost the beginning of AutoCAD, long before Windows was a platform. A top level clickable name reveals commands and/or sub menus below. These commands support macros and even autolisp statements. The menu disappears when a command is selected and/or the menu loses input focus. Drop-down menus are not enabled by default. You can turn them on by entering the command MENUBAR and setting it to 1. An example of a drop-down menu can be found below:



Toolbars

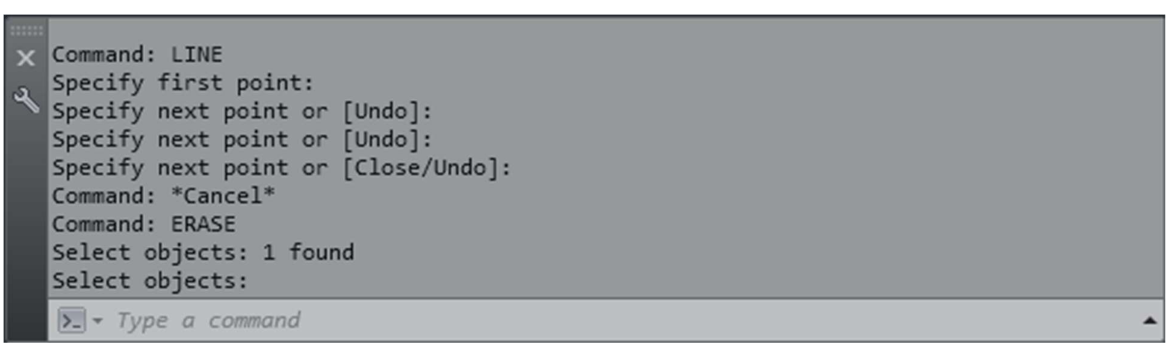
Toolbars go back to the early 1990's in AutoCAD. These are flat panels that contain buttons and or drop-down lists. Each button contains an icon and a macro to perform a command or macro. Toolbars can be floating or docked.

Palettes

There are various palettes available in AutoCAD. Palettes are special windows that can docked, floating and made to collapse when not in use. You do not have to close palettes in order to work with graphic data on screen. Most palettes support transparency (with proper hardware support) to allow them to remain on screen during AutoCAD commands.

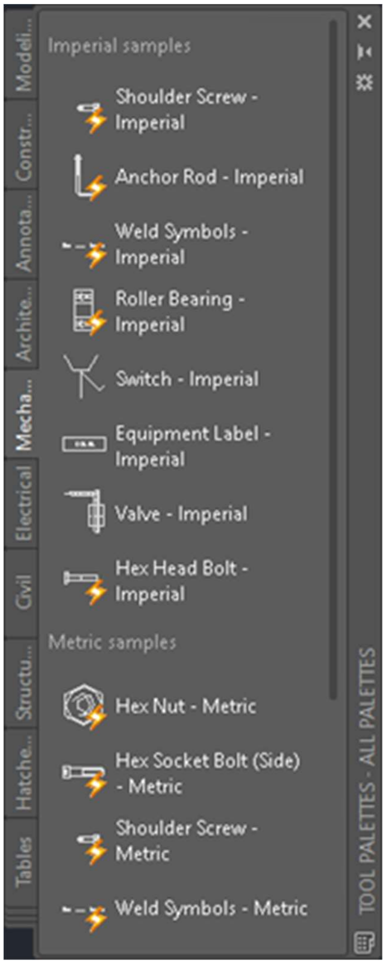
Command Line

The command line is a palette where you can type in command names and/or command responses, and the view the history of both. If the command line is docked, it has a fixed number of visible lines. Floating command line palettes can expand when needed to show you more data. The F2 key in both cases will toggle open/closed, a larger command line history window. A typical floating command line is shown here:



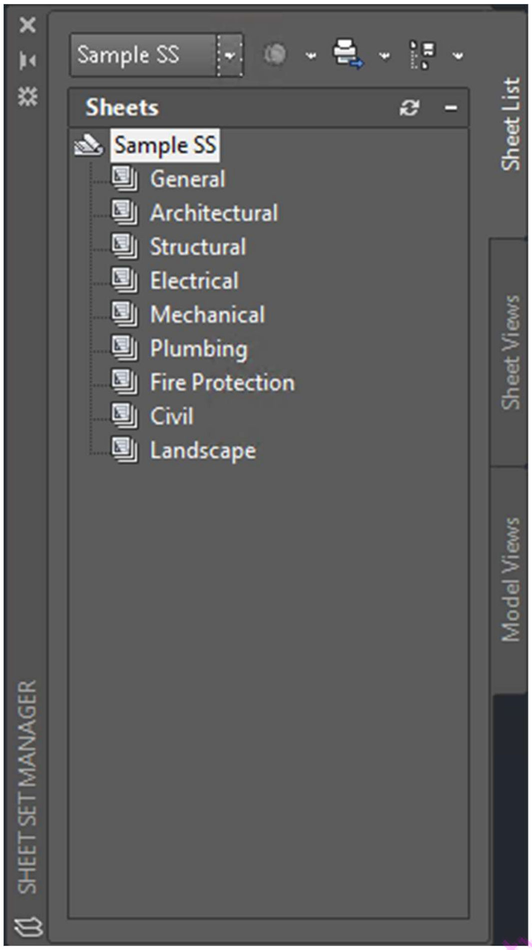
Tool Palette

Tool Palettes contain buttons to insert blocks, execute commands, create hatches, just to name a few items. Users are free to customize the content. A sample is shown below:



Sheet Set Manager

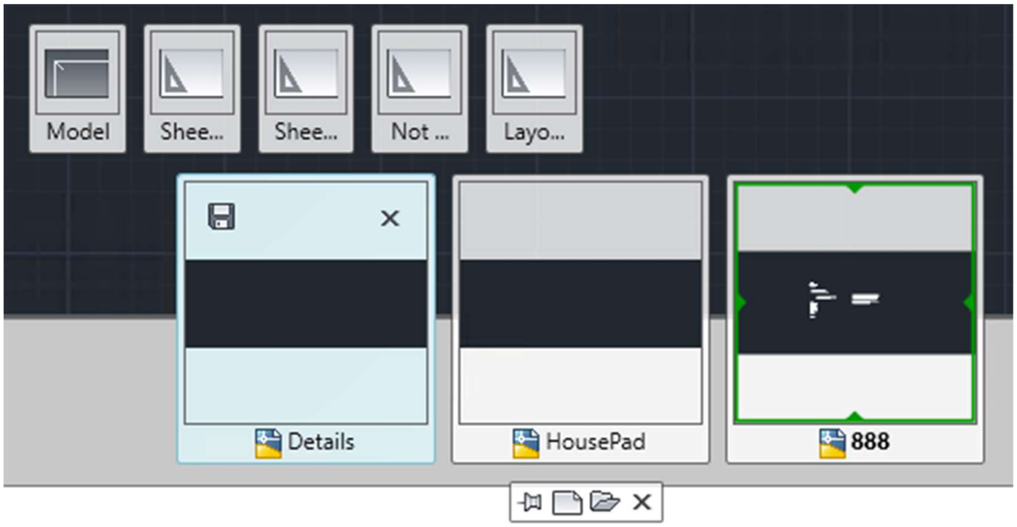
The Sheet Set Manager is a tool that allows you to organize sheets, streamline printing and archiving, and automate annotation on drawing sheets among other uses. A sample is shown below:



There are many other palettes, such as the Quick Calculator, Drawing Recovery Manager, Visual Styles Manager, the Materials Browser, etc.

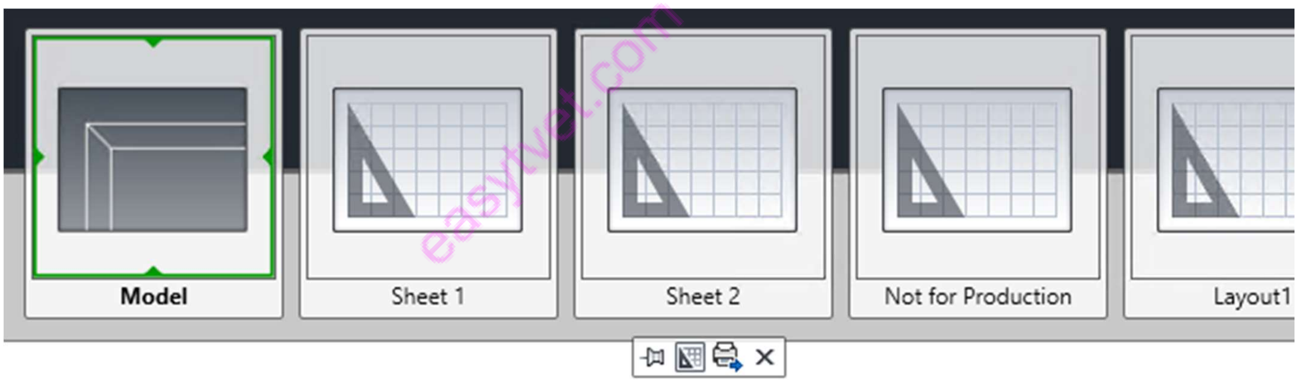
Quick View Drawings

Before File Tabs, there was Quick View Drawings. Although no longer enabled by default as a UI element, this command still works from the command line (Command: QVD). It reveals a miniature preview of each open document, and allows you to switch to another document. As the mouse is hovered over a document preview, the layouts of that drawing appear, allowing you to switch directly to a selected layout.



Quick View Layouts

Introduced as sort of replacement for Layout Tabs, Quick View Layouts has suffered the same fate as Quick View Drawings. That is to say it is still part of the software, but hidden away. This command (QVL) reveals miniature previews of all of the layouts of the current open document. Hover over a preview enables the option to print it, or clicking on one switches to that layout.



Info Center

Info Center has been through a few iterations and name changes since it was introduced. It resides in the Title Bar area, just to the left of the Windows control buttons. It contains a help search bar, Autodesk A360 sign in, social media links, and a Help drop-down menu. InfoCenter has been linked to excessive "phoning home" and is frequently disabled and hidden by many CAD managers. There is no UI method of controlling the visibility of this element, it must be done in the registry, or with a 3rd party add-on such as this one. Below is the default InfoCenter bar.

Screen Menu

The Screen Menu goes back to the beginnings of AutoCAD on DOS and UNIX. The Screen Menu is composed of nested menus. Clicking on one entry usually replaces the screen menu contents with another menu, until you get to a particular command. There is always a back and/or home choices too. Most people do not know it still exists in AutoCAD 2018 today. To access it, you must know the secret code.

Well, it is not too secret, just type in.

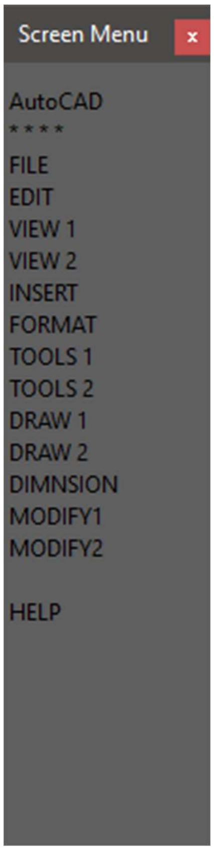
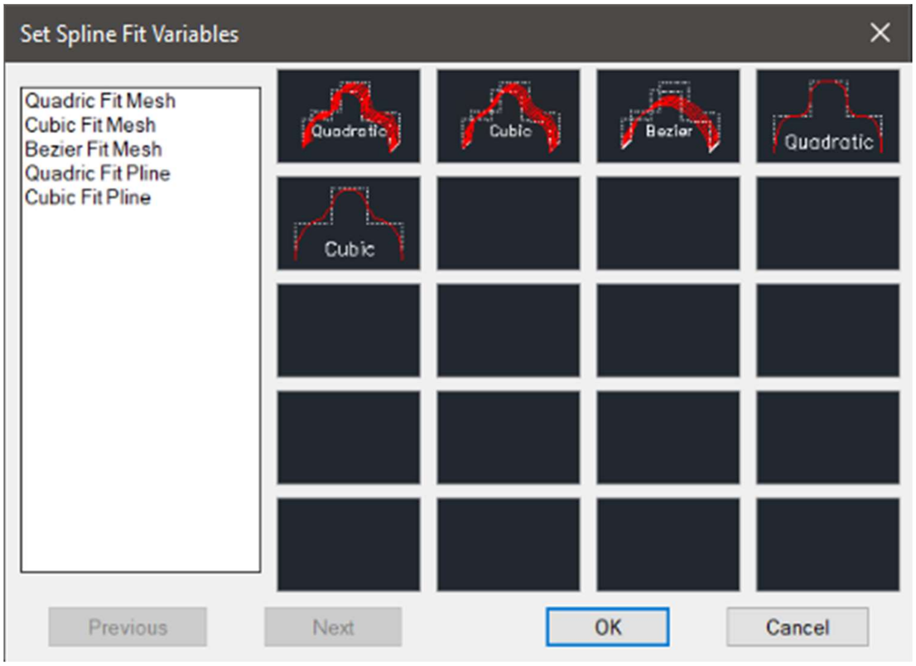


Image Tile Menu

Last, but not least, unless you've been around for ~20 years or so, you have probably never seen an Image Tile Menu. We were able to actually get one of these to work in AutoCAD 2018 as seen below. These were largely replaced by Tool Palettes and Design Center around the AutoCAD 2000 era.



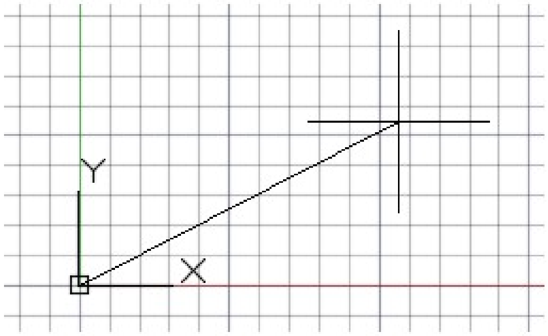
Lines

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 Cartesian coordinates 0,0. It's generally 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.

Grid Display

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

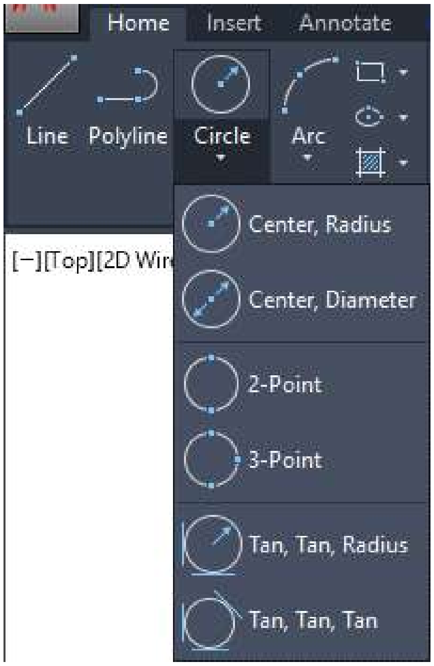
Lines can serve as reference and construction geometry such as

- Property line setbacks
- The mirror line of a symmetrical mechanical part
- Clearance lines to avoid interferences
- Traversal path lines

Circles

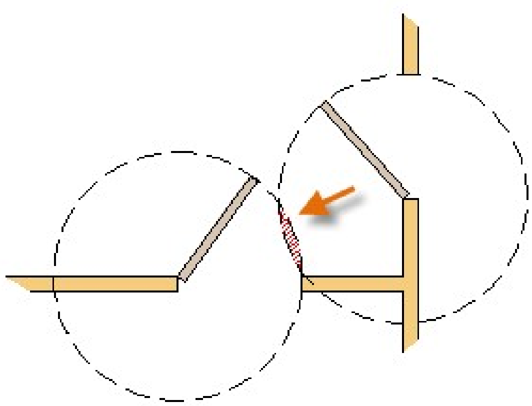
The default option of the CIRCLE command requires you to specify a center point and a radius.

The other circle options are available from the drop-down:



Alternatively, you can 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

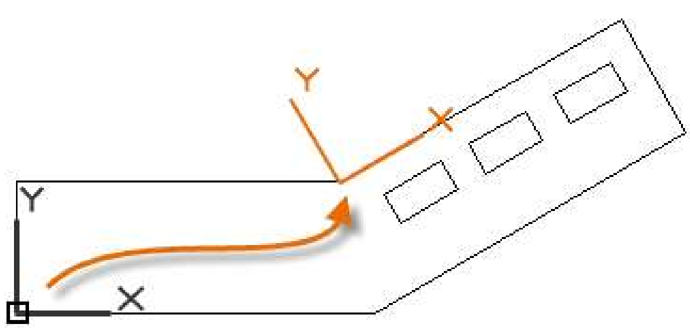
- Geometry that needs to have fixed-width segments
- Continuous paths for which you need to know the total length
- Contour lines for topographic maps and isobaric data
- Wiring diagrams and traces on printed circuit boards
- Process and piping diagrams

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.

The User Coordinate System (Optional)

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 and place the UCS to change the origin point and the X or Y axis.

For example, by reorienting the UCS, you can create rectangles that are automatically aligned with the X axis as shown.



To restore the user coordinate system to its original location, enter UCS in the Command window and press Enter to specify the default <World> option.

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

LIMITATIONS OF CAD

a) 32 – bit word computer is necessary because of large amount of computer memory and time
b) The size of the software package is large
c) Skill and judgment are required to prepare the drawing
d) Huge investment

SCALING OF DRAWING:

zoom command displays the object at a specified scale factor. The value entered is relative to the limits of the drawing. for example, entering 2 doubles the apparent display size of any objects from what it would be if it were zoomed to the limits of the drawing. If you enter a value followed by xp, auto CAD specifies the scale relative to paper scale units for example; entering 0.5xp displays model space at half the scale of paper space units. The following illustration shows several viewports arranged in paper space. the view in each view port is scaled relative to paper space. the first view is scaled 1=1 relative to paper space (1xp), the second is scaled 0.5=1 relative to paper space (0.5xp), and so on.

ZOOM

This increase or decreases the apparent size of objects in the current view port

At the command prompt, enter zoom

All/center/dynamic/extents/left/previous/vmax/window/<scale(x/xp)>: enter an option or value, specify a point, or press enter

TEXT: The text in software is indicated by fonts. the fonts define the shapes of the text characters that make up each character set. In AUTOCAD, you can use true type fonts in addition to AUTOCAD's own compiled shape (SHX) fonts.

A font is indicated by various parameters like

i. Style :these are four types: normal,bold,italic,underline
ii. Size: this is the size of characters
iii. Colour: there are facilities to colour the characters selecting layer.
iv. Type: different types of fonts may be used:

Mono text: COMPUTER AIDED DESIGN

Romans: COMPUTER AIDED DESIGN

Romand: COMPUTER AIDED DESIGN

Dtext: This displays text on the screen as it is entered. AutoCAD can create text with a variety of character patterns, or fonts. These fonts can be stretched, compressed, oblique, mirrored, or aligned in a vertical column by applying a style to the font .text can be rotated, justified, and made any size.

At the command prompt, enter text

Justify/style/<start point>: specify a point or enter an option

TEXT: This creates a single line of text. AutoCAD can create text with a variety of character patterns, or fonts. These fonts can be stretched, compressed, oblique, mirrored, or aligned in a vertical column by applying a style to the font.

At the command prompt, enter text

Justify/style/<start point>: specify a point or enter an option

QTEXT: This controls the display and plotting of text and attribute of objects.

At the command prompt, enter text

ON/OFF <current>: enter on or off, or press enter

TRANSFORMATIONS: These are the modifications in the drawn objects.

There are different types of transformations used

MOVE: This allows to move or displace objects a specified distance in a specified Direction

At the command prompt, enter move

Select objects: use an object selection method

Base point or displacement: specify a base point (1)

Second point of displacement: specify a point (2) or press enter

COPY: This is used for producing a duplicate copy of the drawing.

At the command prompt, enter copy

Select objects: use an object selection method

<Base point or displacement >/multiple: specify a base point(1)

For a single copy or enter m for multiple copies

ROTATE: It moves objects about a base point

At the command prompt, enter rotate

Select objects: use an object selection method

<Rotate angle >/reference: specify an angle or enter r

STRETCH: This moves or stretches objects .AutoCAD stretches lines, arcs, elliptical arcs, splines, rays and polyline segments that cross the selection window.

At the command prompt, enter stretch

Select objects: use the CPOLYGON or cross object selection method(1,2)

Base point or displacement: specify a point (3) or press

Second point of displacement: specify a point ($) or press

EXTEND: This extends an object to meet another object. Objects that can be extended include arcs, elliptical arcs, lines, open 2D, and 3Dpolylines and rays.

At command prompt, enter extend

Select boundary edges

(projmode=UCS, edge mode=no extend)

Select objects: use an object selection method

SCALE: This enlarges or reduces selected objects equally in X and Y directions

At the command prompt, enter scale

Select objects: use an object selection method

Base point: specify a point (1)

<Scale factor>/reference: specify a scale or enter r

TRACE: This creates solid lines.

From the miscellaneous tool bar choose

At the command prompt, enter trace

Trace width<current>: specify a distance, enter a value ,or press enter

From point: specify point (1)

To point: specify a point (2)

To point: specify a point (3) or press to end the command

EXTRUDE: This creates unique solid primitives by extruding existing twodimensional objects extrudes also creates solids by extruding two-dimensional objects along a specified path .we can extrude multiple objects with extrude

At the command prompt enter, extrude

Select objects: use an object selection method

Path/<height of extrusion>: specify a distance or enter p

MIRROR: This is used to producing mirror image of the object

At the command prompt enter, mirror

Select objects: use an object selection method

First point of the mirror line: specify a point (1)

Second point: specify a point (2)

OFFSET: This creates concentric circles, parallel lines and parallel curves, offset creates a creates a new object at a specified distance from an existing object or through a specified point

At the command prompt enter, offset

Offset distance: specify a distance, enter t or press enter

ARRAY: This creates multiple copies of objects in pattern. Arrays are three types.

a) Rectangular Array

b) Path Array

c) Polar Array

Rectangular Array: In this, the object is arranged in an array of rows and columns.

At the command prompt: type ARRAYRECT or select the option from MODIFY toolbar. It asks you to select objects. Select the object and press enter. By default it shows an array of 3 rows and 4 columns. The no. of rows and columns can be changed by selecting the COUnt option (OR) by selecting COLUMNS and ROWS options separately

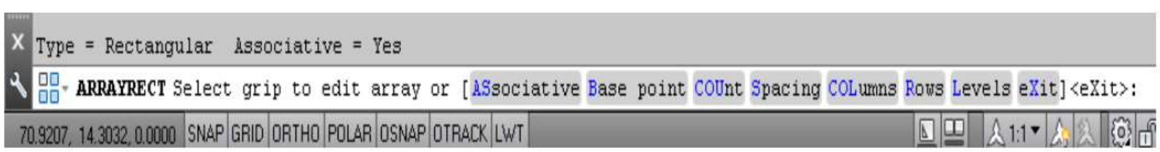


Figure 93 Array Selection

Path Array: In this, an object is arranged in a specified path.

At the command prompt: type ARRAYPATH or select the option from MODIFY toolbar. Then select object to be arrayed. Then select the path through which the object is made to be Array

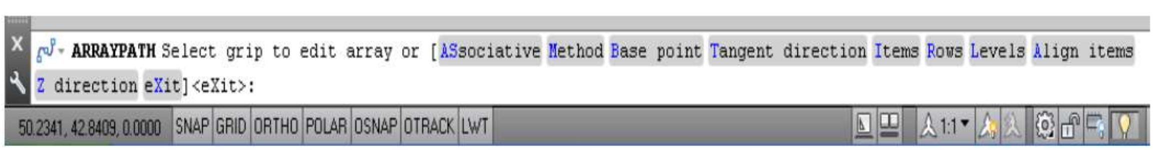


Figure 94 Path Array

CUTTING OF OBJECTS

The drawn objects can be cut or trimmed by using following commands

TRIM: Trims objects at a cutting object defined by other objects. Objects that can be trimmed include arcs, circles, elliptical arcs, lines, open 2D and 3Dpolylines,rays and splines

At the command prompt, enter trim

Select cutting edges:

Select objects: use object selection method

<Select object to trim>/project/edge/undo: select an object, enter an option, or press enter

BREAK: This erases an object or splits the object in to two parts

From the modify toolbar select break flyout

At the command prompt, enter break

Select objects: use an object selection method

First point of the mirror line: specify a point (1) on an object

Enter second point: specify the second break point (2) or enter F

DIMENSIONING IN DRAWINGS:

The dimensions are inserted in the drawing by use of DIM command. There are various types of dimensions used in AutoCAD.

Linear dimensions:

i. Horizontal- this allows horizontal dimensions
ii. Vertical- this allows vertical dimensions
iii. Aligned- this allows inclined dimensions
iv. Rotated- this allows inclined dimensions

Angular dimensions:

This allows angular dimensioning of objects

Radial dimensions:

This allows radial dimensioning of arc or circle

Diametric dimensions:

This allows diameteral dimensions of the circle

For dimensioning of objects, the first point and second point has to be specified. The dimension text must be written and then the position of dimension must be specified

at the command prompt ,enter dim

Dim: Enter a dimensioning mode command

AREA:

This allows calculation of the area and perimeter of objects or of defined areas

From the object properties toolbar, choose the inquiry flyout, then

At the command prompt, enter area

<First point>/object/add/subtract: specify a point or enter option

FILLET

Rounds and fillets the edges of the object

At the command prompt enter fillet

Polyline / Radius / Trim / <Select first object>: use an object selection method or enter an option

Select first object

Select second object: use an object selection method

Enter radius <current>: specify a distance or press

Chain / Radius <Select edge>: Select edges or enter c or r their intersection

CO-ORDINATE SYSTEM

The co- ordinate system can be modified in the AutoCAD. There are two types of coordinate systems used. The WCS (World co- ordinate system) is a universal system in which its origin is at the fixed position. The UCS (User co- ordinate system) is a system in which user can fix his origin at any point.

UCS: This manages user co- ordinate systems

At the command prompt enter **ucs**

Origin / z axis/ 3 point/ object/ view/ X/Y/Z / Prev/ Restore/Save/ Del/?/< world>: enter an option or press enter

WCS: This manages world co- ordinate system

EXPLODE:

This breaks a compound object into its component objects

At the command prompt enter explode

Select objects: use an object selection method.

UNION:

This measures the distance and angle between two points.

At the command prompt, enter union

Select object: Use an object selection method

DIST: This measures the distance and the angle between two points .

At the command prompt area enter dist

First point: Specify a point (1)

Second point : Specify a point (2)

Distance = calculated distance

Angle in XY plane = angle from XY plane = angle

Delta X = change in X

Delta Y = change in Y

Delta Z = change in Z.

REGENERATION OF DRAWING:

ACAD provides a facility of regenerating a drawing to clear the cross points or marks on the screen.

i. REDRAW
ii. REGEN
iii. REGENALL
iv. REGENAUTO

TOLERANCE

This creates geometric tolerances. Geometric tolerances define the maximum allowable variations of form or profile, orientation, location and run out from the exact geometry in a drawing. They specify the required accuracy for proper function and fit the objects drawn in AutoCAD

SKETCH

This creates a series of free hand line segments.

From the miscellaneous toolbar, choose

At the command prompt enter sketch

Follow the prompting

3D FUNCTIONS

BOX

This creates a three-dimensional solid box.

At the command prompt enter box

Center/<corner of the box><0,0,0> :

Specify a point (1), enter c, or press enter

Corner of a box

Specifying a point or pressing defines the first corner of the box.

Cube/length /<other corner>: specify a point (2) or enter an option center

Creates the box by a specified center point

CONE

This creates a 3D solid cone. A cone is solid primitive with a circular or elliptical based tapering symmetrically to a point perpendicular to its base.

At the command prompt enter cone

Elliptical /<center point> <0,0,0> : specify a point , enter e or press enter

CYLINDER

This creates a 3D solid cylinder. A cylinder is solid primitive with a circular or elliptical based to a point perpendicular to its base without a taper.

At the command prompt enter cylinder

Elliptical /<center point> <0,0,0> : specify a point , enter e or press enter

SPHERE

This creates a 3D solid sphere. A sphere is positioned so that its central axis is parallel to the Z-axis of the current UCS. Latitudinal lines are parallel to the XY plane.

At the command prompt enter sphere

Center of the sphere <0,0,0> : specify a point , enter e or press enter

WEDGE

This creates a three dimensional solid with a sloped face tapering along X axis.

At the command prompt enter wedge

Center <corner of the wedge> <0,0,0> : specify a point , enter e or press enter

Follow the prompting

ELEV

This sets an elevation and extrusion thickness of new objects. The current elevation is the Z value that is used whenever a 3D point is expected but only X and y values are supplied.

At the command prompt enter elev

Follow the prompting

SHADE

This displays a flat shaded image of the drawing in the current view port. SHADE removes hidden lines and displays a shaded picture of the drawing.

From the render toolbar, choose

At the command prompt, enter shade

REGION

This creates a region object from a selection set of existing objects. Regions are 2Dimensional areas you create from closed shapes.

REINIT

This reinitializes the input/output ports, digitizer, display and program parameters file.

REPLAY

This displays a GIF, TGA or TIFF image.

From the tool's menu, choose image, then view.

REVOLVE

This creates a solid by revolving a two – dimensional object about an axis. From the solids toolbar, choose

At the command prompt, enter revolve

SHAPE

This inserts a shape. Before inserting a shape, you must load the file containing the desired shape.

ROTATE 3D

This moves objects about a three-dimensional axis

From the modify toolbar, choose the rotate flyout then

Follow the prompting

SECTION

This uses the intersection of a plane and solids to create a region.

AutoCAD creates regions on the current layer and inserts them at the location of the cross – section. Selecting several solids creates separate regions for each solid.

SLICE

This slices a set of solids with a plane.

SHELL

This accesses operating system commands.

REVOLVE

This creates a solid by revolving a two-dimensional object about an axis.

RENDER

This creates a realistically shaded image of a three-dimensional wireframe or solid model. RENDER produces an image using information from a scene, the current selection set, or the current view.

STARTING THE DRAWING

The figures we do in engineering are fitted into a template. In ACAD we manually draw a template known as Drawing sheet in two different formats.

The size of the drawing sheet is ISO A4 210 X 297.

The format is as given in the following figures

Polar Array: In this, an object is arranged in a circular shape.

At the command prompt: type ARRAYPOLAR or select the option from MODIFY toolbar. Then select object to be arrayed. Then select the center point of array. By default, a six items array is created. The No. of items can be changed by selecting the Items option. Angle between the two items can also be changed.

Geometry drawings are developed using CAD

2D DRAWINGS

Aim: to draw the following figure using ACAD

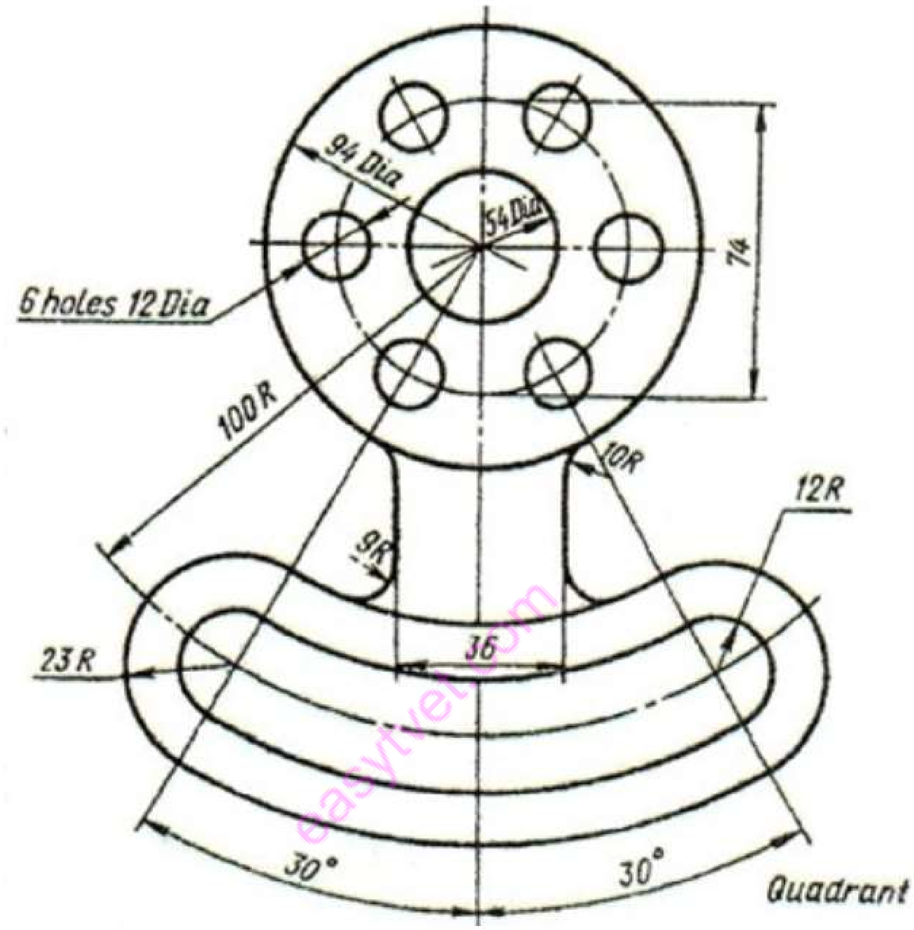


Figure 95 Exercise 1

PROCEDURE

Set the limits of the drawing screen

STEP 1: Draw axis lines in the respective format with their intersection point at **(0,0)**

• Go to **PROPERTIES** tool bar

• Load line type as **ISO LONG DASH SHORT DASH** in the line type area.

• Select line type ISO LONG DASH SHORT DASH in the line type area.

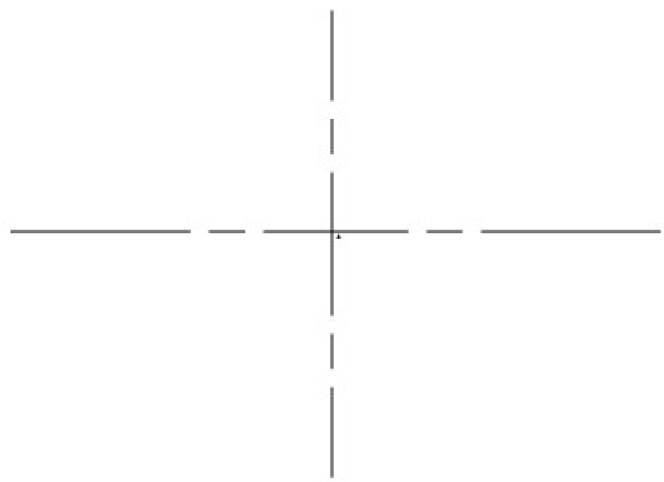


Figure 96 starting drawing center lines

STEP 2 a: Draw circles of given dimensions using circle command with their centre as the intersection of the axis lines

• 3 circles of diameters 94, 74 and 54 are to be drawn

• The circle with 74 diameter is of **ISO LONG DASH SHORT DASH** format

STEP 2 b: Using **POLAR ARRAY** draw the 6 holes on the circle of diameter 74 each of 12 dia.

STEP 3: Draw two construction lines at an angle of 30o to the vertical axis line

STEP 4: With A as center an radius 100 draw an arc between the above lines

STEP 5: Offset the arc on the either side by the distances as mentioned in the figure.

STEP 6: Complete the figure by using fillet command.

STEP 7: Give dimensions to the completed figure.

Command: _qsave

PRECAUTIONS:

Put **ORTHO ON** where ever necessary.

Use the required modify tool bar commands like **TRIM, ERASE, COPY, MIRROR** ETC.,

Aim: to draw the following figure using ACAD

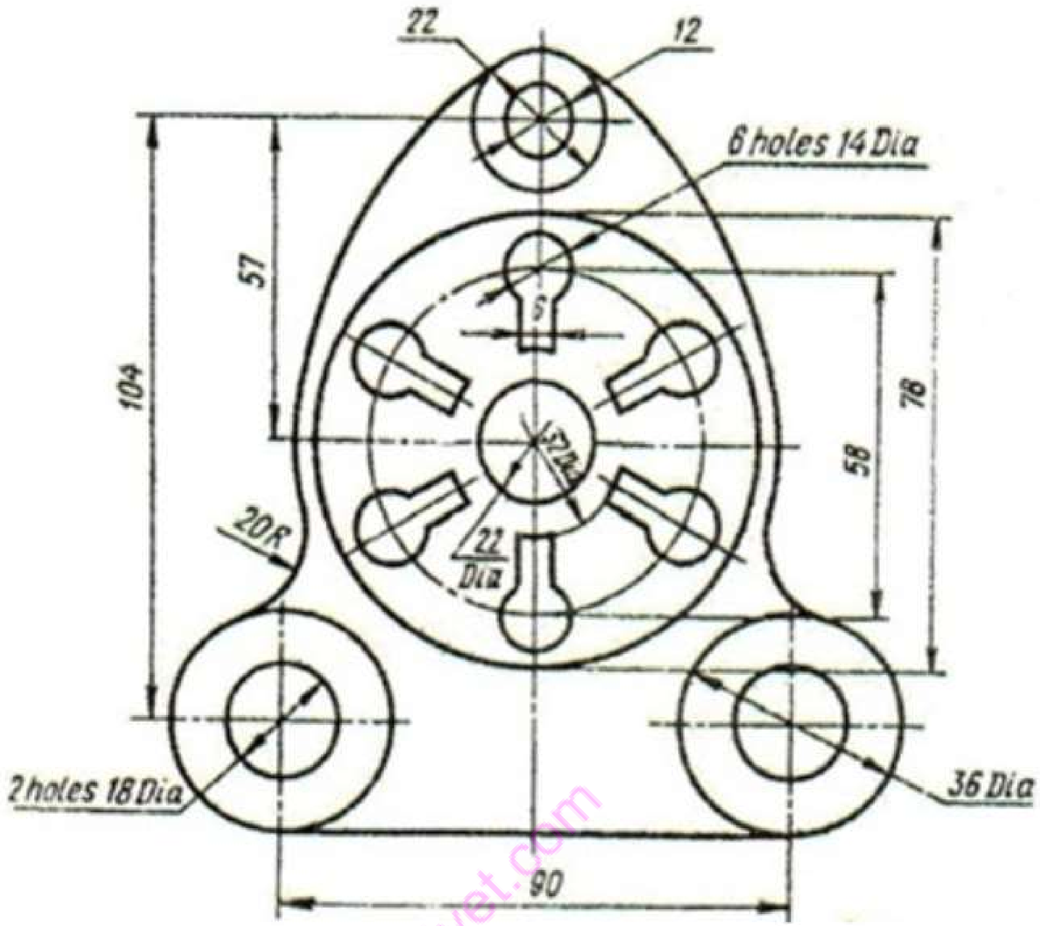


Figure 97 Exercise 2

PROCEDURE

Set the limits of the drawing screen

STEP 1: Draw axis lines in the respective format with their intersection point at **(0,0)**

STEP 2: Draw circles of given dimensions using circle command with their centre as the intersection of the axis lines.

STEP 3: Using **POLAR ARRAY** draw the 6 key holes on the circle of diameter 58 of given dimensions

STEP 4: For the outer cover use **CIRCLE** command and the in-command prompt area type ***TAN TAN RADIUS***. This gives the idea of drawing the outer cover

STEP 5: Give dimensions to the completed figure.

Command: _qsave

PRECAUTIONS:

Put **ORTHO ON** wherever necessary.

Use the required modify tool bar commands like **TRIM, ERASE, COPY, MIRROR** ETC.,

Orthographic drawings are developed using CAD

Orthographic drawings are a very common style of drawing and are easily created with CAD. In this exercise, we will use CAD to draw the front, top, and right side views of the object shown at the right. We will start with a third angle view then try some first angle views in the exercises. The dimensions of the object are shown at the right and we will make our CAD drawing dimensionally correct.

Unlike some of our previous drawings, we will use coordinates to draw the lines instead of simply clicking with the mouse. In the last assignment, you drew solid lines but sometimes you need dashed or

dotted lines. CAD can draw many different types of lines but the line type or style must be loaded before they can be used. The line types are loaded with the commands:

Starting CAD

You can start ACAD by either double clicking on the program Icon on the desktop or by clicking on the program name in the Start menu. The program will start and after a minute or so should display a screen similar to the one shown below. The dialog box in the middle will aid you in getting started

at either creating a new drawing or continuing your work on a drawing that is not finished.

If you are continuing work on a drawing, click on the "A" icon in the extreme

upper left corner of the window and Open->Drawing. A "Select File" dialog box will

open allowing you to select the drawing file you want to open.

The Initial Screen

ACAD has a very versatile user interface that allows you to control the program in several different ways. At the top of the window is a row of menus. Clicking on the Home, Insert, or Annotate causes another selection of menus to appear. This new selection of commands is frequently called a Ribbon or a

Dashboard. You can operate the program by clicking on the icons in these menus. Another method of using the program is typing in the command names. This is frequently faster than using drop down menus for frequently used commands because you do not have to search for the correct menu or icon. You just type in the command name. For the most part, we will use this approach in this series of tutorials. The commands that you type will appear at the bottom of the of the ACAD window.

The LINE Command

Now that you have started AutoCAD and configured tool bars you want, you are ready to start learning to use the program. We will start with relatively simple commands and eventually, in later lessons, look at some of the more complex things that AutoCAD can do. The first command we will look at drawing straight lines. At the keyboard, type:

line

and press the ENTER key. You can use either upper or lower case when you type in ACAD commands.

The program will respond with:

Specify First Point:

Each line has a beginning and ending point and the program wants you to specify the beginning point of the line. You enter the beginning point by either typing the point coordinates at the keyboard or by clicking the mouse on a location of the screen where you want the line to begin. It is certainly much simpler to click with the mouse than it is to type in coordinates but engineering drawings are drawn precisely to scale and for the most part we will have to enter coordinates from the keyboard.

When you type a coordinate, enter the X or horizontal coordinate first followed by a comma and the Y or vertical coordinate. You cannot enter a space between the two coordinates. AutoCAD interprets a space as the ENTER key and assumes that you have finished entering the coordinates.

For Example, you could type:

Specify First Point: 3.5,6

The 3.5 coordinate is the X or horizontal coordinate and the 6 is the vertical coordinate. After you enter the coordinates, press the enter key. The enter key tells the program that you have entered the first coordinate and are ready to enter the coordinates for the next which will be the end of the line. The program responds by displaying:

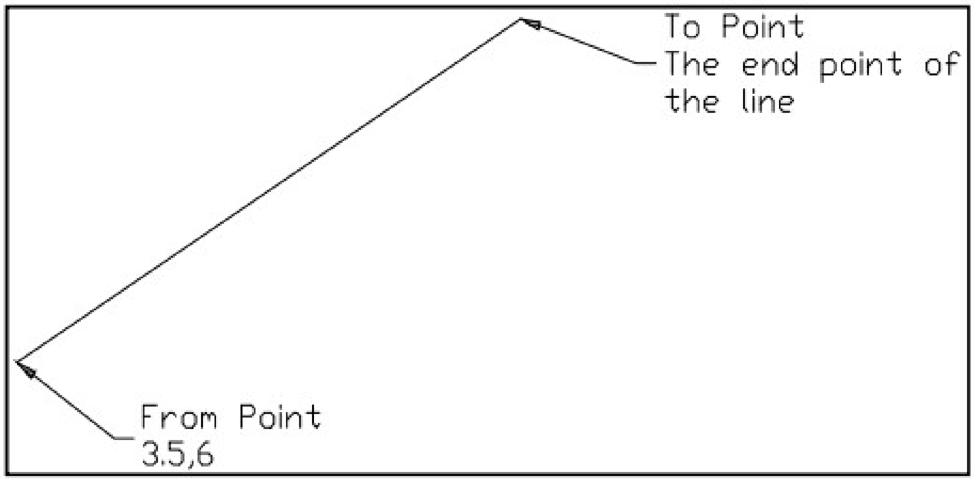


Figure 98 Sample 1

To Point:

If you want a horizontal line that is 5 units long, you enter the coordinates @5,0 which is shown below.

To Point: @5,0

The @ sign tells the program this coordinate is measured from the last coordinate entered. In other words, it says place the end if the line 5 units horizontally from the beginning point and 0 units vertically. The line drawn is shown above.

Using the @ sign to specify relative coordinates is easier than specifying absolute coordinates without the @ sign. The first point we drew had an absolute coordinate of 3.5,6 and the second point had an absolute coordinate of 8.5,6 since it is displaced 5 units horizontally from the first point.

We will continue with this to create the object shown on the right. It has lines, an arc, and a circle. We have drawn the first and we will continue drawing the rest of the lines.

As a shortcut, you can start the LINE command by typing L instead of the entire word LINE. Many AutoCAD commands can be abbreviated to just the first letter of the command.

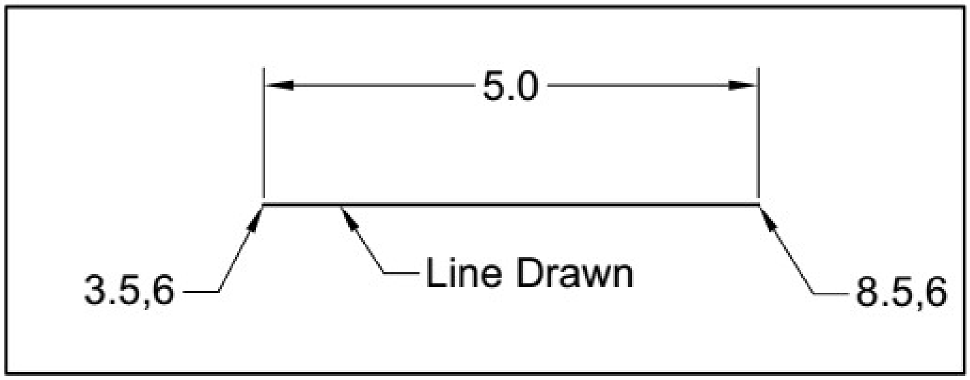


Figure 99 Sample 2

Continue Drawing the Object

We can continue drawing the object shown on the right by adding more lines. If the line command is

still operating, press ENTER to end it.

We will start it again to draw the remaining lines.

You can draw the remaining lines by typing:

line

Specify First Point: 8.5,6 {these are the coordinates of the end of the first line we drew}

To Point: @-2,2

To Point @2, 2

To Point @-5,0

To point {Press ENTER without entering coordinates. This will end the line command}

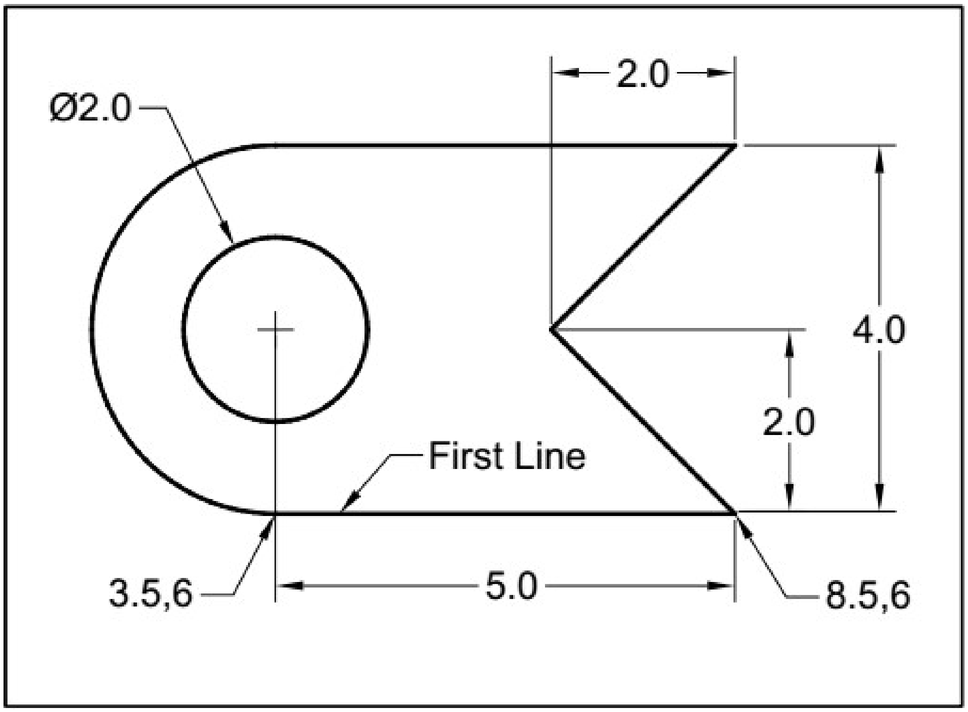
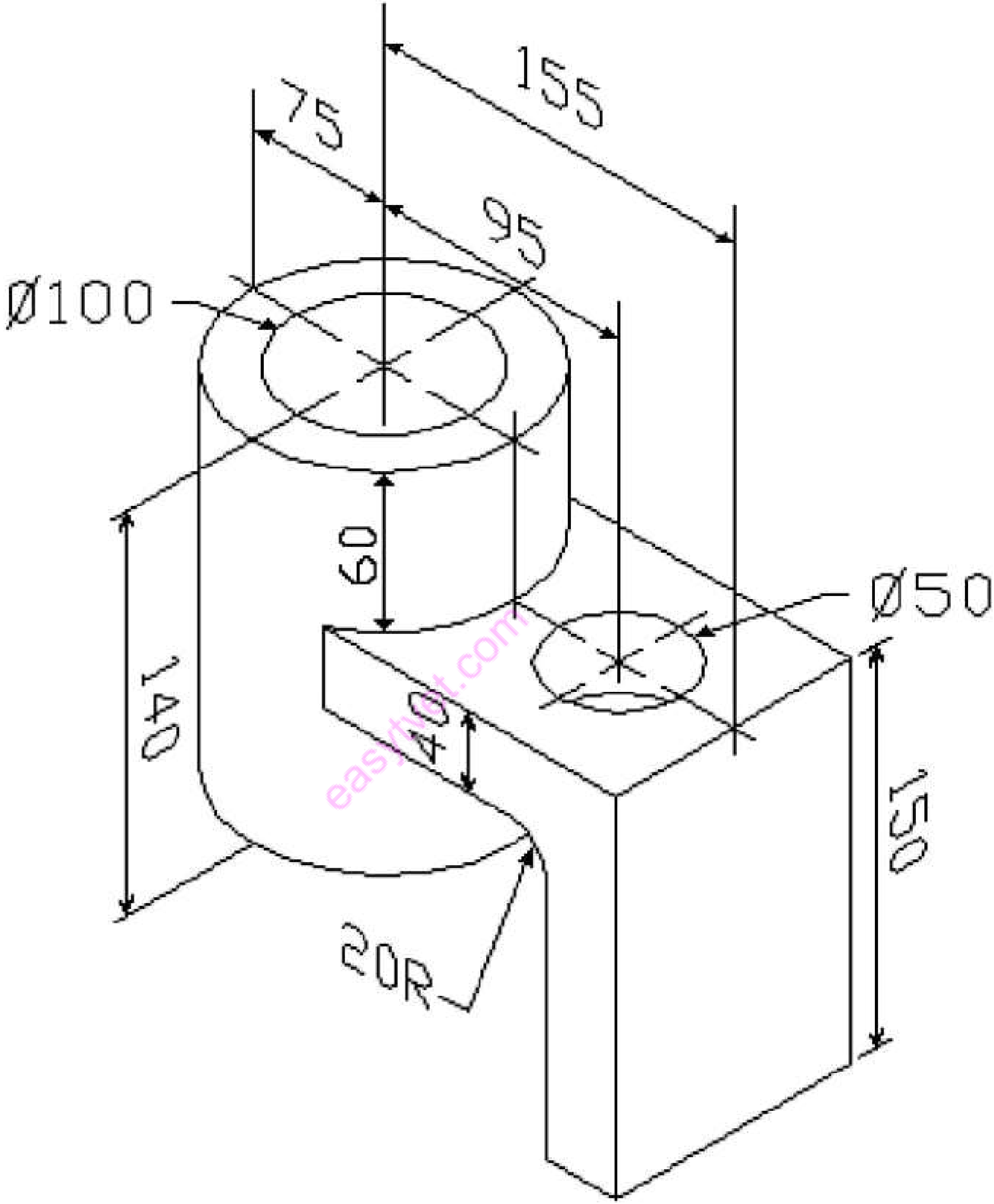


Figure 100 Orthographic figure

3.2.5.4. Learning activities

Below is an orthographic drawing drawn in Isometric. With the help of your trainer, you are required to develop it using CAD.



3.2.5.5. Self-Assessment

1. Define the following

   i. CAD

ii. CADD

iii. CAE

2. List the three types of arrays.
3. List any three reasons for implementing CAD systems.

4. What are palettes?
5. List two types of coordinate systems.

3.2.5.6. Tools, Equipment, Supplies and Materials

xiv. Drawing boards
xv. T squares
xvi. Set squares
xvii. Drawing sets
xviii. Drawing paper
xix. Protractors
xx. Eraser Shield
xxi. Pencils
xxii. Erasers
xxiii. Masking tapes
xxiv. Paper clips
xxv. Drawing curves
xxvi. Technical drawing software'

3.2.5.7. References

https://www.designtechcadacademy.com/knowledge-base/introduction-to-cad

https://www.designingbuildings.co.uk/wiki/Computer_aided_design_CAD

https://static.sdcpublications.com/pdfsample/1-58503-297-2-4.pdf

3.2.5.8. Model Answers.

1. Define the following

i. CAD

Computer-Aided Design, a term usually applied to the software.

ii. **CADD**

Computer-Aided Design and Drafting.

iii. **CAE**

Computer-Aided Engineering

2**. List the three types of arrays**.

- Rectangular Array
- Path Array
- Polar Array

3. List any three reasons for implementing CAD systems.

- Increases the productivity of the designer
- Improves communication:
- Create data base for manufacturing:
- Improves the efficiency of the design.

4. **What are palettes?**

Palettes are special windows that can docked, floating and made to collapse when not in use

5. **List two types of coordinate systems.**

- World co- ordinate system
- Universal system

CHAPTER 3: SCIENTIFIC PRINCIPLES

Unit of learning code: CON/CU/PL/CC/03/5/A

Related Unit of Competency in Occupational Standard: Apply Scientific Principles

3.1. Introduction to the unit of learning

This unit describes the competence in applying scientific principles. It involves applying principles of: units of measurements, force, work, energy and power, friction, heat, acoustics, pressure in fluids, mechanical properties of materials and electrical.

3.2. Summary of Learning Outcomes

1. Apply principles of units of measurements
2. Apply principles of Force, work, energy and power
3. Apply principles of Friction
4. Apply principles of heat
5. Apply principles of acoustics
6. Apply principles of pressure in fluids
7. Apply mechanical properties of materials
8. Apply electrical principles

3.2.1. Learning Outcome 1: Apply principles of units of measurements

3.2.2.1 Introduction to the learning outcome

This unit describes the competence in principles of units of measurements, identification and their conversion.

3.2.2.2 Performance Standard

1.1 Units of measurements are identified based on task given

1.2 Units are converted based on standard conventions.

3.2.2.3 Information Sheet

Definitions of terms

- *Base quantity* - physical quantity chosen by convention and practical considerations such that all other physical quantities can be expressed as algebraic combinations of them
- *Conversion factor*- a ratio that expresses how many of one unit are equal to another unit
- *Derived quantity*- physical quantity defined using algebraic combinations of base quantities
- *Derived units*- units that can be calculated using algebraic combinations of the fundamental units
- *Dimension*- expression of the dependence of a physical quantity on the base quantities as a product of powers of symbols representing the base quantities.
- *English units* - system of measurement used in the United States; includes units of measure such as feet, gallons, and pounds
- *Estimation*- using prior experience and sound physical reasoning to arrive at a rough idea of a quantity's value
- *Law*- description, using concise language or a mathematical formula, of a generalized pattern in nature supported by scientific evidence and repeated experiments
- *Metric system*- system in which values can be calculated in factors of 10 model representation of something often too difficult (or impossible) to display directly
- *Physics*- science concerned with describing the interactions of energy, matter, space, and time; especially interested in what fundamental mechanisms underlie every phenomenon
- *Precision*- the degree to which repeated measurements agree with each other second the SI unit for time, abbreviated s
- *SI units* - the international system of units that scientists in most countries have agreed to use; includes units such as meters, liters, and grams

Introduction to Measurement

Consider a plumber expected to measure the required length of pipe for a piece of work and a carpet installer checking to see the length and width of a room. These are examples of measurement.

Measurement is defined as the action of determining the size or amount of something. This is usually done by using an acceptable measurement tool such as a scale rule. For example, the carpet installer uses a tape measure as his choice of measurement tool to see how long and wide a particular room is whereas the Plumber will use a scale rule is the length of pipe required is less than 300mm long or a tape measure for lengths longer than that.

When measuring weight, The Kilogram (Kg) is used. When measuring the size of a room, feet are used. You can say that a room is 20 feet long, a box weighs 45 pounds, and your computer screen measures 17 inches on its diagonal.
Systems of units are built up from a small number of base units which are defined by accurate and precise measurements of conventionally chosen base quantities. Other units are then derived as algebraic combinations of the base units
Two commonly used systems of units are English units and SI units. All scientists and most of the other people in the world use SI, whereas some use English units.

- The SI base units are international system of units that scientists in most countries have agreed to use. They include;
    - Length – meter (m)
    - Mass - kilogram(kg)
    - time - second(s)

SI units are a metric system of units, meaning values can be calculated by factors of 10. Metric prefixes may be used with metric units to scale the base units to sizes appropriate for almost any application.

- English units – is a system of measurement used in the United States; includes units of measurement such as feet, gallons, and pounds

1. Basic SI Units of Measurement

The International System of Units, or SI, is based on base units from which all other measurement units are derived. These are:

Base Units

SI Base Units common to the Building Services Industry

Base quantity	SI base unit		Description
	Name	Symbol	
Length	Metre	m	The metre is either divided or multiplied by 1000 for greater or smaller units i.e multiplied by 1000 to become kilometres (km) or divided by 1000 to become millimetres (mm). We do not use centimetres (cm) in the construction industry.
Mass	Kilogram	kg	Mass is measured in kilograms. This is not weight, as weight is measured in Newtons. The mass of an object refers to the amount of matter an object contains.
Time	Second	S	The second is the base unit of time. Derivatives of time are measured in multiples of 60, ie. 60 seconds in a minute and 60 minutes in an hour.
Electric current	Ampere	A	Referred to as the amp, this is the unit of electrical current equal to one coulomb per second.
Temperature	Kelvin	K	The kelvin is a unit of measure for temperature based upon an absolute scale. Absolute 0 K is equal to -273°C.
Pressure	Pascals	pa	The Pascal is the SI Unit of pressure. It is defined as 1 Newton per

2. Derived SI Units

We can derive many units from the seven SI base units. For example, we can use the base unit of length to define a unit of volume, and the base units of mass and length to define a unit of density.

Derived units are units that may be stated in terms of base units by means of mathematical symbols of multiplication and division as shown below:

Derived Units

Examples of SI derived units expressed in terms of base units

Derived Quantity	*SI derived unit*		Description
	Name	Symbol	
Area	square metre	m^2	The m^2 is derived from multiplying length and width. It is 2-dimensional.
Volume	cubic metre	m^3	The m^3 is derived from multiplying length, width and height. It is 3-dimensional.
Speed, velocity	metre per second	m/s	The m/s is the distance travelled over time in a straight line and at a constant speed.
Acceleration	metre per second squared	m/s^2	The m/s^2 is the distance travelled over time that includes speeding up, slowing down and changing direction.
Density	Kilograms per metre cubed	Kg/m^3	The kilogram per meter cubed (kg/m^3) is the standard unit of material density in the International System of Units (SI). Material density is expressed directly in base SI units, and cannot be further reduced.
Capacity	Litre	l	Capacity is measured in litres (l). A litre is a measurement of 1000 centimetres cubed (cm^3).
Area	square metre	m^2	The m^2 is derived from multiplying length and width. It is 2-dimensional.

Unit conversion

- **Length**

The standard unit of length in both the SI and original metric systems is the meter (m). One meter is about 39.37 inches or 1.094 yards.

Longer distances are often reported/ represented in kilometers

1 km = 1000 m = 10^3 m

whereas shorter distances can be reported in centimeters or millimeters

1 cm = 0.01 m = 10^{-2} m

1 mm = 0.001 m = 10^{-3} m.

Most working drawings have measurement given in mm.

- **Mass**

The standard unit of mass in the SI system is the kilogram (kg). A kilogram was originally defined as the mass of a liter of water in a cube of water with an edge length of exactly 0.1 meter. One kilogram is about 2.2 pounds.
One gram (g) is exactly equal to 1/1000 or 10^{-3} kg.
Pipes laid below the ground floor level may collapse due to heavy loads if the load bearing capacity is exceeded.

- **Temperature**

Temperature is an intensive property. The SI unit of temperature is the kelvin (K). The IUPAC convention is to use kelvin (all lowercase) for the word, K (uppercase) for the unit symbol. Celsius degrees are the same magnitude as those of kelvin, but the two scales place their zeros in different places.
Water freezes at 273.15 K (0 °C) and boils at 373.15 K (100 °C) by definition, and normal human body temperature is approximately 310 K (37 °C).
It is important to use a given pipe material for the task its specified for. Pipes meant for cold water supply should specifically be used for that task since they may fail if used to supply or carry hot water since they have a smaller wall thickness.

- **Time**

The SI base unit of time is the second (s). Time intervals can be expressed with the appropriate prefixes; for example;
3 microseconds = 0.000003 s = 3×10^{-6}
5 mega seconds = 5,000,000 s = 5×10^{6} s.
Alternatively, hours, days, and years can be used.

When determining the capacity of a storage tank, it is important to ensure that the stored water is enough to serve the occupants for a period of 24hours after the direct water supply is cut off or being maintained.

(It is important to give practical examples of instances where these units of measurement are applied in Plumbing to enhance the relevance of this learning outcome to the trainee)

3.2.2.4 Learning Activities

Practical activity

With the assistance of your trainer, measure the length of a given path.
Example measure the length of administration block to the main gate and indicate the length in;

a) Metres
b) Kilometres
c) Centimetres

Materials Required

- Measuring tape
- Markers
- Pencil
- Drafting book

3.2.2.5 Self-Assessment

1. Convert 35.9 kL to liters.

2. How many cubic centimeters are in 0.883 m^3?

3. A rectangular plot in a garden has the dimensions 36.7 cm by 128.8 cm. What is the area of the garden plot in square meters? Express your answer in the proper number of significant figures.

4. Suppose that you drive the 10.0 km from your Institute to home in 20.0 min. Calculate your average speed
   a) in kilometers per hour (km/h) and
   b) in meters per second (m/s). (Note: Average speed is distance traveled divided by time of travel.)
5. Convert 88.4 m/min to meters/second.

3.2.2.6 Tools, Equipment, Supplies and Materials

- Scale rule
- Pencils
- Eraser
- Drawing paper
- Drawing board
- T-square

3.2.2.7 References

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3.2.3.1 Responses

1. **Convert 35.9 kL to liters.**

   Solution

   1 kL = 1,000 L.

$$35.9\ \cancel{kL} \times \frac{1000\ L}{1\ \cancel{kL}} = 35900\ L$$

2. **How many cubic centimeters are in 0.883 m^3?**

   Solution

$$0.833\ \cancel{m}^3 \times \frac{100\ cm}{1\ \cancel{m}} \times \frac{100\ cm}{1\ \cancel{m}} \times \frac{100\ cm}{1\ \cancel{m}} = 883000\ cm^3 = 8.83 \times 10^5\ cm^3$$

3. **A rectangular plot in a garden has the dimensions 36.7 cm by 128.8 cm. What is the area of the garden plot in square meters? Express your answer in the proper number of significant figures.**

   Solution

$$36.7\ \cancel{cm} \times 128.8\ \cancel{cm} \times \frac{1\ m}{100\ \cancel{cm}} \times \frac{1\ m}{100\ \cancel{cm}} = 0.472696\ m^2 = 0.473\ m^2$$

4. **Suppose that you drive the 10.0 km from your Institute to home in 20.0 min. Calculate your average speed.**
   a) in kilometers per hour (km/h) and
   b) in meters per second (m/s). (Note: Average speed is distance traveled divided by time of travel.)

   Solution

   average speed = distance/time

average speed= 10.0 km20.0 min=0.500 km min

average speed=0.500 kmmin×60 min1 h=30.0kmh.

5. Convert 88.4 m/min to meters/second.

Solution

$$\frac{88.4\ m}{\cancel{min}} \times \frac{1\ \cancel{min}}{60\ s} = 1.47\ m/s$$

3.2.2. Learning outcome 3: Apply principles of Friction

3.2.3.1. Introduction to the learning outcome

This unit describes the competence in applying principles of friction and its application based on scientific principles.

3.2.3.2. Performance Standard

1. Friction is defined and interpreted based on standard conventions
2. The advantages and disadvantages of friction are identified based on scientific principles
3. Simple problems on friction are solved based on task requirements

3.2.3.3. Information Sheet

Definitions of terms

- *Friction* is a force which opposes or tends to oppose the relative motion of two surfaces in contact with each other.
- *Coefficient of friction* is defined as the ratio of the force needed to overcome friction
- *Viscosity* this is the internal friction of a fluid

Force of friction equation

The formula that lets you calculate the friction force is:

$$F = \mu N$$

where:

- F is the force of friction, measured in Newtons;
- μ is the dimensionless coefficient of friction; and
- N is the normal force (perpendicular to the ground surface), expressed in Newtons.

How to find force of friction

1. Choose the normal force acting between the object and the ground. Let's assume a normal force of 250 N.
2. Determine the friction coefficient. We can choose a coefficient of friction equal to 0.13.
3. Multiply these values by each other: (250 N) * 0.13 = 32.5 N.
4. You just found the force of friction! Perhaps you want to check what work it performs?

Types of friction.

- **Static** is between two surfaces when neither are moving (with respect to each other).
- **Sliding** is between two objects sliding over each other (oddly enough) - like when you slide over a wooden floor in your socks.
- **Rolling** is between a surface and a rollable object (wheel, ball, etc.).
- **Fluid friction** is the friction between an object in movement and the medium it's traveling through, e.g., a plane through the air or a fish through water
- **Static friction** acts when the object remains stationary. Imagine you try to pull a heavy box. If we don't take friction into account, even the smallest force should cause some acceleration of the box, according to Newton's second law. In reality, you need to pull quite hard for the box to start moving because of the static friction force.
- **Kinetic friction** acts on a moving object or, in other words, on an object with nonzero kinetic energy. If there were no kinetic friction, any object that you nudge (for example, a toy car) would never stop moving, as, according to Newton's first law, no force would act on it, so it would keep on going with a constant velocity.

How to measure the coefficient of friction

There are two easy methods of estimating the coefficient of friction: by measuring the angle of movement and using a force gauge. The coefficient of friction is equal to tan(θ), where θ is the angle from the horizontal where an object placed on top of another starts to move. For a flat surface, you can pull an object across the surface with a force meter attached. Divide the Newtons required to move the object by the object's mass to get the coefficient of friction.

The SI unit of friction

Like all forces, the unit for friction is the Newton, which is equal to 1 kg·m·s-2. In Imperial, the force unit is the pound of force, lbf, 1 of which is roughly 4.45 N. The coefficient of friction is dimensionless, and therefore has no units.

Laws of friction

It is difficult to perform experiments involving friction and thus the following statements should therefore be taken merely as approximate descriptions: -

1. Friction is always parallel to the contact surface and in the opposite direction to the force tending to produce or producing motion.
2. Friction depends on the nature of the surfaces and materials in contact with each other.
3. Sliding (kinetic) friction is less than static friction (friction before the body starts to slide).
4. Kinetic friction is independent of speed.
5. Friction is independent of the area of contact.
6. Friction is proportional to the force pressing the two surfaces together.

Measuring frictional forces

We can relate weight of bodies in contact and the force between them. This relationship is called coefficient of friction. Coefficient of friction as the ratio of the force needed to overcome friction Ff to the perpendicular force between the surfaces Fn. Hence

$\mu = Ff / Fn$

Examples

1. A box of mass 50 kg is dragged on a horizontal floor by means of a rope tied to its front. If the coefficient of kinetic friction between the floor and the box is 0.30, what is the force required to move the box at uniform speed?

   Solution

   $Ff = \mu Fn$

   $Fn = \text{weight} = 50 \times 10 = 500$ N

   $Ff = 0.30 \times 500 = 150$ N

2. A block of metal with a mass of 20 kg requires a horizontal force of 50 N to pull it with uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surface and the block. (take g = 10 m/s)

   Solution

Since motion is uniform, the applied force is equal to the frictional force

F_n = normal reaction = weight = $20 \times 10 = 200$ N

Therefore, $\mu = F_f / F_n = 50/200 = 0.25$.

Applications of friction

1. Match stick
2. Chewing food
3. Brakes
4. Motion of motor vehicles
5. Walking

(Plumbing Applications- Rotation of moving parts in different Plumbing machines- (Electric Diestocks, Drills, Hydraulic Machines, During cutting of steel pipes)

Methods of reducing friction

1. Rollers
2. Ball bearings in vehicles and machines
3. Lubrication / oiling
4. Air cushioning in hovercrafts

(Give different Plumbing Examples)

Lubrication of moving parts-The electric Diestock is manufactured with its own oil drum that keeps recycling and supplying the oil to the moving parts as it is in use.

To easen the cutting and threading processes, one is required to spray or oil the pipe with a suitable lubricant to reduce friction between the pipe and the cutting/ threading tool.

Viscosity

Viscosity of a liquid decreases as temperature increases. When a body is released in a viscous fluid it accelerates at first then soon attains a steady velocity called terminal velocity. Terminal velocity is attained when $F + U = mg$ where F is viscous force, U is upthrust and mg is weight.

Advantages of friction:

1. Friction enables us to walk freely.
2. It helps to support ladder against wall.

3. It becomes possible to transfer one form of energy to another.
4. Objects can be piled up without slipping.
5. Breaks of vehicles work due to friction

Disadvantages of friction:

1. It always resists the motion, so extra energy is required to overcome it.
2. It causes wear and tear of machines.
3. It decreases the life expectancy of moving parts of vehicles.
4. Since friction is very useful in some cases while harmful in some cases, friction is called a necessary evil.

3.2.3.4. Learning Activities

Practical activity

a) Pull a heavy box on a fairly flat surface and note down your findings.
b) Suggest ways you can make the box move easily and apply them

Materials and Supplies

- A relatively heavy box
- A flat surface/floor
- Rollers
- Rope

3.2.3.5. Self-Assessment

1. A wooden box of mass 30 kg rests on a rough floor. The coefficient of friction between the floor and the box is 0.6. Calculate
2. What are the five advantages of friction?

3. Which four day-to-day operations do we apply friction?
4. A block of metal with a mass of 20 kg requires a horizontal force of 50 N to pull it with uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surface and the block. (take g = 10 m/s)
5. Discuss any five types of friction.

3.2.3.6. Tools, Equipment, Supplies and Materials

- A relatively heavy box
- A flat surface/floor
- Rollers
- Rope

3.2.3.7. Reference

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3.2.3.8. Model Answers

1. **A wooden box of mass 30 kg rests on a rough floor. The coefficient of friction between the floor and the box is 0.6. Calculate**
   a) The force required to just move the box
   b) If a force of 200 N is applied the box with what acceleration will it move?

2. What are the five advantages of friction?

a) Friction enables us to walk freely.
b) It helps to support ladder against wall.
c) It becomes possible to transfer one form of energy to another.
d) Objects can be piled up without slipping.
e) Breaks of vehicles work due to friction.

3. Which four day-to-day operations do we apply friction?

a) Match stick
b) Chewing food
c) Brakes
d) Motion of motor vehicles
e) Walking

4. A block of metal with a mass of 20 kg requires a horizontal force of 50 N to pull it with uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surface and the block. (take g = 10 m/s)

Solution

Since motion is uniform, the applied force is equal to the frictional force

F_n = normal reaction = weight = $20 \times 10 = 200$ N

Therefore, $\mu = F_f / F_n = 50/200 = 0.25$.

5. Discuss any five types of friction.

- Static is between two surfaces when neither are moving (with respect to each other).
- Sliding is between two objects sliding over each other (oddly enough) - like when you slide over a wooden floor in your socks.
- Rolling is between a surface and a rollable object (wheel, ball, etc.).
- Fluid friction is the friction between an object in movement and the medium it's traveling through, e.g., a plane through the air or a fish through water.
- Static friction acts when the object remains stationary
- **Kinetic friction** acts on a moving object or, in other words, on an object with nonzero kinetic energy. If there were no kinetic friction, any object that you nudge (for example, a toy car) would never stop moving, as, according to Newton's first law, no force would act on it, so it would keep on going with a constant velocity.

3.2.3. Learning outcome 2: **Apply principles of Force, work, energy and power**

3.2.2.1. Introduction to the learning outcome

This unit describes the competence in applying principles of force, work, energy and power based on standard conventions. It also involves the various forms of energy and its conversion to other forms and scientific calculations involving energy.

3.2.2.2. Performance Standard

1. Force, work, energy and power are defined based on standard conventions
2. Forms of energy are described based on the state of the matter
3. Energy is converted according to scientific principles
4. Simple calculations on work, energy and power are solved based on the task requirements

3.2.2.3. Information Sheet

Definitions of terms

- *Work* is said to be done when a body or object moves with the application of external force.
- *Power* can be defined as the rate at which work is done i.e. energy converted.
- *Energy* is the ability to perform work
- A *force* is a push or pull upon an object resulting from the object's interaction with another object

Introduction to principles of Force, work, energy and power

Energy, force, heat and power are closely linked. It is almost impossible to have one without the other.

The first law of thermodynamics states that: ‘Energy can neither be created nor destroyed. Energy is transferred from one form to another.’

The SI Units

- The unit of power - The watt is the SI unit for power. It is equivalent to one joule per second (1 J/s) or in electrical units, one volt ampere (1 V·A) (DC circuits).
- The unit of heat - The Joule is unit of heat. 4.186 joule of heat energy (equals one calorie) is required to raise the temperature of 1 g of water from 0oC to 1oC. This is usually rounded up to 4.19j/g for calculation purposes.
- The Unit of energy – also the joule (see above)

.

1. Forms of energy.

a) Chemical energy: - this is found in foods, oils charcoal firewood etc.

b) Mechanical energy: - there are two types;

   i. Potential energy – a body possesses potential energy due to its relative position or state

   ii. Kinetic energy – energy possessed by a body due to its motion i.e. wind, water

   iii. Wave energy – wave energy may be produced by vibrating objects or particles i.e. light, sound or tidal waves.

   iv. Electrical energy – this is energy formed by conversion of other forms of energy i.e. generators.

Transformation and conservation of energy

Any device that facilitates energy transformations is called transducer. Energy can be transformed from one form to another i.e. mechanical – electrical – heat energy. The law of conservation of energy states that “energy cannot be created or destroyed; it can only be transformed from one form to another”.

2. Work

Work is done when a force acts on a body and the body moves in the direction of the force.

Work done = force × distance moved by object

$W = F \times d$

Work is measured in Nm. 1 Nm = 1 Joule (J)

Examples

1. Calculate the work done by a stone mason lifting a stone of mass 15 kg through a height of 2.0 m. (take g=10N/kg)

   Solution

   Work done = force × distance

   $= (15\times 10) \times 2 = 300$ Nm or 300 J

2. A girl of mass 50 kg walks up a flight of 12 steps. If each step is 30 cm high, calculate the work done by the girl climbing the stairs.

   Solution

   Work done = force × distance

   $= (50\times 10) \times (12 \times 30) \div 100 = 500 \times 3.6 = 1{,}800$ J

3. Power

Power is the time rate of doing work or the rate of energy conversion.

Power (P) = work done / time

$P = W / t$

The SI unit for power is the watt (W) or joules per second (J/s).

Examples

1. A person weighing 500 N takes 4 seconds to climb upstairs to a height of 3.0 m. what is the average power in climbing up the height?

   Solution

   Power = work done / time = (force × distance) / time

   $= (500 \times 3) / 4 = 375$ W

4. Machines

A machine is any device that uses a force applied at one point to overcome a force at another point. Force applied is called the effort while the resisting force overcome is called load. Machines makes work easier or convenient to be done. Three quantities dealing with machines are;-

a) Mechanical advantage (M.A.) - this is defined as the ratio of the load (L) to the effort (E). It has no units.

   M.A = load (L) / effort (E)

b) Velocity ratio – this is the ratio of the distance moved by the effort to the distance moved by the load

   V.R = distance moved by effort/ distance moved by the load

c) Efficiency – is obtained by dividing the work output by the work input and the getting percentage

   Efficiency = (work output/work input) × 100

= (M.A / V.R) × 100

= (work done on load / work done on effort) × 100

Examples

1. A machine; the load moves 2 m when the effort moves 8 m. If an effort of 20 N is used to raise a load of 60 N, what is the efficiency of the machine?

   Solution

   Efficiency = (M.A / V.R) × 100 M.A = load/effort =60/20 = 3

   V.R =DE/ DL = 8/2 = 4

   Efficiency = ¾ × 100 = 75%

Some simple machines

a) Levers – this is a simple machine whose operation relies on the principle of moments

b) Pulleys – this is a wheel with a grooved rim used for lifting heavy loads to high levels. The can be used as a single fixed pulley, or as a block-and-tackle system.

These machines are used in the lifting of heavy equipment or materials on site.

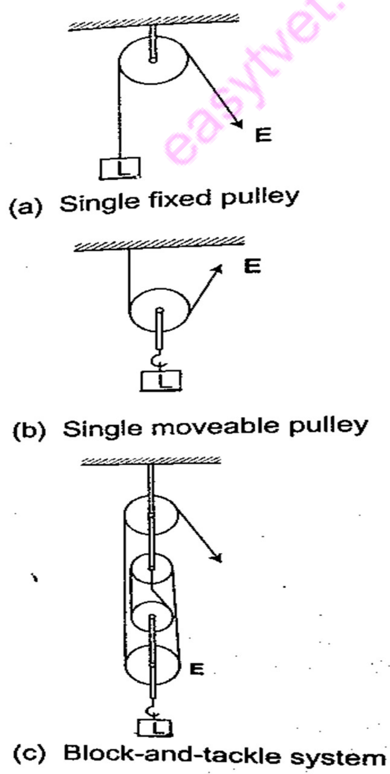

Figure 101:Pulleys

M.A = Load/ Effort

V.R = no. of pulleys/ no. of strings supporting the load

Example

A block and tackle system has 3 pulleys in the upper fixed block and two in the lower moveable block. What load can be lifted by an effort of 200 N if the efficiency of the machine is 60%?

Solution

V.R = total number of pulleys = 5

Efficiency = (M.A /V.R) × 100 = 60%

0.6 = M.A/ 5 =3, but M.A = Load/Effort

Therefore, load = 3 ×200 = 600 N

c) Wheel and axle – consists of a large wheel of big radius attached to an axle of smaller radius.

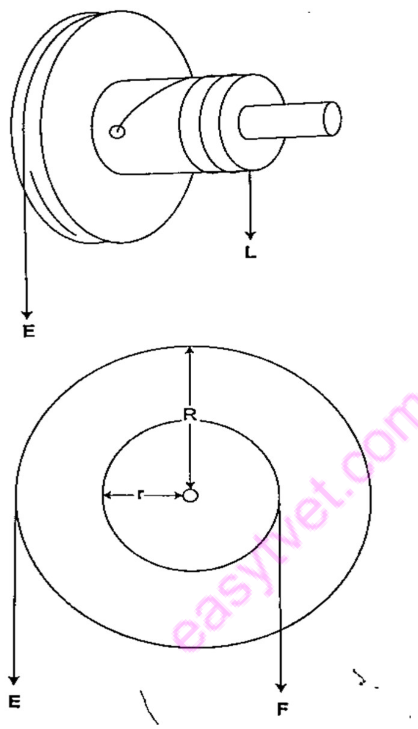

Figure 102: Wheel and axle

V.R = R/r and M.A = R/r

Example

A wheel and axle is used to raise a load of 280 N by a force of 40 N applied to the rim of the wheel. If the radii of the wheel and axle are 70 cm and 5 cm respectively. Calculate the M.A, V.R and efficiency.

Solution

M.A = 280 / 40 = 7

V.R = R/r = 70/5 = 14

Efficiency = (M.A/ V.R) × 100 = 7/14 × 100 = 50 %

d) Inclined plane: -

V.R = 1/ sin θ M.A = Load/ Effort

Example

A car weighing 1,600 kg is lifted with a jack-screw of 11 mm pitch. If the handle is 28 cm from the screw, find the force applied.

Solution

Neglecting friction M.A = V.R

V.R = $2\pi r$ /P = M.A = L / E

1,600 / E = ($2\pi \times 0.28$) / 0.011

E = (1,600 × 0.011 × 7) / 22×2×0.28 =10 N

e) Gears: - the wheel in which effort is applied is called the driver while the load wheel is the driven wheel.

V.R = revolutions of driver wheel / revolutions of driven wheel

Or

V.R = no. of teeth in the driven wheel/ no. of teeth in the driving wheel

f) Pulley belts: -these are used in bicycles and other industrial machines

V.R = radius of the driven pulley / radius of the driving pulley

g) Hydraulic machines

V.R = R2 / r2 where R- radius of the load piston and r- radius of the effort piston

Example

The radius of the effort piston of a hydraulic lift is 1.4 cm while that of the load piston is 7.0 cm. This machine is used to raise a load of 120 kg at a constant velocity through a height of 2.5 cm. given that the machine is 80% efficient, calculate;

a) The effort needed
b) The energy wasted using the machine

Solution

a) V.R = R2 / r2 = (7×7) / 1.4 × 1.4 = 25

Efficiency = M.A / V.R = (80 /100) × 25 = 20

But M.A = Load / Effort = (120×10) / 20 = 60 N

b) Efficiency = work output / work input = work done on load (m g h) /80

= (120 × 10× 2.5) / work input

80 / 100 = 3,000 / work input

Work input = (3,000 × 100) /80 = 3,750 J

Energy wasted = work input – work output

= 3,750 – 3,000 = 750

3.2.2.4. Learning Activities

Practical activity

Assemble a single fixed pulley system on a higher surface and safely lift various masses as shown below.

Materials and Supplies needed for the practical activity

- Pulley
- Rope
- A convenient mass
- Nails
- Timber
- Claw hammer

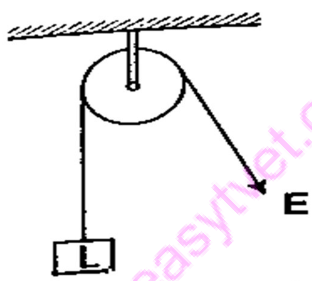

Figure 103: Single fixed pulley

3.2.2.5. Self-Assessment

1. A force of 7.5 N stretches a certain spring by 5 cm. How much work is done in stretching this spring by 8.0 cm?
2. A car travelling at a speed of 72 km/h is uniformly retarded by an application of brakes and comes to rest after 8 seconds. If the car with its occupants has a mass of 1,250 kg. Calculate;
   a) The breaking force
   b) The work done in bringing it to rest
   c) Work done
3. A spring constant k = 100 Nm is stretched to a distance of 20 cm. calculate the work done by the spring.

4. A box of mass 500 kg is dragged along a level ground at a speed of 12 m/s. If the force of friction between the box and floor is 1200 N. Calculate the power developed.
5. A man uses an inclined plane to lift a 50 kg load through a vertical height of 4.0 m. the inclined plane makes an angle of 300 with the horizontal. If the efficiency of the inclined plane is 72%, calculate;
   a) The effort needed to move the load up the inclined plane at a constant velocity.
   b) The work done against friction in raising the load through the height of 4.0 m. (take g= 10 N/kg)

3.2.2.6. Tools, Equipment, Supplies and Materials

- Pulley
- Rope
- A convenient mass
- Nails
- Timber
- Claw hammer

3.2.2.7. References

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3.2.2.8. Model Answers

1. **A force of 7.5 N stretches a certain spring by 5 cm. How much work is done in stretching this spring by 8.0 cm?**

   Solution

   A force of 7.5 produces an extension of 5.0 cm.

   Hence 8.0 cm = (7.5 ×8)/ 5 = 12.0 N

   Work done = ½ × force × extension

   = ½ × 12.0 × 0.08 = 0.48 J

2. **A car travelling at a speed of 72 km/h is uniformly retarded by an application of brakes and comes to rest after 8 seconds. If the car with its occupants has a mass of 1,250 kg. Calculate;**

   a) **The breaking force**

   b) **The work done in bringing it to rest**

   c) **Work done**

   Solution

   F = ma and a = v – u/t

   But 72 km/h = 20m/s

   a = 0 -20/8 = - 2.5 m/s

   Retardation = 2.5 m/s

   Braking force F = 1,250 × 2.5

   = 3,125 N

   Work done = kinetic energy lost by the car

   = ½ mv2 – ½ mu2

   = ½ × 1250 × 02 – ½ × 1250 × 202

   = - 2.5 × 105 J

3. **A spring constant k = 100 Nm is stretched to a distance of 20 cm. calculate the work done by the spring.**

   Solution

   Work = ½ ks2

   = ½ × 100 × 0.22

   = 2 J

4. **A box of mass 500 kg is dragged along a level ground at a speed of 12 m/s. If the force of friction between the box and floor is 1200 N. Calculate the power developed.**

   Solution

Power = F v

= 2,000 × 12

= 24,000 W = 24 kW.

5. **A man uses an inclined plane to lift a 50 kg load through a vertical height of 4.0 m. the inclined plane makes an angle of 300 with the horizontal. If the efficiency of the inclined plane is 72%, calculate;**

   a) **The effort needed to move the load up the inclined plane at a constant velocity.**

   b) **The work done against friction in raising the load through the height of 4.0 m. (take g= 10 N/kg)**

   Solution

   a) V.R = 1 / sin C = 1/ sin 300 = 2 M.A = efficiency × V.R = (72/100)× 2 = 1.44

   Effort = load (mg) / effort (50×10)/ 1.44 = 347.2 N

   b) Work done against friction = work input – work output

   Work output = m g h = 50×10×4 = 2,000 J

   Work input = effort × distance moved by effort

   347.2 × (4× sin 300) = 2,777.6 J

   Therefore work done against friction = 2,777.6 – 2,000 = 777.6 J

3.2.4. Learning outcome 4: Apply principles of heat

3.2.4.1. Introduction to the learning outcome

This unit describes the competence in applying principles of heat, methods of heat transfer, sources of heat and their effects.

3.2.4.2. Performance Standard

1. Sources of heat are identified based on scientific principles
2. Effects of heat on matter is identified based on scientific principles
3. Methods of heat transfer are identified and interpreted based on scientific principles

3.2.4.3. Information Sheet

Definitions of terms

- *Temperature* represents the amount of thermal energy available
- *Heat* is the form of energy that is transferred between systems or objects with different temperatures
- *Heat flow* represents the movement of thermal energy from place to place

Basics of Heat Transfer

In the simplest of terms, the discipline of heat transfer is concerned with only two things: temperature, and the flow of heat.

On a microscopic scale, thermal energy is related to the kinetic energy of molecules. The greater a material's temperature, the greater the thermal agitation of its constituent. Several material properties serve to modulate the heat transferred between two regions at differing temperatures.

Everything on Earth and in space is made of matter. Matter can exist in 3 states:

1. Liquid
2. Solid
3. Gas

Each of these states can be changed by the addition or removal of heat. For example, if heat is applied to ice (solid), it becomes water (liquid) and if more heat is applied, the water will evaporate to become steam (gas). These transitions will also work in reverse when heat is taken away – steam to water to ice. Each of these phases is given a name:

- Ice (solid) to water (liquid) = melting
- Water (liquid) to steam (gas) = evaporation/vaporisation
- Steam (gas) back to a water (liquid) = condensation
- Water (liquid) to ice (solid) = (solidification)

Under certain conditions, it is possible to miss out certain states. For instance, ice under controlled conditions will go straight from ice to a gas, completely missing out the liquid water stage:

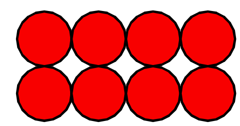
- Solid to gas = sublimation

- Gas to solid = deposition

Solids

The table shows some of the properties of solids:

Property	Reason
Solids have a fixed shape and cannot flow	The particles cannot move from place to place
Solids cannot be compressed or squashed	The particles are close together and have no space to move into

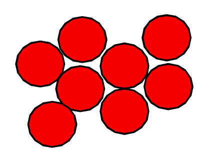


Examples : Different Pipe materials (Galvanized Iron, Copper, P.V.C Plastic e.t.c.

Liquids

The table shows some of the properties of liquids:

Property	Because
Liquids flow and take the shape of their container	The particles can move around each other
Liquids cannot be compressed or squashed	The particles are close together and have no space to move into



Examples Lubricating oil

Gases

The table shows some of the properties of gases:

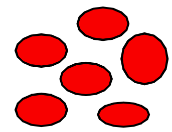
Property	Because
Gases flow and take the shape	of

their container

Gases can be compressed or squashed

The particles can move quickly in any direction

The particles are far apart and can move into any space



Examples Carbon (iv) oxide gas - used for fire fighting

Difference between latent heat and sensible heat

Table 5: Latent heat vs sensible heat

Sensible heat	**Latent heat**
When heat is directly applied to water, its temperature will rise until it reaches its boiling point. The resulting increase in the heat of the water is known as sensible heat because the application of heat has led to hotter water: Water @ 0^oC to water @ 100^oC = a change in temperature due to the application of heat. **There is no change of state.**	Changes of state are also a result of heat added but here, the added heat leads to a change in state **without** an increase in temperature. Latent heat does not affect the waters temperature. Water @ 100^oC to Steam at 100^oC = a change in state due to the application of heat. **There is no change in temperature** The process is reversible.

Heat energy is needed to increase the temperature of an object. The amount of energy needed depends on the mass of the object, the type of material it is made from, and the temperature increase.
Heat energy is also absorbed when substances melt or boil, but the temperature does not alter during a change of state. The amount of energy needed to melt or boil something depends upon the mass of the object and the type of material it is made from.

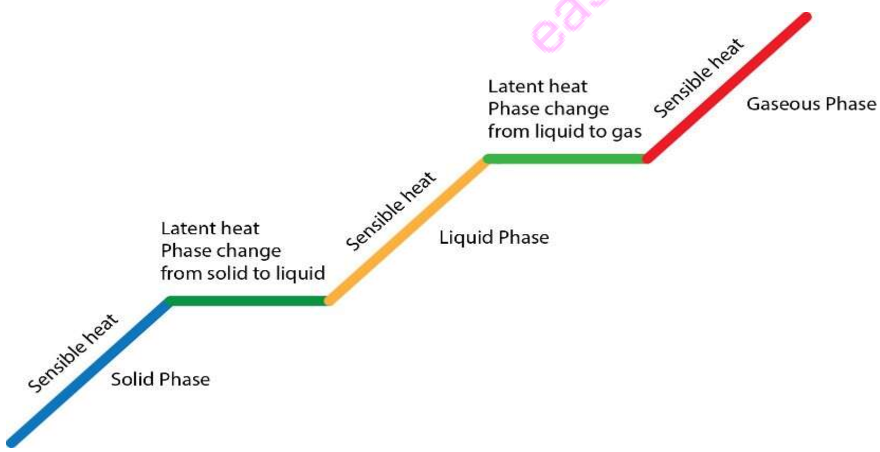


Figure 104: Heat phase Diagram

Methods of heat transfer

- Conduction
- Convection
- Radiation

Heat can be transferred from one place to another by three methods: conduction in solids, convection of fluids (liquids or gases) and radiation through anything that will allow radiation to pass. The method used to transfer heat is usually the one that is the most efficient.

Conduction

Conduction occurs when heat travels through a substance, the heat passing directly from one molecule to another.

If a piece of copper tube is heated at one end, the heat will quickly be felt at the other end. This occurs because kinetic energy in the form of heat is directly transferred from one copper atom to another very quickly.

The same principle can be applied to the conduction of electricity, as good conductors of heat are generally also good conductors of electricity.

The rate at which a material will conduct heat is known as the coefficient of thermal conductivity. It is measured in W/m2K.

$$Thermal\ conductivity = \frac{heat\ x\ distance}{area\ x\ temperature\ difference\ (\Delta t)} = W$$

The table below shows the coefficient of thermal conductivity of some common materials.

Table 6: Thermal conductivity

Thermal Conductivity of Materials	
Material	Thermal Conductivity W/m/K
Silver	406.0
Copper	397.0
Gold	317.0
Aluminum	225.0
Brass	109.0
Steel	50.2
Lead	34.7
Polyethylene HD	0.5

Wood	0.113

Convection

Convection occurs when heat is transferred through a fluid i.e. a gas or a liquid. Convection takes place because the warm fluid is less dense than the cool fluid. As the lighter, warm fluid rises, it releases heat into the surrounding environment. As this happens, the warm fluid loses its heat, becomes denser and falls by the effect of gravity, to begin the process again.

In a hot water system, this is known as gravity circulation as hot water rises and cooler water moves down to replace it, causing a circular motion.

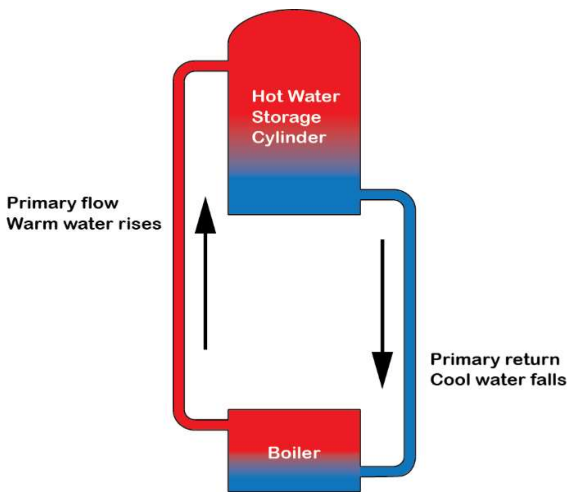


Figure 105: Convection

Radiation

On Earth, we get the heat to warm our planet from the Sun. The Sun's heat travels over 90,000,000 miles through the cold vacuum of space to warm the Earth's surface. The heat is felt because it travels objects will transmit and receive heat in the form of thermal radiation (often called infrared radiation). The hotter an object is the more thermal radiation it will emit.

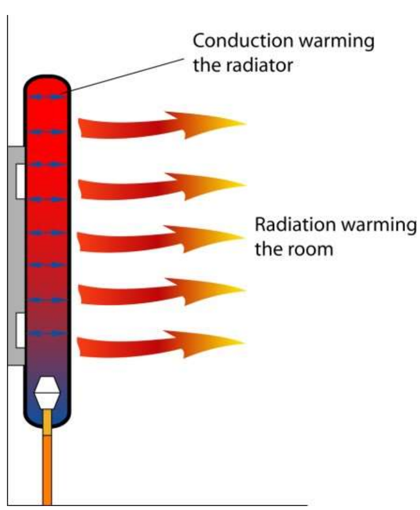


Figure 106: Radiation

How SI units of energy, heat and power are Related and Derived

- Energy – Joules (J) - the SI unit of work or energy, equal to the work done by a force of one newton when its point of application moves one metre in the direction of the force. It is equivalent to one 3600th of a watt-hour.
- Specific Heat Capacity (kJ/kg/°C) – This is the amount of energy required (in joules or kilojoules) to increase the temperature of 1kg of a substance by 1°C. Water, for example, has a SHC of 4.19 kJ/kg/°C. This means that it takes 4190joules of energy to raise the temperature of 1kg of water by 1°C.
- Power – Watts (W) - The watt (abbreviated W) is the International System of Units standard unit of power (or energy per unit time). It is the equivalent of one joule per second. The watt is used to specify the rate at which energy is dispersed, or the rate at which electro-magnetic energy is radiated, absorbed, or dissipated. The Watt can be used to describe electrical power or heat power.

To recap, the S.I. units of measurement of energy, heat and power are:

• Energy	The Joule (J)
• Heat	The Joule (J)
• Power	The Watt (W)
• Specific Heat Capacity	kilojoules per kilogram per degree Celsius (kJ/kg/°C)

The Specific Heat Capacity of water is 4.19kJ/kg/OC

Calculations using the Specific Heat Capacity of Water

Example 1 - How many kilojoules would it take to heat 200 litres of water from 40°C to 80°C? The formula for this is:

$$L\ x\ \Delta t\ x\ SHC\ of\ water$$

Where:

L = litres

□t = temperature
difference SHC of water = 4.19

Therefore

$200 \, x \, (80 – 40) \, x \, 4.19 = \mathbf{33520 \, kJ}$

3.2.4.4. References

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3.2.4.5.Model Answers

1. Discuss the three Methods of heat transfer
   - Conduction
   - Convection
   - Radiation
2. Calculate how many kilowatts it would take to raise the temperature of the 200 litres water by 40°C assume that you require 200 litres of water at 80°C in 2 hours' time:

   2 x (60 x 60) = 7200

   $200 \, x \, (80 - 40) \, x \, 4.19 = 4.65 \, kW$

This shows that to increase the temperature of 200 litres of water from 40°C to 80°C in 2 hours would take 4.65 kW of heat.

3. Which are the three states of matter giving two properties for each.

- Liquid
- Solid
- Gas

4.How many hours would it take for 200 litres of water to be heated by 40°C using a 6kW of power?

Water has a specific heat capacity of 4.19 kJ/kg/°C and that 1 W = 1 J/s. The formula for this is:

$l\ x\ t\ x\ SHC$

kW

Where:

L	=	litres
t	=	Temperature
kW	=	kilowatts
SHC	=	Specific Heat Capacity

Therefore:

$200x\ 40\ x\ 4.19 = 5586.666667\ seconds$

5. How many kilojoules would it take to heat 200 litres of water from 40°C to 80°C? The formula for this is:

$L\ x\ \square t\ x\ SHC\ of\ water$

temperature difference SHC of water = 4.19

$200\ x\ (80 - 40)\ x\ 4.19 = \mathbf{33520}\boldsymbol{kJ}$.

3.2.5. Learning outcome 5: Apply principles of pressure in fluids

3.2.5.1. Introduction to the learning outcome

This unit describes the competence in applying principles of pressure in fluids based on scientific laws. It also involves simple scientific calculations for pressure in liquids.

3.2.5.2. Performance Standard

1. Density and variation of pressure is defined based on scientific principles
2. Laws are identified based on scientific principles
3. Simple calculations on pressure in liquids are performed based on scientific principles

3.2.5.3. Information Sheet

Definitions of terms

- *Pressure - Physics defines pressure as force per unit area.*
- *Force* - is the influence on a static object that causes the motion of the object to change. If the object is subjected to force, it will begin to move.
- *Flow rate*- is the volume of fluid, which passes per unit time

INTRODUCTION TO PRESSURE

Pressure is defined as the force acting normally (perpendicularly) per unit area.

The SI units for pressure is newton per metre squared (N/m2). One Nm-2 is known as one Pascal(Pa).

Pressure = normal force / area or pressure = thrust / area. Another unit for measuring

pressure is the bar. 1 bar = 105 N/m2. 1millibar = 100 N/m2.

Calculating pressure

Example

A rectangular brick of weight 10 N, measures 50 cm × 30 cm × 10 cm. calculate the values of the maximum and minimum pressures which the block exert when resting on a horizontal table.

Solution

Area of the smallest face = 0.3 × 0.1 = 0.03 m2.

Area of the largest face = 0.5 × 0.3 = 0.15 m2.

Maximum pressure = 10 N / 0.03 = 3.3 × 102 N/m2.

Minimum pressure = 10 N / 0.15 = 67 N/m2.

PRESSURE IN LIQUIDS.

The following formula is used to determine pressure in liquids.

Pressure = h ρ g, where h – height of the liquid, ρ – density and g – is force of gravity.

Example

A diver is 10 m below the surface of water in a dam. If the density of water is 1,000 kgm^3 determine the pressure due to the water on the diver. (Take g = 10 Nkg-1)

Solution

Pressure = h ρ g = 10 × 1000 × 10 = 100,000 Nm-2.

Ways of measurement of pressure in fluids

U-tube manometer

It is a transparent tube bent into U-shape. When a liquid is poured into a u-tube it settles at equal level since pressure depends on height and they share the same bottom.

Consider the following diagrams;

For the levels to differ the pressure P1 must be greater than P2, hence

P1 = P2 + hρg.

If P1 is the lung pressure, P0 is the atmospheric pressure, then if the difference is ‘h’ then lung pressure can calculated as follows.

P1 = P0 + hρg.

Example

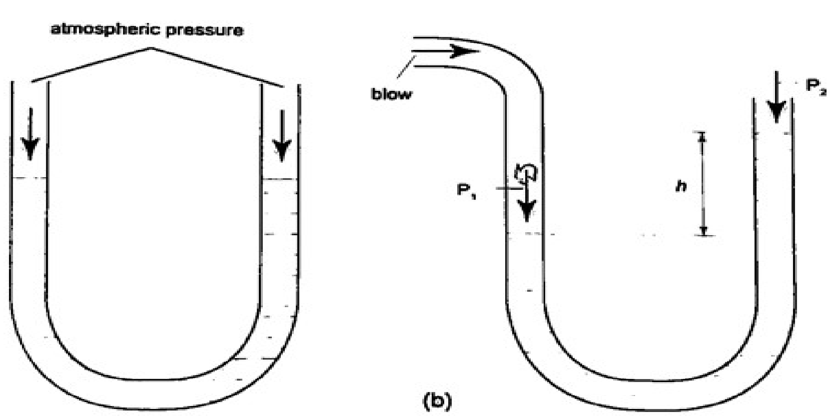
A man blows into one end of a U-tube containing water until the levels differ by 40.0 cm. if the atmospheric pressure is 1.01 × 105 N/m2 and the density of water is 1000 kg/m3, calculate his lung pressure.

Solution

Lung pressure = atmospheric Pressure + liquid pressure

P1 = P0 + hρg. Hence P1 = (1.01 × 105) + (0.4 × 10 × 1000) = 1.05 × 105 N/m2.

Measuring pressure



1. Simple mercury barometer– it is constructed using a thick walled glass tube of length 1 m and is closed at one end. Mercury is added into the tube then

inverted and dipped into a dish containing more mercury. The space above the mercury column is called torricellian vacuum. The height ‘h’ (if it is at sea level) would be found to be 760 mm. Atmospheric pressure can be calculated as,

$P = \rho g h$ =>where ρ (mercury)- 1.36×104 kg/m3, g- 9.81 N/kg, h- 0.76 m.

Then $P = (1.36 \times 104) \times 9.81 \times 0.76 = 1.014 \times 105$ Pa.

This is the standard atmospheric pressure, sometimes called one atmosphere. It is approximately one bar.

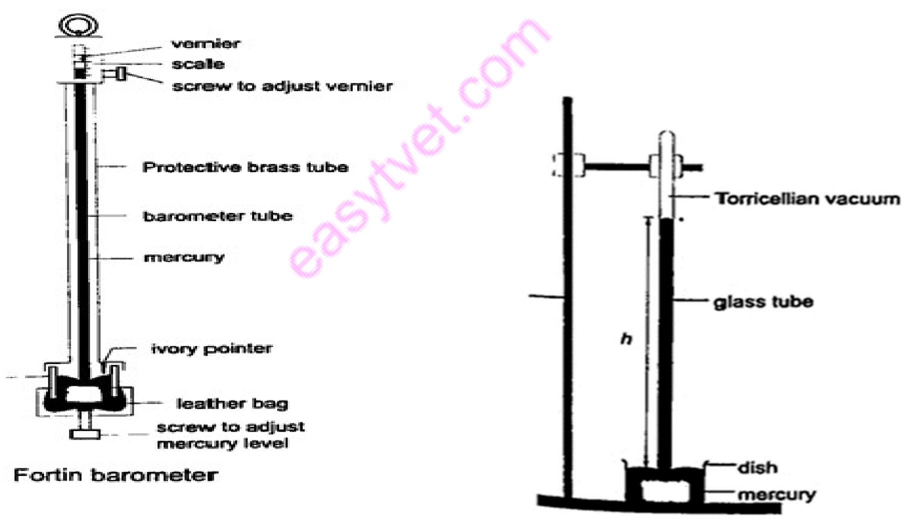


Figure 107:Mercury Barometer

2. Fortin barometer–this is a more accurate mercury barometer. The adjusting screw is adjusted first to touch the mercury level in the leather bag.
3. Aneroid barometer– increase in pressure causes the box to contract, the movements are magnified by the system of levers and is transmitted to the pointer by the fine chain and this causes the pointer to move. The scale is suitably calibrated to read pressure. Since pressure falls or rises as altitude falls or rises, the pointer can also be calibrated to read altitude.

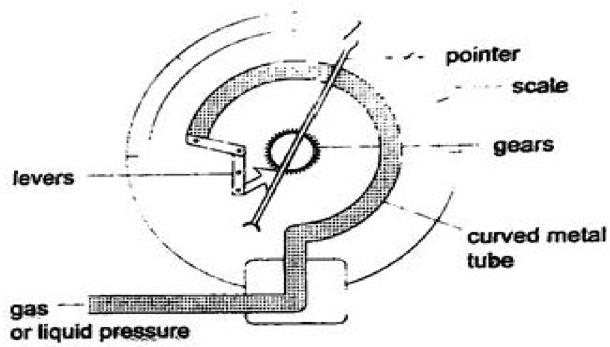


Figure 108:Aneroid Barometer

Examples

The height of the mercury column in a barometer is found to be 67.0 cm at a certain place. What would be the height of a water barometer at the same place? (densities of mercury- 1.36 × 104 kg/m3 and water- 1.0 × 103 kg/m3).

Solution

Let the pressure due to water be h1 ρ1 g1 and that of water be h ρ g. Then

h1 ρ1 g1 = h ρ g. Hence h1 = (6.7 × 10-1) × (1.36 × 104) / 1.0 × 103 = 911.2 cm or 9.11 m.

Application of pressure in gases and liquids.

1. Rubber sucker– this is a shallow rubber cap. Before use it is moistened to get a good seal then pressed firmly on a smooth surface so that the air inside is pushed out. The atmospheric pressure will then hold it firmly against the surface as shown below. They are used by printing machines to lift papers, lifting glass panes, heavy metal sheets etc.
2. Drinking straw– when a liquid is drawn using a straw air is sucked through the straw to the lungs. This leaves the space in the straw partially evacuated. The atmospheric pressure pushing down the liquid in the container becomes greater than the pressure inside the straw and this forces the liquid into your mouth.

3. The syringe– they work in the principle as the straw. They are used by the doctors in hospitals for giving injections. Bicycle pump– it uses two valves, one in the pump (greasy leather) and the other in the tire. When the handle is pushed in, the pressure inside the barrel becomes greater than the one in the tire and this pushes air inside. The valve in the tire is made such that air is locked inside once pumped.
4. The siphon– it is used to empty tanks which may not be easy to empty by pouring their contents out. The tubing must be lowered below the base of the tank. The liquid flows out due to pressure difference caused by the difference in height (h ρ g).
5. Lift pump.
6. Force pump.

Applications of pressure in Plumbing Systems

Positioning of tanks at high levels

The use of pumps to pump water to the storage vessels because it is against gravity.

Flowrate

In plumbing and heating, the volumetric. The SI unit is m^3/s: in other words, the volume of water (in m3) that flows every second (s). However, since we know that 1m3 of water has a mass of 1000kg and that 1 kg of water is equal to 1 litre, then the flow rate can also

be represented in various other ways too:

- m^3/s
- l/s
- kg/s

For example, if a tap discharges $0.3m^3/s$, then:

$0.3m^3/s = 300\ li\ =\ 300kg$

In this case, the flow rate could be quoted as $0.3m^3/s$ or 300l/s or 300kg/s.

The Application of Pressure and Flow Rate Measurements

Pressure and flow rate are the key points that any plumbing system will be measured by. If the flow rate or the pressure is poor, then this can be the result of poor design, poor installation or both. Good plumbing design and installation will deliver the desired pressure and flow rate for a given specification. However, we must also be aware that too much pressure or too high a flow rate can be detrimental as they can cause noise and erosion problems in pipework and fittings and this may lead to breakdown or failure of the pipework or components.

Force

If the object is subjected to force, it will begin to move. Consider the following example:

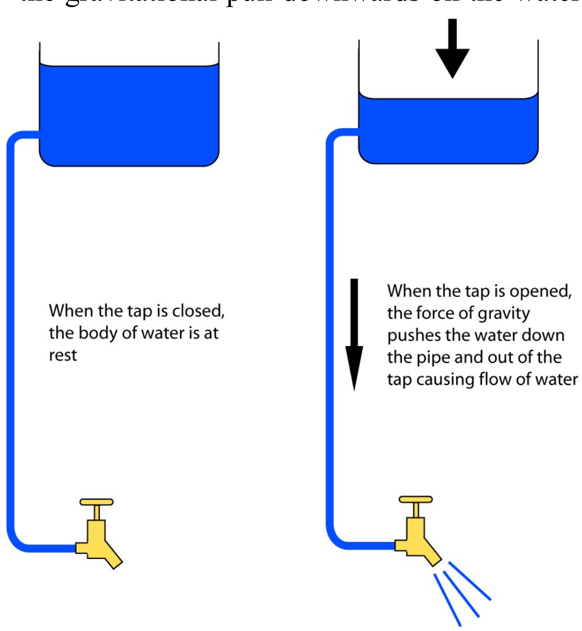
A pipe is connected to a cistern at one end and a tap at the other. The cistern is situated in the roof space and the tap is in the bathroom. While the tap is closed, the water can be said to be at rest because it is not moving. When the tap is opened, the water moves from the cistern, down the pipe and out of the tap. The water is being acted upon by the force of gravity causing it to move. We can calculate the amount of force acting downwards on the cistern that causes the water to flow.

The cistern contains 100 litres of water. Since 1 litre = 1 kg, then the mass of the cistern is 100kg. Therefore:

$Kg\ x\ 9.81 = N\ 100\ x\ 9.81 = 981N$

So, the force acting on the water is 981 N.

Force, however, does not give the pressure of the water at the tap. Force only gives an indication of the gravitational pull downwards on the water. Water pressure is calculated slightly differently and



this will be discussed in Part C, a little later in the unit.

Figure 109: Force in Water

Pressure

The weight of, say, a cistern sitting on a platform in a roof space is measured in N/m2 or Newtons per square metre. If the cistern was of equal dimensions (length, width and height), then the weight being exerted onto the platform would be the same irrespective of whether the cistern was on its bottom, side or end.

If the cistern has unequal dimensions for the length, width and height, then different pressures will be exerted depending on which of the sides is face down.

Example:

A cistern measuring 0.9m long x 0.8m wide x 0.7m high is to be installed on a platform in a roof space. What pressure would it exert on the platform if:

- The cistern was placed on its bottom (length x width)
- The cistern was placed on its side (length x height)
- The cistern was placed on its end (width x height)

Before we can attempt these calculations, we must first determine the mass of the cistern in kg. The formula for this is:

Mass = $Length\ x\ width\ x\ height$ = $volume\ in\ m$Y 0.9 x 0.8 x 0.7

= 0.504mY

Then, we must convert the volume into mass of water. To do this we must multiply the volume by 1000 to convert the mass into litres.

$Volume\ x$ 1000 = $litres$ 0.504 x 1000 = 504 $litres$

Since 1 litre of water has a mass of 1 kg, then:

$Litres = kg$

504 $litres$ = 504 kg

From an earlier calculation we know that:

So:

$Kg\ x\ 9.81 = N$

$$504\ x\ 9.81 = 4944.24\ N$$

Therefore, the cistern has a force of 4494.24 N

The formula for finding the pressure exerted is:

$$\text{Pressure} = Force \div A\ rea = Pressure$$

- Area of the bottom of the cistern:

$$0.9\ x\ 0.8 = 0.72m'$$

$$4944.24 \div 0.72 = 6867N\ pressure$$

- Area of the side of the cistern:

$$0.9\ x\ 0.7 = 0.63m'$$

$$4944.24 \div 0.63 = 7848N\ pressure$$

- Area of the end of the cistern:

$$0.8\ x\ 0.7 = 0.56m'$$

$$4944.24 \div 0.56 = 8829N\ pressure$$

From these calculations we can see that the greater the surface area for a known mass of water, then the less force is exerted by the mass on to the platform. This is very important when we are deciding on where to place large cisterns that will contain a lot of water. The greater area we can present to the platform, the better the spread of the weight across the platform, creating less stress on the structure.

Water Pressure

Water pressure can be measured when the water is flowing and when it is not flowing. These methods are known as:

1. Static pressure (head) – Water that is not flowing

2. Dynamic pressure – Water that is flowing

3. Static pressure (head) – Water that is not flowing

The image shows a cistern full of water with a pipe connected to a tap. It is the distance between the cistern and the tap (measured from the bottom of the cistern to the outlet of the tap) that creates the water pressure. It is measured in Pascals (pa). This is known as the 'static head' or 'head of water'. Every metre of height (or head) between the two increases the water pressure by 10 Kpa (kilopascals):

As we have seen previously, water pressure is also measured in bar and psi.

methods are known as:

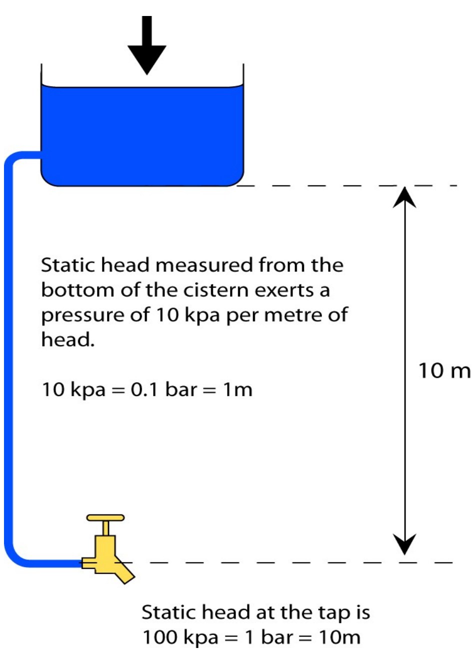


Figure 110: Demonstration of water pressure

The image shows a cistern full of water with a pipe connected to a tap. It is the distance between the cistern and the tap (measured from the bottom of the cistern to the outlet of the tap) that creates the water pressure. It is measured in Pascals (pa). This is known as the 'static head' or 'head of water'. Every metre of height (or head) between the two increases the water pressure by 10 Kpa (kilopascals):

As we have seen previously, water pressure is also measured in bar and psi.

$1m\ of\ head = 10kpa = 0.1\ bar$

So:

$10m\ head = 100\ kpa = 1\ bar$

Dynamic Pressure – Water that is Flowing

Dynamic pressure is also known as working pressure. It is the pressure of the water when it is flowing. This will generally be less than the static pressure because it is affected by other factors:

If the static pressure of the water is increased, then the effect would be that the flow rate of the water and is velocity would also increase.

The relationship between velocity, pressure and flow rate in systems

- Increasing the static water pressure will increase the velocity of the water, and therefore the flow rate, because the water is flowing with more force through the pipe.

- Decreasing the static pressure will also decrease the water velocity and therefore reduce the flow rate.

- Decreasing the pipe size will reduce the flow rate and increase the velocity because of the Bernoulli Effect

The Bernoulli effect

The Bernoulli Effect describes the relationship between flow velocity and pressure of a fluid, i.e. water. It states that when the water passes through a reduction in pipe size, then the velocity of horizontal flow will increase and the pressure will decrease.

This effect was discovered by Daniel Bernoulli in 1738.

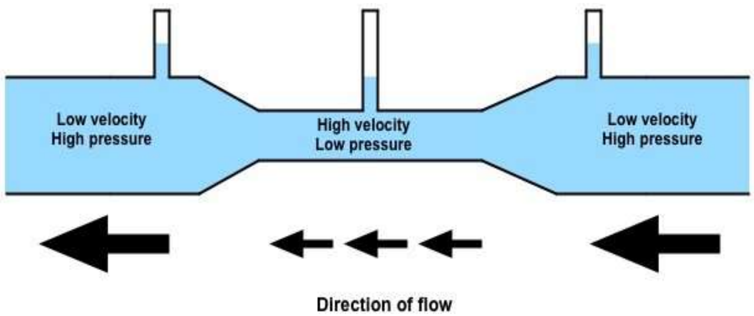


Figure 111: The Bernoulli effect

If the water is moving uniformly through the pipe, then the only forces acting on the water are its own weight and the static pressure of the water itself. If the pipe reduces in size, the water must speed up, because the same amount of water is trying to flow through a smaller space. The only way the water will move faster is if the pressure behind the fluid is greater than the pressure in front. Thus, the pressure must decrease as velocity increases.

Increasing the pipe size has a reverse Bernoulli Effect and this increases the pressure and reduces the velocity.

Reasons why pipework restricts the flow of liquids and gases

The material of the pipe

Different materials offer different resistance to the flow of water. Copper tubes and plastics are smooth internally and give little resistance to the flow of water. Low Carbon Steel, by contrast, is very rough internally and offers a greater resistance. This in turn decreases the pressure.

Changes of direction

Elbows, bends and the junction of tee fittings also offer resistance to flow and this too will reduce the pressure. An elbow, for example, has the same resistance as around 0.5m of pipe (0.3m of pipe if machine made bends are used). So if the pipe run has 6 elbows (or 6 changes of direction), this is equivalent to an extra 3m of pipe.

Length of pipe run

Again, the greater the length of pipe, the more resistance is encountered. This will effectively reduce the pressure and the flow rate of both water and gases

Pipe size

The bigger the pipe, the greater the volume of water or gases.

Restrictions such as valves and stop taps

These reduce both pressure and flow rate because they offer resistance to smooth water flow.

Reductions in pipe size

A pipe size reduction reduces the pressure and the flow rate BUT increases the velocity. It is known as the Bernoulli Effect.

Roughness of material surface

The rougher the pipe material, the greater the resistance to flow.

Principles of a Siphon

The principle of a siphon is to move water from a high place to a low place using only atmospheric pressure and the cohesive properties of water.

3.2.5.4. Learning Activities

Practical activity

a) Assemble a water closet with a siphonic flush, Test the WC and note the pressure application.

Materials and Supplies

- A complete WC

- Caulk
- Safety gear
- Adjustable spanner
- Water hose

5.1.1.4.1. Self-Assessment

1. Discuss the five factors why pipework restricts the flow of liquids and gases
2. A man of mass 84 kg stands upright on a floor. If the area of contact of his shoes and the floor is 420 cm^2, determine the average pressure he exerts on the floor. (Take g =10 N/Kg)
3. The density of mercury is 13,600 kgm-3. Determine the liquid pressure at a point 76 cm below the surface of mercury. (Take g = 10 Nkg-1)

4. The height of the mercury column in a barometer is found to be 67.0 cm at a certain place. What would be the height of a water barometer at the same place? (Densities of mercury and water are 1.36 × 104 kg/m3 and 1.0 × 103 kg/m3 respectively.)
5. Which three types of water pressure are you familiar with

3.2.5.5. Tools, Equipment, Supplies and Materials

- A complete WC
- Caulk
- Safety gear
- Adjustable spanner
- Water hose

3.2.5.6. References

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3.2.5.7. Model Answers

1. **Discuss the five factors why pipework restricts the flow of liquids and gases**

The material of the pipe

Different materials offer different resistance to the flow of water. Copper tubes and plastics are smooth internally and give little resistance to the flow of water.

Changes of direction

Elbows, bends and the junction of tee fittings also offer resistance to flow and this too will reduce the pressure.

Length of pipe run

The greater the length of pipe, the more resistance is encountered. This will effectively reduce the pressure and the flow rate of both water and gases

Pipe size

The bigger the pipe, the greater the volume of water or gases.

Restrictions such as valves and stop taps

These reduce both pressure and flow rate because they offer resistance to smooth water flow.

Reductions in pipe size

A pipe size reduction reduces the pressure and the flow rate BUT increases the velocity. It is known as the Bernoulli Effect.

2. **A man of mass 84 kg stands upright on a floor. If the area of contact of his shoes and the floor is 420 cm^2, determine the average pressure he exerts on the floor. (Take g =10 N**/Kg)

   Solution

   Pressure = force / area = 840 / 0.042 = 20,000 Nm-2.

3. **The density of mercury is 13,600 kgm-3. Determine the liquid pressure at a point 76 cm below the surface of mercury. (Take g = 10 Nkg-1)**

   Solution

   Pressure = h ρ g = 0.76 × 13,600 × 10 = 103,360 Nm-2.

4. **The height of the mercury column in a barometer is found to be 67.0 cm at a certain place. What would be the height of a water barometer at the same place? (Densities of mercury and water are 1.36 × 104 kg/m3 and 1.0 × 103 kg/m3 respectively.)**

   Solution

   Let the pressure due to water be h1ρ1g1 = h ρ g, hence;

   h1 = h ρ / ρ1= (6.7 × 10-1) × (1.36 × 104) = 911.2 cm or 9.11 m.

5. **Which three types of water pressure are you familiar with**

- Static pressure (head) – Water that is not flowing
- Dynamic pressure – Water that is flowing
- Static pressure (head) – Water that is not flowing

3.2.6. Learning outcome 6: Apply principles of acoustic

3.2.6.1. Introduction to the learning outcome

This unit describes the competence in applying principles of sound and their effects on the surroundings. It also lays emphasis on the effective methods of sound proofing and insulation.

3.2.6.2. Performance Standard

1. Sources of sound are identified based on scientific principles
2. Effects of sound on surrounding areas is identified based on scientific principles
3. Methods of sound insulation are identified and interpreted based on scientific principles

3.2.6.3. Information Sheet

Introduction

The main application of acoustics is to make the music or speech sound as good as possible. It is achieved by reducing the sound barriers and increasing the factors that help in proper transmission of sound waves. Initially, acoustics was used only in industries which are based on sound like an auditorium, theatre but today, the application of acoustics has spread to many fields like medicine, warfare, architectural industries, etc.

Definitions of terms

- *Acoustics* - the science that deals with the study of sound and its production, transmission, and effects.
- *Acoustician*- a scientist or researcher who studies acoustics
- *Acoustic energy* – is the disturbance of energy which passes through matter in the form of a wave.
- *Transduction* - the process in which some other form of energy is converted into sonic energy producing a sound wave
- *decibel (dB)* – Is the unit of measuring the amplitude of sound. The more amplitude a sound has, the louder it is.

Sound is created by vibration in an elastic medium such as air, water, and solids such as building materials. Sound travels outward through air molecules at a speed of about 1130 feet per second, quite slow in relation to the speed of light, which is about 186,000 miles per second. The vibration of the air particles in a sound wave sets the eardrums in motion. Sound is a series of pressure variations in air that take the form of periodic compressions and rarefactions. Sound travelling in air exhibits a longitudinal wave motion.

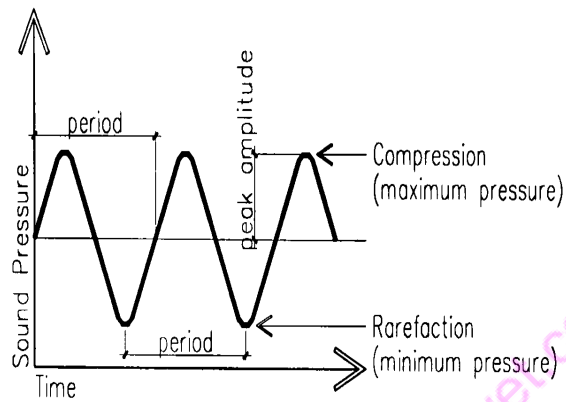

Figure 112:Vibration of Particle in Air.

- ✓ The number of complete to-and-fro vibrations that the source makes in one second is called the **frequency** of vibration.
- ✓ The time required for one complete vibration cycle is called the **period**. Consequently, the reciprocal of frequency is period.
- ✓ The greater the number of complete cycles, the higher the frequency. Frequency is measured in hertz,
- ✓ which represents cycles per second.
- ✓ **Wavelength** is the distance a sound wave travels during one cycle of vibration. The relationship between wavelength, frequency, and velocity (or speed) of sound is expressed as:

λ= c/f

where λ = wavelength, c = velocity of sound in feet per second, and f = frequency of the sound in hertz. Low-frequency sounds are characterized by long wavelengths and high frequency sounds are characterized by short wavelengths. While sound travels relatively slew in air, it may travel as fast as 16,000 feet per second along steel pipes and duct walls or through other building materials. It is therefore crucial to block or isolate paths where sound energy can travel through building materials to sensitive areas, even great distances away, where it can be regenerated as airborne sound.

Acoustic Energy

In other words, it is the energy concerning the mechanical vibrations from its components is called Acoustic Energy. Any acoustic event has the following stages.

- Cause or Generating Mechanism
- Acoustic wave propagation
- Reception Effect

Sound waves carry energy throughout the propagating medium. The acoustic wave equation is the fundamental equation that describes sound wave propagation. Wave propagation is the key process in any of the acoustic event. Sound propagates in liquids as a pressure wave and in solids as longitudinal or transverse waves.

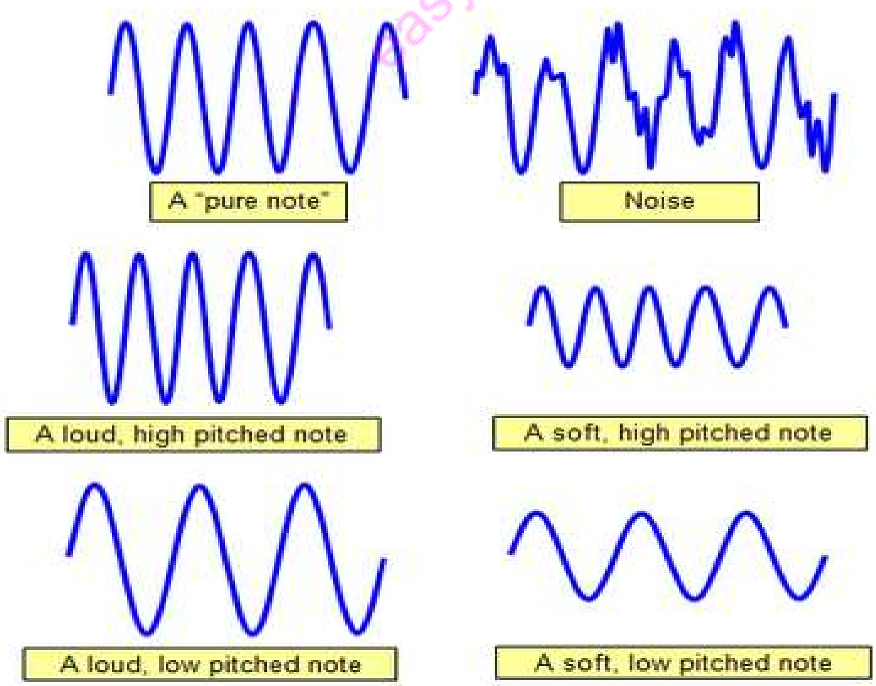

Figure 113:Sub-disciplines of Acoustics

TYPES OF ACOUSTICS

1. **Environmental Noise**

Environmental Acoustics is concerned with vibration and noise caused by roadways. Railways, aircraft and general activities that are related to the environment. The main goal of these is to reduce vibration and noise that affects the environment.

2. **Ultrasounds**

Ultrasounds are the sounds with a frequency greater than the human audible limit. However, there is no difference in physical properties when compared to normal sound. Ultrasound is used in many fields. Ultrasonic devices are used in measuring distances and in detecting objects. Ultrasound imaging is used in physics.

3. **Infrasounds**

Infrasounds are the sounds with a frequency of less than 20 Hz. The study of such sounds is called infrasonics. Applications include detection of petrol formation under the earth and the possibility of earthquakes.

4. **Vibration and Dynamics**

It is the study of how mechanical systems vibrate and interact with their environment. Applications include Vibration control which helps to protect a building from earthquakes and ground vibrations used in railways.

PRINCIPLES OF ACOUSTICS

In order to improve acoustic performance there are a number of items that can be considered.

1. The Mass Law. Essentially one of the most effective ways in enhancing acoustic performance on a frontage is to increase the mass or weight of its main surface components. Going by the Mass Law, for every doubling of weight of a material, it equates to a 6dB improvement.

Therefore, a 12mm thick glass will give a 6dB improvement in performance, over a 6mm thick glass.

2. Separating the elements in a front build up. The separating of the elements disrupts the pattern of the sound waves as they pass through the front and makes it harder for them to reach the inside surface. Including different materials in the frontage build up can be used as a method for controlling sound. Different materials will absorb and block different sounds, so a variety of materials can work together to achieve the required result.

3. The glass specifications themselves, by using laminated glass, especially one with an acoustic interlayer, you can often achieve the marginal gains that are often required.

4. When using double glazed units on a project, consider using different thicknesses / compositions of glass for the inner and outer panes, as the different thicknesses will resonate at different frequencies.

SOUND INSULATION

Sound insulation relates to the total ability of a building element or building structure to lower the sound transmission through it. Two types of sound insulation might be referred to – airborne sound insulation and impact sound insulation. It's crucial to keep in mind that the weakest link in the construction has a large impact on the overall sound insulation.

The level of sound insulation relies on the following general principles:

- flexibility/rigidity
- efficiency
- mass
- isolation.

The efficiency of each strategy of insulation can vary with the kind of sound, however in the majority of constructions all the principles of insulation matter.

- **Mass**

For example, the typical SRI of a brick wall increases from 45 dB to 50 dB when the thickness is increased from 102.5 mm to 215 mm. This doubling of mass does not need to be achieved by a doubling of thickness as the mass of a wall for sound insulation purposes is specified by its surface density determined in kilograms per square metre (rather than per cubic metre). Concrete blocks of different densities can produce the very same surface area density by differing the densities of the blocks.

- **Resonance.**

The Mass Law states that the sound insulation of a single-leaf partition has a linear relationship with the surface density (mass per system area) of the partition, and increases with the frequency of the sound.

Windows and doors are necessary parts of a building however a knowledge of the uniformity concept can prevent effort being lost on the insulation of the wrong locations. To enhance the insulation of a composite structure the component with the most affordable insulation must be improved first off. Walls dealing with loud roads need to consist of the minimum of windows and doors, and they must be well insulated.

Any doubling of frequency is a change of one octave. For example, a brick wall provides about 10 dB more insulation against 400 Hz sounds than versus 100 Hz noises. This modification, from 100 to 200 Hz and after that 200 to 400 Hz, is a rise of two octaves.Sound insulation increases by roughly 5 dB whenever the mass is doubled.

For increasing sound insulation typically involve increasing the thickness of masonry, plaster and glass. Where a construction does not obey the Mass Law it is due to the fact that other factors such as airtightness, stiffness and isolation have an effect.

- **Efficiency.**

Single-leaf construction includes composite construction such as plastered brickwork, as long as the layers are bonded together. Theory predicts an insulation increase of 6 dB for each doubling of mass, however for practical constructions the following working rule is preferable.

Typical air gaps:

- Wall– floor gaps.
- Gaps around doors.
- Poor window seals.
- Unsealed pipe runs.
- Unsealed cable runs.
- Permeable blockwork.

- **Isolation.**

Loss of insulation by resonance occurs if the event sound waves have the exact same frequency as the natural frequency of the partition. The increased vibrations that take place in the structure are handed down to the air therefore the insulation is reduced. Resonant frequencies are usually low and probably to trigger problem in the air areas of cavity construction.

- **Airtightness.**

The overall sound insulation of a construction is considerably reduced by small locations of poor insulation. An unsealed door occupying 25 per cent of the area of a half-brick wall lowers the average sound insulation of that wall from around 45 dB to 23 dB. The final sound insulation is affected by relative locations but is always closer to the insulation of the poorer part than to the better component.

The effectiveness of sound insulation depends upon frequency and the Mass Law likewise predicts the list below impact on frequency.

- **Flexibility**

Heavyweight structures with high mass transmit less sound energy than lightweight structures. The high density of heavyweight materials restricts the size of the sound vibrations inside the material so that the final face of the structure, such as the inside wall of a room, vibrates with less movement than for a light-weight material.

Flexible (non-stiff) materials, integrated with a high mass, are best for high sound insulation. Flexibility is not usually a preferable structural property in a wall or a floor.

3.2.6.4. Learning Activities

Practical activity

- Tie a 4foot piece of string to a table leg.
- Pull it tight and pluck it.
- Repeat this with a different kind of string.

Materials and Supplies

- 3 pieces of string, each 4 feet long (different kinds)
- 2 large paper clips
- Paper towels

3.2.6.5. Self-Assessment

1. What do you understand with the following terms;

    a) Frequency
    b) Period
    c) Wavelength

2. Discuss the crucial factors considered when carrying out insulation of a given room
3. In your own understanding, highlight the five types of acoustics and give an application for each.
4. Which are the three stages for the generation of acoustic Energy.
5. Briefly discuss the principles of acoustics

3.2.6.6. Tools, Equipment, Supplies and Materials

- 3 pieces of string, each 4 feet long (different kinds)
- 2 large paper clips
- Paper towels

3.2.6.7. References

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3.2.6.8. Response

1. What do you understand with the following terms;

   a) **Frequency** - The number of complete to-and-fro vibrations that the source makes in one second

   b) Period - the time required for one complete vibration cycle is called the. Consequently, the reciprocal of frequency is period.

   c) Wavelength -is the distance a sound wave travels during one cycle of vibration

2. Discuss the crucial factors considered when carrying out insulation of a given room

   - flexibility/rigidity
   - efficiency
   - mass
   - isolation.

3. In your own understanding, highlight the five types of acoustics and give an application for each.

i. Environmental Noise

Environmental Acoustics is concerned with vibration and noise caused by roadways. Railways, aircraft and general activities that are related to the environment.

ii. Musical Acoustics

Musical acoustics is concerned with the study of physics of music i.e., how sounds are used to make music. Areas of study include human voice, musical instruments, and music therapy.

iii. Ultrasounds

Ultrasounds are the sounds with a frequency greater than the human audible limit.. Ultrasound is used in many fields. Ultrasonic devices are used in measuring distances and in detecting object

iv. Infrasounds

Infrasounds are the sounds with a frequency of less than 20 Hz. The study of such sounds is called infrasonics. Applications include detection of petrol formation under the earth and the possibility of earthquakes.

v. Vibration and Dynamics

It is the study of how mechanical systems vibrate and interact with their environment. Applications include Vibration control which helps to protect a building from earthquakes and ground vibrations used in railways.

4. Which are the three stages for the generation of acoustic Energy.

    - Cause or Generating Mechanism
    - Acoustic wave propagation
    - Reception Effect

5. Briefly discuss the principles of acoustics

i. The Mass Law. Essentially one of the most effective ways in enhancing acoustic performance on a frontage is to increase the mass or weight of its main surface components. Going by the Mass Law, for every doubling of weight of a material, it equates to a 6dB improvement.

ii. Separating the elements in a front build up. The separating of the elements disrupts the pattern of the sound waves as they pass through the front and makes it harder for them to reach the inside surface. Including different materials in the frontage build up can be used as a method for controlling sound. Different materials will absorb and block different sounds, so a variety of materials can work together to achieve the required result.

iii. The glass specifications themselves, by using laminated glass, especially one with an acoustic interlayer, you can often achieve the marginal gains that are often required.

iv. When using double glazed units on a project, consider using different thicknesses / compositions of glass for the inner and outer panes, as the different thicknesses will resonate at different frequencies.

3.2.7. Learning outcome 7: Apply mechanical properties of materials

3.2.7.1. Introduction to the learning outcome

This unit describes the competence in applying principles of mechanical properties for materials and the respective tests involved for various materials to ascertain their mechanical properties.

3.2.7.2. Performance Standard

1.Mechanical properties are identified and interpreted based on type of material
2.Advantages and disadvantages of materials are identified based on use of materials
3.Materials are tested based on type of material.

3.2.7.3. Information Sheet

Definitions of terms

- *Mechanical properties* are physical properties that a material exhibits upon the application of forces
- *Test* - the determination of the technological and operational properties of materials, primarily by the use of machines and instruments

INTRODUCTION

The mechanical properties are those which affect the mechanical strength and ability of a material to be molded in suitable shape. Some of the typical mechanical properties show huge applications in space and automobile industries. These properties are associated with the capability of the materials to resist mechanical forces and load and they are measured in terms of the behavior of the material when subjected to a force. Mechanical properties may be determined to provide either design data for the engineer or as a check on the standard of raw materials. Mechanical properties may be changed by heat treatment process and the working temperature. Mostly, the strength, toughness and hardness of materials are to be measured after the metal forming process.

- **Stiffness**

It is the ability of a material to resist deformation under stress. Modulus of elasticity is the measure of stiffness. Material which suffers slight deformation under load has a high degree of stiffness or rigidity. Steel beam is stiffer or more rigid than aluminium beam. Finally, it means that the ability of material to resist elastic deflection is known as stiffness.

- **Elasticity**

It is the property of materials to regain its original shape after deformation when the external forces are removed. Example is the extension or compression of a spring. This property is desirable for Materials used in tools and machines. Steel is more elastic than rubber. Elasticity is a tensile property of the material. Proportional limit and elastic limit indicate elasticity. It is also known as Non-Permanent deformation. It consists of two sub properties within this elastic region. They are proportional limit and elastic limit. Proportional limit is the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress. Proportional limit applications are precision instruments, springs etc... The greatest stress that a material can endure without taking up some permanent set is called elastic limit. Beyond the elastic limit, material does not regain its original form and permanent set occurs.

- **Plasticity**

It is the ability of material to undergo some degree of permanent deformation without rupture or failure. That means, this is the property of a material to deform permanently under the application of a load. Plastic deformation will take place only after the elastic range has been exceeded by the process of slipping when the shear stress on the slip plane reaches a critical value. Displacement caused by slipping is permanent and the crystal planes do not return to their original positions even after the removal of the stresses. Applications are forming, shaping, extruding, hot & cold working process, forging, ornamental work, stamping, rolling, drawing, pressing, etc. Aluminum is a good plasticity material.

- **Ductility**

It is the property of a material which enables it to draw out into thin wire with the application of a tensile force. Ductile material must be both strong and plastic. Ductile materials are gold (most ductile material), mild steel, copper, aluminium, nickel, zinc, tin. Ductility usually measured by the terms, percentage elongation and percentage reduction in area. Ductility is thought of as a tensile quality. Ductile material combines the properties of plasticity and tensile strength. It is also mentioned as a capacity of a material to undergo deformation under tension without rupture or the ability of a material to withstand cold deformation without fracture. Ductility of a material is to stretch under the application of tensile load and retain the deformed shape on the removal of the load. If subjected to a shock load the material would yield and become deformed. Ductile material can be worked into a shape without loss of strength. All materials which are formed by drawing are required to be ductile, e.g. drawing into wire form.

- **Brittleness**

Breaking of a material with little permanent distortion simply states the property of brittleness. Brittle materials when subjected to tensile loads snap off without giving any sensible elongation. Usually the tensile strength of brittle materials is only a fraction of their compressive strength. Examples of brittle materials are glass, bricks, cast iron etc… It is also a tendency of a material to fracture when subjected to shock loading or a blow. Material that shatters is also a brittle material.

- **Malleability**

It is the ability of materials to be rolled, flattened or hammered into thin sheets without cracking by hot or cold working. Malleable material should be plastic but it is not essential to be strong and malleability is considered as a compressive quality. Examples for malleability Al, Cu, Sn, Pb, soft steel, wrought iron. This is the property of a material to deform permanently under the application of a compressive load. A material which is forged to its final shape is required to be malleable. Forging, Rolling processes are malleability.

- **Toughness and Testing**

It is the ability of a material to withstand bending without fracture due to high impact loads. Toughness of material decreases when it is heated. It is also measured by the amount of energy that a unit volume of the material has absorbed after being stressed up to failure point and is the area under stress strain curve. For example, if a load is suddenly applied to a piece of mild steel and then to a piece of glass, the mild steel will absorb much more energy before failure occurs. Thus mild steel is said to be much tougher than a glass. This property is desirable in parts subjected to shock and impact loads. Notch toughness is the measure of the metal's resistance to brittle fracture in presence of flaw or notch and fast loading conditions. Examples are Mn-steel, wrought iron, MS, etc…it can be also defined as property of absorbing energy before fracture. To the opposite of brittleness, the ability of a material is to resist fracture under shock loading.

- **Resilience**

The property of a material to absorb energy and to resist shock and impact loads are known as resilience. Generally, it is mentioned by the amount of energy absorbed per unit volume within elastic limit. This is essential for spring materials. Two kind of resilience are available. Proof resilience: Maximum energy which can be stored in a body up to elastic limit is called the proof resilience. But the Proof resilience per unit volume is called modulus of resilience.

- **Creep**

When a part is subjected to a constant stress at high temperature for a long period of time, it will undergo a slow and permanent deformation called creep. Property is considered in designing IC engines, boilers, turbines. Simplest type of creep deformation- viscous flow Plastics, rubber and amorphous materials are very temperature sensitive to creep. Stress for a specified rate of strain at a constant temperature is called creep strength. When a material sustains steady loads for long periods of time, the material may continue to deform until they may tend to fracture under the same load. This is called creep. If a load is applied and left on the sample for months or years, the sample will slowly extend.

- **Fatigue**

It is a failure of materials under cyclic loads. When a part is subjected to a repeated or fluctuating stresses, the fracture takes place under a stress whose maximum value is less than the tensile strength of the material. For instance, the components of high speed aero and turbine engine are of this type. This is the property of a material to withstand continuously varying and alternating loads. If a part is loaded once to a stress near the yield stress, it will not break. However, if it is loaded repeatedly to this level, it will eventually break. This failure is called fatigue. Fatigue is an important goal in the design of moving machinery. Basically three stages of fatigue processes are

i) Initial fatigue
damage which leads to crack nucleation and crack initiation.

ii) Progressive cyclic growth of a
crack, this is the crack propagation stage, until the remaining un-cracked cross section of a part becomes too weak to withstand the loads applied.

iii) Final stage is the sudden fracture.

- **Hardness**

Property of a material to resist penetration by another material is known as hardness. It embraces many different properties such as resistance to wear, scratching, deformation etc.. Hardness of materials can be meant like resistance to abrasion, deformation or indentation.

- **Machinability**

Machinability is defined as the ease with which a material can be machined such as drill, lathe work, Cutting. Machinability of metal is indicated by percentage (%) that is known as machinability index. Standard metal used for the 100% machinability rating is the free-cutting steel. Materials with good machinability may be cut with relatively little power and low cost. Alloys containing more than 10% Si are the most difficult to machine because hard particles of free silicon cause rapid tool wear.

Mechanical property	Testing method
Elasticity, plasticity	Tensile test, compression test, bending test, torsion test
Stiffness, material behaviour under static load	
Creep behaviour	Creep rupture test
Hardness	Brinell, Rockwell, Vickers
Toughness	Impact test
Fatigue behaviour, fatigue strength	Wöhler fatigue test

- **Tensile Strength -** The maximum force a material can withstand when being pulled apart. Some materials such as plastics and some metals will stretch when subjected to tensile strength, while other materials like cast iron and concrete will simply snap with no deformation of shape.
- **Compressive strength -** The maximum force a material can withstand when being crushed
- **Shear strength** - The maximum force a material can withstand when being ripped.
- **Torsion strength** - The maximum force a material can withstand when being twisted (see above).
- **Heat and Electrical Conductivity** - The measure of how well a material conducts heat or electricity.
- **Heaviness** - The denseness of a material. A dense material will be heavy in relation to its size.
- **Strength** - The measure of how materials withstand heavy loads without breaking.

MATERIALS TESTING

Materials testing studies the behaviour of materials under different loads. In particular, the relationship between the acting in quality assurance. There is a range of standardized testing methods to characterize the mechanical properties of materials

Figure 114: Material testing

1. Compression test to determine flow curves

Compression tests are less significant for testing metallic materials compared to tensile tests. However, when studying building materials such as natural stone, brick, concrete, wood etc., the compression test is fundamentally import- ant. A standardized specimen with a known cross section is loaded uniformly with low increasing force in the longitudinal direction. A uniaxial stress state prevails in the specimen. The ratio of stress to compression can be shown from the plotted force-path diagram. The stress-compression diagram shows clearly the different behaviour of the various separate materials and provides the characteristic values for compression strength, 0,2% offset yield point and the compression yield stress.

2. Bending tests for the study of deformation behaviour

The most frequently studied bending load in materials testing is the three-point bending test. Using this method, a beam mounted on two supports is studied under a single force applied to the centre. The bending test demonstrates the relationship between the load of a bending beam and its elastic deformation. The effects of modulus of elasticity and second moment of area are shown.

3. Shear test to study the load capacity against shearing

The shear test is applied when testing screws, rivets, pins and parallel keys in order to determine the shear strength of the material or the behaviour of the material under shear strain. To do this, the shear stresses are produced in the specimen by means of external shear forces until the specimen shears off. The resistance of a material against the shear stress can be determined by two different methods, the single-shear and the double-shear testing method.

4. **Torsion test to study the plastic behaviour of materials**

Sheets and strips are subject to high demands in terms of their cold formability for deep drawing. No cracks are allowed to occur when working with these thin sheets.

The cupping test checks the cold formability in sheets. Components that are subjected to rotary movements are twisted. This twisting is referred to as torsion. The torsional stiffness determined in the torsion test serves as orientation for the load capacity of the material. This method is applied in shafts, axles, wires and springs and to assess the impact behaviour of tool steels.

5. **Impact test to determine the toughness property**

The impact test is a method with sudden loading and is suit- able primarily for determining the cleavage fracture tendency or toughness property of a material. This test method does not provide any values of material characteristics. The determined values of the impact test, the notched-bar impact strength, do not fit directly into calculations on strength. Rather, they help only with a rough selection of materials for a specific task.
The deformation behaviour is often an important criterion for the selection of materials. It can be used to identify quickly which of the selected materials are brittle or tough.

6. **Fatigue strength test**

Materials behave differently under lasting static loads at increased temperatures than they do under the same load at without an increase in load lead to a slow but steady irreversible plastic deformation, also known as creep.

The fatigue strength defines the load limit up to which a material that is loaded dynamically withstands without breaking. Moving machine parts in particular are subject to dynamic loads, caused by vibrations for example. In this case, a fracture occurs after a high number of load cycles with stresses that are far below the yield point and far below the fracture stress.

7. **Principle of the creep rupture test**

In the creep rupture test, a specimen is subjected to load at constant stress and constant temperature. This experiment is performed multiple times with different stresses, but always at the same temperature. The plastic deformations are measured in continuous intervals. All measured values can then be transferred to a creep diagram. The measured elongation shows long, even load time, this leads to fracture of the specimen. A characteristic curve, which is known as the creep curve. The creep rupture test determines the characteristic values for the creep strength and the various strain values.

APPLICATIONS OF MECHANICAL PROPERTIES

The mechanical properties of materials are fundamentally important in terms of materials science. Every mechanical property has specific applications in designing components in manufacturing automobile, forging, power plant, aerospace etc. Some of the applications and its properties are given in the table below.

Table 8. Properties and applications

Sl.no.	Properties	Applications
1	Proportional limit	Precision instruments, springs
2	Plasticity	forming, forging, shaping, extruding, hot & cold working, ornamental work, stamping, rolling, drawing, pressing
3	Elasticity	Desirable for materials used in tools and machines.
4	Malleability	rolling, hammering
5	Toughness	Desirable for shock & impact loads.
6	Resilience	Springs
7	Creep	in designing IC engines, boilers, turbines
8	Hardness	resistance to wear, scratching, deformation

9	Fatigue	high speed aero and turbine engine

3.2.7.4. Learning Activities

Practical activity

With the help of your trainer, undertake a compression test on a building stone or on a concrete block and determine the compressive strength.

Include a test for tensile strength

Materials and Supplies

- Compression testing machine
- A building stone
- Writing materials

3.2.7.5. Self-Assessment

1. Discuss at least eight properties of materials
2. Which are the three stages of fatigue processes?
3. Highlight the application of the following tests;

    i. Plasticity
    ii. Elasticity
    iii. Malleability
    iv. Toughness

4. Briefly explain the procedure of undertaking the Fatigue strength test

5. Discuss the principle of the creep rupture test.

3.2.7.6. Tools, Equipment, Supplies and Materials

- Compression testing machine
- A building stone
- Writing materials

3.2.7.7. References

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3.2.7.8. Responses

1. Discuss at least eight properties of materials

- Hardness - The resistance of material to being cut, deformed or bent.
- Toughness - The amount of energy a material can absorb without breaking or fracturing.
- Tensile Strength - The maximum force a material can withstand when being pulled apart. Some materials such as plastics and some metals will stretch when subjected to tensile

strength, while other materials like cast iron and concrete will simply snap with no deformation of shape.

- Compressive strength - The maximum force a material can withstand when being crushed
- Shear strength - The maximum force a material can withstand when being ripped.
- Torsion strength - The maximum force a material can withstand when being twisted (see above).
- Malleability - The amount of hammering and shaping a material can withstand without breaking, splitting or cracking. Malleability is particularly desirable in metals such as sheet lead.
- Ductility - The amount that a material can be pulled, pushed, stretched or deformed without breaking. It is often characterized by a material's ability to be stretched into a wire. Copper is a very ductile metal because it can be easily bent and formed into different shapes.

2. Which are the three stages of fatigue processes?

i. Initial fatigue
ii. Damage which leads to crack nucleation and crack initiation.
iii. Progressive cyclic growth of a crack, this is the crack propagation stage, until the remaining un-cracked cross section of a part becomes too weak to withstand the loads applied.
iv. Final stage is the sudden fracture.

3. Highlight the application of the following tests;

i. Plasticity - forming, forging, shaping, extruding, hot & cold working, ornamental work, stamping, rolling, drawing, pressing
ii. Elasticity - Desirable for materials used in tools and machines.
iii. Malleability - rolling, hammering
iv. Toughness - Desirable for shock & impact loads.

4. Briefly explain the procedure of undertaking the Fatigue strength test

Materials behave differently under lasting static loads at increased temperatures than they do under the same load at without an increase in load lead to a slow but steady irreversible plastic deformation, also known as creep.

The fatigue strength defines the load limit up to which a material that is loaded dynamically withstands without breaking. Moving machine parts in particular are subject to dynamic loads, caused by vibrations for example. In this case, a fracture occurs after a high number of load cycles with stresses that are far below the yield point and far below the fracture stress.

5. **Discuss the principle of the creep rupture test.**

   In the creep rupture test, a specimen is subjected to load at constant stress and constant temperature. This experiment is performed multiple times with different stresses, but always at the same temperature. The plastic deformations are measured in continuous intervals

3.2.8. Learning outcome 8: Apply electrical principles

3.2.8.1. Introduction to the learning outcome

This unit involves identifying, applying and interpretation of electrical principles based on international standards while observing occupational safety and health practices. It also involves identification and installation of simple electrical circuits.

3.2.8.2. Performance Standard

1. Electrical principles are identified based on scientific principles
2. Electrical standards are interpreted based on international standards
3. Occupational safety and health practices are identified based on statutory and sector regulations.
4. Simple electrical circuits are identified based on international standards.

3.2.8.3. Information Sheet

Definitions of terms

- *Atom* - the smallest particle of a chemical element that can exist.
- *Neutron* - a subatomic particle of about the same mass as a proton but without an electric charge, present in all atomic nuclei
- *Proton* - a stable subatomic particle occurring in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron.
- *Nucleus* - the positively charged central core of an atom, consisting of protons and neutrons and containing nearly all its mass.
- *Conductivity* – how well a material allows electron movement
- *Resistivity* - how well a material resists electron flow is called
- *Voltage* - the difference in electron concentration. Also known as the potential difference
- *Resistance* is the opposition to electron movement through a conductor
- *Current* - is The rate at which electricity flows through an appliance
- *Power* - when electricity is converted into other forms of energy, such as light, heat or mechanical

The basic principles of electron flow theory

Everything on Earth is made up of atoms. Atoms are not solid. At the centre of every atom is a nucleus, which consists of an equal number of positively (+) charged protons and negatively (-) charged neutrons, making the atom electrically neutral. The neutrons play no role in the electrical properties of atoms. Their sole purpose is to hold the nucleus together. Without them, the nucleus would fly apart. Revolving around the nucleus is the electron. These too have a negative (-) charge.

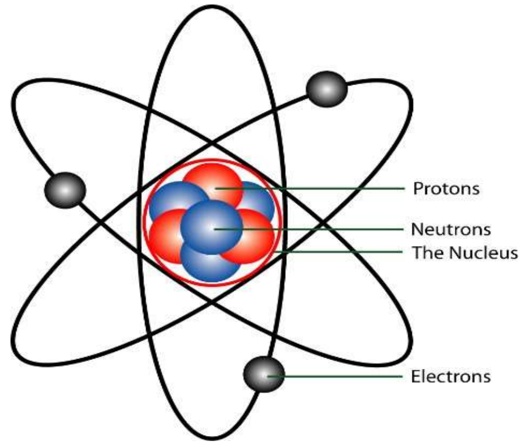


Figure 115:The nucleus of an atom

As can be seen from the image, the atom is very similar to a mini solar system, with electrons orbiting the nucleus like the planets around the sun, and, just like a solar system, those electrons nearer the nucleus orbit more quickly than those further away. The electrons that are furthest away are less attracted to the atom and are easily deflected from their weak orbits, to be attracted by other atoms. It is this constant movement of electrons from one atom to another that makes electricity possible. Materials that allow the free movement of electrons are called conductors. Those that prevent movement are called insulators.

Measurements of Electrical Flow

Electricity is measured in two ways:

1. By the number of electrons flowing. This is called the current and it is measured in Amperes or Amps.
2. By the amount of pressure, or the push, which causes the current to flow. This is measured in Volts.

Voltage is created by the electrons which, being negatively charged, repel each other. When electrons are concentrated in one place, they will flow freely away provided the path is clear for them to do so. It is the Voltage (or push) that makes them move. If there are lots of electrons in one place, the Voltage is high and many electrons will flow through the conductor. The more electrons that flow, the better the conductor.

The direction of movement of the negatively charged electrons is random unless a force acts upon them to move them in the same direction. This is Electro-Motive Force (EMF), better known as electricity.

Material Conductivity and Resistance

- **Conductivity** – conductivity is the ability of the material to allow the movement of electricity. A good conductor allows free movement of electrons; whereas a poor conductor resists the flow of electrons. Silver is the best conductor of electricity with copper a close second. However, copper is much cheaper to manufacture into electrical cables and has less mass (silver = 10490kg/m3: copper = 8960kg/m3).
- **Resistivity** – resistivity is the opposition to electron flow. It is the resistance of the material against the flow of electricity. When a metal resists the flow of electricity, the energy can be transformed into other forms of energy, such as heat and light. For example, when electricity passes through the resistance of a heating element in an electric kettle, the water will eventually boil. Similarly, when electricity passes through the filament of a light lamp, light is generated. The amount of resistance will depend on the material.

Types of Current

There are two different types of electricity:

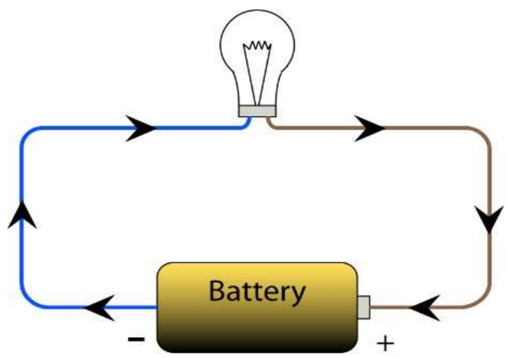
Direct Current (DC)

Direct Current is generated by a number of sources. It can be generated by photo-voltaic (PV) panels or as a result of an electrochemical reaction. DC current can be stored in cells and batteries.

In a DC circuit, the electrons will always flow from the negative (-) pole to the positive (+) pole. The

direction of the electrons, known as the polarity, never changes. The negative electrons will seek the positive. It never reverses

Figure 116:A simple DC circuit



The symbol for DC Current

Alternating Current (AC)

Alternating Current does not travel in one direction. It reverses its direction of travel from positive to negative and from negative to positive, constantly. In other words, it alternates. AC current alternates 50 times every second. This is known as the frequency and is measured in Hertz.

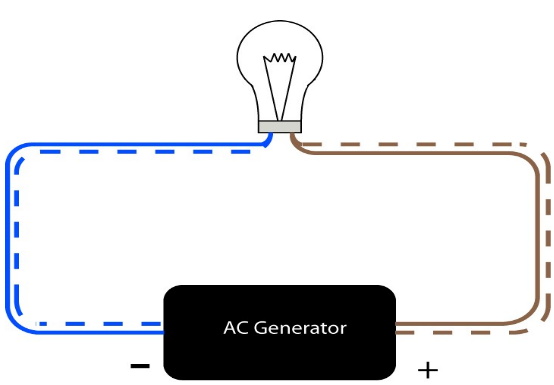


Figure 117:A simple AC circuit

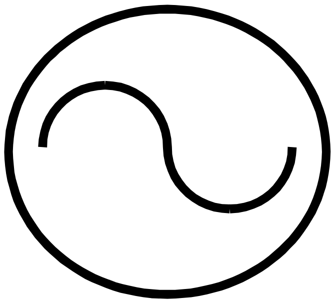


Figure 118: The symbol for AC Current

Below is a table of the advantages and disadvantages of AC current:

The advantages and disadvantages of AC current	
Advantages	Disadvantages
• Voltages can be transformed easily from one voltage to another. DC voltage is hard to transform. • AC current can be transported over long distances without excessive voltage loss making it much more efficient than DC voltage.	• AC current cannot be stored. It is generated at power stations and bulky portable generators. • AC power tools need long cables, which can be a trip hazard. DC power tools use battery power and are much more portable than AC power tools.

Voltage (volts)

In a circuit where there are more electrons in one part of the circuit than the other, the electrons will flow from the area of concentration to the area where they are absent. The higher the voltage, then it can be assumed that there is a greater imbalance and the harder the electrons will repel each other. This leads to greater current or flow (in amps) in the circuit.

The voltage in a circuit can be calculated:

$$Amps\ (I)\ x\ Resistance\ (\Omega\ or\ R)$$

Resistance

Every electrical circuit has resistance. Some circuits have more resistance than others. In some circuits, resistance is necessary to reduce the amount electrons flowing, whilst in others as little resistance as possible will ensure high current flow.

The interaction between current (or electron flow), voltage (current flow) and resistance is shown in Ohm's Law. As the voltage increases, more electrons will flow. Increasing the voltage leads to an increase in current. However, if the resistance is increased, this reduces the current flow and the amps in the circuit.

The resistance in a circuit can be calculated:

$$Voltage\ (V) \div Amps\ (I) = Ohms\ (Resistance)(\Omega)$$

Current

Is measured in amps. The easiest way to understand current is through a water analogy.

A 15mm pipe at 2 bar pressure will deliver a set flow rate. If we want to increase that flow rate, we would need a bigger pipe. If we increased the pipe size to 22mm, then the pressure would be the same but the flow rate would be greater.

In electrical terms, the voltage is the pressure and the current is the flow rate. If we increase the cable size, the voltage remains at 230V but the current is greater.

The SI unit of measurement of electrical current is the Ampere or amp (i). The current in a circuit can be calculated:

$$Voltage\ (V) \div Ohms\ (Resistance)(\Omega\ or\ R) = Amps\ (I)$$

Power

When electricity is converted into other forms of energy, such as light, heat or mechanical, it is called power. It is equal to the sum of the current and the voltage.

An immersion heater, rated at 3kW simply means that the electrical energy is converted into heat to warm the water. Electrical power is the rate at which electrical energy is consumed and is defined as 1 joule per second.

The SI unit of measurement of electrical power is the Watt (W). The power in a circuit can be calculated:

$Amps\ (I)\ x\ Volts\ (V) = Watts$

Carrying out simple electrical calculations

Ohm's law states:

'The current through a conductor between two points is equal to the voltage across the two points, and inversely proportional to the resistance between them.'

It defines the relationship current, voltage, resistance and power.

According to Ohm's law:
'1 Ohm is the resistance through which 1 volt will maintain a current of 1 amp.'

In theory, if we have 2 electrical values, then we can calculate a third. In the following calculations:

$$\boldsymbol{I} = current \quad \boldsymbol{V} = voltage$$
$$\boldsymbol{R} = resistance \quad \boldsymbol{P} = power$$

The diagrams below show Ohm's triangle and the power triangle. By covering the Unit you are calculating with your finger, the remaining units are needed in the calculation. For example, if we are calculating voltage, cover the 'V' and we are left with $I\ x\ R$. If we are calculating resistance, cover the 'R' and we are left with:

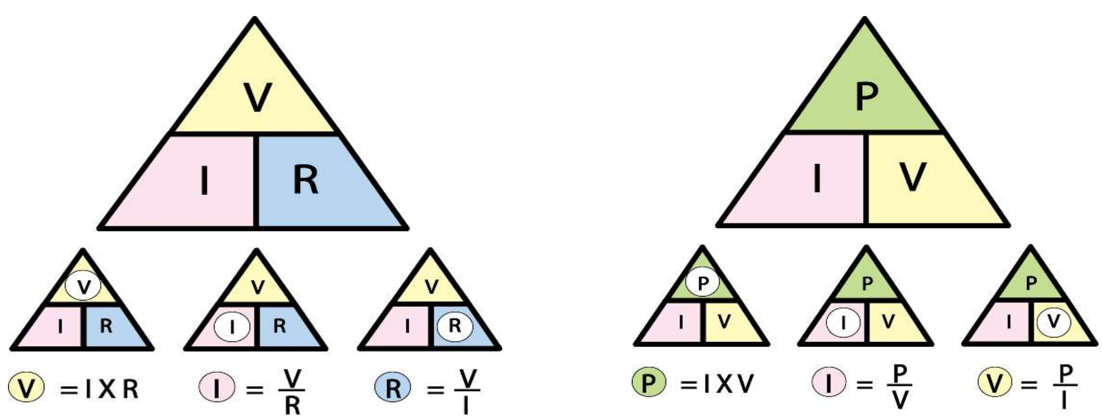


Figure 119:Ohm's Law equations

Simple calculations using Ohm's Law

Example 1 – What size of over current protection device will be needed to protect a circuit that has a 3kW immersion heater installed on a 230V supply?

The formula for this is:

$$I = P \div V$$

Therefore:

First, convert the kilowatts to watts by multiplying by 1000:

$\mathbf{3}\boldsymbol{kw} = \mathbf{3000}$

$\mathbf{3000} \div \mathbf{230}$

$= \mathbf{13}\ \boldsymbol{amps}$

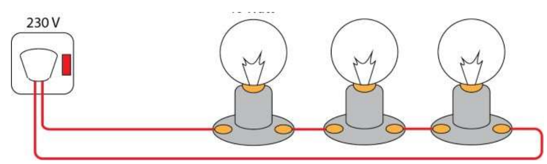
Voltage, current and resistance in series and parallel circuits

There two types of circuit:

A. Series

B. Parallel

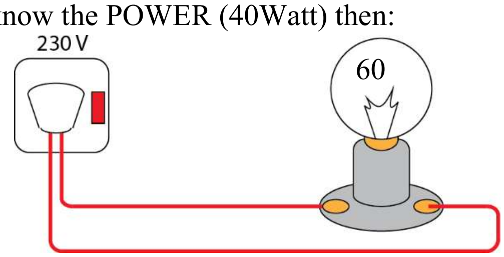
Series Circuits



A series circuit has only one path from the power source through the circuit loads and back to the power source. In this instance, the current MUST flow through ALL of the loads.

This circuit depends upon all of the lamps working perfectly. If one of the lamps fails, then the whole circuit will fail and none of the lamps will light up. This is because the current flows from one lamp to the next. It is the ONLY path from the power source and back again.

Consider the circuit to the right. The circuit has one lamp connected to a 230V electricity supply. The lamp will glow at full brightness simply because it is receiving all of the current. To find the resistance in the circuit, we must first find the current (I). Since we know the POWER (40Watt) then:



The current (amps) is:

$$\frac{60}{230} = 0.26087\ amps$$

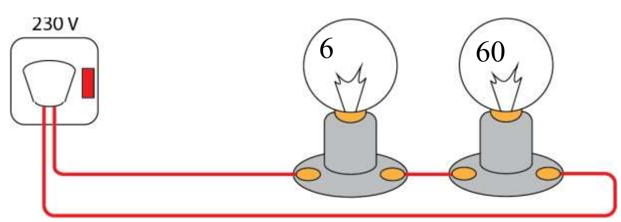
Now, we can apply Ohm's law to find the resistance:

$$R = \frac{V}{I}$$

Therefore:

$$\frac{230}{0.26087} = 881.6651\ Ohms$$

If a second lamp with the same 40 Watts is added to the circuit, then the resistance in the circuit will double and the current flow is half that when there was only one lamp. The voltage is now only 115V to each lamp and this halves the brightness emitting from each lamp. Both lamps have the same voltage drop.



Again, firstly, we must find the current:

Therefore, the current (amps) is:

$$I = \frac{W}{V}$$

$$Bulb\ 1 = \frac{60}{230} = 0.26087\ amps$$

$$Bulb\ 2 = \frac{60}{230} = 0.26087\ amps$$

Now, we can apply Ohm's law to find the resistance of each light lamp:

$$R = \frac{V}{I}$$

Now the total resistance of the circuit:

$$RT = R1 + R2$$

$$RT = 881.6651 + 881.6651 = 1763.3307\ Ohms$$

To find the current across the circuit using the total resistance:

$$I = \frac{V}{R}$$

Therefore:

$$\frac{230}{1763.3307} = 0.13043\ amps$$

To find the voltage, since each lamp is 40 Watts with a resistance of 1763.3307 Ohms and the total circuit current is 0.13043 amps, to find the voltage to each lamp:

$$V = I\ x\ R$$

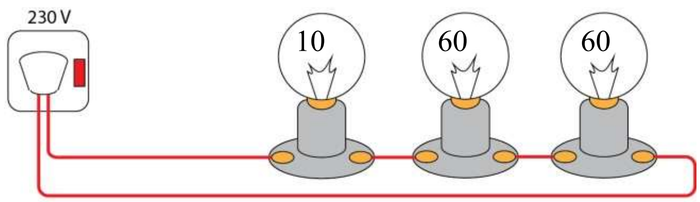
$$0.13043\ x\ 881.6651 = 114.99V$$

Because each lamp is only drawing 115V, each lamp will only glow with half its potential brightness. To find out how many Watts is being generated:

$$\boldsymbol{P = I\ x\ V}$$

Therefore:

$$\mathbf{0.13043}\ \boldsymbol{x}\ \mathbf{230 = 29.999}\ \boldsymbol{Watts}$$



We must find the current to each light lamp:

$$I = W/V$$

$$Lamp\ 1 = \frac{10}{230} = 0.043479\ amps$$

$$Lamp\ 2 = \frac{60}{230} = 0.26087\ amps$$

$$Lamp\ 3 = \frac{60}{230} = 0.26087\ amps$$

Now, we can apply Ohm's law to find the resistance of each light lamp:

$$R = \frac{V}{I}$$

Therefore :

$$R1 = \frac{230}{0.043479} = 5289.91\ Ohms$$

$$R2 = \frac{230}{0.26087} = 881.6651\ Ohms$$

$$R3 = \frac{230}{0.26087}$$

$$= 881.6651\ Ohms$$

Now find the total resistance of the circuit:

$$RT = R1 + R2 + R3$$

$$RT = 5289.91 + 881.6651 + 881.6651$$

$$= 7053.2402\ Ohms$$

To find the current across the circuit using the total resistance:

$$I = \frac{V}{R}$$

Therefore:

$$\frac{230}{7053.2402} = 0.03261\ amps$$

To find the voltage to each lamp:

$$V = I \ x \ R$$

$$Volts\ @\ Lamp\ 1 = 0.03261\ x\ 5289.91 = 172.503\ Volts$$

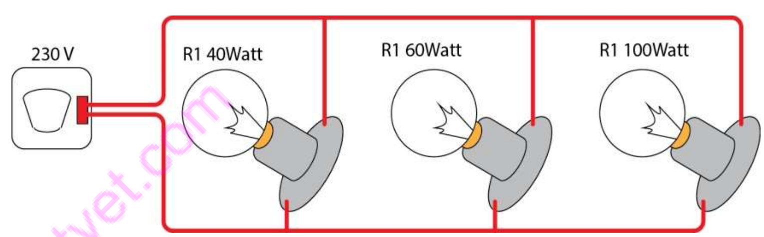
$$Volts\ @\ Lamp\ 2 = 0.03261\ x\ 881.6651 = 28.75\ Volts$$

$$Volts\ @\ Lamp\ 3 = 0.03261\ x\ 881.6651 = 28.75\ Volts$$

Because each lamp is drawing less voltage, each lamp will only glow with a fraction of its potential brightness.

Parallel Circuits

A parallel circuit has at least 2 independent paths in the circuit.



In a parallel circuit, each light lamp has its own independent path to the power source. This means that the lamps are unaffected by each other. If one lamp fails, the other two will continue to work. Voltage is equal across all components. However, the current increases when more light lamps are added and if too many are installed, then the circuit will overload.

3.2.8.4. Learning Activities

Practical activity

Assemble a circuit in a series as shown in the diagram below

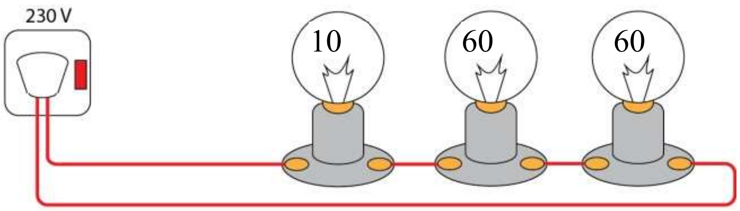


Figure 120: A series circuit

Materials and Supplies

- Battery
- Bulbs (10W, 60W x 2)
- Connecting wires
- Pliers
- Clips

3.2.8.5. Self-Assessment

1. Using the Ohm's Law Formula calculate the voltage in a circuit which has a resistance of 115 Ohms and a current of 2 amps.

$$\boldsymbol{V = I \ x \ R}$$

$$115\ x\ 2 = 230\ volts$$

2. Calculate the resistance in a circuit when the voltage is 110V and the current is 45 amps.

$$\Omega = V \div I$$

$$110 \div 45 = 2.44\ Ohms$$

3. What are the two advantages of AC over DC voltage?
   - AC voltages can be transformed easily from one voltage to another. DC voltage is hard to transform.
   - AC current can be transported over long distances without excessive voltage loss making it much more efficient than DC voltage.
4. Distinguish between conductivity and resistivity giving an example.
   - Conductivity is the ability of the material to allow the movement of electricity. A good conductor allows free movement of electrons; whereas a poor conductor resists the flow of electrons. Silver is the best conductor of electricity with copper a close second.
   - Resistivity is the opposition to electron flow. It is the resistance of the material against the flow of electricity. When a metal resists the flow of electricity, the energy can be transformed into other forms of energy, such as heat and light. For example, when electricity passes through the resistance of a heating element in an electric kettle, the water will eventually boil.
5. In your own understanding, discuss how voltage is created.

   Voltage is created by the electrons which, being negatively charged, repel each other. When electrons are concentrated in one place, they will flow freely away provided the path is clear for them to do so. It is the Voltage (or push) that makes them move. If there are lots of electrons in one place, the Voltage is high and many electrons will flow through the conductor

3.2.8.6. Tools, Equipment, Supplies and Materials

- Battery
- Bulbs (10W, 60W x 2)
- Connecting wires
- Pliers
- Clips

3.2.8.7. References

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Tillery, B., Slater, S. J., & Slater, T. F. (2016). *Physical Science* (11th ed.). McGraw-Hill Education.

3.2.8.8. Responses

1. Using the Ohm's Law Formula calculate the voltage in a circuit which has a resistance of 115 Ohms and a current of 2 amps.

$$\boldsymbol{V = I \; x \; R}$$

$$\mathbf{115 \; \boldsymbol{x} \; 2 = 230 \; \boldsymbol{volts}}$$

2. Calculate the resistance in a circuit when the voltage is 110V and the current is 45 amps.

$$\boldsymbol{\Omega = V \div I}$$

$$\mathbf{110 \div 45 = 2.44 \; Ohm\boldsymbol{s}}$$

3. What are the two advantages of AC over DC voltage?
   - **AC voltages can be transformed easily from one voltage to another. DC voltage is hard to transform.**
   - **AC current can be transported over long distances without excessive voltage loss making it much more efficient than DC voltage.**

4. Distinguish between conductivity and resistivity giving an example.
   - **Conductivity is the ability of the material to allow the movement of electricity. A good conductor allows free movement of electrons; whereas a poor conductor resists the flow of electrons. Silver is the best conductor of electricity with copper a close second.**
   - **Resistivity is the opposition to electron flow. It is the resistance of the material against the flow of electricity. When a metal resists the flow of electricity, the energy can be transformed into other forms of energy, such as heat and light. For example, when electricity passes through the resistance of a heating element in an electric kettle, the water will eventually boil.**
5. In your own understanding, discuss how voltage is created.

   Voltage is created by the electrons which, being negatively charged, repel each other.

When electrons are concentrated in one place, they will flow freely away provided the path is clear for them to do so. It is the Voltage (or push) that makes them move. If there are lots of electrons in one place, the Voltage is high and many electrons will flow through the conductor

CORE UNITS

CHAPTER 1: WATER SUPPLY SYSTEMS

Unit of learning code CON/CU/PL/CR/01/5/A
Related Unit of Competency in Occupational Standard; Water supply and systems

1.1 **Introduction to the unit of learning**

This unit specifies the competencies required to install water supply and systems. It involves preparing working drawings, identifying materials, quantifying and costing, identifying and using pipework tools and equipment, installing pipe works, designing simple pipework and install water distribution system. It applies in the construction industry.

1.2 **Summary of Learning Outcomes**

1. Prepare working drawings
2. Identify materials, quantify and cost
3. Identify and use pipework tools and equipment
4. Install pipe works
5. Design simple pipework
6. Install Water distribution system

1.2.1 Learning Outcome 1: Prepare working drawing

1.2.1.1 Introduction to the learning outcome

This outcome specifies the competencies required to prepare working drawings. It involves preparing working drawings, interpreting different types of drawings like architectural, mechanical, electrical, plumbing, manufacture and others during standard installation of water pipes and systems in buildings. It applies in the construction industry.

1.2.1.2 Performance Standard

1. Drawings are identified and selected based on the working drawings.
2. Scale of the drawing is read based on the drawing.
3. Measurements are converted based on best practice.
4. Symbols are identified based on standard practices.
5. Isometric pipework drawings are sketched based on best practice.
6. Simple working drawings are prepared based on specifications

1.2.1.3 Information Sheet

Engineering drawing is a two dimensional representation of three dimensional objects. In general, it provides necessary information about the shape, size, surface quality, material, manufacturing process, etc., of the object. It is the graphic language from which a trained person can visualize objects.

Drawings prepared in one country may be utilized in any other country irrespective of the language spoken. Hence, engineering drawing is called the universal language of engineers. Any language to be communicative, should follow certain rules so that it conveys the same meaning to everyone.

Terms and Concepts

Sketch; A sketch is a quickly executed, freehand drawing that is usually not intended as a finished work.

Assembly drawings; Assembly drawings show how different parts go together, identify those parts by number, and have a parts list, often referred to as a bill of materials.

Construction plan; is a detailed document, both written and visual which outlines how you will complete a **project** or portion of one

Elevation; refers to an orthographic projection of the exterior (or sometimes the interior) faces of a building that is a two-dimensional drawing of the building

Section view; is a view used on a drawing to. Show an area or hidden part of an object by. Cutting away or removing some of that object.

Section; shows a view of a structure as though it had been sliced in half or cut along another imaginary plane.

Classifications of drawing

Engineering drawing; it's a two-dimensional visual representation of three-dimensional objects and are used as a universal means of communication in industry.

Such drawings should be clear, concise and accurate. They should convey all information complete and specified once only about:

- Information about the shapes, sizes and position of components
- Material requirements
- Instructions about the method of manufacture

Engineering drawing has three main parts;

- One or more views of an engineering component/object or an assembly of components
- Dimensions, symbols, explanatory and instruction notes
- A title blocks

Assembly drawing

A drawing that shows the various parts of a machine in their correct working locations is an assembly drawing.

Manufacturing Drawing

They detailed component specifications. These are mostly used by suppliers, manufacturers, and contractors to understand production quantities, materials required, and processes to be followed during the delivery and installation of these components on-site.

Engineering drawings are extremely important as they provide a plethora of information to the manufacturer, including:

- Type of material required for manufacturing and supply
- Detailed product dimensions
- Surface and cosmetic finishes
- Welding information
- Hardware requirements

Types of Working Drawing; what is working drawing in construction cannot be understood without knowing about its types. In construction, working drawing is further of 5 types. These include the following:

- Architectural Drawing
- Structural Drawing
- Electrical Drawing
- Plumbing and Sanitary Drawings
- Finishing Drawing

Plumbing drawings

A **plumbing drawing** is a type of technical drawing that provides visual representation and information relating to a plumbing system.

Uses of plumbing drawings.

It is used to convey the engineering design to plumbers or other workers who will use them to help install the plumbing system.

It is also used to show clearly the location of fixtures, sanitary ware, pipework, valves and so on, and illustrates how fresh water is to be supplied into a building and waste water removed. To illustrate the separate hot and cold water supply, the pipe runs will usually be colored red and blue respectively. Drainage pipes should be illustrated with the grade (slope) indicated. Where manholes are included, a manhole schedule should detail the name, invert level, cover level, and depth.

Plumbing layout is usually drawn into a copy of the floor plan for proper orientation with existing plumbing fixtures, walls and partition outlines, and other utility features.

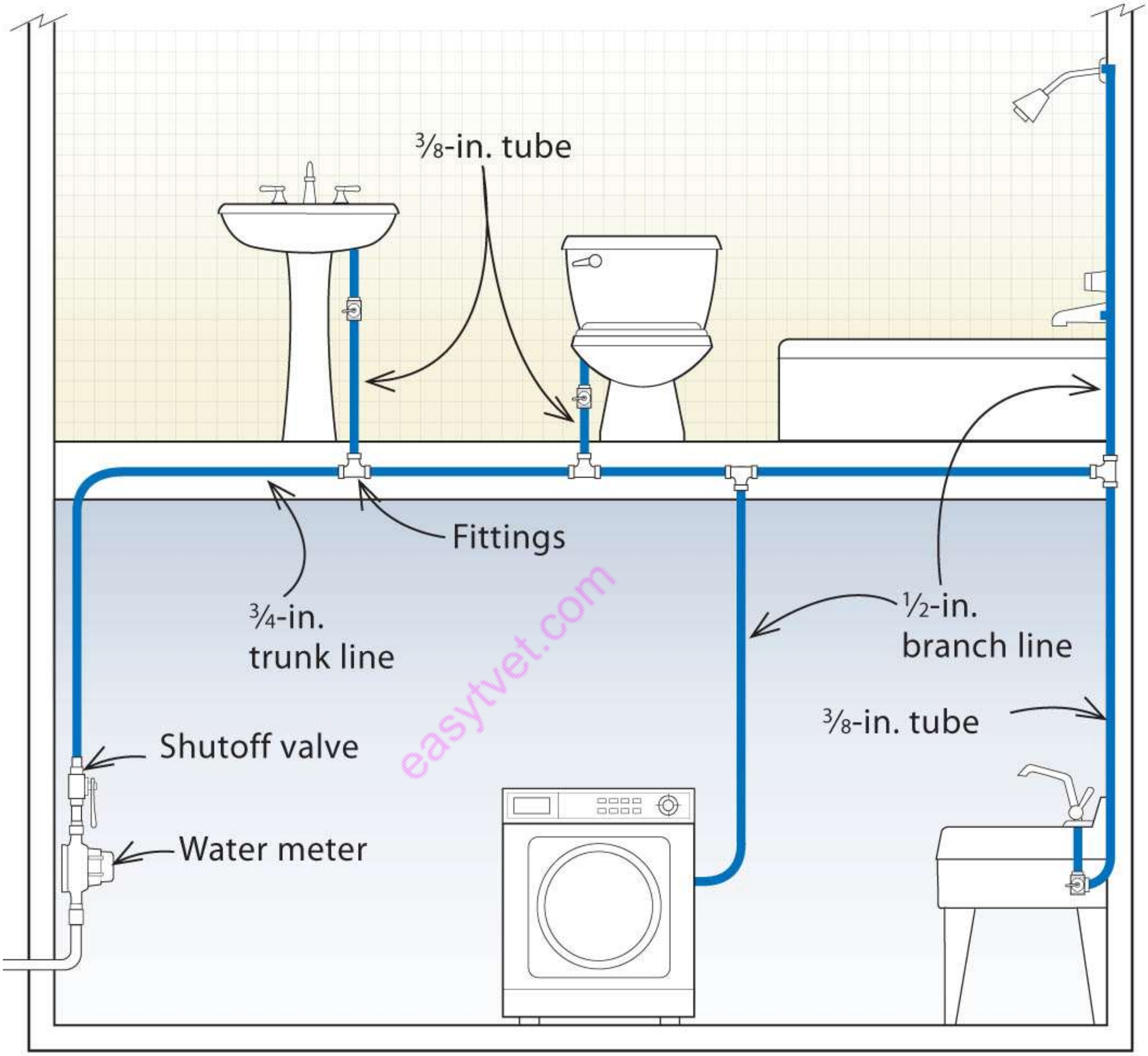


Figure 121:: **Plumbing Layout**

Isometric plumbing drawing.

It is a drawing with details representing pipes, fittings, and fixtures at a 45° angle, in plain terms it's the plumbing drawing scheme. The goal is to represent three-dimensional designs on two-dimensional drawings

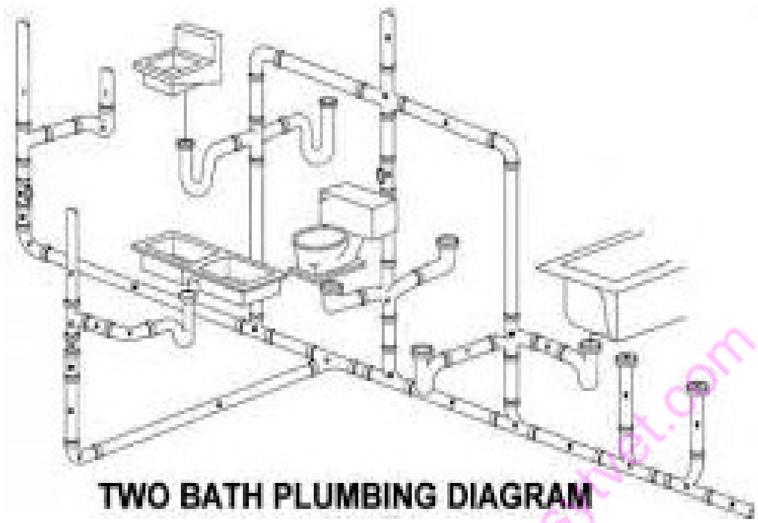


Figure 122: isometric drawing

Features of Piping Isometric Drawing

It is not drawn to the scale, but it is proportionate with exact dimensions represented. Pipes are drawn with a single line irrespective of the line sizes, as well as the other configurations such as reducers, flanges, and valves. pipes are shown in the same size.

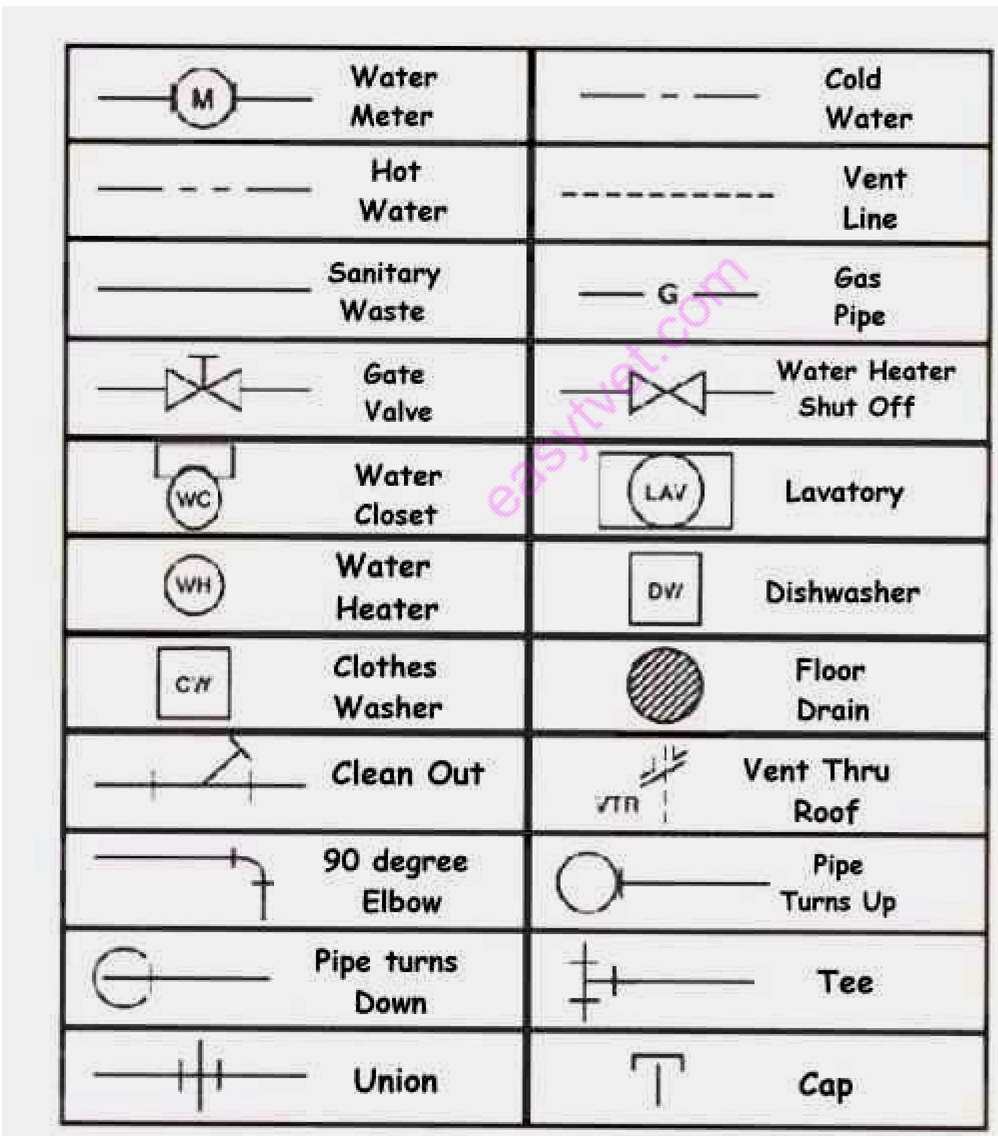
DRAWING SYMBOLS

Because of the small scale used in most drawings, standard graphic symbols are used to present complete information concerning construction items and materials. These typ ical symbols are used so frequently in construction drawings that their meanings must be familiar not only to the preparer, but to the user as well.

Plumbing symbols

Symbol is a form of a sign that may have deep meaning.

Plumbing symbols are used when drawing house plans and diagrams. The purpose of these symbols is to indicate where the different elements of your plumbing system are located.

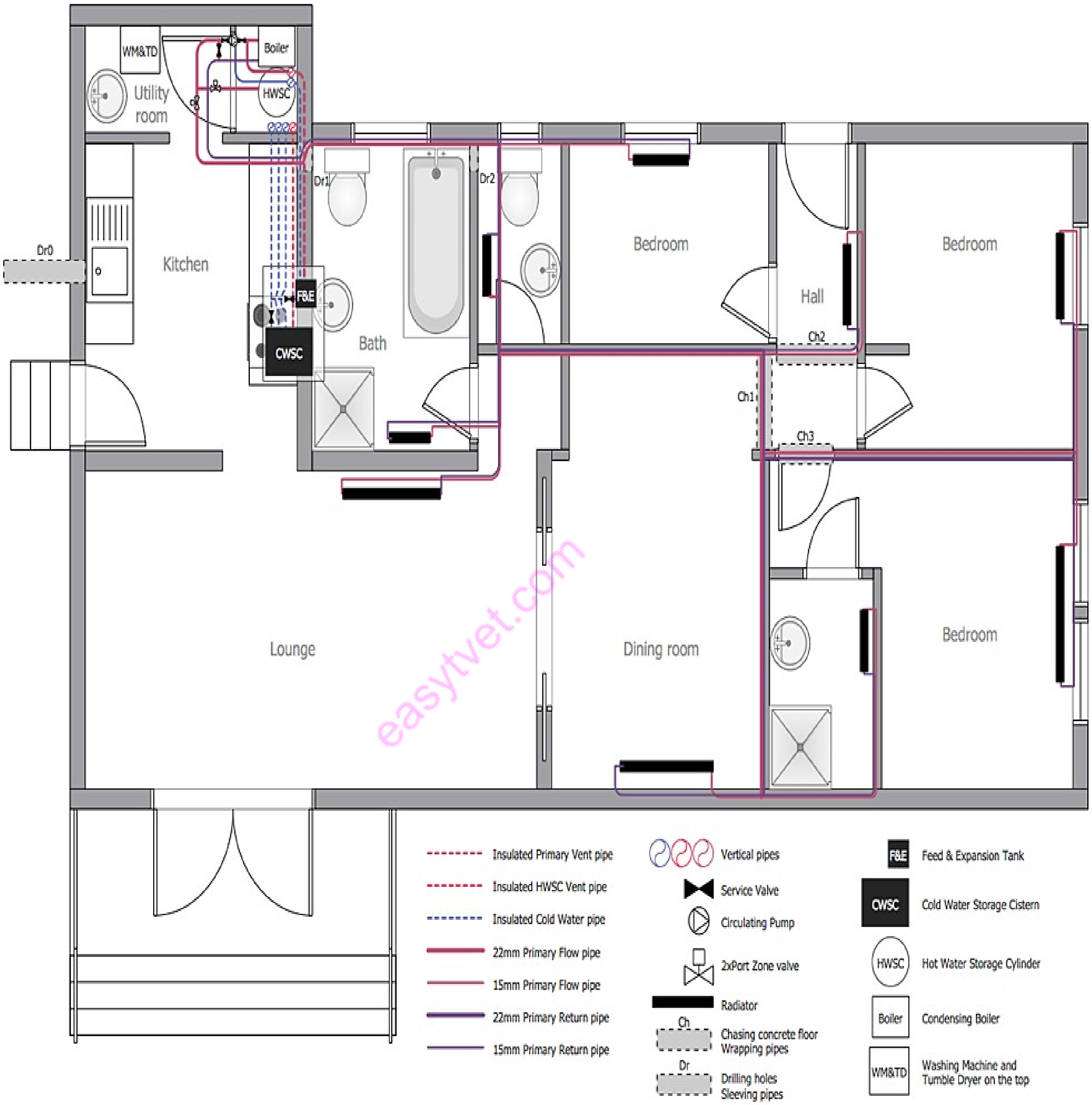


Plumbing symbols.

Floor plan

A **floor plan** is a drawing to scale, showing a view from above, of the relationships between rooms, spaces, traffic patterns, and other physical features at one level of a structure.

Dimensions are usually drawn between the walls to specify room sizes and wall lengths. Floor plans may also include details of fixtures like sinks, water heaters, furnaces, etc. Floor plans may include notes for construction to specify finishes, construction methods, or symbols for electrical items.



WM&TD
Boiler
HWSC
Utility room
Kitchen
Dr0
Dr1
Dr2
F&E
CWSC
Bath
Bedroom
Hall
Bedroom
Ch2
Ch1
Ch3
Lounge
Dining room
Bedroom
Insulated Primary Vent pipe
Insulated HWSC Vent pipe
Insulated Cold Water pipe
22mm Primary Flow pipe
15mm Primary Flow pipe
22mm Primary Return pipe
15mm Primary Return pipe
Vertical pipes
Service Valve
Circulating Pump
2xPort Zone valve
Radiator
Ch
Chasing concrete floor Wrapping pipes
Dr
Drilling holes Sleeving pipes
F&E
Feed & Expansion Tank
CWSC
Cold Water Storage Cistern
HWSC
Hot Water Storage Cylinder
Boiler
Condensing Boiler
WM&TD
Washing Machine and Tumble Dryer on the top

Floor plan

SCALE DRAWING

Scaling is a drawing method used to enlarge or reduce a drawing in size while keeping the proportions of the drawing the same. Scales are generally expressed as ratios and the most common scales used in furniture drawing are **1:1**, **1:2**, **1:5**, and **1:10** for reducing and possibly **2:1** for enlarging.

Scaling is used to either:

- **Reduce** the drawing in size so that it will fit onto the page, or
- **Enlarge** the drawing in size so that all required details are clearly visible.

Drawings can be scaled up or down using either a calculator or a scale rule.

To scale a drawing using a calculator:

- **Divide** the measurement by the scale if you want to **reduce** the drawing in size, or
- **Multiply** the measurement by the scale if you want to **increase** it in size.

Example 1: Scaling down

- A 50mm line is to be drawn at a scale of **1:5** (ie 5 times less than its original size). The measurement **50mm** is **divided** by **5** to give **10mm**. A 10mm line is drawn.
- A 50mm line is to be drawn at a scale of **1:2**. The measurement **50mm** is **divided** by **2** to give **25mm**. A 25mm line is drawn.

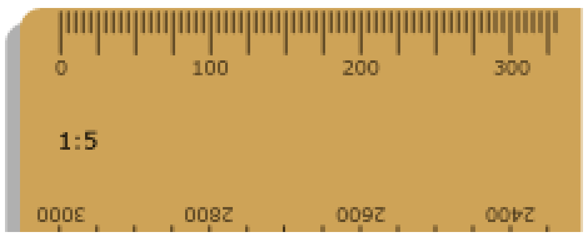
Example 2: Scaling up

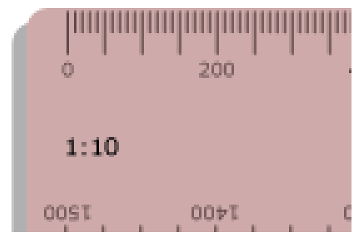
- A 50mm line is to be drawn at a scale of **5:1** (ie 5 times more than its original size). The measurement **50mm** is **multiplied** by **5** to give **250mm**. A 250mm line is drawn.
- A 50mm line is to be drawn at a scale of **2:1**. The measurement **50mm** is **multiplied** by **2** to give **100mm**. A 100mm line is drawn.

To scale a drawing using a scale rule:

Scale rules allow us to directly set out measurements onto a drawing without having to convert them to their scaled sizes by using a calculator first.

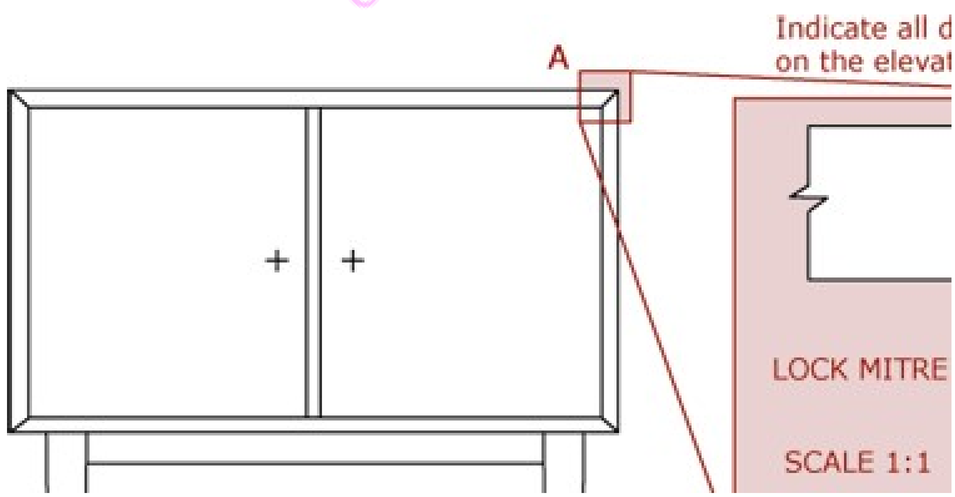
The whole process is made easier because these conversions are already made for us. On a scale rule which has divisions of **1:5**, each division represents 5mm and the measurements on the rule indicate this.





On a scale rule which has divisions of **1:10** each division represents 10mm and the measurements on the rule indicate this.

This is an example of a scaled drawing. Notice that the elevation is drawn at a scale of 1:10. Included in the drawing is detail A, and this is drawn additionally at a scale of 1:1, or full size.



MEASUREMENTS

Measurement is the transformation of drawn information into descriptions and quantities, undertaken to value, cost, and price construction work, as well as enabling effective management.

Imperial measurements

Miles, feet and inches are old units of length. These are known as imperial units of length but are not now commonly used in mathematics. There are 12 inches in a foot. An inch is roughly equal to 2.5 centimeters.

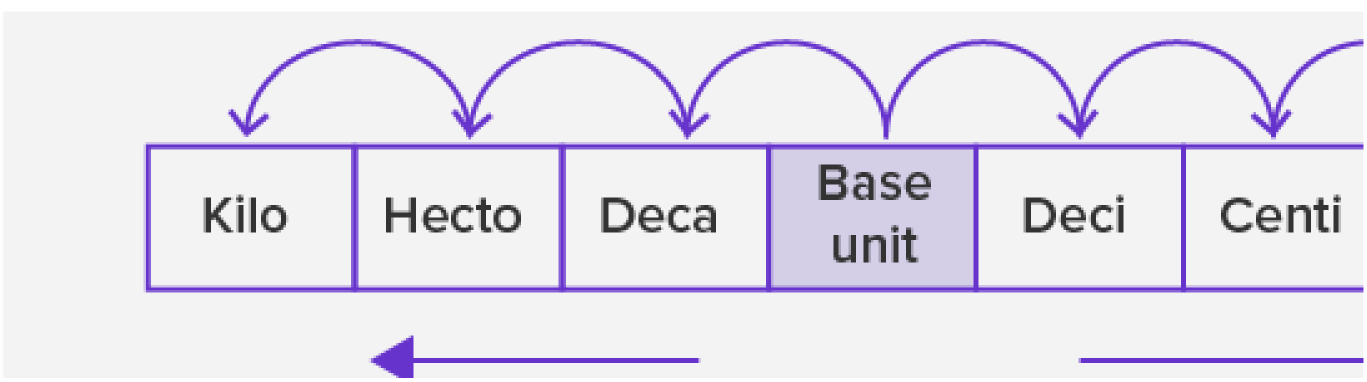
How can you convert imperial measurement to metric measurements?

- 1 foot (12 inches) is equal to 30 centimeters
- 1 inch is about 25 millimeters or 2.54 centimeters
- A 3-foot measurement is almost exactly 1 meter

What is Metric System?

The metric system is a system of measurement that uses the meter, liter, and gram as base units of length (distance), capacity (volume), and weight (mass) respectively.

To measure smaller or larger quantities, we use units derived from the metric units



- The given figure shows the arrangement of the metric units, which are smaller or bigger than the base unit.
- The units to the right of the base unit are smaller than the base unit. As we move to the right, each unit is 10 times smaller or one-tenth of the unit to its left. So, a 'deci' means one-

tenth of the base unit, 'centi' is one-tenth of 'deci' or one-hundredth of the base unit and 'milli' is one-tenth of 'centi' or one-thousandth of the base unit.

Linear Measure

10 millimeters (mm) =	1 centimeter (cm)	
10 centimeters =	1 decimeter (dm)	= 100 millimeters
10 decimeters =	1 meter (m)	= 1,000 millimeters
10 meters =	1 dekameter (dam)	
10 dekameters =	1 hectometer (hm)	= 100 meters
10 hectometers =	1 kilometer (km)	= 1,000 meters

Area Measure

100 square millimeters (mm^2) =	1 sq centimeter (cm^2)
10,000 square centimeters =	1 sq meter (m^2)
=	1,000,000 sq millimeters
100 square meters =	1 are (a)
100 ares =	1 hectare (ha)
=	10,000 sq meters
100 hectares =	1 sq kilometer (km^2)

=	1,000,000 sq meters

Volume Measure

10 milliliters (ml) =	1 centiliter (cl)	
10 centiliters =	1 deciliter (dl)	= 100 milliliters
10 deciliters =	1 liter (l)	= 1,000 milliliters
10 liters =	1 dekaliter (dal)	
10 dekaliters =	1 hectoliter (hl)	= 100 liters
10 hectoliters =	1 kiloliter (kl)	= 1,000 liters

How to Measure Pipe and Fitting Sizes

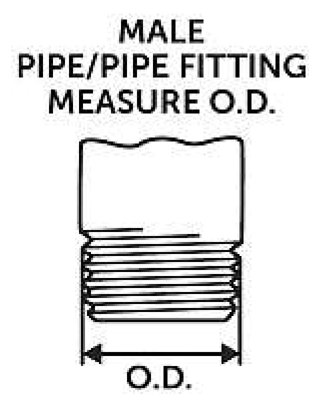
Convert Actual Diameter to Nominal Diameter

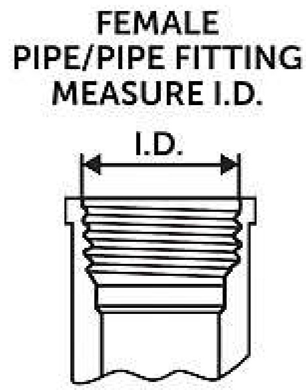
The easiest way to find what nominal pipe size you need is to use follow these steps and use the conversion chart below.

For Male Threads

1. Measure the Outside Diameter (OD) of your pipe or pipe fitting:

- Wrap a string around the pipe
- Mark the point where the string touches together
- Use a ruler or measuring tape to find the length between the tip of the string and the mark you made (circumference)
- Divide the circumference by 3.14159



2. Use the chart on this page to find the nominal diameter (pipe size).	
For Female Threads 1. Measure the Inside Diameter (ID) of your pipe or pipe fitting (use a ruler or tape measure). 2. Use the chart on this page to find the nominal diameter (pipe size).	

Nominal Diameter Conversion Chart

(All Measurements in Inches)

Outside or Inside Diameter	Decimal Equivalent	Nominal Diameter	Typical Threads Per Inch
5/16	0.313	1/16	27
13/32	0.405	1/8	27
35/64	0.540	1/4	18
43/64	0.675	3/8	18
27/32	0.840	1/2	14
1-3/64	1.050	3/4	14
1-5/16	1.315	1	11-1/2
1-21/32	1.660	1-1/4	11-1/2

1-29/32	1.900	1-1/2	11-1/2
2-3/8	2.375	2	11-1/2
2-7/8	2.875	2-1/2	8
3-1/2	3.500	3	8
4	4.000	3-1/2	8
4-1/2	4.500	4	8

Pipes vs. Tubing

Pipe and tubing are not measured the same way. Tubing is measured and named based on the actual outside diameter of the tube.

PEX, or Cross-Linked Polyethylene Tubing, is another technology fast becoming popular, and it is measured and named by inside diameter.

Example:

Pipe vs. Tubing	**Outside Diameter**
1/2" size pipe	27/32"
1/2" size tubing	1/2"

1.2.1.4 Learning Activities

Practical activity

- Study the architectural drawing below and identify the plumbing symbols used.

Figure 123: Floor Plan

1.2.1.5 Self-Assessment

1. What is a plumbing layout?
2. Drawing symbols are very crucial in every drawing, state their purpose.
3. What is the purpose of scales in drawings?
4. Define metric measurement giving examples.
5. List four types of drawings a plumber shall encounter in the site while installing sanitary appliance.

1.2.1.6 Tools, Equipment, Supplies and Materials

Tools/Equipment:	Materials:
• Drawing boards • T square • Set square • Blueprint machine/printer • Steel rule • Lettering stencil • Scale rule	• Drawing papers • Drawing pencils • Drawing sets • Masking tape • Construction drawings • Classroom and classroom resources • Manufacturer's drawings

1.2.1.7 References

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1.2.1.8 Model Answers

1. What is a plumbing layout?

The plumbing layout is usually drawn into a copy of the floor plan for proper orientation with existing plumbing fixtures, walls and partition outlines, and other utility features.

2.2.1.1 **Drawing symbols are very crucial in every drawing, state their purpose**.

Drawing symbols are used to present complete information concerning construction items and materials**.**

2.2.1.1 What is the purpose of scales in drawings?

Scaling is a drawing method used to enlarge or reduce a drawing in size while keeping the proportions of the drawing the same

2.2.1.1 Define metric measurement giving examples.

The metric system is a system of measurement that uses the meter, liter, and gram as base units of length (distance), capacity (volume), and weight (mass) respectively.

5) List four types of drawings a plumber shall encounter in the site while installing sanitary appliances

- Architectural Drawing
- Structural Drawing
- Plumbing and Sanitary Drawings
- Finishing Drawing
- Electrical Drawing
- Mechanical drawing

1.2.2 Learning Outcome 2: Identify materials, quantify and cost

1.2.2.1 Introduction to the learning outcome

This outcome specifies the competencies required to install water supply and systems. It involves, identifying materials, quantifying and costing during standard installation of water pipes and systems in buildings. It applies in the construction industry.

1.2.2.2 Performance Standard

1. Materials are identified and selected based on working drawings and specifications

2. Materials are quantified and costed as per the market rate
3. Materials schedule are prepared based on best practice
4. Supplies are identified based on specifications

1.2.2.3 Information Sheet

The process of project cost estimation is central to setting up the foundation for making key decisions, taking initiatives, budgeting activities and controlling expenditures. Cost forecasts and projections are used to establish a set of metrics against which project success will be measured, and to communicate work progress to the stakeholders at any given point in time.
Definition of terms.

- **Cost estimates;** A *cost estimate* establishes the base line of the project cost at different stages of development of the project.
- **Bills of quantities:** A Bill of Quantities (BoQ) lists the total materials required to complete the architect's design for a construction project, such as a house or other structure
- **Construction cost estimating** is the process of forecasting the cost of building a physical structure.

Pipe materials and supplies

Pipe Material Selection

Pipe exteriors must be able to withstand demanding surrounding conditions, such as high and ambient temperatures, different levels of humidity, and some degree of wear. Due to these conditions, it is essential to consider the type of fluid contained within the system, the internal temperatures, and the internal pressure.
Therefore, careful consideration should be given to the material. There are a number of factors that should be considered before choosing the plumbing materials:

1) **Corrosive water**

Problems such as corrosive water can cause damage to the system, which is made of metal. Repeated failures of the plumbing system can cause the system to last for only a couple of years. To choose the right material, check the quality of water with local department or installer. You should know how the system gets affected by the quality of the plumbing materials. Certain types of pipes are corroded easily, resulting in contamination. Plumbing materials such as PEX do not tend to corrode and maintains the quality of the water.

2) **Water pressure**

Choose the materials that perform well under high water pressure. PVC pipes vary in thickness depending on the location they are used. Plastic products are designed for applications with high pressure.

3) **Water flow**

For low operating cost and better water flow, the surface of pipes should be smooth. Brass piping provides long lasting benefits that does not rust the interior and maintains the smoothness inside the pipe.

4) **Heat & temperature**

There are some plumbing materials that cannot withstand high temperature e.g pvc pipes. Hence, one should choose the material that tolerates high temperature. Pipes that carry hot water need to be protected so that the heat loss is nominal. Different materials with insulating properties are used to carry hot water.

5) **Sunlight**

The UV rays from the sun can deteriorate the quality of plastic pipes. A number of factors like how deep it is, where it is being installed, rate of flow etc. determine the life of plastic piping. In other words, exposed pipes need a lot of attention and maintenance.(i.e,a ppr and G.I pipe can withstand exposure to sunlight)

6) **Characteristics of material**

There are different types of materials such as Copper, PVC, PEX, and CPVC etc. that are used depending upon their application. There are some other plumbing pipes that include – brass, galvanized iron and black mild steel pipe. The ability of a pipe to take stress is evaluated on the type of application.GALVANISED Iron pipes are also used to carry water.

Figure 124: Plumbing Material

Common Pipe Materials

The most common types of plumbing piping materials are:

- Cast iron for plumbing waste lines
- PVC (PolyVinyl Chloride) for plumbing waste lines
- Chromed brass for plumbing waste lines
- Chromed copper for water supply lines
- Galvanized iron for water supply lines
- Copper (rigid and flexible) for water supply lines
- CPVC (Chlorinated Poly-Vinyl Chloride) for water supply lines
- PEX (Cross-linked Polyethylene) for water supply lines
- Black iron for gas pipe

Ppr-for water supply

Cast iron

Appearance: Large-diameter heavy metal pipe, dull black with a rough, mottled surface.

Description: High-quality sanitary waste drain pipe that is heavy and deadens the sound of flowing wastewater very well. This pipe is strong and long-lasting but hard to cut—often requiring a special cutting tool with sharp chain cutting wheels. Repairs are often made using plastic PVC piping. Cast iron is rarely used in new construction; instead many use plastic PVC or ABS (acrylonitrile butadiene styrene) pipe.

Prevalent Use: Use for main soil stack waste lines and vent pipes.

Cutting and Fitting: Requires heavy-duty reciprocating saw or a special cutting tool called a cast-iron pipe cutter. Securing cast-iron pipes and fittings together is done using special methods, including lead in soil pipe joints.

PVC (Poly-Vinyl Chloride)

Appearance: White rigid plastic.

Description: PVC is now the de-facto standard in-home waste line materials. It is a strong, chemical-resistant rigid pipe that is heat resistant and easily cut and fit. It is often used to repair sections of broken cast-iron waste pipe as well as repairs to other drain lines.

Prevalent Use: Use for sanitary waste lines, vent pipes, and drain traps.

Cutting and Fitting: PVC pipe is easily cut with a hacksaw or tubing cutter. The sections are joined together mechanically, using plastic pressure fittings for later removal, or permanently joined using special chemical solvent.

Chromed Brass

Appearance: Bright, shiny chrome-finished pipe of larger diameter (more than one inch).

Description: Chromed brass is often used in place of PVC for exposed waste line applications, such as “P” traps or other drain traps where appearance is important.

Prevalent Use: Exposed drains and traps.

Cutting and Fitting: Easily cut with a hacksaw, and joined with slip fittings.

Chromed Copper

Appearance: Bright, shiny chrome finished pipe of smaller diameter (3/8" or less).

Description: Chromed copper pipe is often used where the appearance of exposed water supply lines is important.

Prevalent Use: Exposed water supply lines, such as supply tubing for toilets or pedestal sinks.

Cutting and Fitting: Easily cut with a tubing cutter or hacksaw, and joined with chromed brass compression fittings.

Galvanized Iron

Appearance: Dull silver-gray rigid metal pipe.

Description: Galvanized iron pipe was once a popular method of plumbing water supply lines in the home, but it gradually fails due to corrosion and rust. For this reason, it is no longer commonly used and has been largely replaced with copper pipe or PEX plastic pipe. Galvanized iron pipe is difficult to cut and join and not easily fabricated on site. Repairs are usually done by replacing the pipes with copper or PEX.

Prevalent Use: Water supply lines and drain lines.

Cutting and Fitting: Can be cut using a reciprocating saw or hacksaw. The pipe is joined by using threaded galvanized iron fittings.

Copper (Rigid and Flexible)

Appearance: Dull, copper-colored metal pipe.

Description: Copper pipe comes in two types: rigid and flexible. The rigid type comes in several wall thicknesses: K, L, and M. Type M is the one normally used for water supply pipes. Copper is more corrosion resistant and readily available. Copper is a soft metal and can be easily cut and fabricated. It is also prone to damage, may develop pinholes over time, and can rupture from frozen water in pipes.

Rising costs for copper have caused PEX and CPVC to be used more frequently. Copper comes in three grades:

- M for thin wall pipe (used mainly inside homes);
- L for thicker wall pipe (used mainly outside for water services); and
- K, the thickest (used mainly between water mains and the water meter).

Prevalent Use: Rigid copper pipes are used for longer runs of water supply, and in some cases as waste lines. Flexible copper is used in short runs, for water supply, and for the water supply tubing for refrigerators and dishwashers. Copper may also be used for gas piping.

Cutting and Fitting: Copper pipe is easily cut with a tubing cutter or hacksaw. Sections are joined together with soldered copper connectors or copper compression fittings. The flexible copper pipe may also be terminated by flaring its end and using brass flare fittings.

CPVC (Chlorinated Poly Vinyl Chloride)

Appearance: Dull white or cream-colored plastic.

Description: CPVC is a cheaper rigid plastic that is designed to withstand high pressure and temperature.

Prevalent Use: CPVC is used for hot and cold water supply piping.

Cutting and Fitting: The pipe is easily cut with a tubing cutter or hacksaw. CPVC is joined permanently together using plastic fittings and solvent glue, or with grip fittings where the pipes may need to be disassembled in the future

PEX (Cross-linked Polyethylene)

Appearance: Typically blue (cold water), red (hot water), or white flexible plastic pipe.

Description: PEX is made of cross-linked HDPE (high-density polyethylene) polymer and is an incredible piping material that has been in use. PEX is strong and flexible, withstanding temperatures from below 32 F to 200 F. PEX is corrosion resistant, and unlike copper pipe, it will not develop pinholes. Because PEX is flexible and uses fewer connections and fittings, it is easier and faster to install. The reduced number of required fittings in a PEX system also reduces the possibility of leaks.

Prevalent Use: Water supply, radiant heating pipe and upgrade of older systems.

Cutting and Fitting: PEX is cut and fit with specialized fittings and tools.

Black mild steel

Appearance: Dull black rigid pipe, usually one inch or less in diameter.

Description: Black pipe looks almost exactly like galvanized iron pipe, except it is darker and specifically designed for gas applications.

Prevalent Use: Natural gas or propane supply pipes. It is often used for feeding gas supply to the furnace, boiler, or water heater.

Cutting and Fitting: Can be cut using a reciprocating saw or hacksaw. The pipe is joined using threaded black pipe fittings.

PPR Pipe

PPR pipe is a straight and rigid cylindrical pipe, made from Polypropylene Random Copolymer plastic, produced through a continuous extrusion process. They are commonly offered in green or white color, and in outer diameter sizes ranging from 20mm to 110mm making the pipe walls far thicker than PVC. PPR pipe is accompanied by a series of connection fittings, parts, and accessories available for every pipe diameter.

Application of PPR Pipe

- **PP-R pipes** are used to install hot and cold water systems, including central heating systems.
- **PP-R pipes** are a part of building heating system, including floor, wall and radiant heating systems.

PP-R pipes can be directly purified water drinking water supply system

The main specification followed are as follows;

- Manufacturer's specification; this is where the manufacturer specifies where to use specific materials; where to GI, pvc or even brass.
- Clients' specifications based on economic and ergonomic factors; here the client is the final decision maker depending on what he/she likes the most and can afford it (there is no problem with finances as long as it's available in the market).
- Standard specifications; these are from the industrial experts i.e., experienced, they advise you accordingly as to why you should prefer one material over the other.

Types of Pipe Fittings

- Adaptor
- Barb
- Coupling
- Cross
- Double Tapped Bushing
- Elbow
- Mechanical Sleeve
- Nipple
- Plug and Cap
- Reducer
- Tee
- Union
- Wye

Adaptor

Adaptors connect pipes that are not the same type. Because an adaptor can be male or female on one end, it can turn a pipe male or female.

Barb

A barb connects hoses to pipes. It is usually male at one end. The other has a barbed tube, which is a ridged and tapered cone.

It may also have a type of clamp to keep it secure. Barbs are made of plastic if they carry cold water and brass if they carry hot water.

Coupling

A coupling makes it easy to connect two pipes that have the same diameter and are the same type. It's also used to repair a broken or leaking pipe. Along with a normal coupling, two other types are the **compression coupling** and **slip coupling**.

The compression fitting is connected between two pipes via rubber seals or gaskets on both sides which prevents leaking. A slip coupling includes two pipes, one of which slides out of the other pipe to a various length, to repair a specific length of damaged pipe.


Cross

A cross fitting has openings on all four of its ends and can connect four pipes. Cross fittings come with three inlets and an outlet or three outlets and an inlet.

Because they are the connecting point for four pipes, they are under more stress than other types of fittings and typically built tougher than other fittings.


Double Tapped Bushing

This is a type of nipple, but it has threading on both the inside and the outside. Because this center hole is threaded (tapped) from both top and bottom, it’s referred to as double-tapped.

A double tapped bushing is also a type of reducer, but does not have a reducer’s flexibility. A double tapped bushing is usually female.

Elbow

Not surprisingly, this sort of fitting has a bend that reminds you of the arm joint. They help the flow of water change direction. Elbows come in several degrees, including 22.5, 45, and 90 degrees.

Reducer elbow variations also exist for when the piping diameters being connected are different. Elbow fittings can be made of different materials, and most are female.

Mechanical Sleeve

This connects two pipes through the use of a screw or other device. This makes the fitting easy to install. The mechanical sleeve or coupling is usually made of rubber that is inserted inside a metal jacket (stainless steel clamp).

When the clamp is tightened, it compresses the rubber inside to make a tight seal. Because this fitting can be slightly flexed, it can accommodate small misalignments in hard to install locations.

Nipple

This is a short fitting that can be made of metals such as copper, brass or steel or chlorinated polyvinyl chloride (CPVC). Instead of connecting two pipes, a nipple connects two fittings.
If it has a continuous threading, it is a closed nipple. They are usually male and come in varying lengths.

Plug and Cap

Plugs and caps are both used to close up pipe openings during inspections and repairs. The main difference is that a plug is male while a cap is female. Most often, caps and plugs are threaded. Plugs and caps are made of several materials, including metal, plastic or rubber and can be welded, soldered, glued, or threaded into the pipe.

Reducer

This fitting makes a flow smaller and thus reduces it. Reducers come in two types. The concentric reducer joins two pipes on the same axis, and the eccentric reducer is used to join pipes of different diameters.

The **concentric reducer** looks like a cone, while **eccentric reducers** look somewhat like bells with offset center lines. They prevent air bubbles in the pipes.

Tee

A tee has an inlet and an outlet and is shaped like the letter "T." These fittings come in different sizes and are considered sturdier than the cross fitting.

A diverter tee is used in heating systems that use water. They come with directional markings and need to be installed correctly for the system to operate.

Union

Unions can have either male or female threads. They are similar to couplings, but the difference is unions are easy to remove making them convenient for maintenance or a planned future replacement.

A coupling, on the other hand, is more permanent and needs to be cut out. A union contains three parts: nut, male end, and female end. The nut is used to join the male and female ends.

Wye

Built in the shape of the letter "Y," this fitting is made to connect three pipes. Y fittings allow the pipes to change their elevations and to branch out into fresh water lines or drains.

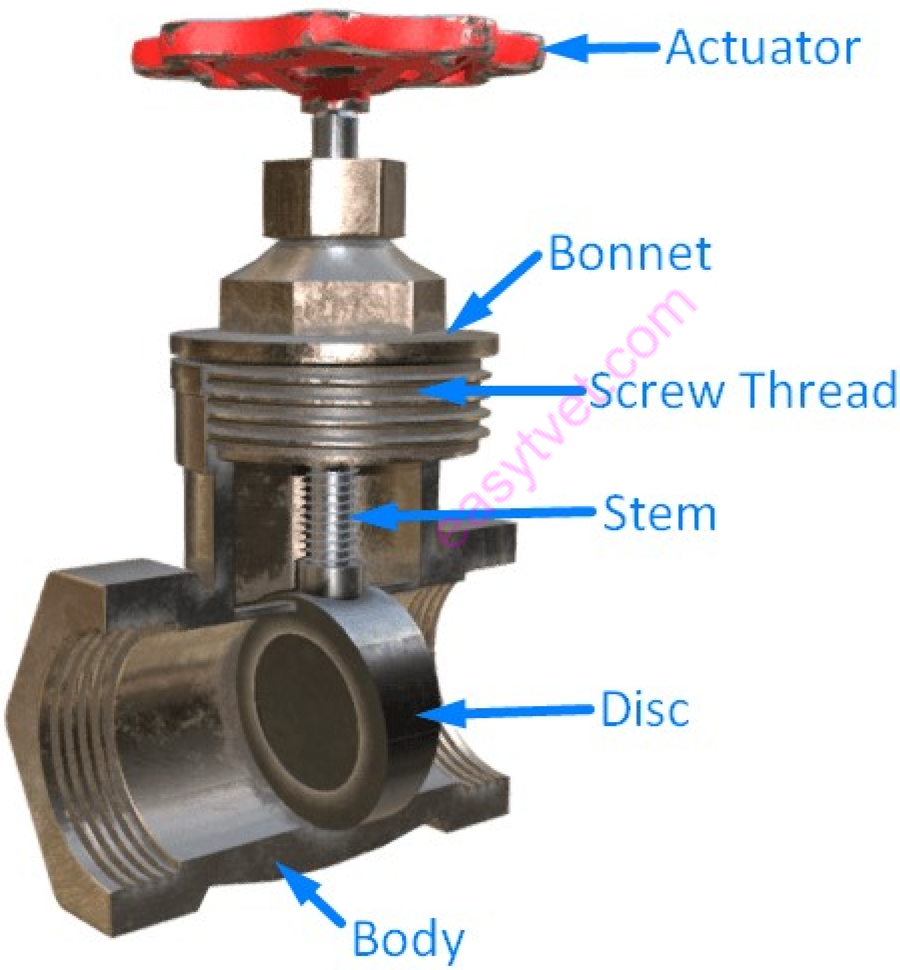
Wyes are similar to tee fittings but the smoother angling reduces friction and turbulence in the water. This fitting is most commonly used to connect a vertical drainpipe to a horizontal one.

TYPES OF VALVES

Valves are mechanical devices used to control, direct, and regulate the flow of water by opening, closing, or partially obstructing the flow. They can be made up of different materials like bronze, PVC, brass, etc. There are different types of valves namely;

Gate Valve

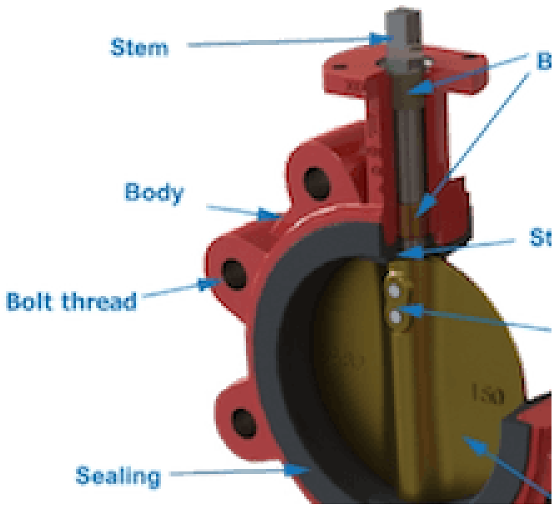
Gate valve is the most widely used type of valve in plumbing systems. It includes a wedge-shaped metal gate that can be lowered (with the use of a twist-type handle or knob) to stop the flow of water or raised to allow the flow to continue.



Butterfly Valve

This valve has a rotating metal disc that allows and inhibits the water flow, creating an image similar to that of a butterfly due to which is called a butterfly valve.

These valves are very compact, light, and relatively short, making them significantly lighter than the other types.

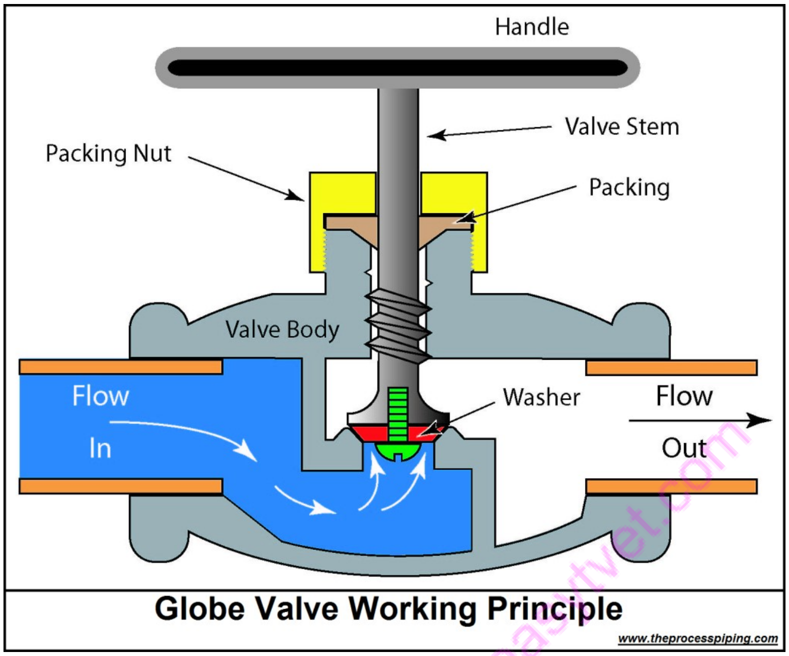


Ball Valve

Ball valves are the most reliable and common type of valves used to regulate the flow of water. It involves a rotating sphere with a hole that is attached to a lever handle to operate the valve.

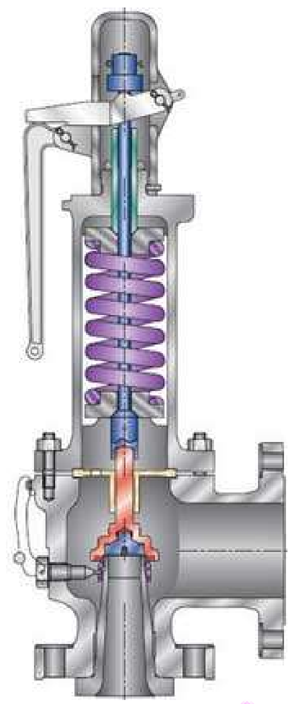
Globe Valve

The Globe valve is commonly used to regulate or limit the water flow in plumbing applications, where the flow needs to be adjusted regularly.
The interior design features contain a stopper on the end of a valve stem that is raised and lowered by the valve's twist knob. Globe valves get their name due to the globe-like or ball-like appearance of their body.



Pressure Relief Valve

Pressure relief valves are used in the plumbing system to reduce water pressure to the desired limit and protect equipment or piping systems from bursting. The mechanism consists of a spring and diaphragm adjusted to a specific limit, depending on the pressure of the water supply.
The pressure relief valves are also known as **pressure-reducing valves**, **pressure safety valves**, and **pressure balance valves**.



Factors to consider when selecting an ideal supplier a supplier

When choosing the ideal plumbing supplier for your needs, whether they're home plumbing or commercial, larger scale projects, you need to weigh up the differences, options and benefits between various plumbing suppliers.

Choosing the best plumbing supplier should be based on mainly;

- availability of the required materials
- the lower price shall be termed as most economical
- the highest quality materials shall be considered
- the distance of the required material shall be a factor.

Plumbing Estimates:

The Basics

Set the tone when meeting clients for the first time by offering them a plumbing estimate with all the details needed to hire your company. A thorough and clear outline of the estimate can help you land the job!

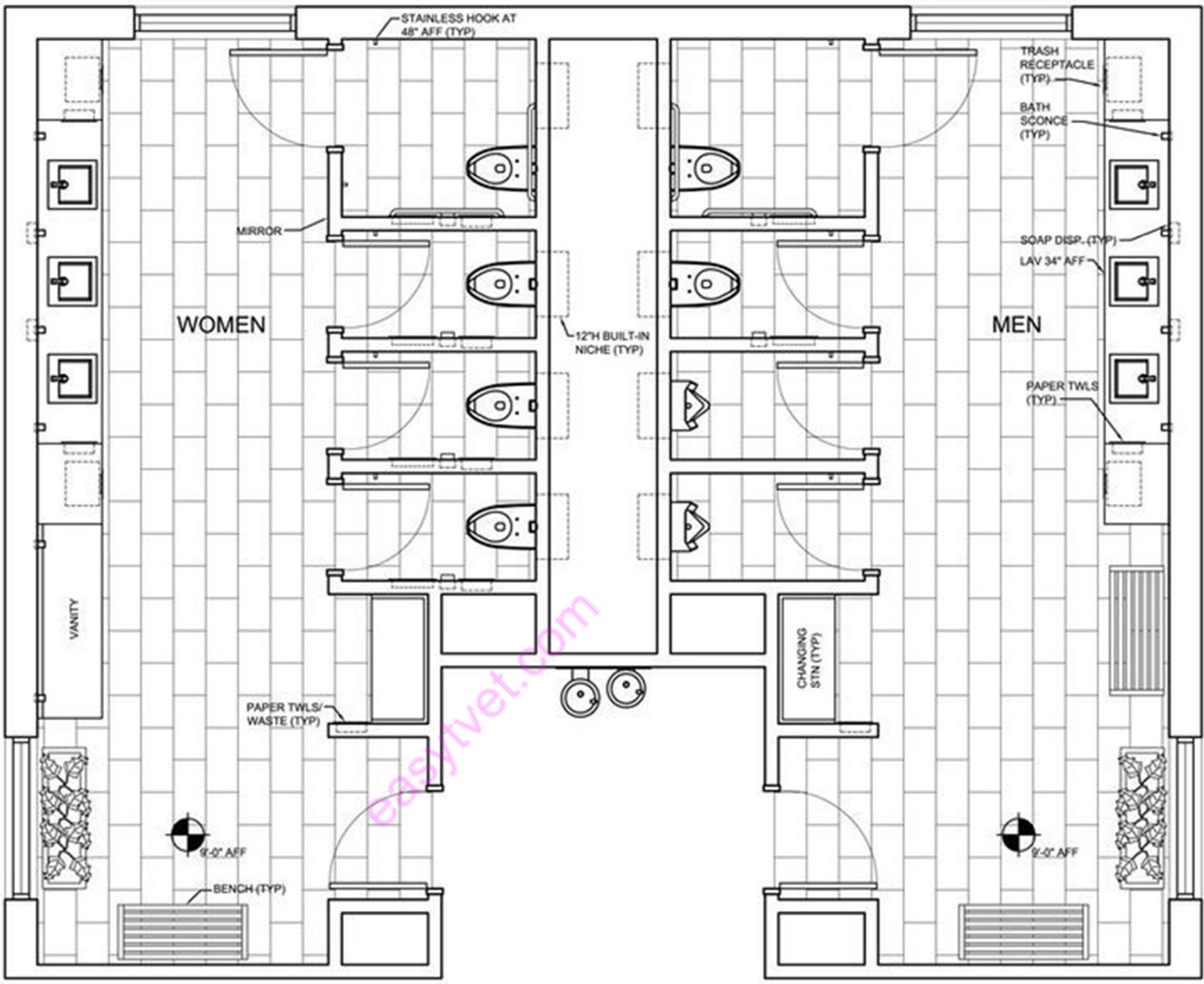
Cost estimation is an extremely important stage of a project in any industry requiring work in the field, and invoicing a plumbing business is no different than construction job estimation for that matter. While you can offer a verbal estimate, a written one helps make your business look more professional. Check the average estimations range in your local area and create the outline ahead of time so it's easy to plug in the information, plus the consistency is helpful for you and your potential clients. Cover the following points:

- Contact information
- Summary of the project
- Materials list
- Cost estimate
- Permits required
- Your insurance and licensure details
- Work guarantee

1.2.2.4 Learning Activities

You are required to Study the floor plan below and;

- Identify and select the materials based on the working drawing
- Quantify and cost the materials using the current market rate.



1.2.2.5 Self-Assessment

1. State where the following types of pipes are used.

   i. **CPVC**

ii. **Cast iron**
iii. **PP-R pipes**

2. Define a valve
3. List four factors that should be considered before selecting a supplier.

4. Which type of valve is used to reduce the water pressure in the pipe systems?

1.2.2.6 Tools, Equipment, Supplies and Materials

Table 4: Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Pipe wrench • Pipe cutter • Hacksaw • Pipe Threading Equipment • Vise - Bench • Tap and Punch • Files • Screwdrivers • Drill with various sizes of bits • Mallet • Ball hammer • Masonry chisel • PPR machine / Heat Fusion • equipment • Pipe bender	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Various types of pipe support • Sandpapers • Threading oil • Thread tape • Assorted pipes • Assorted fittings

1.2.2.7 References

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1.2.2.8 Model answers

1) State where the following types of pipes are used.

i. **CPVC** is used for hot and cold water supply piping.
ii. **Cast iron** Use for main soil stack waste lines and vent pipes
iii. **PP-R pipes** are used to install hot and cold water systems, including central heating systems.

2) Define a valve

Valves are mechanical devices used to control, direct, and regulate the flow of water by opening, closing, or partially obstructing the flow

3) Choosing the best plumbing supplier should be based on mainly;

- availability of the required materials
- the lower price shall be termed as most economical
- the highest quality materials shall be considered
- The distance of the required material shall be a factor.

4) Which type of valve is used to reduce the water pressure in the pipe systems?

Pressure relieve valve

1.2.3 Learning Outcome 3: Identify and use pipework tools and equipment

1.2.3.1 Introduction to the learning outcome

This outcome specifies the competencies required in identifying, using pipework tools and equipment's as it applies in the construction industry.

1.2.3.2 Performance Standard

1. Personal Protective Equipment is used in line with occupational safety and health requirements
2. Pipework tools and equipment are identified based on job requirements.
3. Pipework tools and equipment are used based on best practice and manufacturer's manual.
4. Pipework tools and equipment are cared for and maintained based on manufacturer's manual and workplace policy
5. Pipework tools and equipment are stored based on work place policy.

1.2.3.3 Information Sheet

A plumber requires several tools for the fitting work for plumbing, fixing a tap or to carryout repairs. These tools help the plumber in performing his/her work properly, and therefore it is important that the tools are used systematically and handled carefully to avoid any damage. They should be kept at a designated place after use. The tools can be categorized as per the nature of work like holding tools, fitting tools, cutting tools, pipe threading and bending tools, etc.

Personal Protective Equipment (PPES)

Protective gears are essential in all plumbing services, such as pipe installation, system repairs, etc. The right personal protective equipment for a plumber comprises of gloves, boots, overall/dustcoat eye protection, protective helmet, and eye protection. Also, sometimes a plumber may need respiratory protective equipment. Eye protection is essential when the plumber is using power tools.

PPE. The main objective of a protective gear for a plumber is to reduce plumber exposure to hazards related to plumbing. Below are essential PPE for plumbers commonly used on plumbing and their benefits.

Figure 125: PPEs

1. Face and Eye Protection

Spectacles, safety goggles, and full-face shields are essential protective gears a plumber should consider using when handling the task. This safety gears are commonly used when handling power tools.

2. Head Protection

Protective helmets are important in a plumbing site because they prevent injuries from flying or falling objects. Falling or flying objects might lead to severe head injuries, which will cost a plumber a huge amount of money in the long run. Therefore, it's a great idea to invest in a suitable protective helmet.

3. Hand and Skin Protection

There are different types of gloves that can be used as PPE for plumbers. These types include cut-resistant gloves, rubber gloves, heat-resistant gloves, chainsaw gloves. Gloves are essential when a plumber is handling tasks that involve hot materials, electricity, and slippery objects.

4. Respiratory Protection

Production of toxic substances is common in plumbing sites. Respiratory protection gears, such as respirators, are designed to protect a plumber from fumes, dust, and other dangerous substances that could lead to respiratory problems. Respiratory protection gears are important in areas where there's air contamination.

5. Hearing Protection

Noise pollution in plumbing sites can lead to permanent hearing impairment. Earplugs and earmuffs are the common hearing protection equipment in plumbing projects. Note that earplugs are effective in reducing low-frequency noise, whereas earmuffs are effective in preventing high-frequency noise.

TYPES OF TOOLS AND EQUIPMENTS

The major tools used in plumbing are categorized as:

Holding tools

- Bench vice
- Pipe vice

Fitting tools

- Pipe wrenches
- Water-pump plies
- Spanners

Cutting tools

- Pipe cutter
- Hacksaw

Pipe bending tools

- Pipe bending machine
- Threading dies

Other tools

- Chisel
- Hammer
- Chain wrench
- Rover jumper
- Trowel
- Screw driver
- File
- Plier
- Caulking tools
- Drill machine
- Drill bit
- Hanger
- Measuring tape
- Plumb rule and bob
- Spirit level
- Spade
- Shovel
- Pickaxe
- Mortar pan
- Mason square
- Water level tube

Holding tools.

Tools which are used for holding the pipes, pipe fittings and fixtures for plumbing operations are called holding tools. Some of the commonly used holding tools are mentioned below.

Bench vice

A vice is a tool used for holding an object for various tasks like filing, chipping, sawing, threading, tapping, bending, etc. The bench vice has two jaws, one of which is fixed and the other is movable. These jaws are fitted with plates for a better grip on the object during the task. The vice size depends on the width of the jaw. A bench vice is fixed to a table or a bench through a bolt. A vice is opened and closed with the help of a handle attached to a spindle. In this way, the object is held tightly. Bench vices hold the objects and allow use of other tools to complete the tasks

Pipe vice

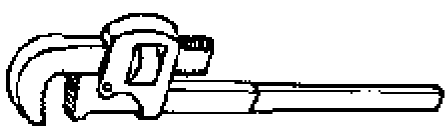
It is a tool used for holding a pipe for carrying out assembly, disassembly, threading, cutting, etc. Pipe vices are of two types: (i) Open side pipe vice (ii) Fixed side pipe vice Standard sizes of vices are 80 mm, 105 mm, 130 mm, 170 mm, etc., as per the opened size of the jaws.

Fitting tools.

While holding tools are used to keep the objects in place, fitting tools are used for carrying out various plumbing operations like cutting, tightening, fixing and other small tasks.

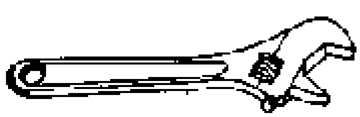
Pipe Wrenches

These are hand tools used for tightening and loosening the nuts and bolts. Wrenches hold slippery or small nuts and bolts for loosening or tightening them. Mostly, two types of wrenches are used—adjustable and non-adjustable. These are useful particularly in case of odd-sized nuts and bolts. These tools hold a pipe and pipe fittings for screwing or unscrewing. This is a very common tool, especially for small diameter pipes up to 50 mm.



Adjustable spanner

This type of wrench is used to loosen or tighten the nuts and bolts of any odd and regular sizes. It is used for tightening and loosening valves, cocks, geysers, flexible pipes, etc. It is a good maintenance tool for repair of plumbing items like valves, cocks, pumps, etc.



Water-pump plier

It is a common plier used by plumbers for holding, tightening and loosening work during fixing process. Steel is used for manufacturing water-pump pliers. These are available in only one standard size of 250 mm length. The maximum width possible between the two jaws is 40 mm.

Spanners

This tool is used for tightening and loosening nuts and bolts of standard size. The standard spanners used are:

Ring spanners

These spanners have full circular closed ring at both ends. It is difficult to slip and cause damage. It is made through forging process, with a burnished finish or a chrome-plating.

Combination spanners

These spanners are open at one end and closed at the other.

Cutting tools

Tools that are used for cutting the pipes, fixtures and bolts, etc., are known as cutting tools. Some of the commonly used cutting tools are mentioned below.

Pipe cutter

This is a manual tool used to cut a pipe at the work site, especially when it is difficult to use a hacksaw frame. This tool has a sharp, round cutting wheel which is pressed with to and fro rotary motion for cutting a pipe.

Hacksaw

This tool is generally used with both the hands. It cuts material like plastic pipe, steel rod, angle iron, sheets, iron pipes, etc. It can also be used for cutting the bolt heads and nuts when they are jammed. Important parts of a hacksaw are—handle, frame, blade and adjusting wing nut.

Pipe bending tools

In most of the plumbing operations, pipes are required to be bent at different angles as per requirement, for which pipe bending tools are used. Some of these tools are mentioned below.

Pipe bending machine

This equipment is used to bend or turn pipes. The size and strength of the machine depends upon the diameter of the pipe and the type of the pipe material to be bent. The mechanical or hand-operated pipe bending machines are available for 3/8– 1″ diameter pipes. For higher ranges, i.e., 1/2–2″, 1/2 – 3″, 1/2– 4″ and 2– 6″, hydraulic hand-operated machines are used.

OTHER TOOLS.

Apart from the already mentioned holding, fitting, cutting and bending tools, various other tools are also used in plumbing operations. These are listed below.

Chisel

It is made of hard metal and is mostly used for cutting concrete surface and making grooves in the walls with the help of a hammer.

Hammer

These are general purpose workshop hand tools used for straightening of sections, riveting, striking of nails and inserting the component by striking, inserting keyways and fitting by striking.

Chain wrench

The common holding tools do not help much in case of large diameter pipes. For these, chain wrenches are used. A chain wrench consists of a toothed block, a handle and a chain. The chain is round, grooved and held on the toothed end of the block. The chain grips the pipe fitting and screws or unscrews. The chain wrench is available in 3″, 4″, 6″, 8″ and 12″,with the length 475 mm, 585 mm, 834 mm, 1100 mm and 1360 mm respectively. These sizes are designated by the maximum diameter of the pipe it can hold.

Screwdriver

This tool is often used by plumbers to fit the screws. Screwdrivers have a sharp tip which can easily fit into various screws.

Files

These hand tools are used for a variety of work, like removing of sharp edges, metal removal, shaping of jobs, smoothening of surfaces, finishing, producing different shapes, etc. The file has five parts: tang, heel, face, edge and point or tip. Various types of files of different shapes like hand round, pillar, square, three square, half round, flat, knife edge and needle file are used as per the work.

Pliers

They are important tools used for holding small objects and for tightening or loosening various parts. Several types of pliers are used by a plumber during work. Pliers can be used for cutting purpose also.

Caulking tools

For filling the gaps in the wall, caulking tools are used. This tool helps in filling and removing material in the building.

Drill machine

One of the common but important tools used for making a hole in a metal or wood, or concrete surface. A drill machine is fitted with a cutting tool like a drill bit. The attachment is tightened with a key.

Drill bits

These are the tools used to make cylindrical holes by cutting the material. Bits are fitted in a tool which rotates it and make the hole. For non-cylindrical shaped holes, specialised bits are used.

Hangers

The purpose of a pipe hanger is to hold or support a pipe or a group of pipes from a slab, beam, ceiling or other structural elements.

Measuring tape

It is used for measuring the length of an item. The measuring tape is manufactured in various material like steel, cloth and PVC.

Plumb rule and bob

This is a useful tool to ensure verticality and uniformity during construction of walls, columns and wooden frames like doors and windows. It also helps in levelling the surface of the floor. It consists of a holding pipe, thread and a plumb bob made of wood and metal. The plumb bob is connected to the holding pipe with the thread.

Spirit level

It is used to check the horizontality or levelling of the floor, roof, door, window frame

Trowel

It is used for mixing cement and sand for masonry work. It is used for plastering the surface.

Spade

A spade is used for digging purpose and for mixing cement, sand and concrete.

Water level tube

This tube is used to check and transfer water levels, etc.

EQUIPMENT MAINTENANCE

It includes routine upkeep as well as corrective repair work. Equipment may include heavy workshop machines.

Types of maintenance

There 4 general types of maintenance; corrective, preventive, risk-based and condition-based maintenance.

1. **Corrective maintenance**; Maintenance is carried out following detection of an anomaly and aimed at restoring normal operating conditions.
2. **Preventive maintenance**; Maintenance carried out at predetermined intervals or according to prescribed criteria, aimed at reducing the failure risk or performance degradation of the equipment

Below is a preventive maintenance checks of a water pump.

Preventive maintenance checks	
Daily	• Cleaning • Lubricating oil • Coolant level • Report minor defects
Weekly	• Lubricating oil • Coolant level • Filters • Hydraulic & pneumatic lines
Monthly	• Spindle drive belt • Hydraulic pumps & oil • Movement of axes
Biannually	• Machine alignment • Replace oils & filters

3. **Risk-based maintenance**; Maintenance carried out by integrating analysis, measurement and periodic test activities to standard preventive maintenance
4. **Condition-based maintenance**; Maintenance based on the equipment performance monitoring and the control of the corrective actions taken as a result.

the surface being worked on.

Why is it important to use the correct tools and equipment?

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

Tools and equipment storage

Why should tools and equipment be securely stored?

You are responsible for making sure that all tools and equipment are well organized and maintained in good working condition. They should be stored in a separate secure place so that they are safe and easy to find. This is usually best done in a place which is separate from the office.

Proper storage of tools and equipment

Section a space on your building and make it a storage place for tools.

Tools Preparation and Storage

Preparation

- Clean tools after each use
- Repair any broken parts
- defective tools must be isolated
- Use metal protectant spray on all metal parts
- Never store tools on the unprepared ground
- Get creative with storage options the heavy ones near/on the prepared raised ground and the lighter ones on top
- Make a list of all items that are stored

Storage

To keep these tools safe and in good working condition, it’s better to keep them in and not limited to:

- Racks
- Cabinets
- Drawers
- Pegs on wall
- Shelves
- Tool boxes

Make sure to label the boxes with its contents so you will be able to find the tool when you need it. Keep an inventory list of the tools that you have and where they are stored.

Figure 126: pegging on wall

1.2.3.4 Learning Activities

Practical activities

Below is a pipework installation, you are required to study it and;

- Identify the Personal Protective Equipment used in line with occupational safety and health requirements
- Identify the Pipework tools and equipment to be used.

1.2.3.5 Self-Assessment

1. Types of personal protective equipment (PPE) to guarantee your safety
2. Which are four safety risks a plumber faces on places of work?
3. What is the importance of tools in plumbing?
4. What tools do plumbers use to unclog drains?
5. Which material will you use to threaded pipe connection to prevent leakage?
6. I need to cut a new piece of copper pipe for the supply run to my sink. What are the best tools and techniques to use?

1.2.3.6 Tools, Equipment, Supplies and Materials

Tools/Equipment:	Materials:
• Pipe wrench • Pipe cutter • Hacksaw • Pipe Threading Equipment • Bench-vice • Tap and Punch • Files • Screwdrivers • PPR machine / Heat Fusion • equipment • Pipe bender	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Various types of pipe support • Threading oil • Thread tape • Pipe clamp • Adhesive

1.2.3.7 References

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1.2.3.8 Model Answers

1. **Types of personal protective equipment (PPE) to guarantee your safety**
    - Safety for the head. Wearing a helmet offers protection and can prevent head injuries.
    - Protect your eyes.
    - Hearing protection.
    - Maintain a good respiration.
    - Protect your hands with the right gloves.
    - Protection for the feet.
    - Wear the correct work clothing
2. **Which are four safety risks a plumber faces on places of work?**

   Any four

- Exposure of hazardous substances like lead, Sulphur dioxide
- Exposure to combustible and flammable materials
- Working in awkward positions
- Lifting of heavy objects
- Risks of eye injuries from flying particles
- Burns from hot equipment or steam lines
- Risks of electric shocks while working for ground water pipes

3. **What is the importance of tools in plumbing?**

   A plumber requires several tools for the fitting work for plumbing, fixing a tap or to carryout repairs. These tools help the plumber in performing his/her work properly, and therefore it is important that the tools are used systematically and handled carefully to avoid any damage
4. **What tools do plumbers use to unclog drains**?

To dislodge clogs located farther down the drainpipe, use a cable auger, or plumber's snake, a long, flexible steel cable wound around a spool that's fitted with a hand crank

5. **Which material will you use to threaded pipe connection to prevent leakage?**
   - Teflon tape

6. **I need to cut a new piece of copper pipe for the supply run to my sink. What are the best tools and techniques to use?**
   It's best to use a pipe cutter with a specially designed blade for copper pipe. You can also use a fine-toothed hacksaw, but making a straight cut with it is more difficult. After you've cut the pipe, clean off any burrs (inside or out) with a half-round file.

1.2.4 Learning Outcome 4: Install pipe works

1.2.4.1 Introduction to the learning outcome

This outcome specifies the competencies required to install pipe works as it applies in the construction industry.

1.2.4.2 Performance Standard

1. Positions of pipes are set out and marked based on working drawings
2. Pipes are threaded based on standards and specifications.
3. Pipes are jointed in accordance with best practices and manufacturer's instructions.
4. Pipes are cut based on type of pipe, drawing specifications and job requirements
5. Flanged joints are prepared based on best practices
6. Pipes are bent based on type of pipe, drawing specifications and requirements of the job.
7. Pipes are fitted based on drawing specifications.
8. Housekeeping is conducted as per workplace procedures
9. Safety and health practices are observed based on OSHA functionality tests are conducted based on best practices.
10. Faults in functionality and leakage are corrected based on best practice

1.2.4.3 Information Sheet

Pipes transport water from the sources of water supply to the points of distribution; convey waste from residential and commercial buildings and other civic facilities to the treatment facility or the point of discharge.

Terms and concept

Couplings; A coupling (or coupler) (used in piping or plumbing) is a very short length of pipe or tube, with a socket at one or both ends that allows two pipes or tubes to be joined, welded (steel), brazed or soldered (copper, brass etc.) together.

Adapters; they are used to connect dissimilar pipes.

Unions; A union is a threaded fitting which allows the pipe work to be separated and reconnected without any horizontal movement in the pipe.

Caps; Pipe caps act as protective device and are designed to protect pipe ends of various shapes

Plugs; they are also used for blocking the ends of pipes to prevent the entry of dirt and other contaminants during construction, maintenance or repair of pipelines.

Elbows/bends; It is used to connect two pipes with same or different nominal diameters, and to make the pipe and thus the fluid direction turn to a certain direction of 45 degree or 90 degree.

Tee-Connection; It is a short piece of pipe with a lateral outlet. Pipe Tee is used to connect pipelines with a pipe at a right angle with the line.

Cross; is a kind of pipe fitting that be used in the place where four pipes meet together.

Reducers; A reducer is a kind of pipe fitting used in process piping that reduces the pipe size from a larger bore to a smaller bore (inner diameter).

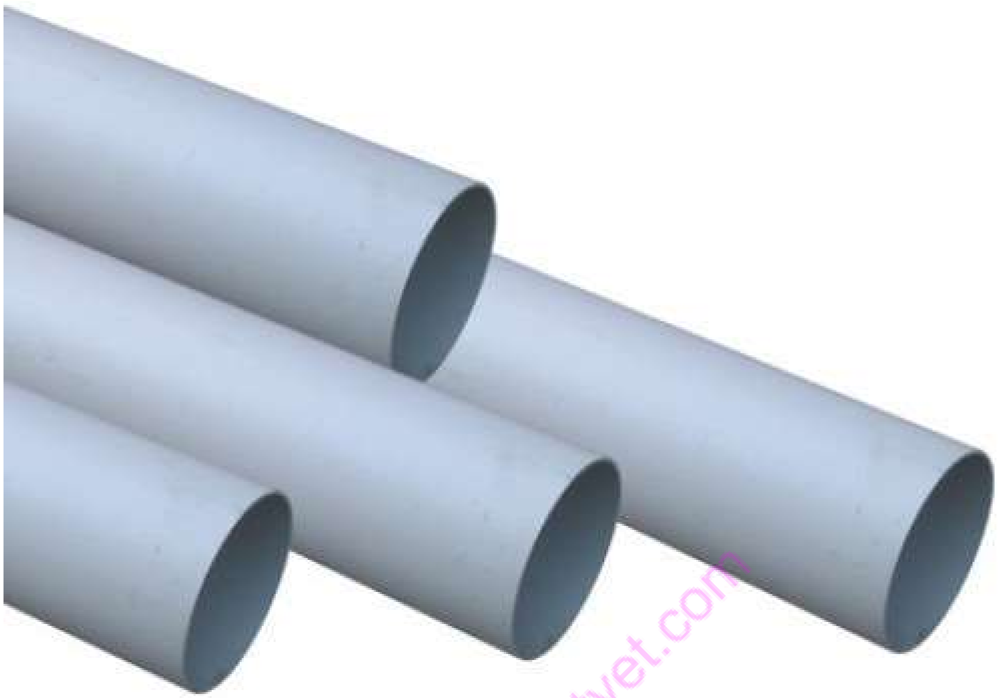
Valves; A valve is a device that regulates, controls, or directs the flow of a fluid by opening, closing, or partially obstructing fluid flow.

Figure 127: Plumbing fittings

Types of pipes

PVC pipes (Polyvinyl Chloride)

PVC pipes are used in a wide variety of piping applications, from transportation of drinking water over drainage solutions to advanced fire-sprinkler systems. This popularity owes to a unique combination of properties: safety, durability/cost-efficiency, environmental performance and recyclability.



G.I (Galvanized Iron) pipes

Description: Galvanized iron pipe was once a popular method of plumbing water supply lines in the home, but it gradually fails due to corrosion and rust. For this reason, it is no longer commonly used and has been largely replaced with copper pipe or PEX plastic pipe. Galvanized iron pipe is difficult to cut and join and not easily fabricated on site by the homeowner. Repairs are usually done by replacing the pipes with copper or PEX.

Prevalent Use: Water supply lines and drain lines in older homes.

PPR pipes

PPR pipe is a straight and rigid cylindrical pipe, made from Polypropylene Random Copolymer plastic, produced through a continuous extrusion process. They are commonly offered in green or white color, and in outer diameter sizes ranging from 20mm to 110mm making the pipe walls far thicker than PVC. PPR pipe is accompanied by a series of connection fittings, parts, and accessories available for every pipe diameter.

Application of PPR Pipe

- **PP-R pipes** are used to build hot and cold water systems, including central heating systems.
- **PP-R pipes** are a part of building heating system, including floor, wall and radiant heating systems.
- **PP-R pipes** can be directly purified water drinking water supply systems.

- **Mild steel**

Mild Steel (MS) pipes are manufactured using low carbon (less than 0.25%) steel. Due to low carbon content the pipes do not harden and are easy to use. As MS Pipes are made from mild steel they can easily be welded and formed in various shapes and sizes for pipelining and tubing purposes. These are generally used for drinking water supply i.e. Plumbing, Firefighting, but can also be used in various other Industrial and Engineering applications. These pipes are usually coated with other metals/paints/varnish etc. to prevent it from rusting but extra care should be taken to prevent it under extreme conditions.

- Copper

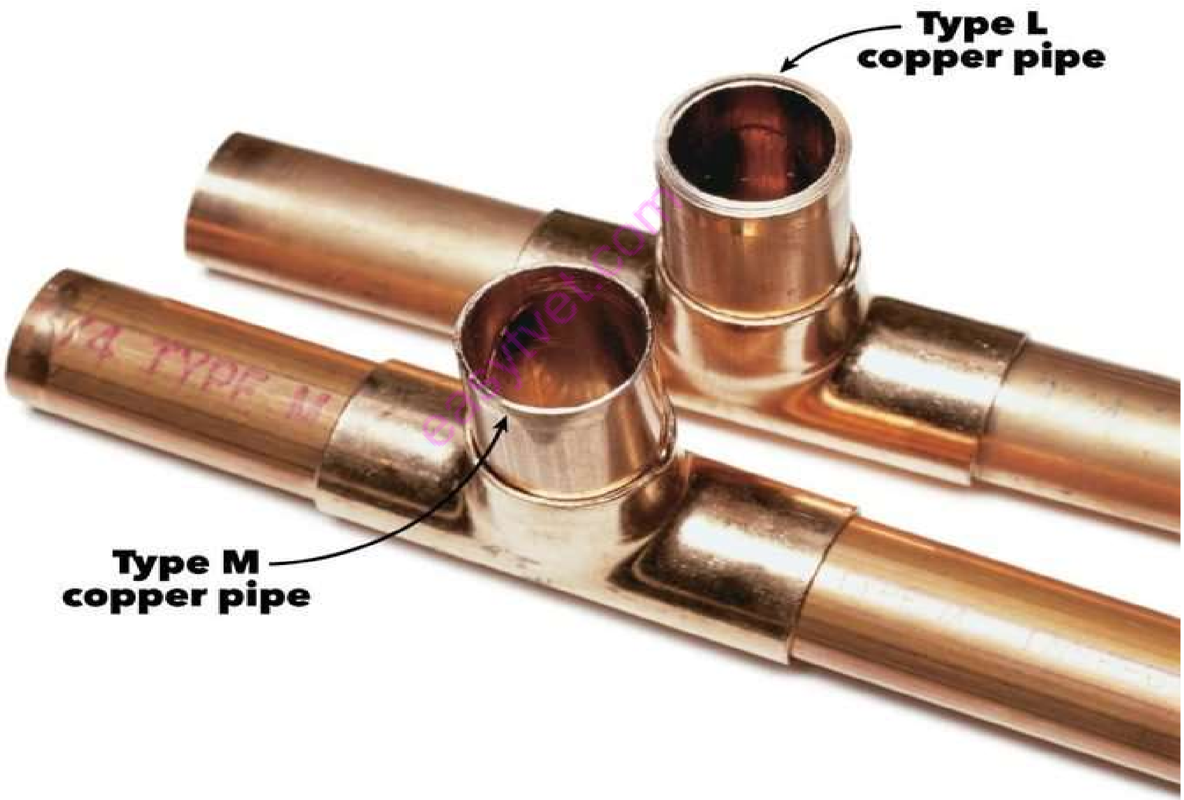
Appearance: Dull, copper-colored metal pipe.

Description: Copper pipe comes in two types: rigid and flexible. The rigid type comes in several wall thicknesses: K, L, and M. Type M is the one normally used for water supply pipes. Copper has proven itself over the decades to be corrosion resistant and very reliable. Copper is a soft metal and can be easily cut and fabricated. It is also prone to damage, may develop pinholes over time, and can rupture from frozen water in pipes.
Rising costs for copper in recent years have caused PEX and CPVC to be used more frequently. Copper pipe costs as much as three times as much as PEX. **Copper**. Copper comes in three grades:

- M for thin wall pipe (used mainly inside homes);
- L for thicker wall pipe (used mainly outside for water services); and
- K, the thickest (used mainly between water mains and the water meter).

Prevalent Use: Rigid copper pipes are used for longer runs of water supply, and in some cases as waste lines in the home. Flexible copper is used in short runs, for water supply, and for the water supply tubing for refrigerators and dishwashers. Copper may also be used for gas piping.

Cutting and Fitting: Copper pipe is easily cut with a tubing cutter or hacksaw. Sections are joined together with soldered copper connectors or copper compression fittings. The flexible copper pipe may also be terminated by flaring its end and using brass flare fittings.



- **CPVC**

Appearance: Dull white or cream-colored plastic.

Description: CPVC is an inexpensive rigid plastic that is designed to withstand high pressure and temperature.

Prevalent Use: CPVC is used for hot and cold water supply piping.

Cutting and Fitting: The pipe is easily cut with a tubing cutter or hacksaw. CPVC is joined permanently together using plastic fittings and solvent glue, or with grip fittings where the pipes may need to be disassembled in the future.

Traps and valves

These include all the main fittings that are used to control flow, shut – off or isolate, draw – off and drain – off water in hot and cold water systems. There are many types available in a range of materials, shape and suit a variety of applications. Traditionally, most are made of brass, bronze and gunmetal because metals are durable and resistant to corrosion.

Increasingly, many are now being made from plastics, because of its resistance to corrosion, low cost and ease to manufacture.

Taps

Taps are designed for general of the flow gradually. The tap is generally made of a spindle connected to a controlling head and the jumper. When the head is turned anti- clockwise, to open the tap, the spindle gradually raises the jumper off the seat and let water flow through the tap. When turned the head is turned clockwise, to shut the tap, the spindle screws down the spindle to lower the jumper on to the seat and shut of the flow. The gradual operation of taps lowers the general risk of water hammer. NB: Water Hammer: this occurs when water flow is stopped instantly causing kinetic energy created in the flow to be passed on to the pipes and fittings in the system causing vibration and noise and possibly damaging the system

They are several taps, which include

1. Bib taps
2. Pillar taps
3. Stop taps / stop cocks
4. Drain taps
5. Mixer taps

1. Bib taps

These are draw - off taps fitted above sanitary appliance such as sinks or to supply water for buckets or hoses**.**

2. Pillar taps

These are draw – off taps fitted to sanitary appliances like sinks, wash basins and baths. They have a long – threaded shank that allows them to be fitted into the appliance. Pillar taps should be high – necked to buckets fit underneath

3. Stop Taps/ stop cocks

These are used to shut off water or control the rate of flow in pipelines. They are commonly fitted to incoming water main in the building or on the feed pipe to individual appliances to shut off the water flow for repair and maintenance.

4. Drain taps

These are fitted to the low point of all systems for drawing down the system.
They are controlled by a removable key to prevent an authorized use.

5. Mixer tap

These are basically a pair of pillar taps, hot and cold, joined together by a common or mixing chamber and / or delivery spout to provide a mixed flow of hot and cold water.

Valves

A valve is a device that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways

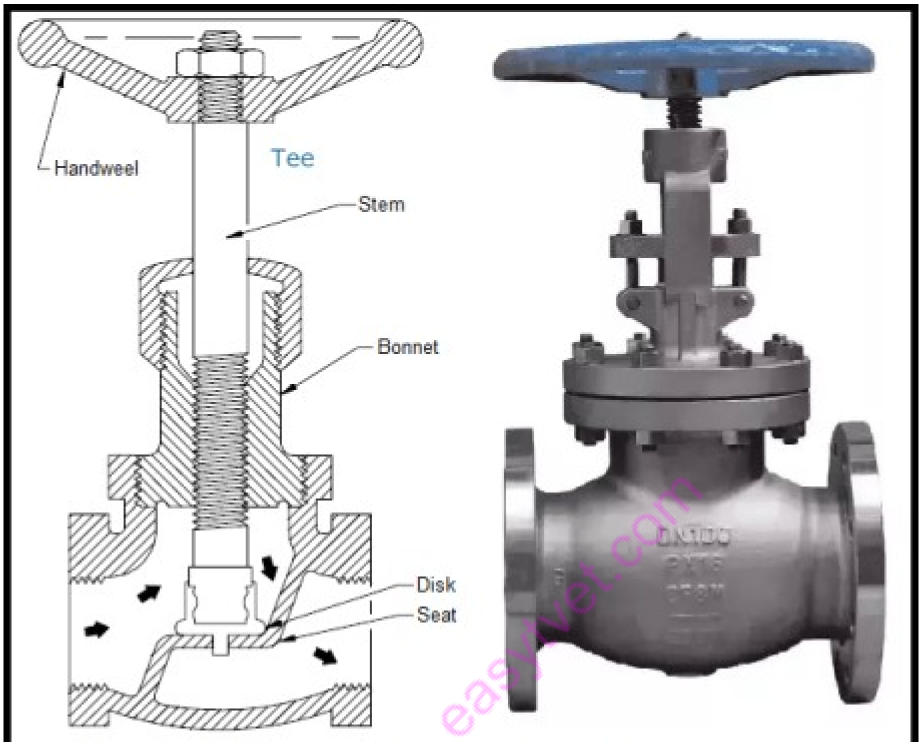
There are several valves available for use by plumber. They include.

1. Globe valves
2. Gate valves
3. Plug valve/ plug cork
4. Ball cork
5. Float valve/ ball valve

1 .Globe valves

They just look like gate valves from the outside but are screw - down operation in operation, just like the stop tap.

They are made with female thread connections

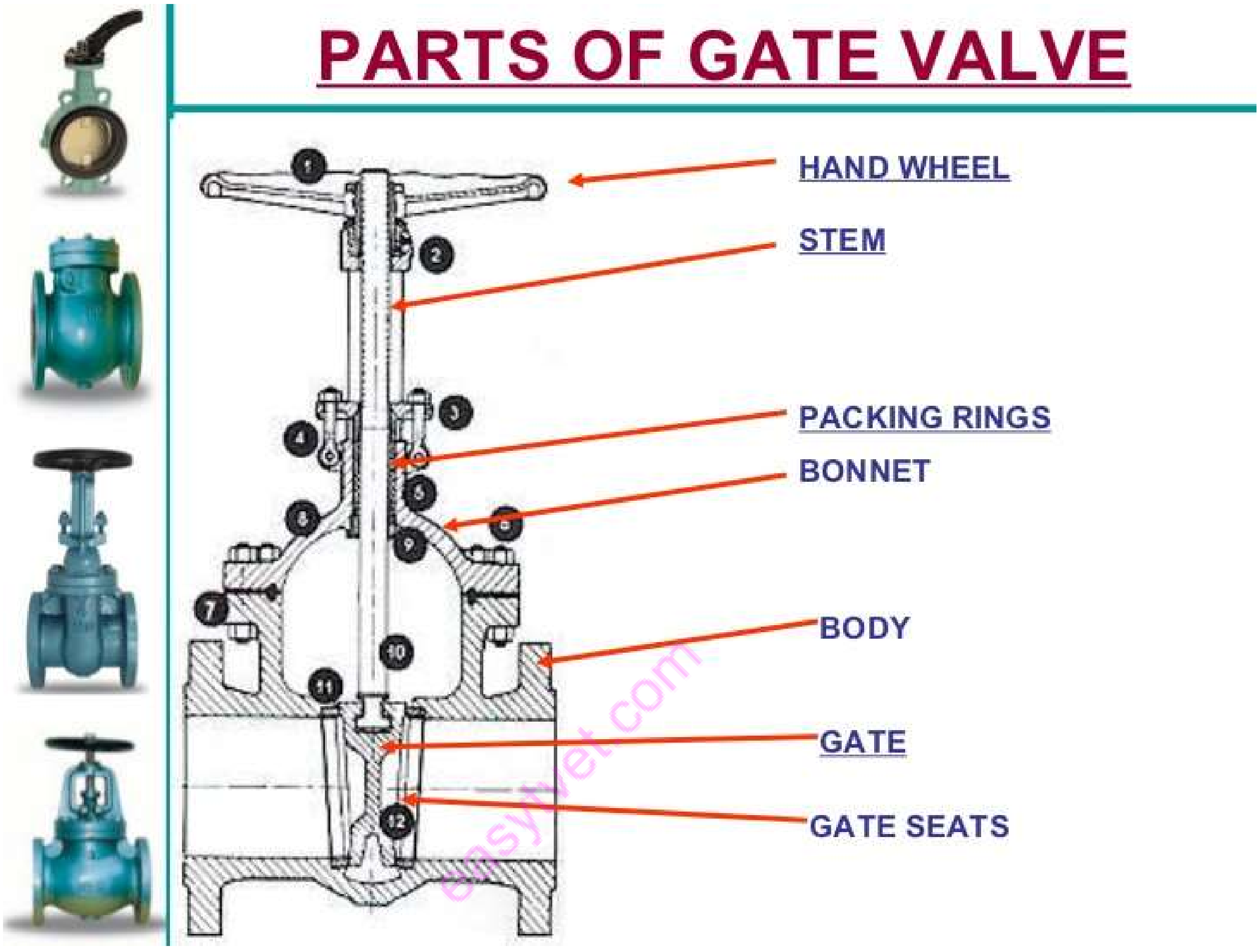


Standard Pattern or Tee Patern Globe Valve Body

www.theprocesspiping.com

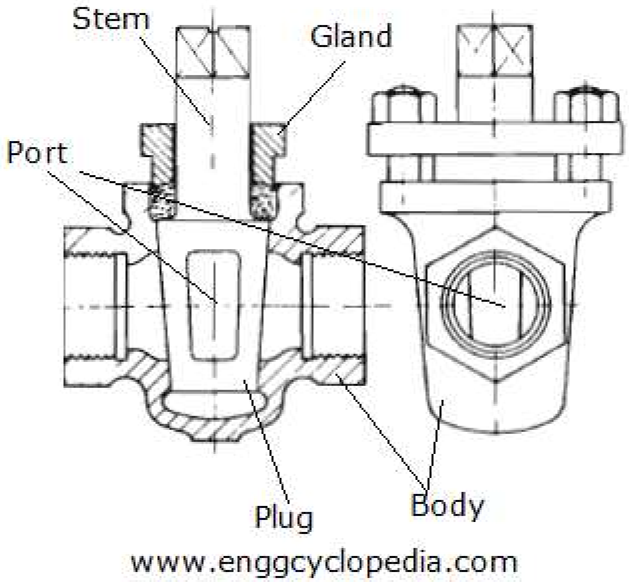
2. Gate valve

A gate valve, also known as a sluice valve, is a valve that opens by lifting a barrier (gate) out of the path of the fluid. Gate valves require very little space along the pipe axis and hardly restrict the flow of fluid when the gate is fully opened.



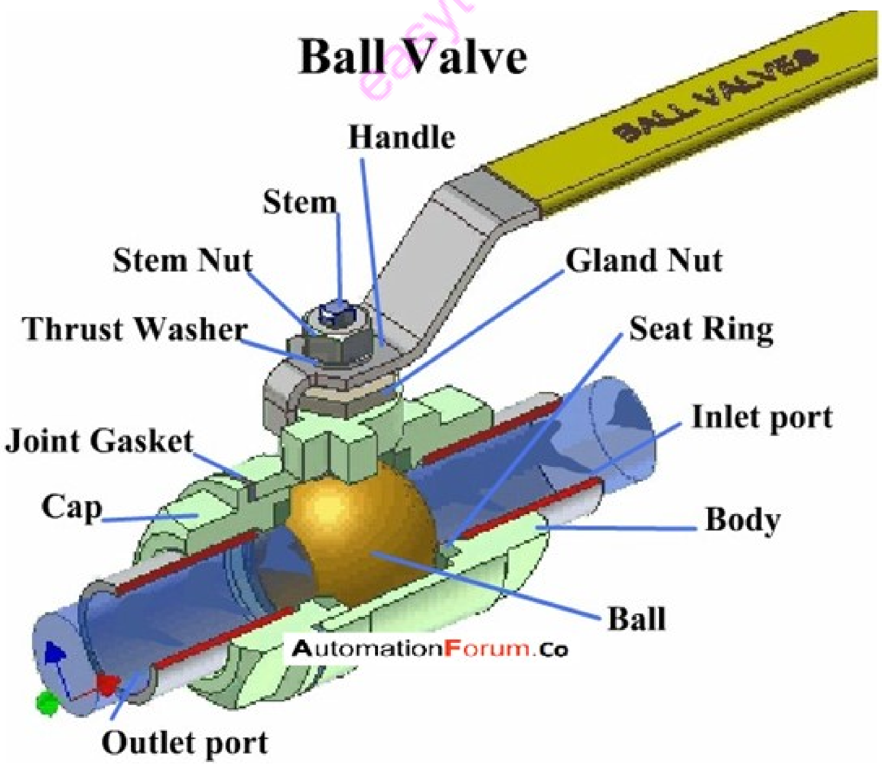
3. Plug cock

A plug valve is shaped like a cylinder or cone and can be rotated inside the valve body to control flow of fluids. Plug valves have one or more hollow passageways often placed horizontally to allow ease of flow through the valve when open.



4. Ball cork

A ball valve is a form of quarter-turn valve which uses a hollow, perforated and pivoting ball to control flow through it. It is open when the ball's hole is in line with the flow and closed when it is pivoted 90-degrees by the valve handle.



5. Float valve/ ball valve

A ball valve/ float valve is a mechanism or machine for filling water tanks, such as those found in flush toilets, while avoiding overflow and backflow.

Pipe joints

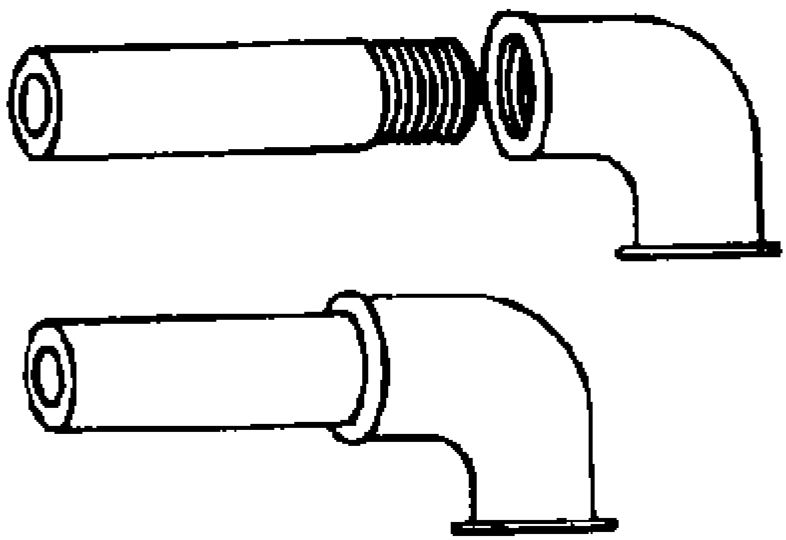
Pipes are connected with the help of joints. A variety of joints are used in an assembly of pipes. Connecting two or more pipes together is called a fitting. Various types of joints could be used in a pipe as per the requirement. Joints are also used for multiple pipe connections, and are an important component of the plumbing system. Generally, the pipe joint fitted can easily sustain the pressure created in the pipe.

Various types of pipe joints are as follows.

1. Threaded joint
2. Welded joint (butt welded, socket welded)
3. Brazed joint
4. . Soldered joint
5. Grooved joint
6. Flanged joint
7. . Compression joint

1. **Threaded joint**

   When pipes are joined by screwing in threads which are provided in the pipe, it is called a threaded joint. The threads are also made in various pipes like PVC, CI pipes, copper pipes and GI pipes, etc. Threaded joints are used from 6 mm diameter to 300 mm



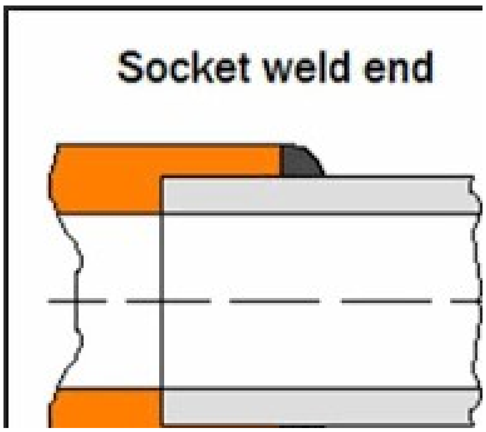
diameter pipes.

2. **Welded joints (Butt-welded joints)**

It is one of the most common methods of joining pipes used in large infrastructure like commercial, institutional and industrial systems. Cost of material are low, but the labour costs are more due to the no availability of trained welders and fitters.

3. **Socket-welded joints**

These are used when there is a high chance of leakage in the joints. Pipes are joined as putting one into other and welded around the joint. Pipes having different diameters are suitable for this type of a joint. Socket-welded joint gives good results as compared to other joints.



4. **Brazed joints**

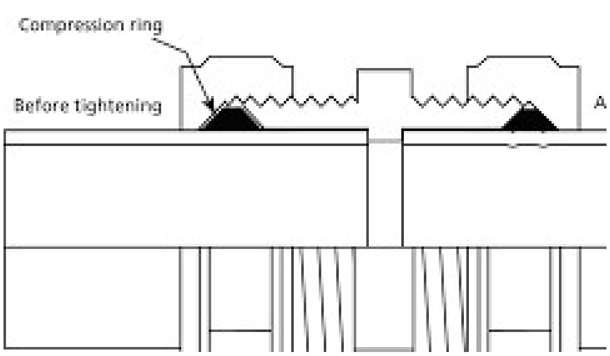
When pipes are joined with the help of molten filler material at above 840°C, it is called brazing. Brazing is done for connecting copper pipes or copper alloy pipes. It is important to note that the melting point of the parent material (pipe material) should be higher than the filler material. Brazed joints have less mechanical strength, and are preferred in case of moderate temperatures

5. **Soldered joints**

Soldering and brazing are similar activities. In soldering, the filler material melts below 840oC. With the help of soldering, copper and copper alloy pipes are joined. During soldering, flux or metal joining material is used to prevent oxidation due to the flame. Soldered joints are suitable for low temperature areas and have low mechanical strength.

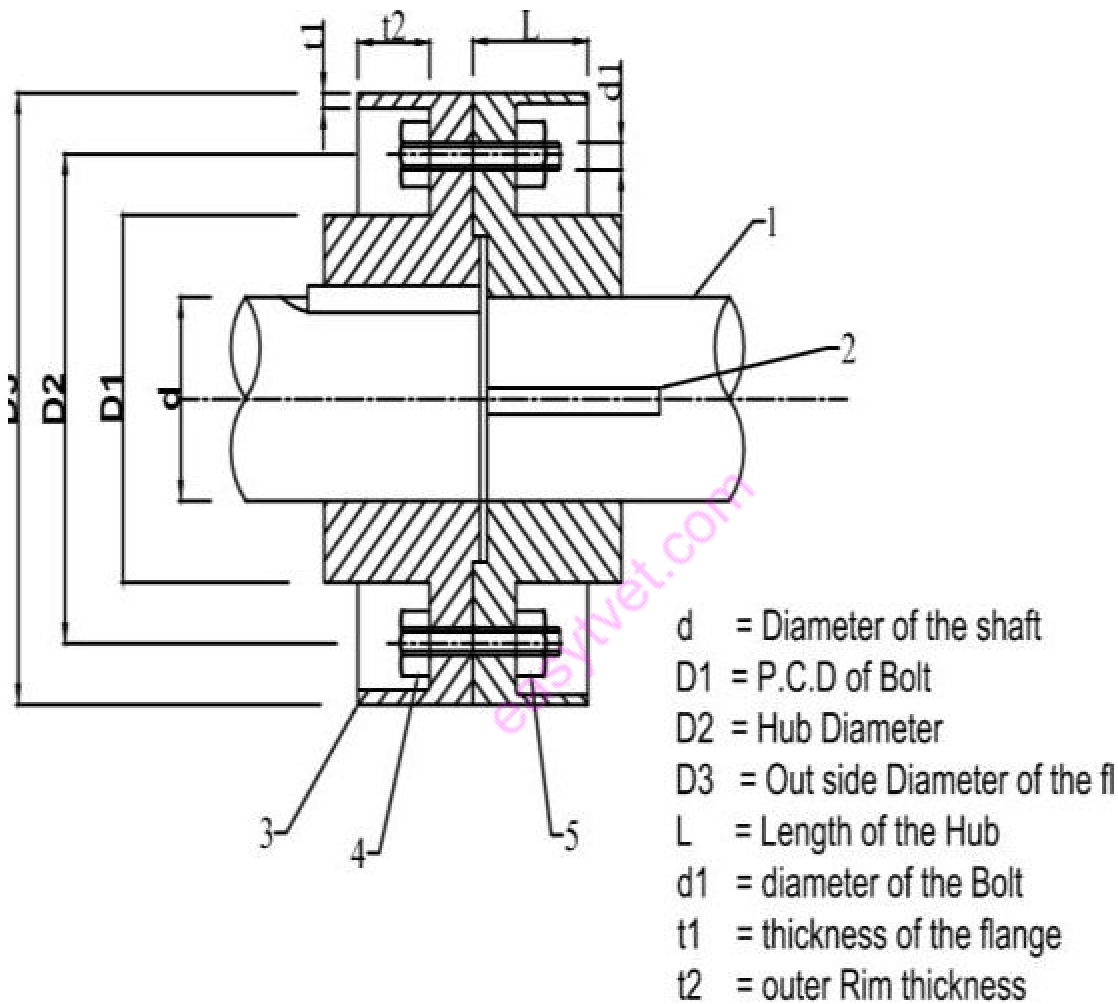
6. **Compression joints**

   These are applied to join the pipe without any preparations. The cost of installation of these joints is very economical. The pipes having plain ends are joined by fixing fittings at their ends, and such a joint is called a compression joint. The pipe ends are joined with threaded fittings or couplings. Joints are placed properly to check the flow pressure, otherwise, leakage may occur. These fittings are manufactured from different types of material. Selection of fittings is done as per requirement



Flanged Joint (with fittings)

The flanged joint design means that pipes are secured by external screws, providing additional joint support for the transportation of substances at high pressure.



- **Piping systems**

  Hot water

  Identify the type of hot water system from layout diagrams

  There are a number of hot water systems in use in the UK. Some of these are open vented systems that remain open to the atmosphere and some provide instantaneous hot water through combination boilers and multipoint water heaters. The differences between each system will become apparent as we work through the system layouts. We will look at:

a). Direct systems

- Containing a back boiler
- Containing a hot water immersion heater

b).In-direct systems

- Single feed, self-venting systems
- Double feed systems with a hot water heating coil

c).Thermal store

d).Instantaneous hot water heaters

- Single point (point of use) heater
- Multipoint heaters

e). Combination boilers

✓ **Direct system of hot water**

A **direct water supply system** is one where the raising main feeds directly the cold **water** taps and a multi-point **water** heater. The mains **water** comes in via a rising main and directly feeds all the cold taps and a multi-point **water** heater - so all the taps and other **water** feeds are at mains **water** pressure.

Indirect system of hot water

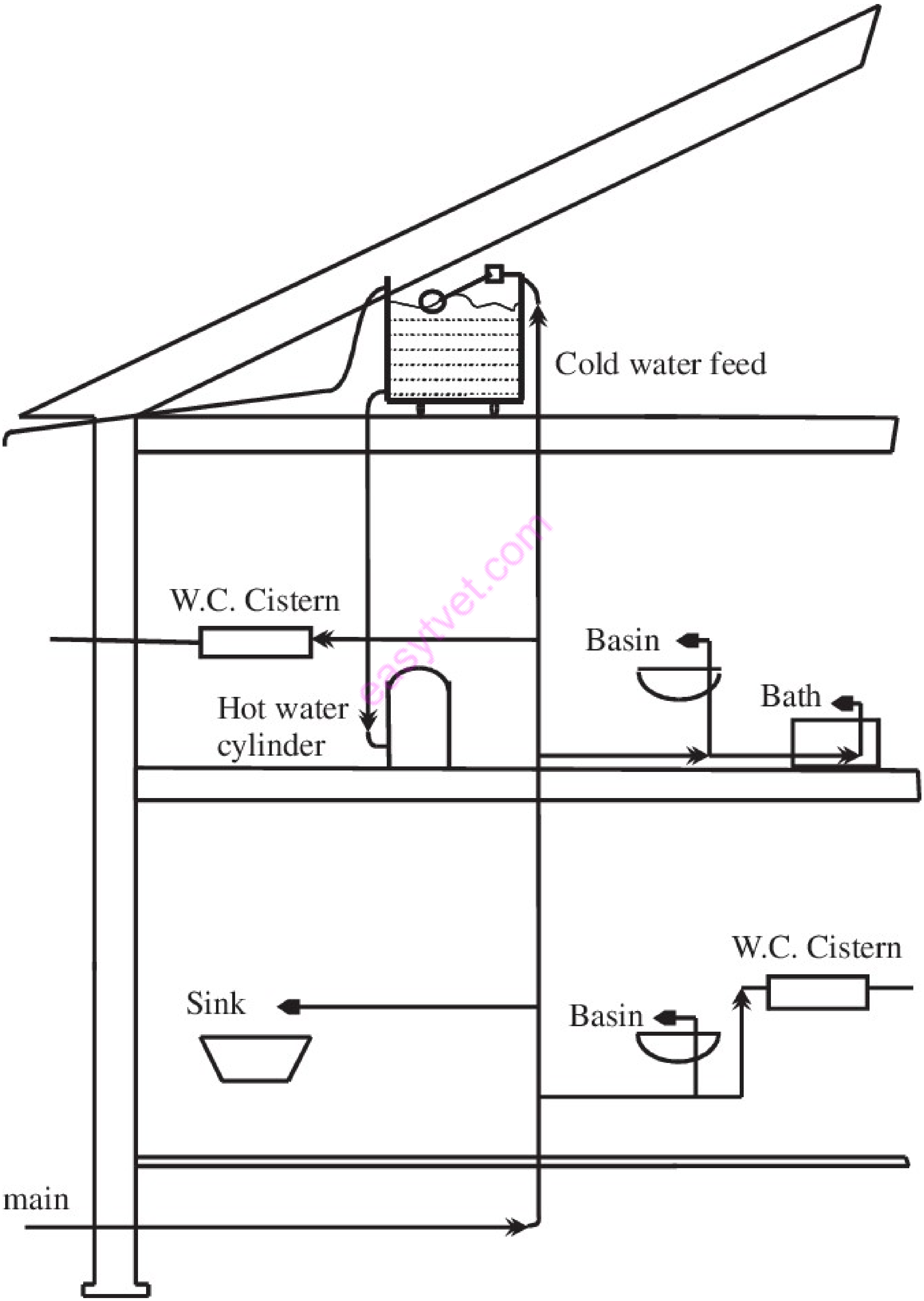
With an indirect water system, the copper hot water cylinder contains a coil of pipe. This coil forms part of a run of pipework attached to the boiler. It is heated directly by the boiler. Indirectly, it heats the water in the cylinder. The coil, or "heat exchanger" forms part of the central heating circuit, and its water heating abilities are purely a by-product of its main function, which is to heat the radiators. This heating is called the "primary" circuit, the pipes running to and from the boiler are called the primary flow and return. The hot water tank operates in exactly the same way as the direct system.

To identify an indirect system, you will see two water tanks in your loft. The second, smaller one, is the feed for the primary circuit. It will top up the system when necessary and will also have a vent pipe over the top. The level of water in this tank will be considerably lower to allow the water to rise as it expands when it gets hot without overflowing.

- **Cold water**

Direct system of cold water

Direct systems source water straight from the mains water supply. All pipes to the cold drew off points are taken directly from the rising main



Cold water feed
W.C. Cistern
Basin
Bath
Hot water
cylinder
W.C. Cistern
Sink
Basin
main

Indirect System of Cold Water Supply

An indirect water supply system is the most common type found in modern houses.

The mains water comes in via a rising main and directly feeds at least one cold tap at the kitchen sink with 'potable' water. The rising main also feeds a storage tank at a high point in the building from where the water is fed to all the other taps using gravity.

Adhesives

Plumbing adhesive is used for sealing leaks, repairing tears, securing tiles, fixing footwear and mending glassware. It bonds aluminum, metal, copper, brass, ABS, PVC, fiberglass and tile.

Depending on the application, the industrial adhesive systems should be:

- **Waterproof:** it goes without saying that the adhesive bonding together two pieces of pipe containing liquids, should not let any of it through.
- **Chemical resistant:** depending on the purpose of the installation, the PVC bonding should be resistant to the feed including all chemicals it may be exposed to. For example, the horticulture industry installations used for delivering fertilizers, must not let the fertilizer affect the pipes and bonds.
- **Resistant to high pressure and discharge:** some industrial pipeline installations are used for delivering and discharging fluids in high pressure conditions. Therefore, the PVC adhesives used in these, must not be affected by the process and vice versa.
- **Safe to use with potable water:** many PVC pipelines are designed to deliver drinking water. Adhesives used for these pipes must comply with food and safety regulations to make sure no residue will end up in the potable water.

Pipe fittings

Pipe Fittings are defined as the piping components that help in pipe routing for directional changes, size changes, and branch connections. Piping Elbows, Piping Reducers, Tee Connections, Outlet Connections, Caps, Crosses, etc are pipe fittings and widely used in both the piping and plumbing industry. Different pipe fittings serve different functions as per layout or process requirements. Pipe fittings are manufactured as separate items and procured separately. Pipe fittings are connected to piping using various end connections. Pipe fittings play an important role in the proper functioning of pipes and tubes in various applications.

- **Elbows**: Used to change the angle or direction of the pipe run. Most commonly in 90 degrees and 45 degree turns. The sweep of the fitting describes how fast a transition or change in direction is made.
- **Street Elbows:** One end of the pipe fitting has male threads and the other end has female threads. These are common in galvanized steel and copper pipe. They are convenient because they do away with the need for a nipple and work well in tight quarters.
- **Tee Fittings:** Shaped like the letter T. Allows for branch lines.
- **Couplings:** Used to join two straight pieces of pipe of the same diameter.
- **Reducers:** Used to join pipes of different diameters. Makes a gradual change in diameter.
- **Bushings:** Used to make the diameter of a pipe fitting smaller. They are different from reducers because they make an abrupt change in diameter and take little space.
- **Unions:** Used to join pieces of pipe where pipes cannot be turned or when a piece of equipment may have to be removed for maintenance or replacement.
- **Adaptor Fittings:** Used to change the end of a non-threaded pipe to male or female threads as needed. Most commonly used in copper and plastic plumbing jobs.
- **Caps:** Used to close the end of a dead-end pipe.
- **Plugs:** Used to close an ending on a pipe fitting normally used for inspection or cleanout.
- **Nipples:** Short lengths of pipe threaded at both ends.
- **Wyes:** Used primarily to gain inside access to DWV (drain-waste-vent) systems.
- **Valves:** Devices that control the flow of liquid or gas through or from a pipe. (Compression valves, ball valves, sleeve-cartridge valves, ceramic disc valves, etc)

- **PVC Fittings:** Come in a wide variety of configurations and may be glued (S) or threaded (T)
- **Copper Tubing Fittings:** Use compression fittings. Common fittings are couplings, ells, and tees.

Examples of assorted fittings.

Pipe bending.

Pipe bending is a technique used in various metal forming processes with the aim of increasing the fabrication capabilities of plumbing fixtures. The pipe can be bent at varying angles and in different directions. The simplest curve turns the tube at an angle of 90 degrees forming an elbow.

Pipe bending machines are typically human powered, pneumatic powered, hydraulic assisted, or electric servo motor. In the pipe bending operation the tube may be supported internally or externally to preserve the cross section of the pipe. In operations where there is flexibility in the shape of the pipe, the pipe does not need to be supported, however there will be some deformation in the both the cross section of the overall pipe and the wall thickness in different areas of the bend.

Physical Effects on Pipe and Tube from Bending

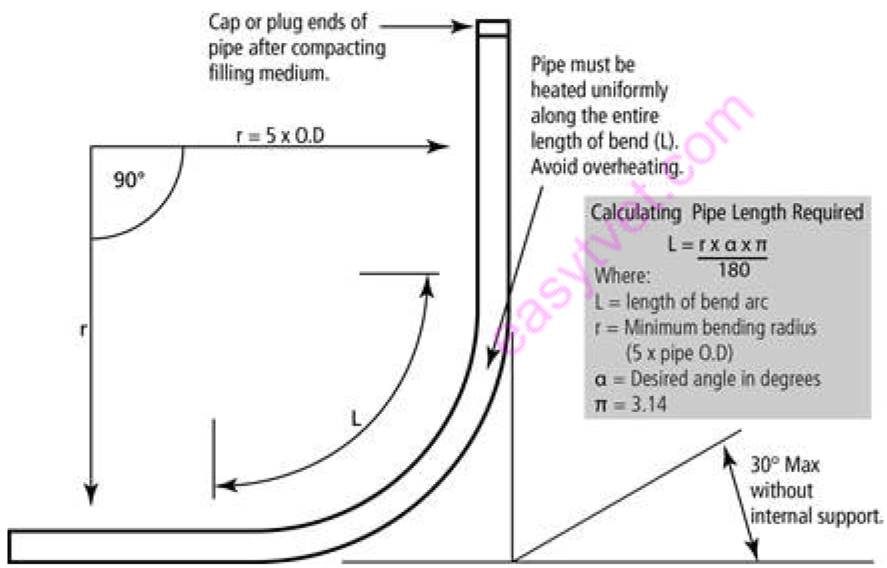
Depending on the bending method used and the material qualities of the pipe or tube being bent some of the following physical effects can be seen after bending:

- Wrinkles on the inner side of the bend
- Stretching of the wall on the outer side of the bend
- Thinning of the wall thickness on the outer side of the bend

- Deformation of the cross section of the pipe or tube causing it to reduce and form an oval shape.

Heat Bending Plastic Pipes

Bending of plastic pipes may be desirable under certain conditions where long radius bends and unusual configurations are required. It is possible to bend various sizes and wall thicknesses of rigid PVC-U, PVC-C and ABS pipe using heat bending techniques for long-radius sweeps for conduit and flow conditions. Irregular angles and U-bends for thermal compensation, and offsets in congested areas can be successfully achieved.



Good housekeeping through OSHA’s rules for walking and working surfaces

It’s clear to see that housekeeping practices have an impact meeting OSHA’s general requirement for walking and working surfaces. The rule states:

- Housekeeping is to be clean, orderly, and sanitary.

- Floors are to be clean and dry.
- Aisles and passageways are to have sufficient clearance. They are to be kept clear, without obstructions that could create a hazard.
- Permanent aisles are to be marked.

Some examples of violations of these rules are: blocked aisles, material lying across an aisle or on the floor, wet or oily floors, or material overhanging high shelves.

Housekeeping solutions

As a good plumber you need to perform the following as housekeeping procedures.

- You should protect the existing works and sanitary appliances
- You should clean your working area at all times during work progress.
- Clearing work area after the job should be done immediately.
- Keeping of work area tidy is always necessary.

Common Plumbing Problems

- Faulty Faucets. The sound of a dripping tap is commonly associated with insanity.
- Leaking Pipes. Pipes make up the bulk of plumbing problems, especially in old houses.
- Dripping faucets.
- Slow draining sink.
- Clogged bath or shower drain.
- Clogged toilet.
- Running toilet.
- Faulty water heater.
- Low water pressure.
- Jammed garbage disposal.
- Low water pressure.

INSPECTION AND TESTING

INSPECTION

Work should be inspected during installation and tests applied on completion, care being taken that all work to be encased or concealed is tested before it is finally enclosed.

Range of inspection - Pipe systems should be tested for tightness and for hydraulic performance. Inspection should be carried out to ensure the following:

a) Work accords with the drawings and specifications;

b) All pipe brackets, clips, etc., are securely fixed;

c) Fixings are correctly spaced.

d) Pipe is protected where necessary by insulation;

e) Embedded pipework is properly protected before sealing-in;

f) All access covers, caps or plugs:

- are so made that the internal faces truly complete the internal bore,
- are accessible,
- cause no obstruction in the pipe bore, and
- are well jointed.

TESTING OF THE SYSTEM

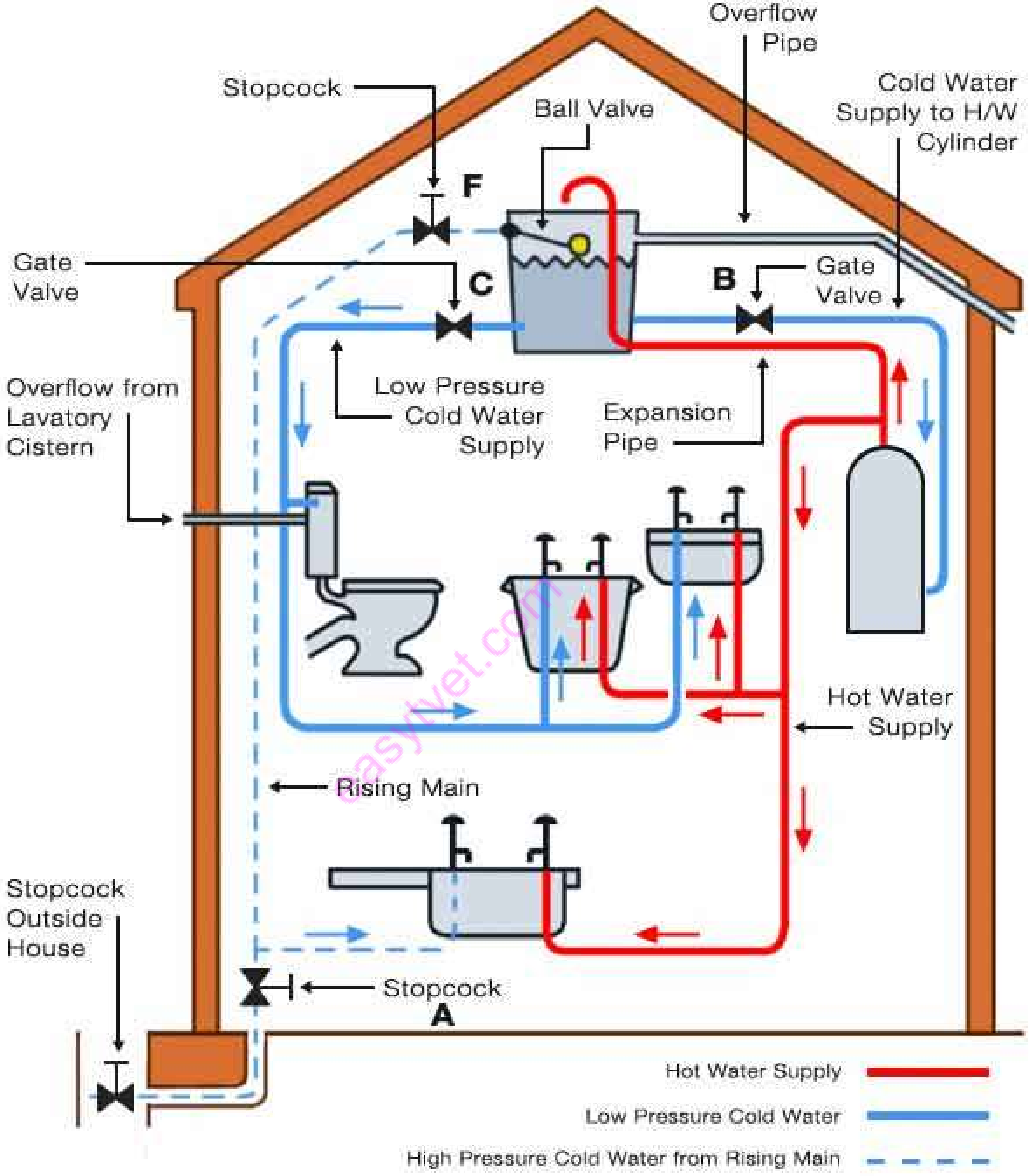
- **Smoke test**; forces smoke-filled air through a sanitary sewer line. The smoke under pressure will fill the main line plus any connections and then follow the path of any leak to the ground surface, quickly revealing the source of the problem.
- **Water test**; the lower end of the pipeline is sealed using a drain plug and the section under test is filled with water. A head of water is created, following a period of settlement and acclimatization, the level of water in the head is monitored for a specified period and the loss of water measured and checked.
- **Air test**; it is done by isolating the section of pipe that needs to be tested using plugs, and setting two different pressures for five minutes each. Any change in pressure over those five-minute time periods is measured and recorded.
- **Pressure test**; it is performed to ensure the safety, reliability, and leak tightness of pressure systems. A pressure test is required for a new pressure system before use or an existing pressure system after repair or alteration. There are two methods for pressure tests: hydrostatic and pneumatic.

1.2.4.4 Learning Activities

With the help of your trainer, you are required to install indirect system of cold water below.

Practical activities.

- Positions the pipes, set out and marked based on below working drawing.
- Thread pipes and carry out pipe jointing
- Cut Pipes based on type of pipe
- Carry out pipe bending based on jobs requirement
- Pipes are fitted based on drawing specifications.



1.2.4.5 Self-Assessment

1) Define a valve and state various types.
2) Precautions should you take while Executing Layout of Pipes
3) State any three physical Effects on Pipe and Tube from Bending
4) State the use of the following fittings.
   - Caps
   - Plugs
   - Nipples
5) Which three methods are suitable for testing modern Drainage Water vent systems (DWV systems) for leaks?

1.2.4.6 Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Pipe wrench • Pipe cutter • Hacksaw • Pipe Threading Equipment • Vise - Bench • Tap and Punch • Files • Screwdrivers • Drill with various sizes of bits • Mallet • Ball hammer • Masonry chisel • PPR machine / Heat Fusion	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Various types of pipe support • Sandpapers • Threading oil • Thread tape • Caulking material

• equipment • Pipe bender	

1.2.4.7 References

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https://www.youtube.com/watch?v=ghcdZRUZ0MU

1.2.4.8 Model answers

1. A valve is a device that regulates, controls, or directs the flow of a fluid by opening, closing, or partially obstructing fluid flow.

   Examples

- Globe valves
- Gate valves
- Plug valve/ plug cork
- Ball cork
- Float valve/ ball valve

2. **Precautions while Executing Layout of Pipe**
   - Pipe work and appliances should be arranged in such a way that allows close grouping of connections with water closet near main soil pipe.
   - The branch pipes should be kept short to reduce noise.
   - When the basin and bath are at some distance from the stack, it would be cheaper and simpler to combine the waste pipes into one.
   - Any bends in the waste pipe should be of large radius.
   - The pipe work in branch connections should be arranged to allow free drainage for the system.
   - All connections to main or branch pipes should be arranged in such a way that prevents cross flow from one appliance to another.
   - Branch connections should be of large radius along the invert.
   - The minimum diameter of soil and waste stacks should be 100 mm and 75 mm respectively.
   - When the pipes are covered, hard to find along the internal face of the walls, they should be of cast iron.

- All pipes including those laid on external face of the wall should be of cast iron on the ground floor.

3. **State any three physical Effects on Pipe and Tube from Bending**

- Wrinkles on the inner side of the bend
- Stretching of the wall on the outer side of the bend
- Thinning of the wall thickness on the outer side of the bend
- Deformation of the cross section of the pipe or tube causing it to reduce and form an oval shape.

4. **State the use of the following fittings.**
    - **Caps:** Used to close the end of a dead-end pipe.
    - **Plugs:** Used to close an ending on a pipe fitting normally used for inspection or cleanout.

- **Nipples:** Short lengths of pipe threaded at both ends.

5. **Which three methods are suitable for testing modern Drainage Water vent systems (DWV systems) for leaks?**

Air

Water

Smoke

1.2.5 Learning Outcome 5: Design simple pipework

1.2.5.1 Introduction to the learning outcome

This outcome specifies the competencies required to design simple pipework as it applies in the construction industry.

1.2.5.2 Performance Standard

1. Number and type of ***appliances*** are identified based on working drawings

2. Flow rates are calculated based on flow charts
3. Pipes are ***sized*** based on standards

1.2.5.3 Information Sheet

System layout and pipework

The water supply system must be designed to achieve appropriate water pressure and flow, and to avoid contamination to potable water.

Water pressure

If the aim is to provide for building users' needs while also using water efficiently, the right water pressure is crucial. If water pressure is too low, this will be inconvenient for building users – for example, because showers have poor water flow, and baths take a long time to fill. If pressure is too high, this will lead to wastage of water, as well as high wear and tear on the system.

Water flow rate

The Building Code requires that sanitary fixtures and appliances have adequate water supply at an adequate flow rate.

Flow rate is affected by:

- Water pressure
- Pipe diameters – The smaller the internal diameter of the pipe, the lower the pressure and flow rate. (Note that pipes are generally referred to by their inside nominal diameter (DN), but it is actually the internal diameter that counts; a pipe rated as DN 15 may have an actual inside diameter ranging between 10–18 mm.)
- Water temperature – higher temperatures will tend to raise pressure and flow rates (note: also see materials below).

Flow rate and pipe size Acceptable Solutions

Pipes must be sized to achieve flow rates set out in accordance with Table 3 (see table below), or the pipes must be sized in accordance with Table 5..

When calculating pipe size, the speed of the water (velocity) moving through the pipes must not exceed 3.0 m/s.

When calculating pipe size, the speed of the water (velocity) moving through the pipes must not exceed 3.0 m/s.

Table 5: Acceptable flow rates for fixtures and appliances

Fixture	Flow rate (l/s) and temperature °C
Basin	0.1 at 45 °C
Bath	0.3 at 45°C
Sink	0.2 at 60°C (hot) and 0.2 (cold)
Shower	0.1 at 42°C
Laundry tub	0.2 at 60°C (hot) and 0.2 (cold)
Dishwasher and washing machine	0.20

System layout

In the design process, the layout of the plumbing system will largely follow room layout. Nonetheless, there are many things to consider which relate to Code compliance, building users' comfort, and sustainability.

When planning a water supply layout, the following must be considered:

- Pipe runs and lengths – Keep pipe runs as short as possible. Pass pipes close to fixtures to minimize the number of branches and unnecessary elbows, tees and joints. Having longer pipe runs and more fixtures will reduce flow rate, increase heat losses, and increase use of materials
- Point of entry into the building – This should be into a utility space such as garage/laundry and include an accessible isolating valve, line strainer and pressure limiting valve (if required)
- Water heating system – Locate centrally to reduce the length of pipe runs to fixtures because longer pipe runs require more water to be drawn off before hot water is discharged. Install a separate point-of-use water heater for fixtures that are more than 10 m from the main water heater
- Noise prevention – Avoid running pipes over or near bedrooms and living areas.

Backflow

Backflow is the unplanned reversal of flow of water (or water and contaminants) into the water supply system. The system must be designed and used to prevent contamination from backflow

Mains connection

Where the water source is a mains supply, the network utility operator is responsible for the water supplied to the property boundary. The property owner is then responsible for providing the pipework to bring the water into the building.

An isolating valve must be fitted at the point of connection to allow for maintenance and repair of the building's water supply system if required.

Pipe materials and specifications

The pipes used in a building must not contaminate potable water supply, and must be suitable for the water pressure, flow rate and temperature of water they will be carrying. This will be influenced by the materials used and also by other factors such as the wall thickness.

Other considerations are durability, ease of installation, cost, and sustainability. Common materials for domestic water supply include copper, polybutylene (PB), polyethylene (PE), polypropylene (PP-3 or PP Type 3), and cross-linked polyethylene (PEX).

Domestic Hot Water Service Systems - Design Procedure

Hot water supply must be adequate to meet building users' needs while also keeping them safe. It should also support efficient use of both energy and water.

Design procedure for domestic hot water service systems

The design of a hot water service system may follow the procedure:

1. Determine the demand of hot water from the consumers - quantity and temperature
2. Select the type, capacity and heating surface of the calorifier - or heat exchanger
3. Select the source of heat available.
4. Design the pipe scheme and determine the size of the pipes

The Demand of Hot Water - quantity and temperature

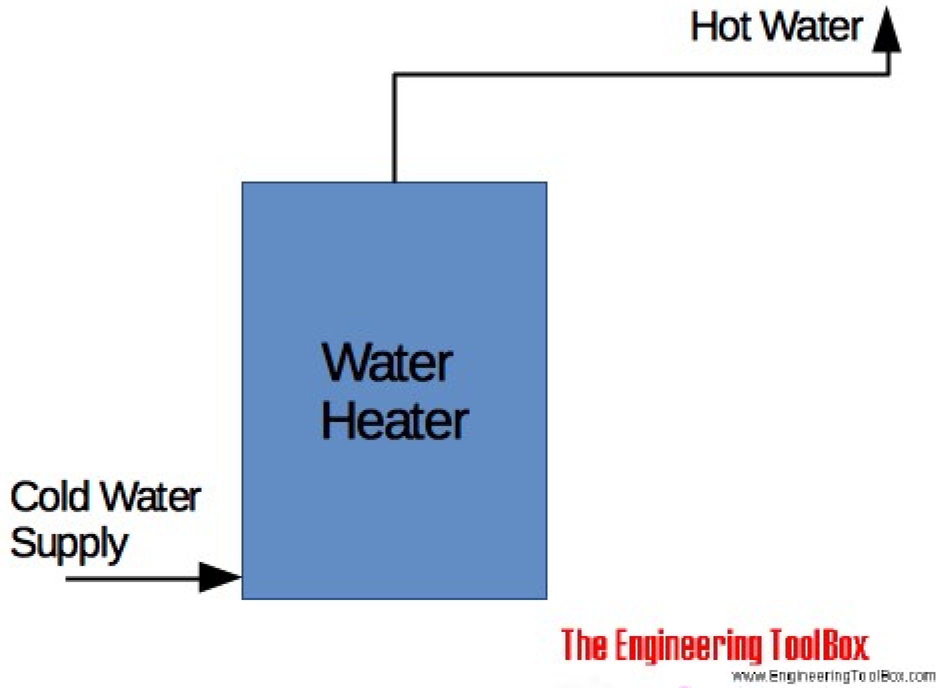
Hot water is normally supplied to fittings and their consumers at *50 - 60 ^oC*. For canteens and professional kitchen temperatures of *65 ^oC* are often required to satisfy hygienic standards. Hot water should not be stored at temperatures below *60 ^oC (140 ^oF)* to avoid the risk of **contamination**.

Where lower temperatures are necessary for safety reasons - as in kindergartens, centers for disabled etc. - the hot water temperature should not exceed *40 - 50 ^oC*. Special care should be taken - like regular disinfection of fittings - to avoid infections.

Note! Hot water can be stored at higher temperatures and reduced to lower supply temperatures by mixing in cold water in blender valves. Storing the hot water at a higher temperatures increases the system overall capacity and reduces the need of storage volume.

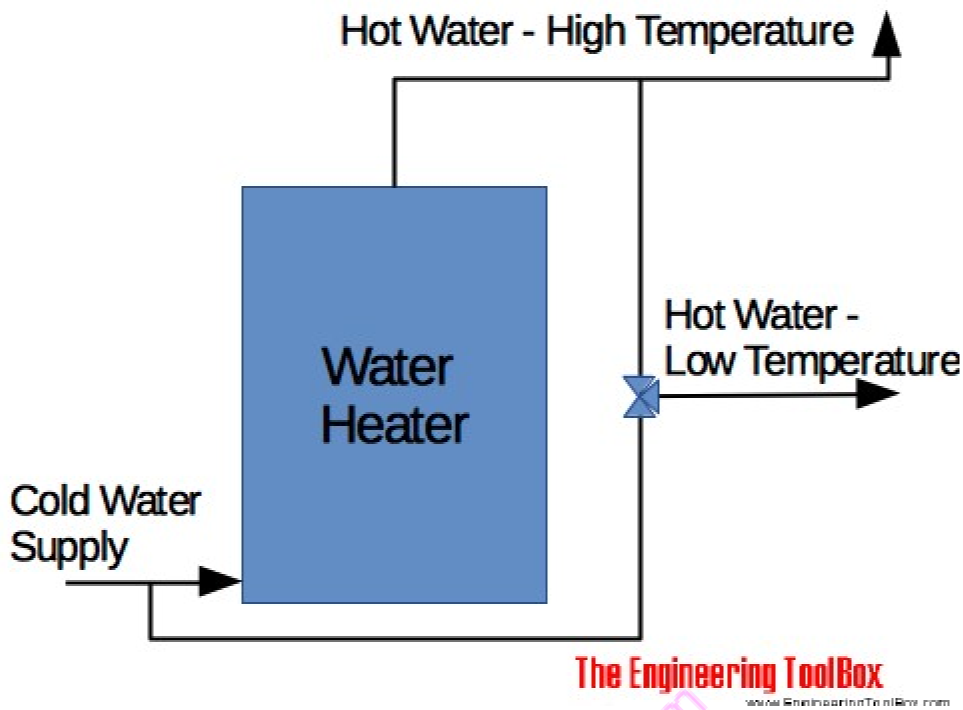
Water Heater - Single Temperature

The water is heated and stored in the same storage tank at the same temperature as supplied to the consumers.



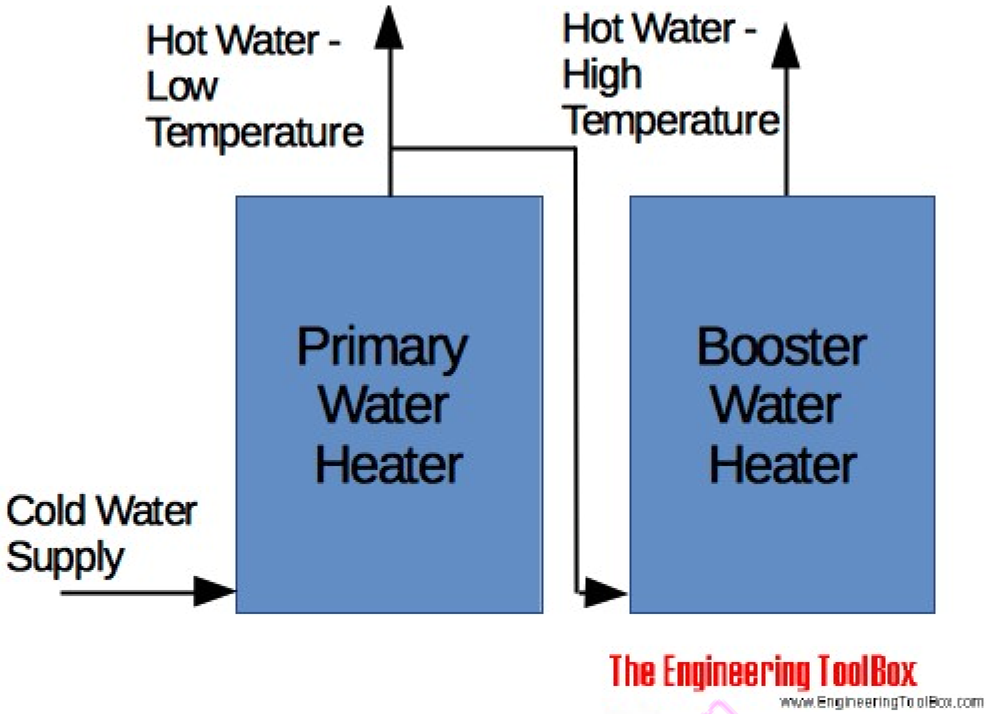
Water Heater - Two Temperature with Mixing Valve

The water is heated and stored in the same storage tank at higher temperature than supplied to most of the consumers. The hot water is mixed down to consumer temperature with cold water before supplied to the fittings.



Water Heater - Two Temperature with Boosting Tank

The water is heated and stored at consumer temperature before distributed to normal consumers. Water from this store is supplied to another heater and storage tank where the water is heated to higher temperatures before distribution.



The quantity of hot water is determined by number of occupants and their consumption habits. Timing is very important since consumption varies over the day.

Key Coding; it's a good idea to code your map to keep the different elements straight like:

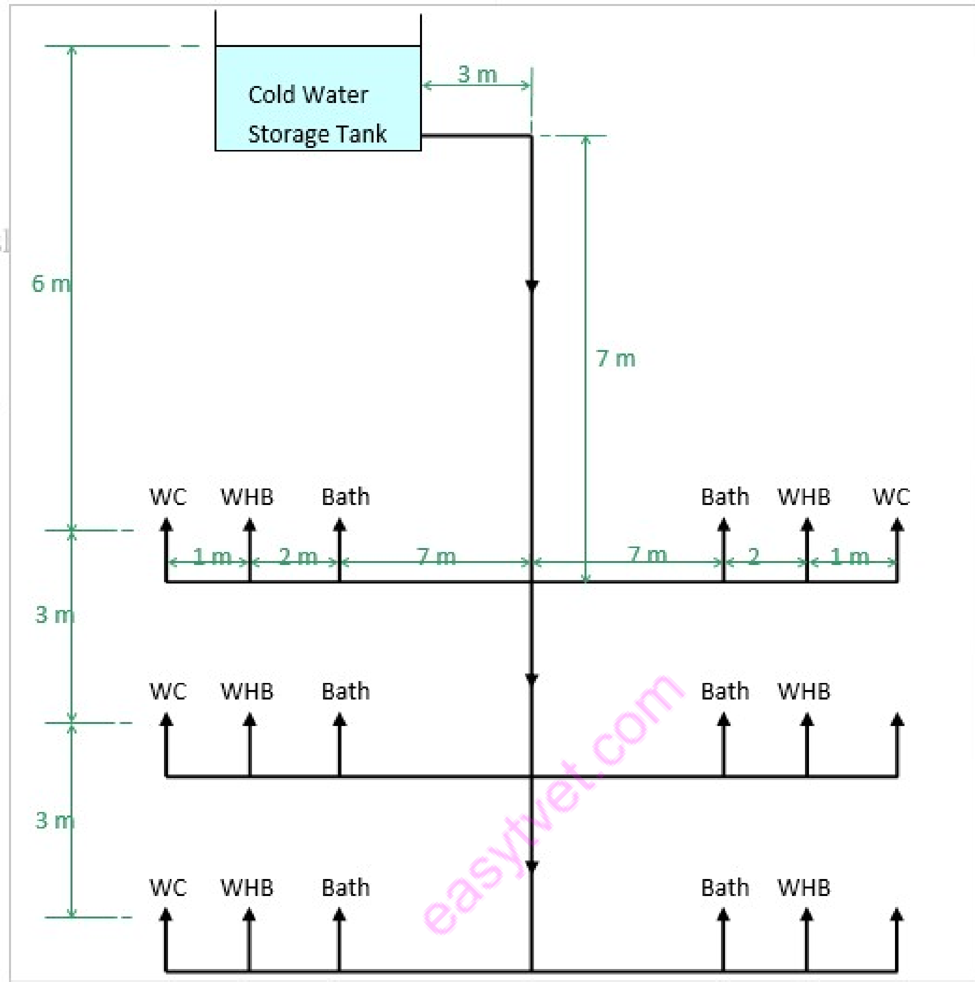
- Show drainpipes with solid lines and supply lines with broken lines.
- Indicate vertical runs with note on the overhead view.
- Mark hot and cold supply lines with colored pencils and color-code drains and vents.
- Point to pipe sizes with a curved leader line to avoid mistaking the leader for a pipe.

Pipe Sizing Procedure for water supply system

NON-PRESSURISED COLD WATER PIPE SIZING

• This method is pipe sizing where the pressure available is not from a pump but from the head available from the tank.

• The higher the tank is above the outlets the more head will be available to force the water through the outlets and overcome pipe work resistances.



Pipe Size Procedure

- Divide system into sections.
- Calculate demand units if simultaneous demand is effective.
- Estimate flow rates in each section.
- Estimate pipe diameter.
- Measure the pipe run for the section.
- Calculate length of pipe equal to resistance of fittings.
- Calculate effective pipe length.
- Determine pressure loss due to friction for pipe

- Calculate pressure consumed by friction.
- Calculate cumulative pressure consumed

Domestic water pipe sizing

The sizing of domestic water supply system must be based on the minimum pressure available for the building in question. The designer must ensure that the required pressure is maintained at the most hydraulically remote fixture and that proper and adequate quantities of flow are maintained at all fixtures. In addition, the designer must ensure that reasonable velocities are maintained in all piping. The velocity of water flowing in a pipe should not exceed 10 feet/sec and should be designed for 7-8 feet per second or less, because high velocities will increase the rate of corrosion leading to pipe failure and cause undesirable noises in the system and increase the possibility of hydraulic shock. The designer should compute and/or know the following:

1. Hydraulically remote fixture
2. Available main pressure
3. Pressure required at individual fixtures
4. Static pressure losses (height of highest fixture relative to main pressure)
5. Water demand (total system, and each branch, fixture)
6. Pressure loss due to friction
7. Velocity

Pipe sizes

May include but not limited to:

- 13mm
- 19mm
- 25mm
- 32mm
- 38mm

PIPING CALCULATION:

LINE SIZING:

- Pipe Line is sized based on continuity equation

$$Q = A \times V$$

Where

- Q= Flow (m^3/sec)
- A= Inside cross section area of pipe (m^2)
- V= Velocity (m/sec)

  From the above equation its clear that;
- When the diameter of the pipe increases the area of the cross-section increases as well as its volume thereby increasing quantity/flow of the water/ liquid and vice versa.

Types of water supply system

1. **Cold water supply**

Two types of cold water supply systems

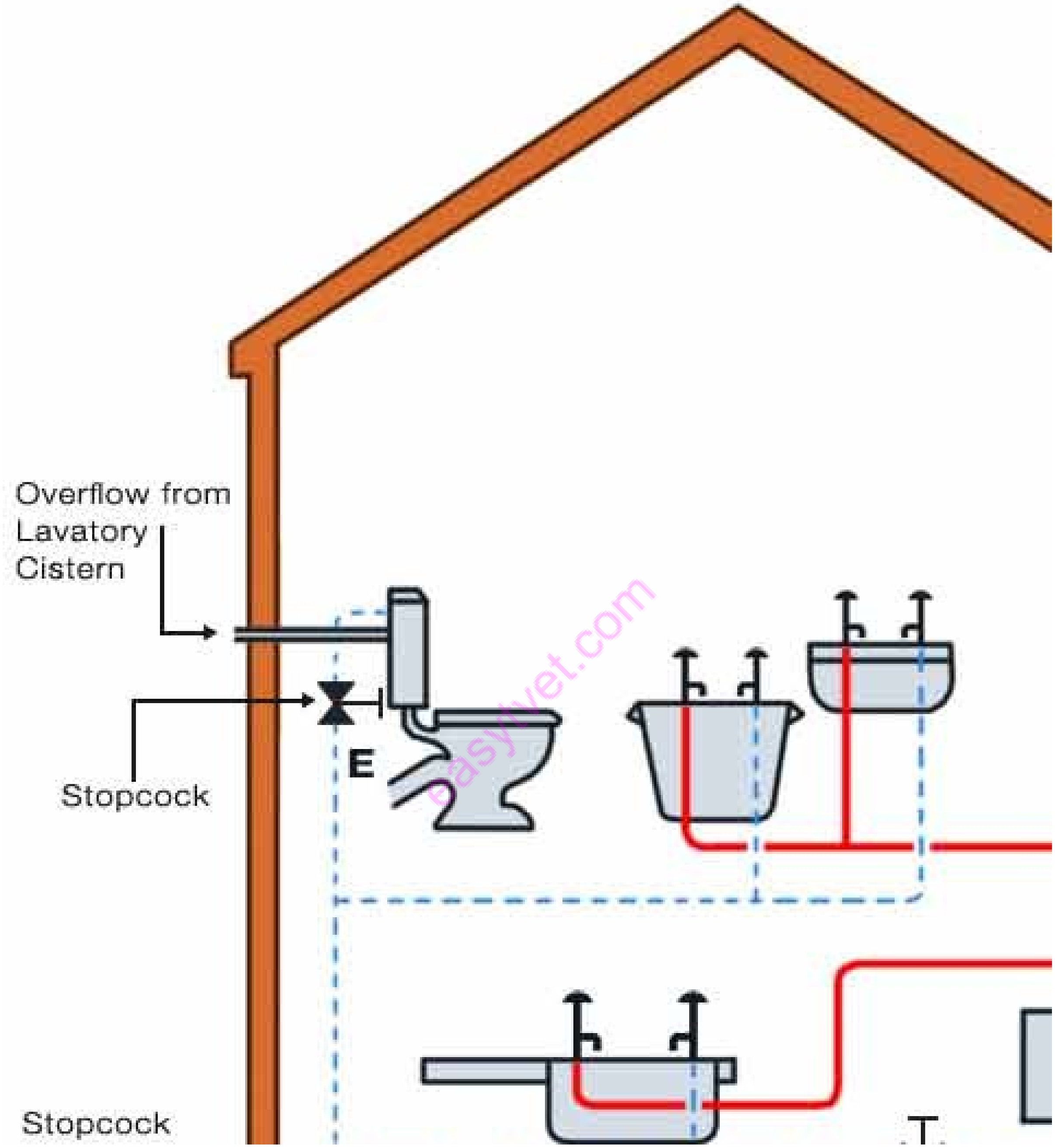
- Direct
- Indirect**.**

Direct water supply

A direct water supply system is one where the raising main feeds directly the cold water taps and a multi-point water heater.

The mains water comes in via a rising main and directly feeds all the cold taps and a multi-point water heater - so all the taps and other water feeds are at mains water pressure. Note that in this article, we are dealing with just the hot and cold water supplies to the taps etc., we are not dealing with the central heating system.

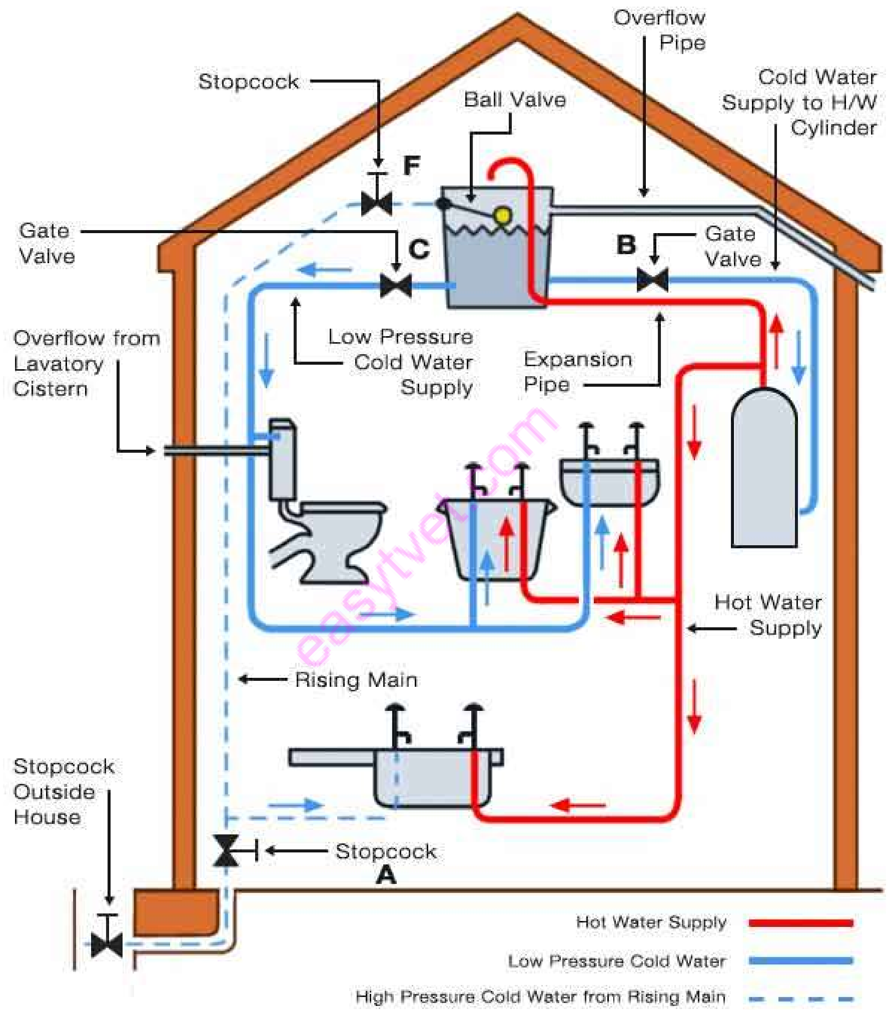
The picture below shows a direct cold water system where cold water is distributed all over the house at mains pressure.



Indirect Cold Water System

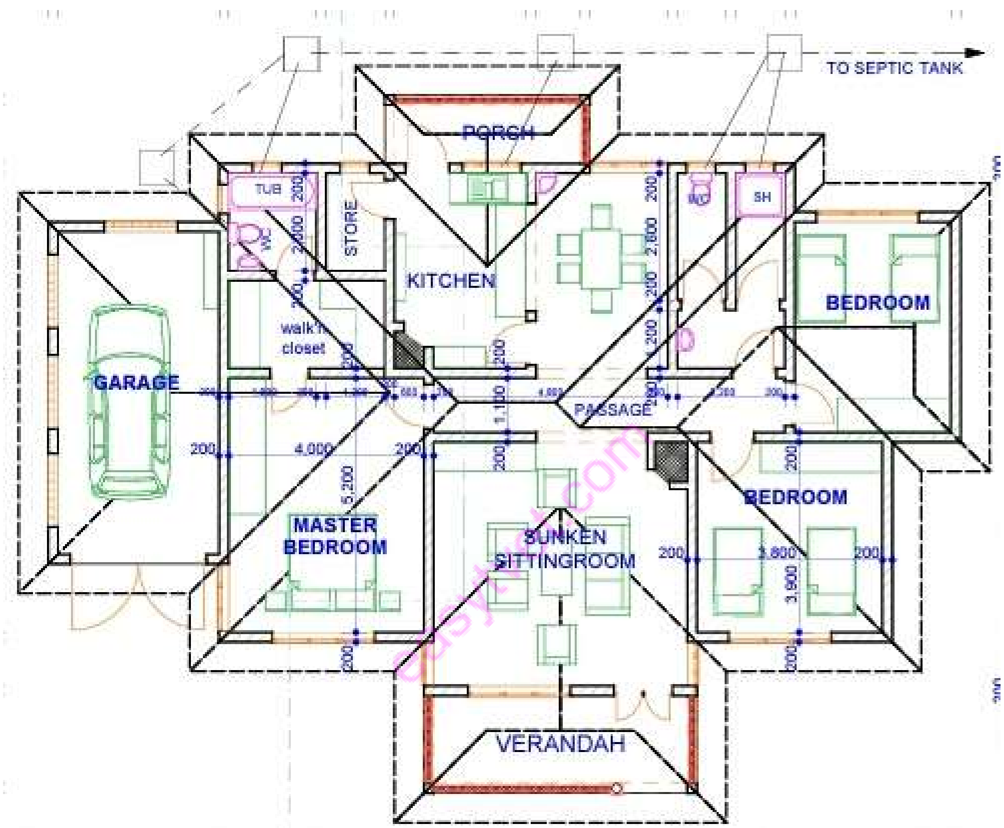
In the indirect cold water system, water comes into house via rising main. It is then branched off to feed at least one tap (in the image above, this is the kitchen and outside tap and the boiler next to the sink) and then continues to a storage tank in the loft. From here it is distributed to the other taps in the house. Overflow pipes are marked The position of stopcocks etc is marked on the diagram below which also shows the hot water path.

Domestic indirect water system



1.2.5.4 Learning Activities

- Design a simple isometric pipe work drawing for the cold water supply for the plan below.;
- Assume any other relevant information.



1.2.5.5 Self-Assessment

1) State two types of cold water supply.
2) Highlight the procedure for designing domestic hot water
3) Distinguish direct from indirect water supply.
4) Explain the term "backflow" Backflow is the unplanned reversal of flow of water (or water and contaminants) into the water supply system

1.2.5.6 Tools, Equipment, Supplies and Materials

- **Drawing boards**
- **T squares**
- **Set squares**
- **Drawing sets**
- **Drawing paper**
- **Protractors**
- **Eraser Shield**
- **Pencils**
- **Erasers**
- **Masking tapes**
- **Paper clips**
- **Drawing curves**
- **Technical drawing software'**

1.2.5.7 References

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1.2.5.8 Model Answers.

1) **State two types of cold water supply.**
   - Direct system
   - Indirect system
2) **Highlight the procedure for designing domestic hot water**

- Determine the demand of hot water from the consumers - quantity and temperature
- Select the type, capacity and heating surface of the calorifier - or heat exchanger
- Select the source of heat available.
- Design the pipe scheme and determine the size of the pipes

3) **Distinguish direct from indirect water supply.**
   In **direct supply**, all the household appliances (fixtures) receive water directly from the mains (i.e direct supplies from the authorities that collects water from source, treats it and distribute same while in **indirect water supply system**, water is first filled into cistern (tank; overhead or underground) from mains and the appliances receive water from the cistern(tank) mostly overhead water tank.
4) **Explain the term "backflow"**
   Backflow is the unplanned reversal of flow of water (or water and contaminants) into the water supply system

1.2.6 Learning Outcome 6: Install Water distribution system

1.2.6.1 Introduction to the learning outcome

This outcome specifies the competencies required to install water distribution systems as it applies in the construction industry.

1.2.6.2 Performance Standard

1. Water distribution systems is identified and interpreted based on the drawing
2. Positions of pipes are set out and marked based on working drawings
3. Water distribution materials and supplies are estimated based on the drawing.
4. Tools and equipment are identified according to job requirement.
5. Water distribution system is installed based on codes of practice
6. Housekeeping is conducted as per workplace procedures
7. Functionality tests are conducted based on best practices.
8. Faults in functionality and leakage are corrected based on best practice.
9. Safety and health practice are observed based on OSHA.

1.2.6.3 Information Sheet

A water distribution system is a part of water supply network with components that carry potable water from a centralized treatment plant or wells to water consumers in order to adequately deliver water to satisfy residential, commercial, industrial and firefighting requirements. A water distribution system consists of pipes, storage facilities, pumps, and other accessories.

Requirements of an adequate distribution system

- Water quality should not deteriorate while in the distribution pipes.
- The system should be capable of supplying water to all the intended places with sufficient pressure head.
- It should be capable of supplying the requisite amount of water during firefighting.
- The layout should be such that no consumer is without water supply, during the repair of any section of the system.
- All the distribution pipes should preferably be laid one metre from or above sewer lines.
- It should be fairly watertight to keep losses (e.g. due to leakage) to a minimum.

Network type

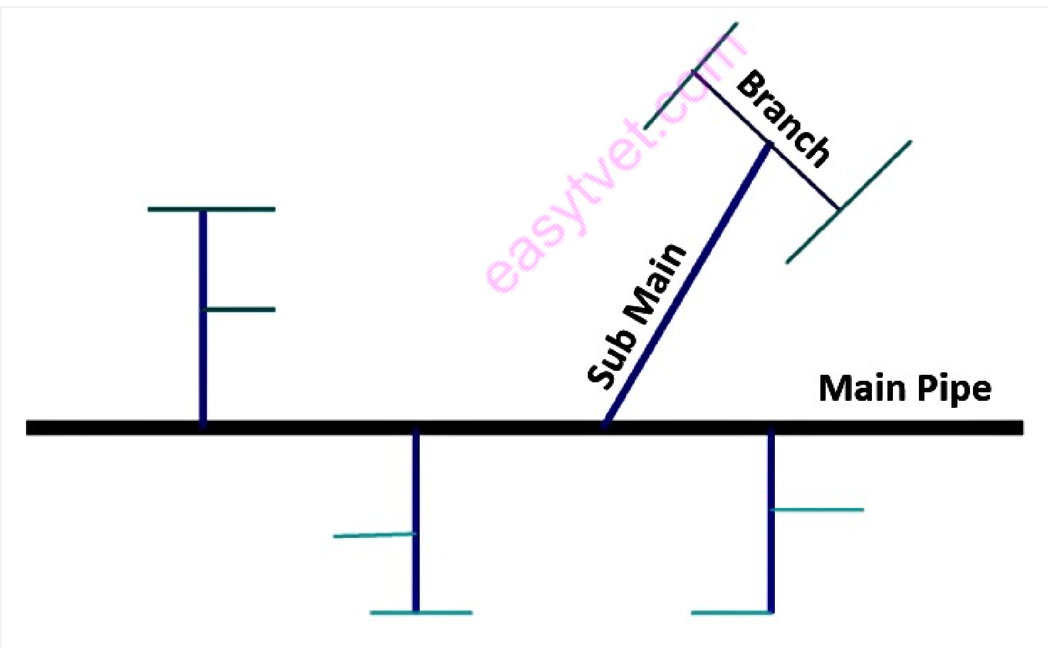
There are four principal methods to design a distribution system:

- Dead end or tree system
- Gridiron system
- Circular or ring system
- Radial system

1. Dead-end or tree distribution system

Description

In the dead end system (also called tree system), one main pipeline runs through the centre of the populated area and sub-mains branch off from both sides. The sub-mains divide into several branch lines from which service connections are provided.



Schematic design of a dead-end distribution system. Source: GONU (2009)

Advantages dead-end System:

- The design calculation is simple and easy.
- A smaller number of cut-off valves are required and the operation and maintenance cost is low.
- Pipe laying is simple

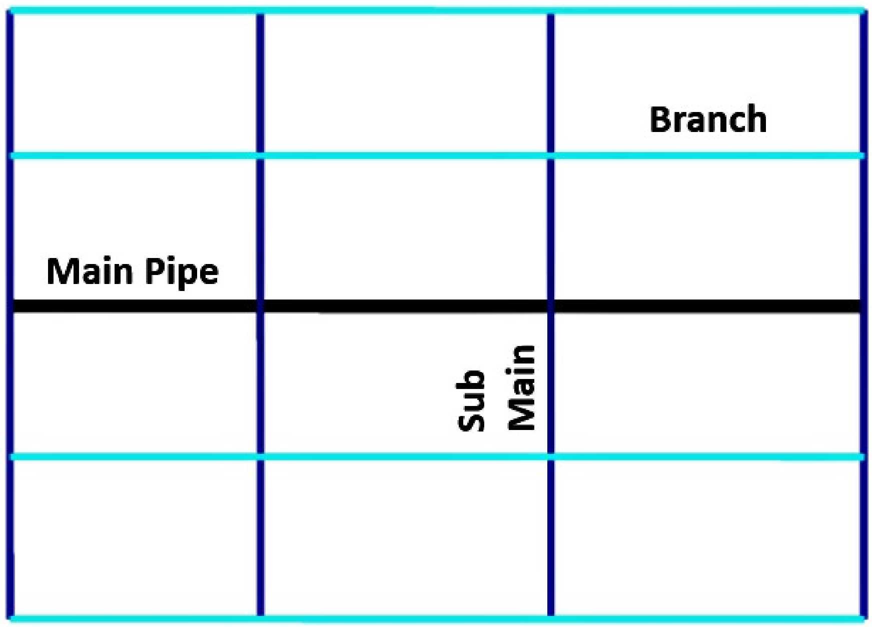
Disadvantages dead-end system:

- The system is less successful in maintaining satisfactory pressure in remote areas and is therefore not favoured in modern waterworks practice
- One main pipeline provides the entire city, which is quite risky
- The head loss is relatively high, requiring larger pipe diameter, and/or larger capacities for pumping units. Dead ends at line terminals might affect the quality of water by allowing sedimentation and encouraging bacterial growth due to stagnation. Water hammer could also cause burst of lines. A large number of scour valves are required at the dead ends, which need to be opened periodically for the removal of stale water and sediment
- The discharge available for firefighting in the streets is limited due to high head loss in areas with weak pressure

2. Gridiron distribution system

Description:

In this system the main supply line runs through the centre of the area and sub mains branch off in perpendicular directions. The branch lines interconnect the sub-mains. This system is ideal for cities laid out on a rectangular plan resembling a gridiron. The distinguishing feature of this system is that all of the pipes are interconnected and there are no dead ends. Water can reach a given point of withdrawal from several directions, which permits more flexible operation, particularly when repairs are required.



Design of the Gridiron distribution system. Source: GONU (2009)

Advantages of the Gridiron distribution system:

- The free circulation of water, without any stagnation or sediment deposit, minimises the chances of pollution due to stagnation.
- Because of the interconnections water is available at every point with minimum loss of head.
- Enough water is available at street fire hydrants, as the hydrant draws water from the various branch lines.
- During repairs, only a small area of distribution is affected.

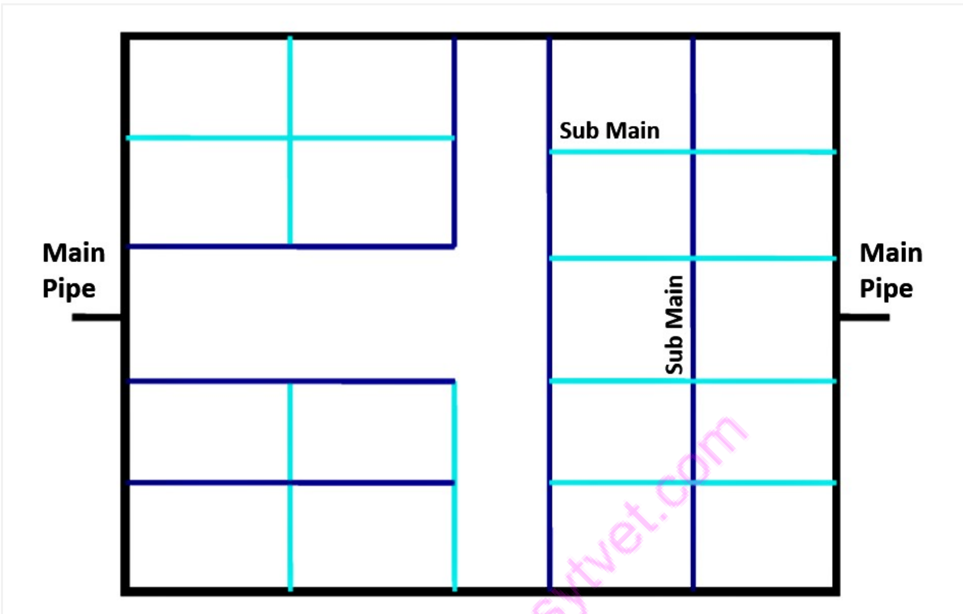
Disadvantages of the Gridiron distribution system:

- A large number of cut-off valves are required.
- The system requires longer pipe lengths with larger diameters.
- The analysis of discharge, pressure and velocities in the pipes is difficult and cumbersome.
- The cost of pipe laying is higher.

3. Circular or ring distribution system

Description:

In a circular or ring system, the supply main forms a ring around the distribution area. The branches are connected cross-wise to the mains and also to each other. This system is most reliable for a town with well-planned streets and roads. The advantages and disadvantages of this system are the same as those of the gridiron system. However, in case of fire, a larger quantity of water is available, and the length of the distribution main is much higher.

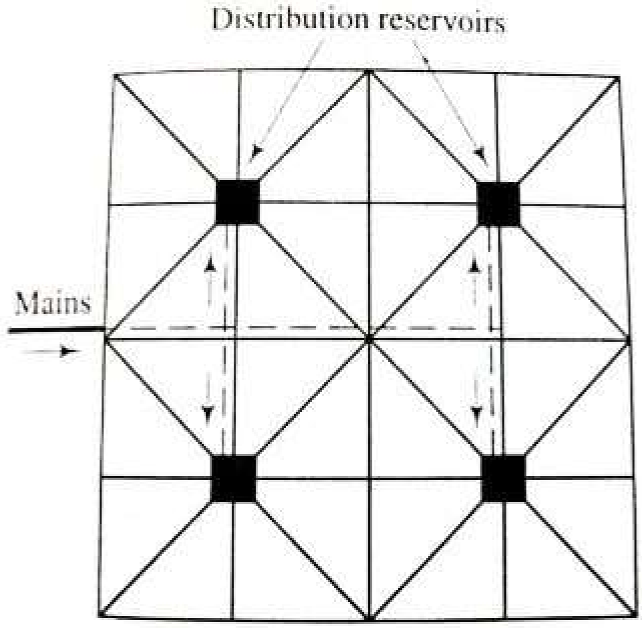


Design of a ring distribution system.

4. Radial distribution system

Description:

In this system, the whole area is divided into a number of distribution districts. Each district has a centrally located distribution reservoir (elevated) from where distribution pipes run radially towards the periphery of the distribution district. This system provides swift service, without much loss of head. The design calculations are much simpler.



Supply Water System

There are two main water systems;

- **Direct Water Supply System:** All water outlets of a house receive water directly from the mains. Portable water is available at all faucets. This is possible where water source delivers water throughout and with high water pressure, sufficient enough to deliver water at an adequate pressure at all taps.
- **Indirect Water Supply System:** Water from mains is conveyed to storage water tanks. Water is then delivered to the house from water storage tank. This system is adopted where water supply from mains is not available throughout the day. It is also used when water pressure in mains is not sufficient enough to deliver water at all faucets with adequate pressure.

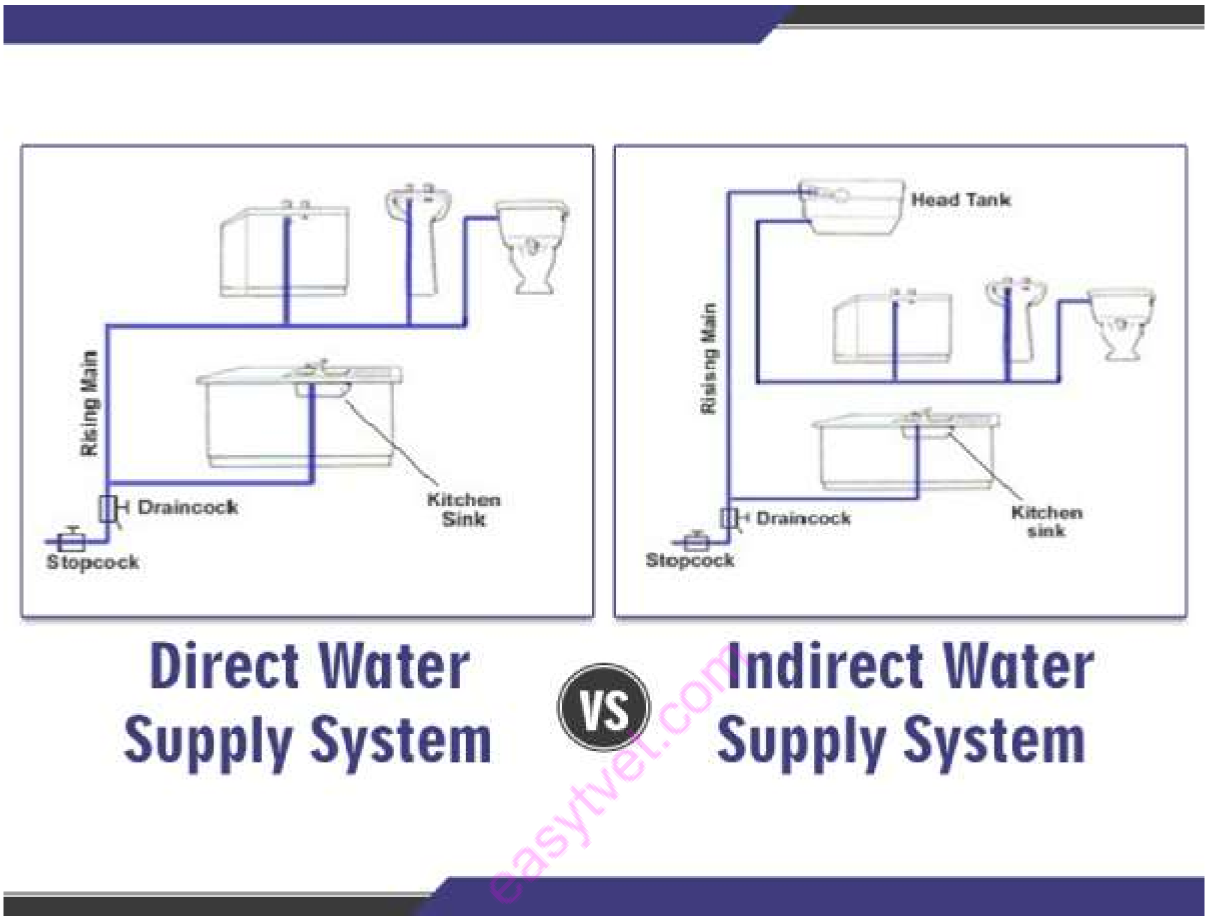


Figure 128: water systems

Direct Water Supply System

Advantages:

- Reduces pipe works and cost of same, as pipes to and from tank for cold water are omitted.
- Good quality drinking water is available at all taps.
- Energy is saved as pumps are not required to pump water to cistern/tanks.
- Installation cost is reduced compared to indirect water supply because no storage tank is required and even reduces maintenance cost of tank (underground as well as overhead).
- It reduces the chances of bacterial contamination.
- Water quality is maintained.

Disadvantages:

- If water is supplied only for specific period of time continuous water flow will not be available and such system cannot survive. As throughout water supply would not be available.
- Pipes have leakage due to high pressures.
- If main pipe gets damaged whole water supply to the home has to be stopped till main is fixed

Indirect Water Supply System

Advantages:

- It imposes less pressure on distribution network, as rising main is not connected to all fixtures directly.
- There is no threat of pipe burst.
- If main is damaged or when water supply is stopped during certain time period; water can still be made available to users from the storage tanks.
- Less wear and tear of all fixtures because of less pressure and plumbing materials.
- Water leakages are less because water pressure will be less from tank and less water will escape and have less loss.

Disadvantages:

- Normally, storage water tanks are kept on roof top due to which there is not enough pressure on immediate lower floor causing problem in working of showers and flush valves in particular.
- Water stored in storage tank degrades over a period of time from quality point of view.
- Additional pipe network is required for carrying water to storage tank and from storage tank to appliances, increasing cost of pipe works and of course of pumps.
- Clean water may not be available at all taps.
- If sufficient pressure is not available, booster pumps are required for getting water at pressure like 7 to 10m height.
- You have to regularly operate and maintain pumps.

- The tank will always need maintenance and may create problem of leakages.
- The tank adds cost to the building.
- The tank also adds to the dead weight of the building.

Tools and equipment's.

- Tubing Cutter
- Hacksaw
- Hole saw kit
- Pipe and tube benders
- Mole grips
- Plumber's torch
- Thread sealing tape
- Pliers
- Press fitting systems
- Flashlight
- Ratcheting pipe threader set

Plumber Wrenches

- Pipe wrench
- Adjustable wrench
- Basin wrench
- Faucet key
- Torque wrench
- Internal pipe wrench

Plumbing Safety Tools

- Gloves
- Goggles
- Heat shields or pads

Testing

- **Smoke test**; forces smoke-filled air through pipe line. The smoke under pressure will fill the main line plus any connections and then follow the path of any leak to the ground surface, quickly revealing the source of the problem.
- **Air test**; it is done by isolating the section of pipe that needs to be tested using plugs, and setting two different pressures for five minutes each. Any change in pressure over those five-minute time periods is measured and recorded.
- **Pressure test**; it is performed to ensure the safety, reliability, and leak tightness of pressure systems. A pressure test is required for a new pressure system before use or an existing pressure system after repair or alteration. There are two methods for pressure tests: hydrostatic and pneumatic.

Good housekeeping through OSHA's rules for installation of hot and cold water system (revisit)

- Housekeeping is to be clean, orderly, and sanitary.
- Floors are to be clean and dry.
- Aisles and passageways are to have sufficient clearance. They are to be kept clear, without obstructions that could create a hazard.

Good housekeeping practices should include but not limited to;

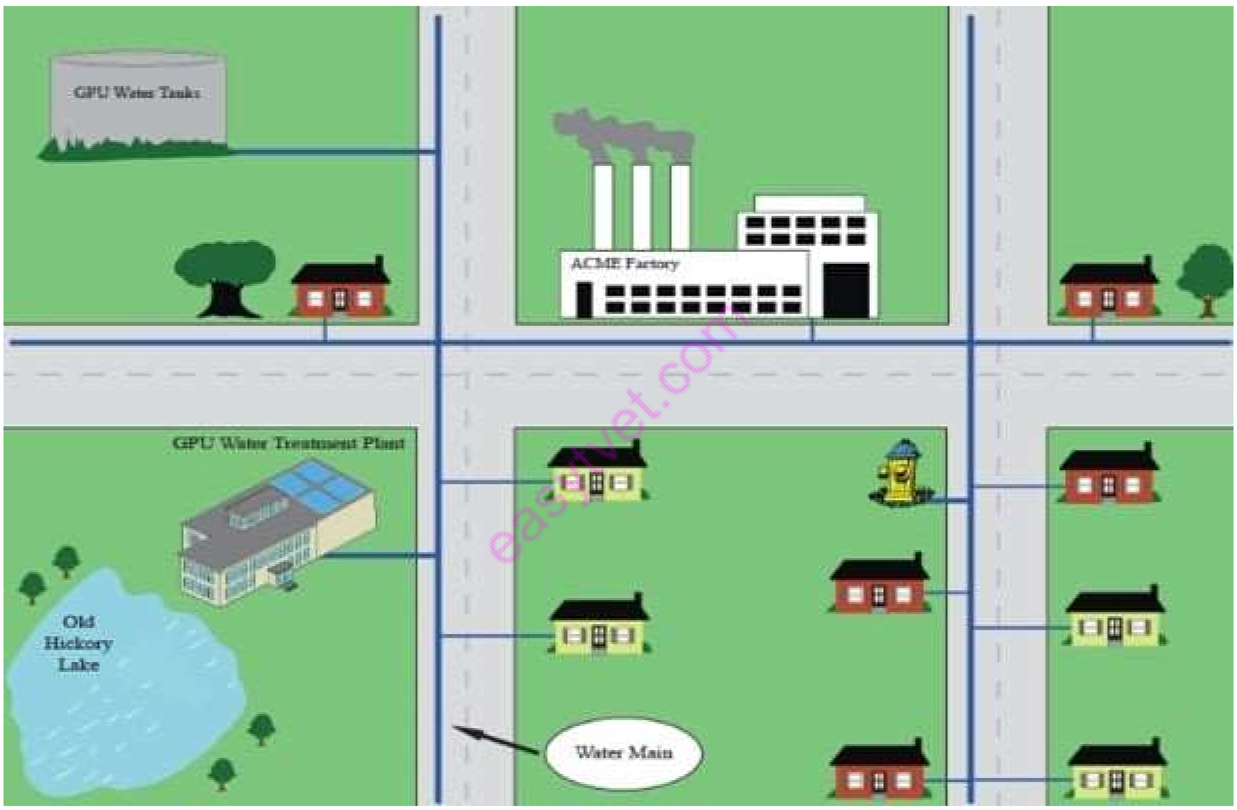
- Floors being kept dry at all times.
- Disposal containers used for liquids or solids that may turn putrid not leaking, and they must have tight fitting covers;
- Sweepings, wastes, and refuse being removed always.
- All exit routes being free and unobstructed i.e., no materials or equipment should be placed, permanently or temporarily, within the exit route.

- Permanent aisles being marked clearly

1.2.6.4 Learning Activities

Below is a system layout of water distribution, with the help of your trainer you are required to ;

- Identify the Water distribution systems based on the drawing
- Positions of pipes are set out and marked based on working drawings
- Identify Tools and equipment according to job requirement.
- Install Water distribution system



1.2.6.5 Self-Assessment

1) Explain the term "water distribution system:
2) List any three requirements of an adequate distribution system.
3) State any two disadvantages of dead end system

4) State four principal method of designing a distribution system.
5) Sketch the dead end or tree system.

1.2.6.6 Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Pipe wrench • Pipe cutter • Hacksaw • Pipe Threading Equipment • Bench-vice • Tap and Punch • Files • Screwdrivers • Drill with various sizes of bits • Mallet • Ball hammer • Masonry chisel • PPR machine / Heat Fusion • equipment • Pipe bender • House keeping equipments. •	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Various types of pipe support • Sandpapers • Threading oil • Thread tape • Caulking material

1.2.6.7 References

Black & Decker (2008). *The Complete Guide to Plumbing (4^{th} ed)*. Minneapolis: Creative Publishing international, Inc. Retrieved from https://www.pdfdrive.com/

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1.2.6.8 Model Answers

1. **Explain the term "water distribution system:**

   A water distribution system is a part of water supply network with components that carry potable water from a centralized treatment plant or wells to water consumers in order to adequately deliver water to satisfy residential, commercial, industrial and firefighting requirements

2. **List any three requirements of an adequate distribution system.**

- Water quality should not deteriorate while in the distribution pipes.
- The system should be capable of supplying water to all the intended places with sufficient pressure head.
- It should be capable of supplying the requisite amount of water during firefighting.
- The layout should be such that no consumer is without water supply, during the repair of any section of the system.
- All the distribution pipes should preferably be laid one metre from or above sewer lines.
- It should be fairly watertight to keep losses (e.g. due to leakage) to a minimum.

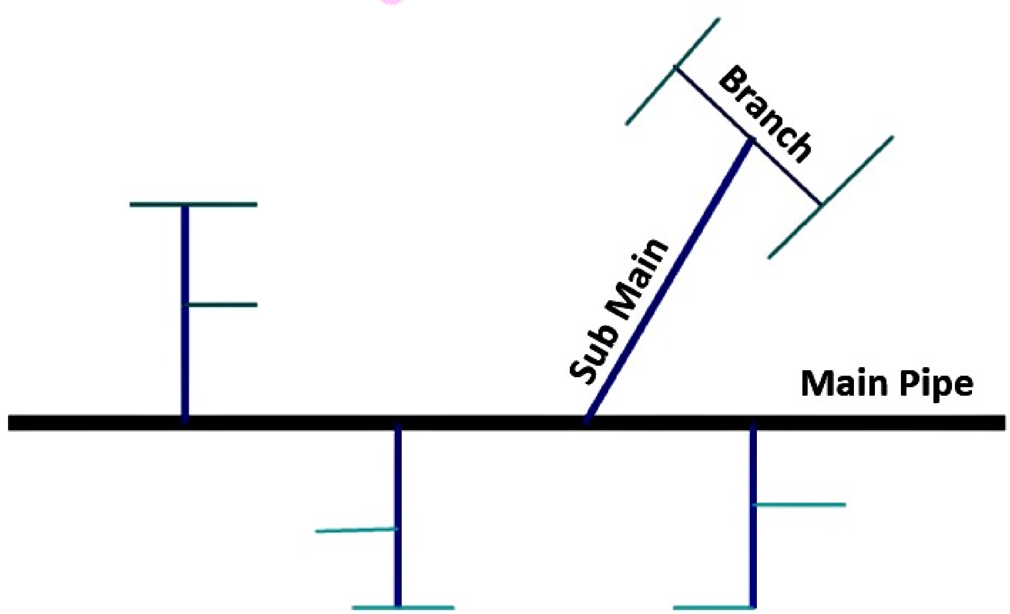
3. State any two disadvantages of dead end system

- The system is less successful in maintaining satisfactory pressure in remote areas and is therefore not favoured in modern waterworks practice
- One main pipeline provides the entire city, which is quite risky
- The head loss is relatively high, requiring larger pipe diameter, and/or larger capacities for pumping units.
- The discharge available for firefighting in the streets is limited due to high head loss in areas with weak pressure

4. State four principal method of designing a distribution system.

- Dead end or tree system
- Gridiron system
- Circular or ring system
- Radial system

5. Sketch the dead end or tree system.



CHAPTER 2: RAINWATER HARVEST AND DISPOSAL

Unit of learning code CON/CU/PL/CR/02/5/A

Related Unit of Competency in Occupational Standard; Install rainwater harvesting and disposal

2.1 Introduction to the unit of learning

This unit specifies the competencies required to harvest and dispose rain water. It involves preparing working drawings, quantifying materials and costing, using tools and equipment, installing rain water goods, testing rainwater goods and harvesting / disposing rainwater. It applies in the construction industry.

2.2 Summary of Learning Outcomes

1. Prepare working drawings
2. Quantify materials
3. Use tools and equipment
4. Install rainwater goods
5. Test rainwater goods

2.2.1. Learning Outcome 1: Prepare working drawings

2.2.1.1. Introduction to the learning outcome

This learning outcome specifies the competencies required to prepare working drawings for rain water harvesting and disposal. It involves preparing working drawings like pictorial, isometric, line, freehand sketching and also conversion of measurements, interpretation of symbols on rainwater goods and harvesting / disposing rainwater as it applies in the construction industry.

2.2.1.2. Performance Standard

1.1 Drawings are identified and selected based on the job.

1.2 Scale of the drawing is determined based on the specifications.

1.3 Measurements are converted based on scale.

1.4 Symbols are identified based on standard practices.

1.5 Isometric pipework drawings are sketched based on drawings.

1.6 Simple working drawings are produced based on specifications.

2.2.1.3. Information Sheet

- **Terms and Concepts**

Working drawing; is a drawing or blueprint based on explanations. It is completed with a thorough plan and views (details, notes, and dimensions) to ensure the product construction or replication without any additional information.

This is a scale drawing which serves as a guide for the construction of a building or for the fabrication of a component. It provides dimensions and graphical information that will be used during construction of a building or fabrication of a component.

There are different types of working drawings:

i **Pictorial drawing**
ii **Isometric Drawing**
iii **Oblique Drawing**
iv **Perspective Drawing**
v **Line Drawing**
vi **Plans**

Pictorial drawing; looks very much like isometric drawing but it does not include any measurement.

Isometric drawing; is the first subcategory of pictorial drawing. Isometric drawings project all sides of a three-dimensional object in a non-foreshortened way. It is based on 30° angles and the same scale is used for all axes.

A Plumbing Isometric drawing is the plumbing drawing scheme and will show the pipes length and direction, pipe fittings, and fixtures at a 30° angle.

An isometric drawing will also depict all components and give details even on the method of connection.

Oblique drawing; depicts the front v iew of a 3D object with the sidelines emerging at a 45° angle from the front side to the back. Opposing isometric drawing, oblique drawing doesn't depict an object with an edge in the foreground.

Perspective drawing; is a drawing technique that allows the artist to project three-dimensional objects as a human would actually see them. This method always includes lines converging into one or up to six so-called vanishing points

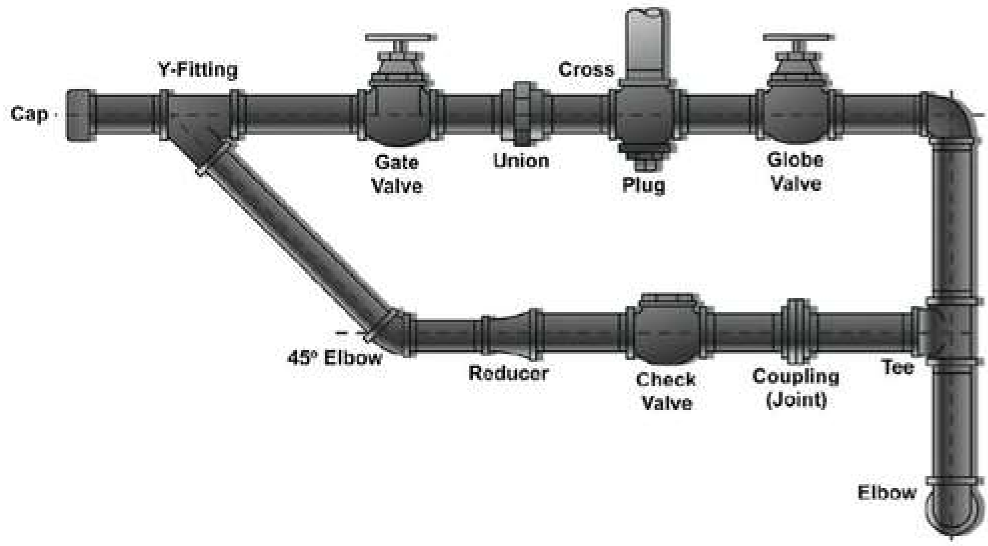


Figure 129: Perspective drawing

Line drawing;

There are different ways in which line drawings can be done.

2.2.2.1. Line drawings can be done using the measuring instruments as depicted

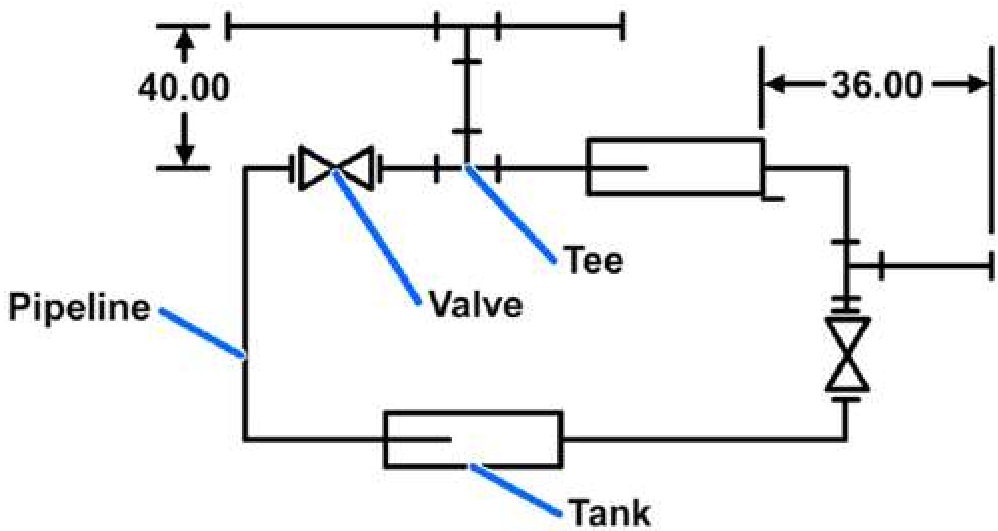


Figure 130: line drawing

2.2.2.2. Free Hand Sketching

Freehand sketching; Freehand drawing is done on many occasions: to explain a piece of design quickly to a colleague and to develop a design. **A free hand sketch** is drawn without measuring instruments. This drawing is drawn with the help of pencil and eraser only. Such drawing is drawn before every type of actual drawing because it takes less time. Then the actual drawing is prepared.

Free hand sketches are commonly used to easily explain a plumbing concept on site.

Principles of Free Hand Sketching.

Following principles should be followed for free hand sketching:

1. The object should be seen thoroughly and pondered over its objectives and concepts.

2. More detailed aspect is considered for selection of a view.

3. Space is specified on a drawing sheet according to the sizes of views.

4. Firstly, the dim lines are drawn so that extra lines may be erased easily.

5. Scale and ruler are not used in drawing, although, ratio and proportion of different parts of an object are considered.

6. Firstly, horizontal lines are drawn then vertical lines are drawn, and arcs and circles are drawn lastly.

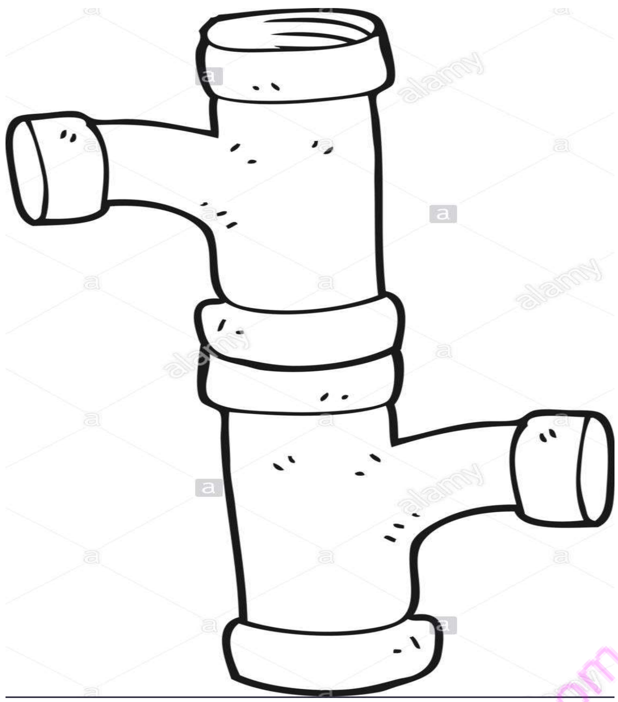


Figure 131: Free hand sketch of a pipe and pipe fittings

Except for the freehand sketches, all other working drawings will be done using the drawing instruments. Scaling will be very important since different scales will be used to adjust the actual measurement of a project to fit into a paper

Purpose of a scale drawing

Scale drawings are a useful tool for any designer, because they can be used to plan, visualize and adjust landscape plans before breaking ground. Scale drawings assign each object the same scale compared to the actual objects

Types of scale

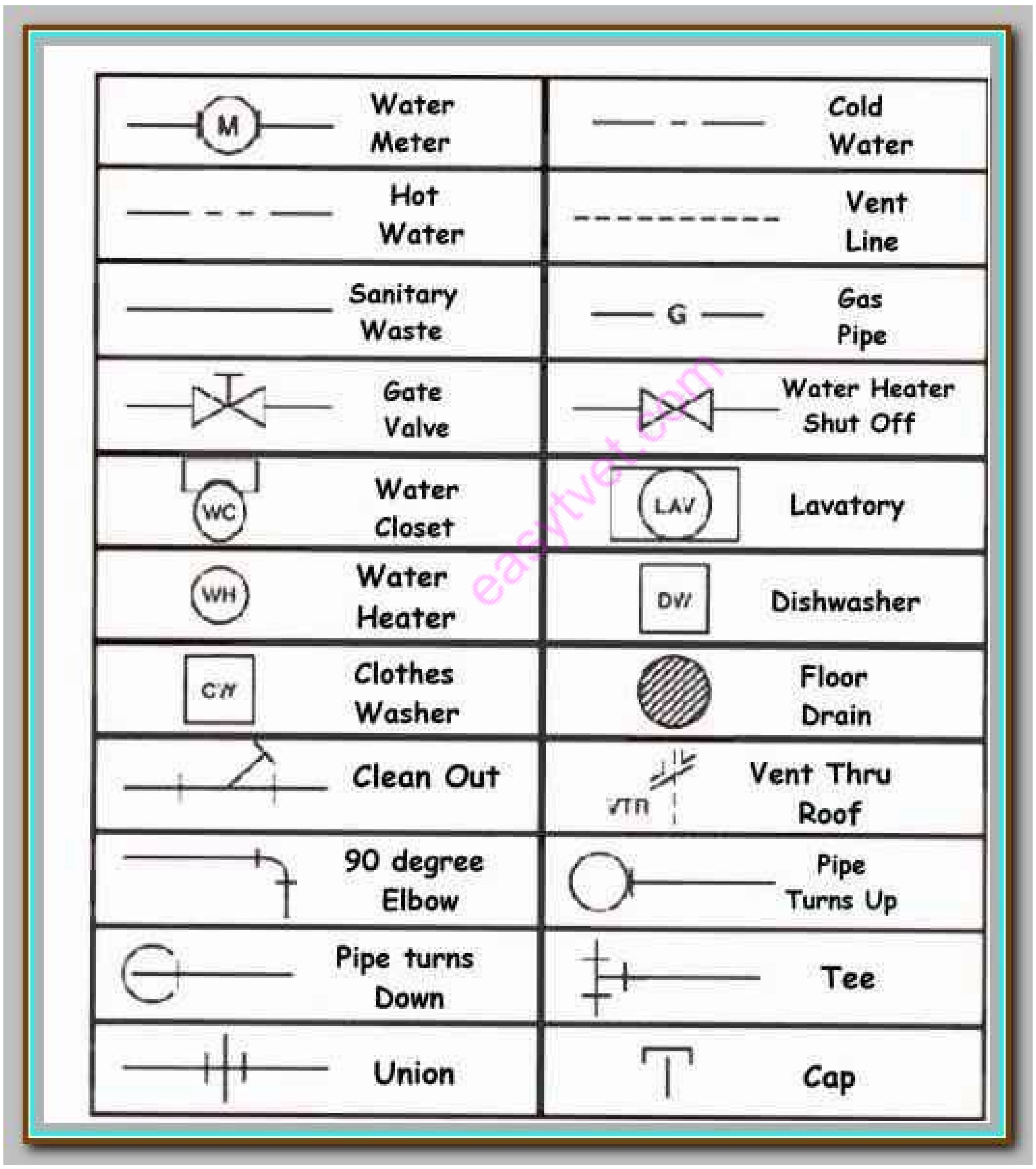
There are Four Scales of Measurement. nominal, ordinal, interval or ratio. Each level of measurement has some important properties that are useful to know. For example, only the ratio scale has meaningful zeros

Symbol

Symbols will be used in Plumbing working drawings to represent different elements.

Plumbing symbols are used when drawing house plans are being designed. The purpose of these symbols is to indicate where the different elements of your plumbing system are located.

It is necessary for the trainee to understand the different plumbing components and their subsequent symbols. Some examples of Plumbing symbols are illustrated on the table below.



2.2.1.4. Learning Activities

Practical Activity

Using the knowledge on Plumbing Symbols, study the Architectural drawing given and identify the different types of sanitary appliances represented.

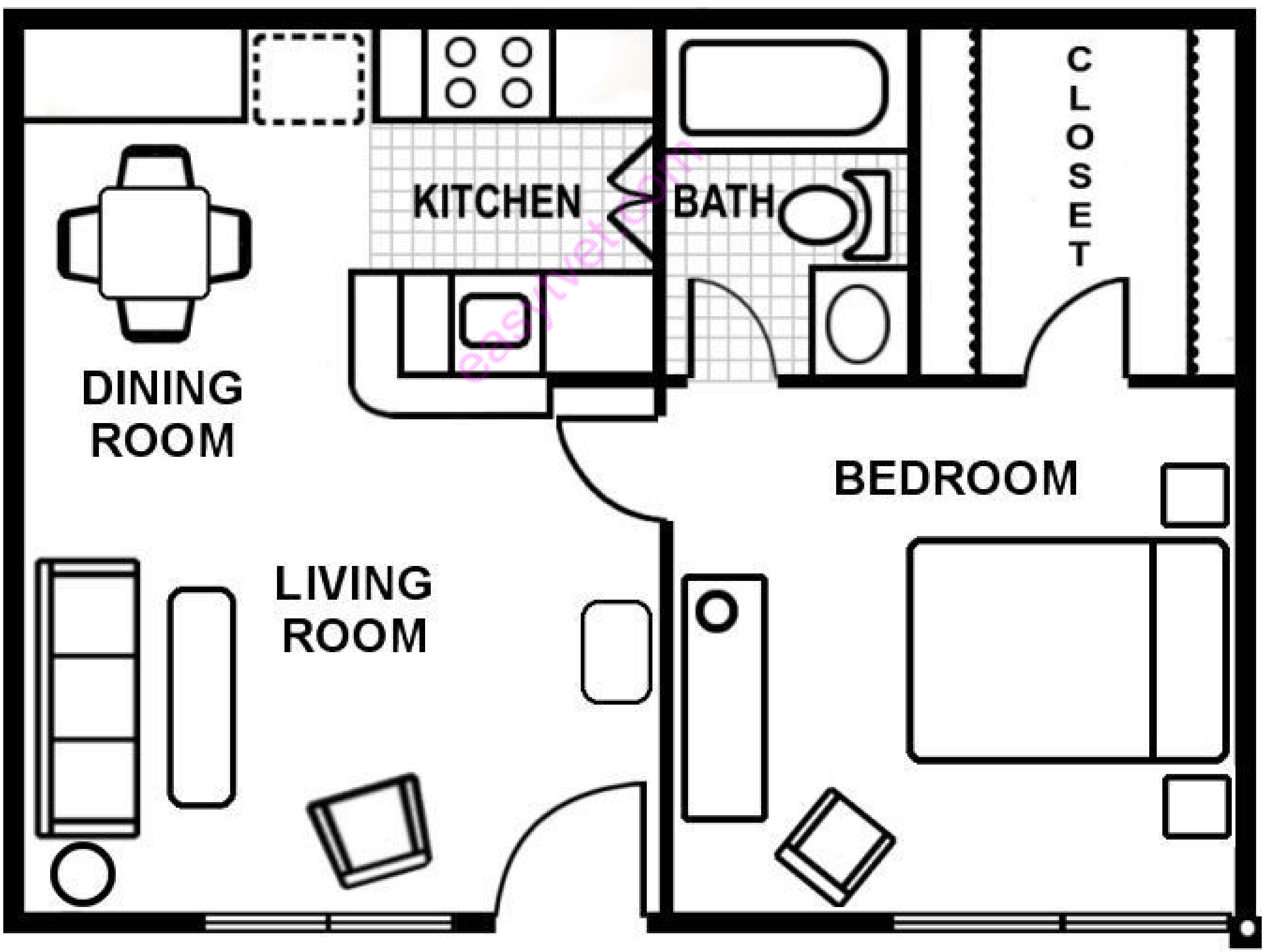


Figure 132: Floor Plan

2.2.1.5. Self-Assessment

6. Define a plumbing layout.
2. What are the THREE functions of building drawings?
3. Why is it appropriate to supply the manufacturer with the engineering drawing?
4. What are rainwater goods parts?
5. In which blueprint would you find specifications on what type of rainwater goods to use?

2.2.1.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	Materials:
• Drawing boards • T square • Set square • Blueprint machine/printer • Steel rule • Scale rule • Compass & Dividers • Protractor • Erasers	• Drawing papers • Drawing pencils • Drawing sets • Masking tape • Construction drawings • Classroom and classroom resources • Manufacturer's drawings

2.2.1.7. References

Black & Decker (2008). *The Complete Guide to Plumbing (4th ed)*. Minneapolis: Creative Publishing international, Inc. Retrieved from https://www.pdfdrive.com/

Chudley, R.G (1988). *Building Construction Handbook (4th ed)*. MA: Reed Educational and Professional Publishing Ltd.

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Treloar, R.D (2012), *Plumbing book (4TH ed).* Iowa: Wiley-Blackwell ltd. Retrieved from https://content.schweitzer-online.de

2.2.1.8. Model Answers

1. Define a plumbing layout?

The plumbing layout is usually drawn into a copy of the floor plan for proper orientation with existing plumbing fixtures, walls and partition outlines, and other utility features.

2. What are the THREE functions of building drawings?

- to develop a design idea into a coherent proposal,
- to communicate ideas and concepts,
- to convince clients of the merits of a design,
- to enable a building contractor to construct it,
- as a record of the completed work.

3. **Why is it appropriate to supply the manufacturer with the engineering drawing?**

Engineering drawings are extremely important as they provide a plethora of information to the manufacturer, including:

- Type of material required for manufacturing and supply
- Detailed product dimensions
- Surface and cosmetic finishes
- Welding information
- Hardware requirements

4. What are rainwater goods parts?

There are really only two main toilet tank parts: The toilet flush valve, which lets water gush into the bowl during the flush, and the fill valve, which lets water refill the tank after the flush. When a toilet runs constantly or intermittently, one of these valves is usually at fault.

5. In which blueprint would you find specifications on what type of rainwater goods to use?

- Plumbing and Sanitary Drawings
- Mechanical drawing

2.2.2. Learning Outcome 2: Quantify and cost materials

2.2.2.1. Introduction to the learning outcome

This outcome specifies the competencies required to quantify and cost materials for rainwater harvesting and disposal. It involves, identifying materials, quantifying and costing during harvesting and disposal of rainwater. Costing of materials is a key concept in the construction industry.

2.2.2.2. Performance Standard

1. Materials are classified based on specifications
2. Materials are estimated and costed as per the market rate
3. Materials schedule are prepared based on best practice
4. Supplies are identified based on specification

2.2.2.3. Information Sheet

Rain water disposal refers to the mechanism of collection and disposal of rain water from the roofs to a storage vessel or directed to a storm drain. There are different materials that can be used for rain water disposal.

- P.V.C Plastics
- Metals. There are two categories of metals. Ferrous Metals and non-ferrous metals. Ferrous metals contain a percentage of iron in them e.g cast iron and steel whereas non-ferrous metals do not contain iron. E.g Aluminium and zinc.
- UPVC ; Plastic is most affordable upfront and quality has improved dramatically, with better seals and more attractive profiles.
- Cupper
- Glass reinforced polyester (GRP)

Rain water components

These are parts of the rainwater disposal system that are inter-connected during water harvesting;

- Gutters
- Gutter unions
- Gutter clips
- Gutter outlets
- Stop ends

- Swan necks
- Down pipes
- Down pipe unions
- Down pipe clips

Others include;

Figure 133: Rainwater components

Factors affecting gutters performance

- Drainage Area. This refers to the sum of the areas of each of your roof's surface.
- Roof Pitch. This will also determine the amount of rainwater it can collect.
- Gutter Pitch. The standard gutter pitch is a quarter-inch drop for every 10 feet.
- Gutter Material.
- Gutter Condition.
- Quality of Installation.

Factors to Consider When Choosing Gutter Sizes

Your Local Climate. One of the biggest factors when picking the right gutter size is your local climate.

The Pitch of The Roof. Your ideal gutter size is also affected by the slope of your roof.
The Size of Your Roof. A low-pitched roof may still require a bigger gutter option if it's large enough.
The Gutter Style.

How to choose rainwater goods material

The rainwater good material chosen depends on the application, water quality and amount of the anticipated rainfall.

Materials are selected based on the following specifications

- Manufacturer's specification
- Clients' specifications based on economic and ergonomic factors
- Standard specifications; these are from the industrial experts i.e., experienced

How is rainwater downpipe calculated?

To calculate the minimum number of downpipes, divide the roof catchment area by the allowable maximum catchment per downpipe. To calculate the average catchment per downpipe, divide the roof catchment area by the number of downpipes.

How to create a schedule of materials using a drawing.

You can opt to use one of either method while creating the schedule of material;

•Using a cutting list: this is where all the material required are broken down and the units put in a table.

2.2.2.4. Learning Activities

To cover:

- Prepare the schedule of material for the rainwater goods if the height of the building is 3m from the ground level. Assume any other relevant information from the figure below:

2.2.2.5. Self-Assessment

1) Which materials are used for water supply and drain pipes?
2) What is the difference between plumbing and sanitary?
3) What is difference between drainage and sewage?
4) What are the FIVE general installation requirements for pipe work in water goods?

2.2.2.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Plumb bob • Measuring tools (Tape measure, infra-red light, rule etc.) • Marking tools • Cutting tools • Fastening tools • files • Wire brushes • Holding tools • Drilling equipment	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Pipes • Gutters • Pipe fittings • Accessory • Adhesives • Sealant

2.2.2.7. References

Black & Decker (2008). *The Complete Guide to Plumbing (4th ed)*. Minneapolis: Creative Publishing international, Inc. Retrieved from https://www.pdfdrive.com/

Chudley, R.G (1988). *Building Construction Handbook (4th ed)*. MA: Reed Educational and Professional Publishing Ltd.

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2.2.2.9. MODEL ANSWERS

1) Which materials are used for water supply and drain pipes?

- Cast iron, PVC, and ABS for plumbing waste (drain) lines.
- Chromed brass, copper, galvanized iron, CPVC, and PEX for water

supply lines

2) What is the difference between plumbing and sanitary?

Plumbing is a controlled system of conveyance of water in a fitted and regulated line. Sanitary systems consist of an assembly of pipes, fixtures, and fittings which gather and directs sewage to the drainage system and from there it is drained to the sewer.

3) What is difference between drainage and sewage?

A drain is a pipe that serves only one building, conveying water and waste water away to a sewer. Sewers (sewerage), are the underground networks of pipes that carry sewage (waste water and excrement), waste water and surface water run-off, from drains to treatment facilities or disposal points

4) What are the FIVE general installation requirements for pipe work in water goods?

- Comply with the durability requirement.
- Be compatible with the support.
- Be installed to allow for thermal movement.
- Be protected from damage.
- Be protected from freezing by insulation.
- Be wrapped in flexible material or sleeved when penetrating masonry/concrete.

2.2.3. Learning Outcome 3:Use tools and equipment

2.2.3.1. Introduction To The Learning Outcome

This learning outcome specifies the competencies required in the use of tools and equipment. It involves, identifying and use of correct tool and equipment during standard installation of the rainwater harvesting and disposal system as it applies in the construction industry.

2.2.3.2. Performance Standard

1. Personal Protective Equipment is used in line with occupational safety and health requirements
2. Rainwater goods tools and equipment are identified based on the requirements of the job.
3. Rainwater goods tools and equipment are used based on manufacturer's instructions.
4. Rainwater goods tools and equipment are cared for and maintained based on manufacturer's manual and workplace place policy.
5. Rainwater goods tools and equipment are stored based on manufacturer's instructions

2.2.3.3. Information Sheet

Tools for Fixing Rainwater Pipes

Tools are essential for proper pipe works, roof works and other construction works.
There are various types of tools used for fixing rai.
1. Plier: it is a handy tool primarily used for gripping and cutting. It is a common tool for many handy trades and occupations.

Figure 134: plier

2. Parrot Plier: it is another shape of plier.

Figure 135: parrot plier

3. Spanner Set: it is a tool usually operated by hand to tighten bolts and nuts.

Figure 136:Spanners

4. Pipe Wrench: A pipe wrench is a tool with two serrated jaws, one adjustable for gripping and turning pipe and the other is fixed.

Figure 137: Pipe wrench

5. Adjustable Wrench: This wrench has an adjustable head to fit into various sizes of nuts and bolts. The wrench can be fitted into fasteners of different sizes.

Figure 138: Adjustable spanner

6. Chain Wrench: it is used for turning large pipes. An adjustable chain circles the pipe with its ends connected to the head whose teeth engage the pipe.

Figure 139: Chain wrench

7. File: it is used to sharpen/grind the pipe.

Figure 140: File

8. Pipe Vice: the vice is used for gripping the pipe.

Figure 141: Pipe vice

9. Hand Hacksaw: it is used for cutting the guttering components. Some hacksaws have pistol grips which keep hacksaw firm and easy in grip. It is used to cut in straight lines also.

Figure 142: Hacksaw

11. Tap Wrench: Tap wrench is a handy tool to operate any small tool that has a square driving head as a part of its body. These are usually cutting tools. Other small handy tools such as hand hammer might employ a tap wrench.

Figure 143:Tap Wrench

12. Measuring Tape: Measuring tape is a ribbon of cloth, plastic or metal with linear measure markings.

Figure 144:Tape measure

13. Calipers: it is an instrument used to measure the diameter of any object.

Figure 145: Calipers

14. Hammer: it is a handy tool with heavy rigid head and a handle used to deliver an impulsive force by striking.

Figure 146:Hammer

15. Steel Rule: it is a flat, linear measuring instrument having different levels of graduations such as 1/4, 1/8, 1/16, 1/32 and 1/64 for standard inch and 1 or 0.5 mm for metric.

Figure 147:Steel rule

16. Trowel: it is a small handy tool with a handle and flat metal blade which is used for digging, spreading plaster or similar materials.

Figure 148: Trowel

17. Screw Driver: it is a tool used for driving screws into their places. It has a thin end which enters the nick in the head of screw.

Figure 149: Screw driver

18. Try Square: it is a tool used for marking and measuring a piece of wood. Square refers to the primary use of tool. It measures accuracy of a right angle. It is a piece of wood; that is rectangular, flat having all edges (faces, sides, ends) at 90 degrees.

Figure 150: Tri square

19. Bench Vice: it is a holding device attached to workbench which has two jaws to hold work piece firmly in place.

Figure 151: Bench vice

20. Chisel: it is a tool used for cutting a hard material such as wood, stone or metal. It is typically made of hard/tempered steel. It is rarely made of common steel which consists of a sharp end (called the blade) attached to a straight handle. The handle and blade of some chisels are made of one piece.

Figure 152: Chisel

21. Spirit Level: A spirit level is an instrument designed to indicate whether a surface is leveled or not.

Figure 153:Spirit Level

22. Caulking Tools: A spigot and socket joint in which the joining material such as lead is compacted by means of caulking tool and hammer.

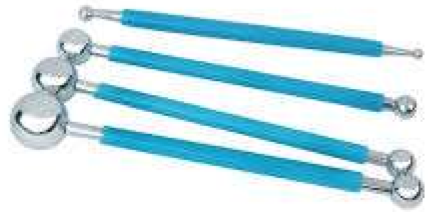

Figure 154:Caulking tool

23. Ratchet Brace: Ratchet brace is equipped with a four-jaw chuck suitable for bit stock, round or hex shanks.

Figure 155:Ratchet Brace

Personal Protective Equipment

Safety Equipment, as implied by its name, includes the gadgets that are used (worn, used) for the protection of life and to avoid injuries or casualties. Generally, safety equipment is the protection that is used by workers to avoid injuries, casualties, life threatening situations etc They include but not limited to;

- protective clothing,

- helmets,
- gloves
- face shields,
- goggles,
- facemasks and/or respirators or other equipment designed to protect the wearer from injury or the spread of infection or illness.

EQUIPMENT MAINTENANCE

It includes routine upkeep as well as corrective repair work. Equipment may include heavy workshop machines.

Types of maintenance

There 4 general types of maintenance; corrective, preventive, risk-based and condition-based maintenance.

1. **Corrective maintenance**; Maintenance is carried out following detection of an anomaly and aimed at restoring normal operating conditions.
2. **Preventive maintenance**; Maintenance carried out at predetermined intervals or according to prescribed criteria, aimed at reducing the failure risk or performance degradation of the equipment.
3. **Risk-based maintenance**; Maintenance carried out by integrating analysis, measurement and periodic test activities to standard preventive maintenance
4. **Condition-based maintenance**; Maintenance based on the equipment performance monitoring and the control of the corrective actions taken as a result.

Why is it important to use the correct tools and equipment?

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

Tools and equipment storage

Why should tools and equipment be securely stored?

You are responsible for making sure that all tools and equipment are well organized and maintained in good working condition. They should be stored in a separate secure place so that they are safe and easy to find. This is usually best done in a place which is separate from the office.

Proper storage of tools and equipment

Section a space on your building and make it a storage place for tools.

Tools Preparation and Storage

Preparation

- Clean tools after each use
- Repair any broken parts
- Defective tools must be isolated
- Use metal protectant spray on all metal parts
- Never store tools on the unprepared ground
- Get creative with storage options the heavy ones near/on the prepared raised ground and the lighter ones on top
- Make a list of all items that are stored

Storage

To keep these tools safe and in good working condition, it's better to keep them in and not limited to:

- Tool Store
- Racks
- Cabinets
- Drawers
- Pegs on wall
- Shelves
- Tool boxes

Make sure to label the boxes with its contents so you will be able to find the tool when you need it. Keep an inventory list of the tools that you have and where they are stored.

Figure 156: pegging on wall

3. Tool Rack

These are wall-mounted or free-standing units that may be designed for specific tool types, or suitable for general use.Tool racks are used to store and organize tools in an exposed manner so that tools are easy to identify, retrieve, and return.

4. TOOL BOX

This is a box or container in which one keeps or carries tools especially those used for a particular task.

2.2.3.4. Learning Activities

1. You are required to visit a site and identify
   a) The different ways of care and maintenance done to their tools
   b) Methods of workplace safety applied
   c) The different methods of storage of tools

2.2.3.5. Self-Assessment

1) Types of personal protective equipment (PPE) to guarantee your safety
2) What is the importance of tools in plumbing?
3) What tools do plumbers use to unclog drains?
4) Which material will you use to threaded pipe connection to prevent leakage?
5) What is a tool often kept on a plumber's tool belt? It is used to take and make measurements.
6) What materials can sanitary appliances be made from?
7) What is a sanitary connection?
8) I need to cut a new piece of copper pipe for the supply run to my sink. What are the best tools and techniques to use?

9) We want to add a second sink in the master bathroom. Can we extend the pipes that are already there?

2.2.3.6. Tools, Equipment, Supplies And Materials

Tools/Equipment:	**Materials:**
• Measuring tools • Hacksaw • Bench-vice • Tin Snips • Files • Scribers • Screwdrivers • Mallets • Blowlamp	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Gutters • Assorted gutter connectors • Adhesives • Sealant • Soldering sticks & Soldering flux

2.2.3.7. References (Motivate series Plumbing)

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2.2.3.8. Model Answers

1) Types of personal protective equipment (PPE) to guarantee your safety

- Safety for the head. Wearing a helmet offers protection and can prevent head injuries.
- Protect your eyes.
- Hearing protection.
- Maintain a good respiration.
- Protect your hands with the right gloves.
- Protection for the feet.
- Wear the correct work clothing

2) **What is the importance of tools in plumbing**?

A plumber requires several tools for the fitting work for plumbing, fixing a tap or to carryout repairs. These tools help the plumber in performing his/her work properly, and therefore it is important that the tools are used systematically and handled carefully to avoid any damage

3) What tools do plumbers use to unclog drains?

To dislodge clogs located farther down the drainpipe, use a cable auger, or plumber's snake, a long, flexible steel cable wound around a spool that's fitted with a hand crank

4) Which material will you use to threaded pipe connection to prevent leakage?

- Teflon tape

5) What is a tool often kept on a plumber's tool belt? It is used to take and make measurements.

- Tape measure

6) **What materials can sanitary appliances be made from?**

Can made from a wide range of materials, including metals, acrylics, glass, and so on, and 'sanitaryware' is sometimes now interpreted to include a wider range of appliances that might be found in sanitary installations such as baths, showers, bins, incinerators, macerators, and so on.

7) **What is a sanitary connection?**

Like regular fittings, sanitary fittings connect sections of piping systems to regulate the flow of fluid, but sanitary fittings are specially designed and made to prevent the entrapment, formation, and spread of bacteria in the piping system.

8) **I need to cut a new piece of copper pipe for the supply run to my sink. What are the best tools and techniques to use?**

It's best to use a pipe cutter with a specially designed blade for copper pipe. You can also use a fine-toothed hacksaw, but making a straight cut with it is more difficult. After you've cut the pipe, clean off any burrs (inside or out) with a half-round file.

9) **We want to add a second sink in the master bathroom. Can we extend the pipes that are already there?**

Yes. You'll need to tap into the existing supply, drain, and vent pipes, run new piping to the desired location, and hook up the new fixture.

2.2.4. Learning Outcome 4: Install rain water goods

2.2.4.1. Introduction to the learning outcome

This outcome specifies the competencies required to install rain water goods. It involves, identifying and use of correct tool and equipment for the correct tool during standard installation of rain water goods in buildings as it applies in the construction industry.

2.2.4.2. Performance Standard

4.1 Types of water harvesting methods are identified based on the local authority by- laws

4.2 Types of rain water disposal methods are identified based on the local authority by- laws

4.3 ***Rainwater goods*** are identified based on the drawing

4.4 Measurements are taken and marking out is done based on the drawing

4.5 Material is cut based on drawings.

4.6 Pieces are jointed based on specifications

4.7 Pieces are assembled based on working drawing

2.2.4.3. Information Sheet

Rainwater Harvesting – is a technology used to collect, convey, and store rainwater from relatively clean surfaces like the roof, rock catchment, or land surface – essentially for later use. This collected rainwater is either directed to recharge groundwater or stored in a rainwater tank.

Methods of Rainwater Harvesting

- Surface Runoff Harvesting. In urban areas, rainwater flows away as surface runoff.
- Rooftop Rainwater Harvesting. It is a system of catching rainwater where it falls.
- Catchment.
- Transportation.
- First Flush.
- Filter.
- Storage of Direct Use.
- Recharging Groundwater Aquifers

Gutter Installation Steps

1. Make a plan; for the rainwater goods to be installed
2. Set a budget; for all materials you need
3. Cover the basis of the project; ensure you have all you require before you start your installation.
4. Prepare your fascia and soffits; perform a thorough inspection of the fascia and soffits. Look for chipped, cracked, or peeling paint, as well as wood rot or missing pieces.
5. Get a helping hand; this is your helper

6. Direct your drainage; ensure you install you with a slight angle for water to drain toward the downspouts and out to the yard.
7. Measure twice, cut once; this is to avoid wastage of materials.
   NOTE; when in doubt then consult the experts to avoid double purchase of materials.

How to install rainwater goods

1. Before starting work, identify position of drain, run a plumb-line and fix gutter outlet. Check fascia is level.
2. Fix support bracket at furthest end and run a string-line to the outlet.
3. From outlet, fix support brackets at a maximum of one metre centres.
4. Insert gutter to the 'insert to here' line on the first fitting. At the other end of the gutter mark the position of the next fitting on the fascia.
5. Remove gutter and fix next fitting using your mark line. Ensuring fittings are level by using a string line.
6. Fit length of gutter and stopend, with support bracket at furthest end.
7. Fit top offset bend to outlet, then using bottom offset determine length of pipe required.
8. Fit a pipe clip below the bottom offset, then at a maximum of two metres apart.
9. Check water tightness by blocking off any outlet and performing a static water test.

Types of Rainwater Harvesting Systems

1. **Water Butt**; One of the most basic types of rainwater harvesting systems; water Butt collects rainwater in a container from natural rainfall and/or drain pipes. The collected water is used mainly for laundry services and watering the garden.

2. **Direct-Pumped**; there two categories

Submersible – Used particularly in domestic settings and is the easiest systems to install. The pump is placed within the underground tank and the harvested water is pumped directly to WCs or other appliances used daily for domestic purposes.

Suction – In this system, the pump is located within the control unit of the house (e.g. utility room). This unit also deals with backup from the mains water supply, hence there is no need to direct mains water down to the underground tank.

Most rainwater harvesting systems need pumps to transfer the collected rainwater from storage tanks to the point of use. Submersible pumps are generally more efficient than suction pumps and do not suffer from the same limitations.

3. **Indirect Pumped;** This type of rainwater harvesting system doesn't rely on gravity to supply water to the outlets. Instead, it pumps the harvested water to a tank which can be at any level in the building. Furthermore, a booster pump is used to provide a pressurized water supply. One of the most significant benefits of this system is that it offers great flexibility to tailor the booster pumps to adjust the flow and pressure requirements of a building.

4. **Indirect Gravity;** This system ensures water is supplied to the outlets by gravity alone. For this, the harvested water is first pumped to the header tank, i.e high-level tank and then allowed to free-flow. In Indirect gravity systems, the pump works only to fill the header tank.

5. **Gravity Only;** In few conditions, a system which functions purely through gravity may be needed. Such systems do not demand pumps hence involves no energy use. With such an arrangement, water can be collected only when collection tanks are located below the level of gutters, yet higher than the outlets which it will supply. Here the only power of gravity is needed to feed collected and harvested water to various parts of the household. Gravity only is one of the most energy-efficient rainwater harvesting systems.

6. **Retention Ponds**; Retention ponds are used to collect surface runoff water and improve the quality of water by natural processes like sedimentation, decomposition, solar disinfection, and soil filtration. This type of pond normally has a mud bottom, but in some cases, it may be lined with concrete. The most common use of water collected and harvested by pond harvesting is watering livestock, however, it can also be used for groundwater recharge, irrigation or any other purpose other than potable uses.

7. **In-Ground Storage;** Underground storage tanks are very popular in areas where the majority of rainfall occurs in one single season. These underground tanks are insulated and have a very low rate of evaporation. In addition, the water stored in these doesn't freeze if it is buried below the frost line, this is a huge advantage that surface storage tanks do not offer. Underground

tanks need to be connected to an electric pump to ensure supply of the stored water to the outlets

Methods of Rainwater Harvesting

- Surface Runoff Harvesting. In urban areas, rainwater flows away as surface runoff. ...
- Rooftop Rainwater Harvesting. It is a system of catching rainwater where it falls at the coverings then it is stored in the underground tanks
- Catchment.
- Transportation.
- First Flush.
- Filter.
- Storage of Direct Use.

Figure 157: Roof rainwater harvesting

Common gutter and downpipe problems on buildings

- **Blocked gutters;** Check for a build-up of leaves, silt and slate debris, as these can often lead to vegetation growth and block up guttering.

Figure 158: blocked gutters

- **Blocked downpipes**; Look for water backing up into the gutter, the gutter overflowing or water forced out of downpipe joints in heavy rain. Water trapped in blocked downpipes can freeze causing the cast iron to split open.

Figure 159: Blocked downpipes

•**Blocked gulley's;** Ensure any open gulley traps at ground level are free from debris, plant growth and gravel. Check there are no blockages in the underground drainage system.

- **Broken Gutter brackets;** Check to see if there are any broken or loose gutter brackets, possibly putting the gutter out of alignment.

Figure 160: gutter brackets

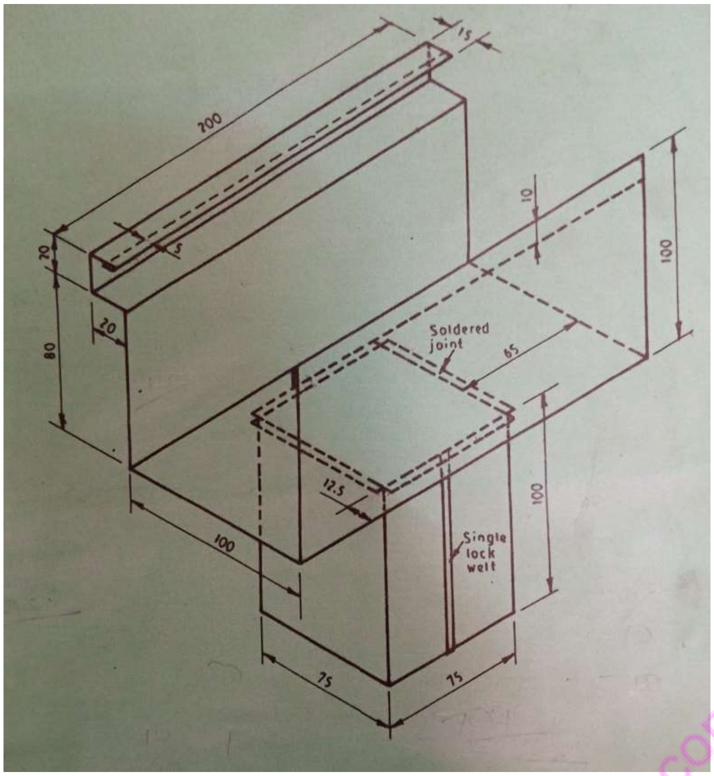
•**Downpipe brackets;** Check for broken, loose or missing brackets possibly causing downpipes to disconnect at the joints. Look for water staining and algae growth on the wall behind joints and down the pipe.

Figure 161:Downpipe brackets

- **Condition of cast iron**; Look for chipped, spilt, flaking paint finishes or rust on cast iron. Problem areas to look out for are the back of gutters where they are tight against the wall or tucked under slates and behind downpipes and at the joints. Check for small holes, tears and thinning of the surface in lead gutters.

2.2.4.4. Learning Activities

Using suitable tools, Fabricate and assemble the guttering system shown



2.2.4.5. Self-Assessment

1) What do you understand with the following faults;
    - Installation faults
    - Manufacturer's faults
2) What are the basic things do you require while installing gutters?
3) What are the different types of sanitary fittings?
4) How can you unclog a sink drain using chemicals?
5) Which three methods are suitable for testing modern Drainage Water vent systems (DWV systems) for leaks?
6) Which three factors my limit you to use a certain appliance and not the other
7) Why does a toilet whistle when flushed?

2.2.4.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	Materials:
• Pipe wrench • Pipe cutter • Hacksaw • Pipe Threading Equipment • Vise - Bench • Tap and Punch • Files • Screwdrivers • Drill with various sizes of bits • Rivets • Mallet • Ball hammer • Masonry chisel • Pipe bender	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Pipes • Gutters • Pipe fittings • Accessory • Adhesives • Sealant • Caulking material

2.2.4.7. References

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2.2.4.8. Model Answers

6. **What do you understand with the following faults;**

- **Installation faults**; this are mistakes made by the plumber during assembling or fixing the sanitary appliance thereby making it to leak/ work inefficiently.
- **Manufacturer's faults**; this is where the appliance itself had problems/make problems during manufacture. It can only be returned to the manufacturer or be rectified by the help of the expert from the manufacturer.

7. **What are the basic things do you require while installing gutters?**

- Step or extension ladder, depending on the height of your roof
- Work gloves
- Safety goggles
- Power drill and two or more rechargeable battery packs
- Permanent markers with a fine tip
- 25-foot tape measure
- Wood screws
- Gutter brackets
- Construction glue and gutter sealant
- Caulking gun (for the glue and sealant)
- Tin Snips (for cutting gutter pieces)

8. **What are the different types of sanitary fittings?**

   - Toilet, kitchen sinks, wash basins, sanitary ware & fittings
   - Wash basins. Pedestal wash basin
   - Toilet seats. One piece toilet seat
   - Wall hung toilets. Wall mounted closets
   - Kitchen sinks. Stainless steel kitchen sinks
   - Sanitary ware. Wash basins
   - Sanitary fittings. Waste couplings
   - Urinals. Urinal sensor

- Toilet fittings.

9. **How to Unclog a Sink Drain Using Chemicals**

  - Be sure to follow all the directions on the packaging and make sure not to use too much.
  - Wear gloves and goggles for safety.
  - Don't mix chemicals. This can produce poisonous gas.
  - Pour chemicals down the drain.

  Note: Chemicals can cause damage to your drainage pipes if used repeatedly, so I would recommend not resorting to this method lightly.

10. **Which three methods are suitable for testing modern Drainage Water vent systems (DWV systems) for leaks?**

  Air

  Water

  Smoke

11. **Which three factors my limit you to use a certain appliance and not the other**

  Manufacturer's specifications

  Engineer's specifications

  Client's specifications

12. **Why does a toilet whistle when flushed?**

Likely, a small chip or hole in your tank cover is allowing air to pass through and causing a whistling sound. It could also be caused by your fill valve, which takes a quick adjustment to fix.

2.2.5. Learning Outcome 5: Test rainwater goods

2.2.5.1. Introduction to the learning outcome

This outcome specifies the competencies required to test rainwater goods. It involves, identifying and use of correct tool and equipment for the correct tool during standard installation of rainwater goods as it applies in the construction industry.

2.2.5.2. Performance Standard

1. Rain water goods are installed based on working drawings
2. Water test is conducted based on best practices.
3. Faults in structure and functionality of rainwater goods are corrected based on best practice
4. ***Housekeeping*** is conducted based on workplace procedures

2.2.5.3. Information Sheet

Rainwater goods; Rainwater goods is a loose term for all products installed on the exterior of a building to protect it from the rain. This includes continuous spouting, downpipes and rainwater heads. Continuous spouting and downpipes assist with drainage, while rainwater heads store water that drips when travelling around the corners of a roof.

Spouting; propelled in a narrow stream of gutter under the eaves of a building.

Downpipes; are the pipes that are usually fixed vertically, extending downwards from your roof to the base of a building; it ensures that rainwater that is collected in the gutter can be channeled effectively to the sewer. Also called downspouts

Rainwater heads/sump; is a container located between the gutter and downpipe that aids the flow of water away from the roof.

Rainwater harvesting; is the collection and storage of rain for reuse on-site, rather than allowing it to run off. These stored waters are used for various purposes, such as gardening, irrigation

Rules for Putting Up Gutters

- Gutter (Fascia) brackets should never be more than 1m apart
- Gutter angles, Stop-ends, Running Outlets, Unions and other gutter fittings should have a bracket (both sides of the fitting where appropriate) within 150mm of the fitting

- A supporting pipe clip should be used on all Shoes, Branches and Bends of the down pipes where necessary and in all cases these pipe brackets should be no more than 1.8m apart
- Silicone spray lubricant should be used on all joints to allow for expansion and contraction

Procedure of Installing New Gutters

Step 1 - Map Out Your Gutter Run
Step 2 - Mark Gutter Positions
Step 3 - Install Downspout Outlets
Step 4 - Hang the Gutter Hangers
Step 5 - Cover the Gutter Corners
Step 6 - Cut the Gutter Sections
Step 7 - Install Gutter Sections
Step 8 - Install the Drain Pipes

How to Remove Old Gutters from Your House

- Remove the Downspout
- Remove the downspout first. Remove the elbow where it's attached to the drop outlet on the gutter, and then the downspout assembly can easily be removed and placed out of your way.
- Remove the Gutters
- Repair Holes
- You can use caulk to fill holes left in the siding once the gutters and downspouts are removed.

Faults in structure and functionality of rainwater goods

1. Blockage. Your gutters can be clogged with debris such as build up from natural materials like leaves or from unnatural materials like tennis balls.

2. Sag. When gutters are leaning on the facia to avoid rotting of fascia board and total gutter collapse. The reason for your gutter sag is most likely the result of a broken hanger or spike. Inspect the problem area and replace broken hardware as necessary.

3. Leaks. Leaking of gutters is mainly brought by blockage. A leak sometimes opens at the joints between sections of gutter, which can simply be resealed. You can patch these leaks, but once a weak spot is established, it will likely be a recurring problem.

4. Poor pitch. If gutters are not placed in a good gradient, then this means that there shall be backflow which will lead to pooling back and high weight. This could have happened during a poorly done gutter installation or can be the result of a house settling. This problem may be hard to identify, but it's important to address as pooling water can lead to corrosion or provide a breeding ground for pests such as mosquitos.

INSPECTION AND TESTING

INSPECTION

Work should be inspected during installation and tests applied on completion, care being taken that all work to be encased or concealed is tested before it is finally enclosed.

TESTING

When rainwater installations are complete, gutters should be tested for watertightness under working
conditions and internal downpipes should also be tested as prescribed in the relevant Building Regulations. Attention should be paid to the requirements of local authorities simple as removing each gutter hanger or other device that holds the gutter in place.

PIPING CALCULATION:

To calculate the minimum number of downpipes, divide the roof catchment area by the allowable maximum catchment per downpipe. To calculate the average catchment per downpipe, divide the roof catchment area by the number of downpipes

Housekeeping solutions

As a good plumber you need to perform the following as housekeeping procedures.

- You should protect the existing works and sanitary appliances

- You should clean your working area at all times during work progress.
- Clearing work area after the job should be done immediately.
- Keeping of work area tidy is always necessary.

2.2.5.4. Learning Activities

- Study the plan and propose the best possible water harvesting methods.
- Identify the faults that my likely occur due to cleaning water in the drainage systems and offer recommendations.

2.2.5.5. Self-Assessment

1. Is harvested rainwater good and safe for my family to drink?
2. How long can rainwater be stored?
3. What do you understand with the following faults;

- Installation faults
- Manufacturer's faults

4. What are the precautions should you take while Executing Layout of Pipes?
5. What are the different types of sanitary fittings?
6. How can you unclog a sink drain using chemicals?

7. Which three methods are suitable for testing modern Drainage Water vent systems (DWV systems) for leaks?
8. Which three factors my limit you to use a certain appliance and not the other
9. Why does a toilet whistle when flushed?

2.2.5.6. Tools, Equipment, Supplies and Materials

Tools/Equipment:	**Materials:**
• Pipe wrench • Pipe cutter • Hacksaw • Pipe Threading Equipment • Vise - Bench • Tap and Punch • Files • Screwdrivers • Drill with various sizes of bits • Mallet • Ball hammer • Masonry chisel • PPR machine / Heat Fusion • equipment • Pipe bender	• Hardhat • Gloves • Dustcoat / overall • Safety shoes / boots • Various types of pipe support • Sandpapers • Threading oil • Thread tape • Caulking material

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https://www.youtube.com/watch?v=ghcdZRUZ0MU

2.2.5.8. Model Answers

1. **Is harvested rainwater good and safe for my family to drink?**

   Yes. 100%. Rainwater harvesting provides water that is healthy, safe, and tastes great.
2. **How long can rainwater be stored?**

   Rainwater can be stored from anywhere between one week and indefinitely. The more consideration you put into your storage system – using the right materials, preventing algae and mosquitos
3. **What do you understand with the following faults;**

- **Installation faults**; this are mistakes made by the plumber during assembling or fixing the sanitary appliance thereby making it to leak/ work inefficiently.
- **Manufacturer's faults**; this is where the appliance itself had problems/make problems during manufacture. It can only be returned to the manufacturer or be rectified by the help of the expert from the manufacturer.

4. **Precautions while Executing Layout of Pipe**
   - Pipe work and appliances should be arranged in such a way that allows close grouping of connections with water closet near main soil pipe.
   - The branch pipes should be kept short to reduce noise.
   - When the basin and bath are at some distance from the stack, it would be cheaper and simpler to combine the waste pipes into one.

- Any bends in the waste pipe should be of large radius.
- The pipe work in branch connections should be arranged to allow free drainage for the system.
- All connections to main or branch pipes should be arranged in such a way that prevents cross flow from one appliance to another.
- Branch connections should be of large radius along the invert.
- The minimum diameter of soil and waste stacks should be 100 mm and 75 mm respectively.
- When the pipes are covered, hard to find along the internal face of the walls, they should be of cast iron.
- All pipes including those laid on external face of the wall should be of cast iron on the ground floor.

5. **Which three methods are suitable for testing modern Drainage Water vent systems (DWV systems) for leaks?**
    - Air
    - Water
    - Smoke

6. **Which three factors my limit you to use a certain material for guttering and not the other**
    - Manufacturer's specifications
    - Engineer's specifications
    - Client's specifications

CHAPTER 3: DRAINAGE SYSTEMS

Unit of learning code: CON/CU/PL/CR/03/5/A

RELATED UNIT OF COMPETENCY IN OCCUPATIONAL STANDARD: INSTALL DRAINAGE SYSTEMS

3.1 Introduction to the unit of learning

This unit specifies the competencies required to install drainage systems. It involves preparing working drawings, quantifying and cost drainage materials, using drainage tools and equipment setting out drainage systems, install above ground drainage system identifying drainage materials and installing below ground drainage system and testing. It applies in the construction industry.

3.2 Summary of Learning Outcomes

1. Prepare working drawings
2. Quantify drainage materials
3. Use drainage tools and equipment
4. Setting out drainage systems
5. Install above ground drainage system
6. Install below ground drainage system

3.2.1 Learning Outcome 1: Prepare working drawings

3.2.1.1 Introduction to the learning outcome

This learning outcome specifies the competences required by the trainee to prepare working drawings to install drainage system as it involves in the construction industry.

3.2.1.2 Performance Standard

1. Drawings are identified and selected based on the job.
2. Scale of the drawing is determined based on the specifications.

3. Measurements are converted based on scale.
4. Symbols are identified based on standard practices.
5. Isometric pipework drawings are sketched based on drawings.
6. Simple working drawings are produced based on specifications.

3.2.1.3 Information Sheet

The subject of working drawings is one to which a draughtsman cannot give too much attention, for accurate plans and details are absolute essentials for the production of good building. It is well to bear in mind that working drawings are working drawings and not pictures. They should merely aim at being accurate diagrams setting forth exactly the work which is required to be done, with such dimensions as are necessary clearly figured on the drawings, and the conventional colours employed to indicate materials whenever they will aid in expressing the architects intention.

Definitions of terms

- ***Working drawings*** - A comprehensive set of drawings used in a building construction project. They include architectural, structural and other engineering drawings.
- ***Symbol*** is a simplified image of component or things they represent.
- **A plan** a view from above showing the arrangement of spaces in building in the same way as a map, but showing the arrangement at a particular level of a building
- *An elevation* is a view of a building seen from one side, a flat representation of one front of a building
- ***Cross section,*** also simply called a section, represents a vertical plane cut through the object, in the same way as a floor plan is a horizontal section viewed from the top
- **Detail drawings** show a small part of the construction at a larger scale, to show how the component parts fit together.

- **Specification** is a precise description of the materials and methods of workmanship to be employed while carrying out the contract work
- **Schedules** give tables of information on ranges of similar items
- **Bill of Quantities** is a measure or price of the amount of materials and labor and other items required for the building work.
- **Drafting/Draughting;** This the ability to compose drawings that communicate how an object functions or is constructed.
- **Draughtsman**
- This is the person who interprets and draws to scale the engineer's design
- **Cross section**-Is a view seen by cutting an object at right angle to the plan on which it stands.

Introduction to Working

At the design stage, sketch drawings and preliminary drawings will be used to show the designer's intentions. Sketch drawings are also often used by site supervisors and craftsmen to show other operatives how a particular problem might be resolved or how a component can be fabricated on site. Once the design is accepted, production of the working drawings can be done.

The following drawings are used in a range of fields namely;

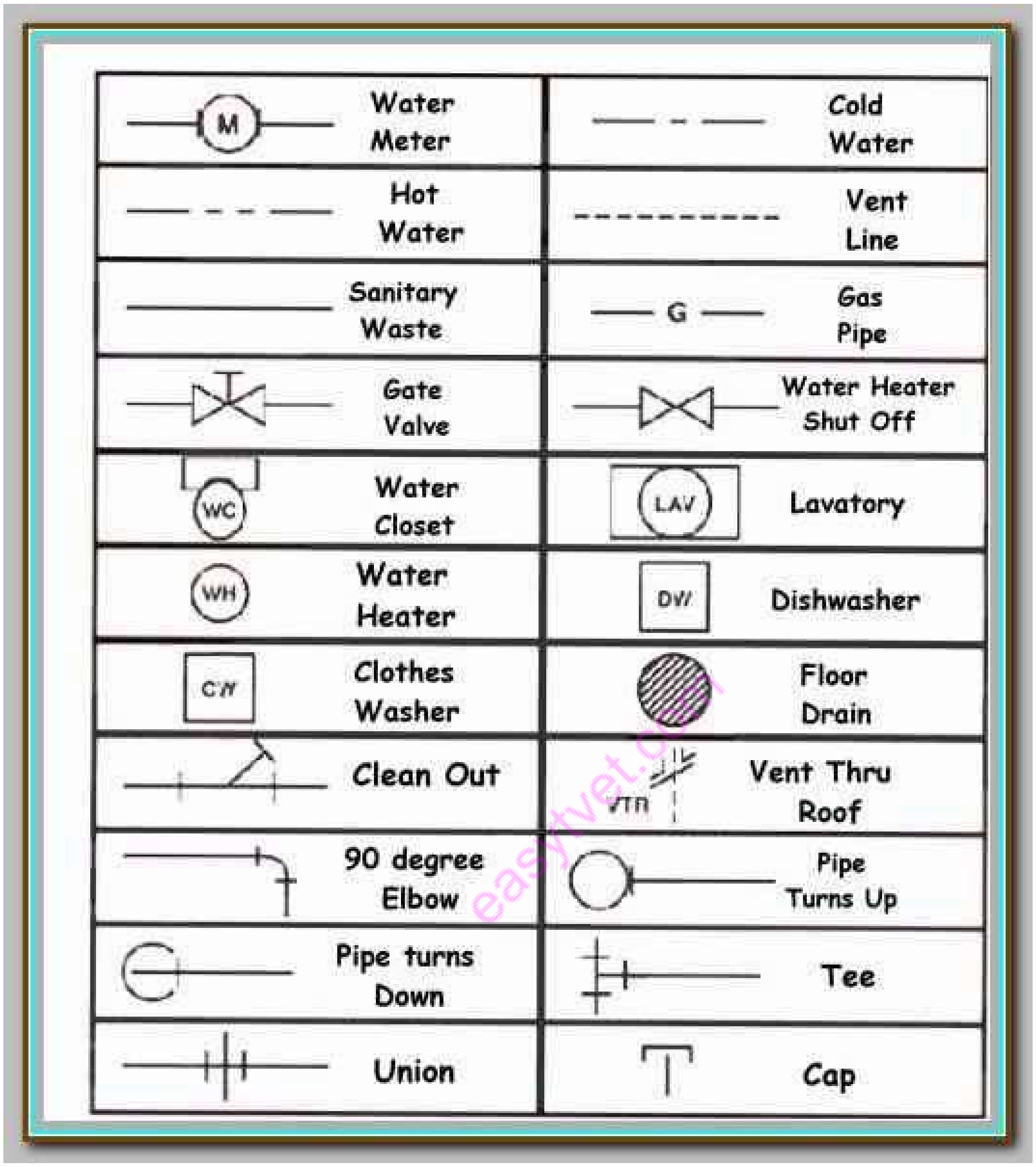
- Mechanical drawings - show information about heating, ventilating, air conditioning and plumbing details in a building.
- A structural drawing includes a plan or set of plans and details for how a building or other structure will be built. They are generally prepared by registered professional engineers, and based on information provided by architectural drawings.
- Architectural drawings are an illustration of what the final product will look like plus an instructional tool on how to achieve it. Architectural drawings can be devoted to depicting an overview of the building i.e., an elevation or they can focus on a particular detail.

A plumbing drawing is a type of technical drawing that provides visual representation and information relating to a plumbing system. It is used to convey the engineering design to plumbers or other workers who will use them to help install the plumbing system.

A **plumbing drawing** is used to show clearly the location of fixtures, sanitaryware, pipework, valves and so on, and illustrates how fresh water is to be supplied into a building and waste water removed. To illustrate the separate hot and cold water supply, the pipe runs will usually be coloured red and blue respectively. Drainage pipes should be illustrated with the grade (slope) indicated. Where manholes are included, a manhole schedule should detail the name, invert level, cover level, and depth.

SYMBOLS.

Plumbing symbols are used when drawing house plans and diagrams. The purpose of these symbols is to indicate where the different elements of your plumbing system are located.



SCALE

Scale drawings allow us to accurately represent sites, spaces, buildings and details to a smaller or more practical size than the original. When a drawing is described as ‘to scale’, it means that each element in that drawing is in the same proportion, related to the real or proposed thing – it is smaller or indeed larger by a particular percentage.

Scaling is a drawing method used to enlarge or reduce a drawing in size while keeping the proportions of the drawing the same. Scales are generally expressed as ratios and the most common scales used in furniture drawing are **1:1**, **1:2**, **1:5**, and **1:10** for reducing and possibly **2:1** for enlarging.

Scaling is used to either:

- **reduce** the drawing in size so that it will fit onto the page, or
- **Enlarge** the drawing in size so that all required details are clearly visible.

Drawings can be scaled up or down using either a calculator or a scale rule.

To scale a drawing using a calculator:

- **divide** the measurement by the scale if you want to **reduce** the drawing in size, or
- **Multiply** the measurement by the scale if you want to **increase** it in size.

Example 1: Scaling down

- A 50mm line is to be drawn at a scale of **1:5** (ie 5 times less than its original size). The measurement **50mm** is **divided** by **5** to give **10mm**. A 10mm line is drawn.
- A 50mm line is to be drawn at a scale of **1:2**. The measurement **50mm** is **divided** by **2** to give **25mm**. A 25mm line is drawn.

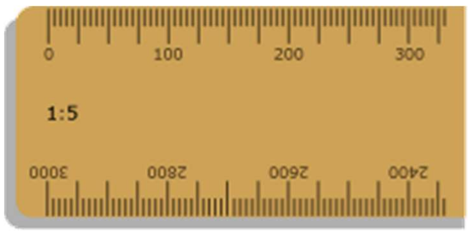
Example 2: Scaling up

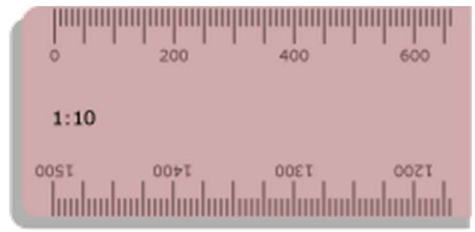
- A 50mm line is to be drawn at a scale of **5:1** (ie 5 times more than its original size). The measurement **50mm** is **multiplied** by **5** to give **250mm**. A 250mm line is drawn.
- A 50mm line is to be drawn at a scale of **2:1**. The measurement **50mm** is **multiplied** by **2** to give **100mm**. A 100mm line is drawn.

To scale a drawing using a scale rule:

Scale rules allow us to directly set out measurements onto a drawing without having to convert them to their scaled sizes by using a calculator first.

The whole process is made easier because these conversions are already made for us. On a scale rule which has divisions of **1:5**, each division represents 5mm and the measurements on the rule indicate this.





On a scale rule which has divisions of **1:10** each division represents 10mm and the measurements on the rule indicate this.

MEASUREMENTS

Measurement is the transformation of drawn information into descriptions and quantities, undertaken to value, cost, and price construction work, as well as enabling effective management.

Imperial measurements

Miles, feet and inches are old units of length. These are known as imperial units of length but are not now commonly used in mathematics. There are 12 inches in a foot. An inch is roughly equal to 2.5 centimeters.

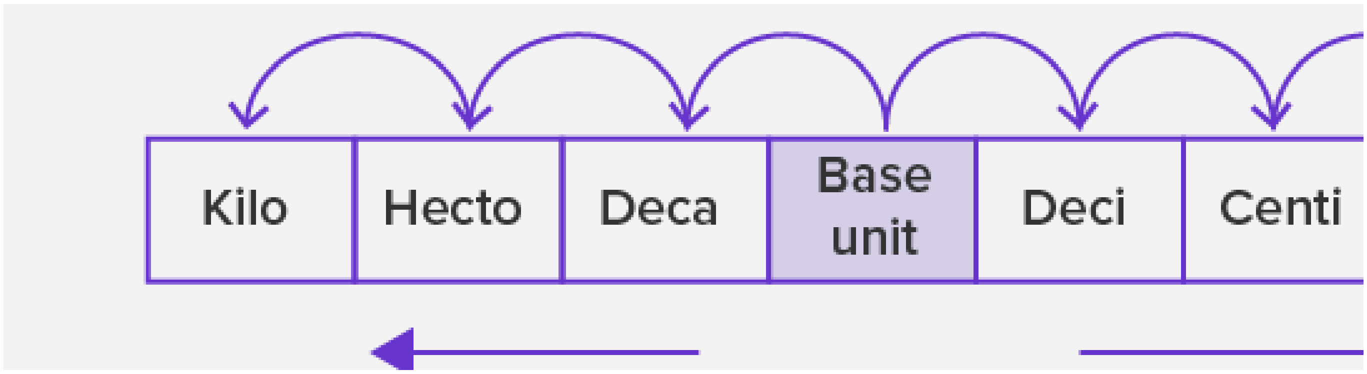
How can you convert imperial measurement to metric measurements?

- 1 foot (12 inches) is equal to 30 centimeters
- 1 inch is about 25 millimeters or 2.54 centimeters
- A 3-foot measurement is almost exactly 1 meter

What is Metric System?

The metric system is a system of measurement that uses the meter, liter, and gram as base units of length (distance), capacity (volume), and weight (mass) respectively.

To measure smaller or larger quantities, we use units derived from the metric units



- The given figure shows the arrangement of the metric units, which are smaller or bigger than the base unit.
- The units to the right of the base unit are smaller than the base unit. As we move to the right, each unit is 10 times smaller or one-tenth of the unit to its left. So, a ‘deci’ means one-tenth of the base unit, ‘centi’ is one-tenth of ‘deci’ or one-hundredth of the base unit and ‘milli’ is one-tenth of ‘centi’ or one-thousandth of the base unit.

Linear Measure

10 millimeters (mm) =	1 centimeter (cm)	
10 centimeters =	1 decimeter (dm)	= 100 millimeters
10 decimeters =	1 meter (m)	= 1,000 millimeters
10 meters =	1 dekameter (dam)	
10 dekameters =	1 hectometer (hm)	= 100 meters
10 hectometers =	1 kilometer (km)	= 1,000 meters

Area Measure

100 square millimeters (mm^2) =	1 sq centimeter (cm^2)
10,000 square centimeters =	1 sq meter (m^2)
=	1,000,000 sq millimeters
100 square meters =	1 are (a)
100 ares =	1 hectare (ha)
=	10,000 sq meters
100 hectares =	1 sq kilometer (km^2)
=	1,000,000 sq meters

Volume Measure

10 milliliters (ml) =	1 centiliter (cl)	
10 centiliters =	1 deciliter (dl)	= 100 milliliters
10 deciliters =	1 liter (l)	= 1,000 milliliters
10 liters =	1 dekaliter (dal)	
10 dekaliters =	1 hectoliter (hl)	= 100 liters
10 hectoliters =	1 kiloliter (kl)	= 1,000 liters

Weight

10 milligrams (mg) =	1 centigram (cg)	

10 centigrams =	1 decigram (dg)	= 100 milligrams
10 decigrams =	1 gram (g)	= 1,000 milligrams
10 grams =	1 dekagram (dag)	
10 dekagrams =	1 hectogram (hg)	= 100 grams
10 hectograms =	1 kilogram (kg)	= 1,000 grams
1,000 kilograms =	1 metric ton (t)	

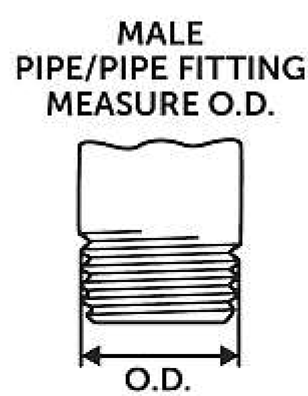
How to Measure Pipe and Fitting Sizes

Convert Actual Diameter to Nominal Diameter

The easiest way to find what nominal pipe size you need is to use follow these steps and use the conversion chart below.

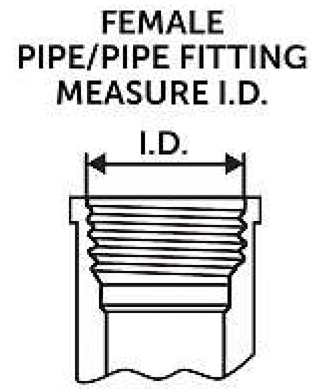
For Male Threads

1. Measure the Outside Diameter (OD) of your pipe or pipe fitting:
   - Wrap a string around the pipe
   - Mark the point where the string touches together
   - Use a ruler or measuring tape to find the length between the tip of the string and the mark you made (circumference)
   - Divide the circumference by 3.14159
2. Use the chart on this page to find the nominal diameter (pipe size).



For Female Threads

1. Measure the Inside Diameter (ID) of your pipe or pipe fitting (use a ruler or tape measure).
2. Use the chart on this page to find the nominal diameter (pipe size).



Nominal Diameter Conversion Chart

(All Measurements in Inches)

Outside or Inside Diameter	**Decimal Equivalent**	**Nominal Diameter**	**Typical Threads Per Inch**
5/16	0.313	1/16	27
13/32	0.405	1/8	27
35/64	0.540	¼	18
43/64	0.675	3/8	18
27/32	0.840	½	14
1-3/64	1.050	¾	14
1-5/16	1.315	1	11-1/2
1-21/32	1.660	1-1/4	11-1/2
1-29/32	1.900	1-1/2	11-1/2
2-3/8	2.375	2	11-1/2

2-7/8	2.875	2-1/2	8
3-1/2	3.500	3	8
4	4.000	3-1/2	8
4-1/2	4.500	4	8

Pipes vs. Tubing

Pipe and tubing are not measured the same way. Tubing is measured and named based on the actual outside diameter of the tube.

PEX, or Cross-Linked Polyethylene Tubing, is another technology fast becoming popular, and it is measured and named by inside diameter.

Example:

Pipe vs. Tubing	**Outside Diameter**
1/2" size pipe	27/32"
1/2" size tubing	1/2"

TYPES OF DRAWINGS

Details and sections

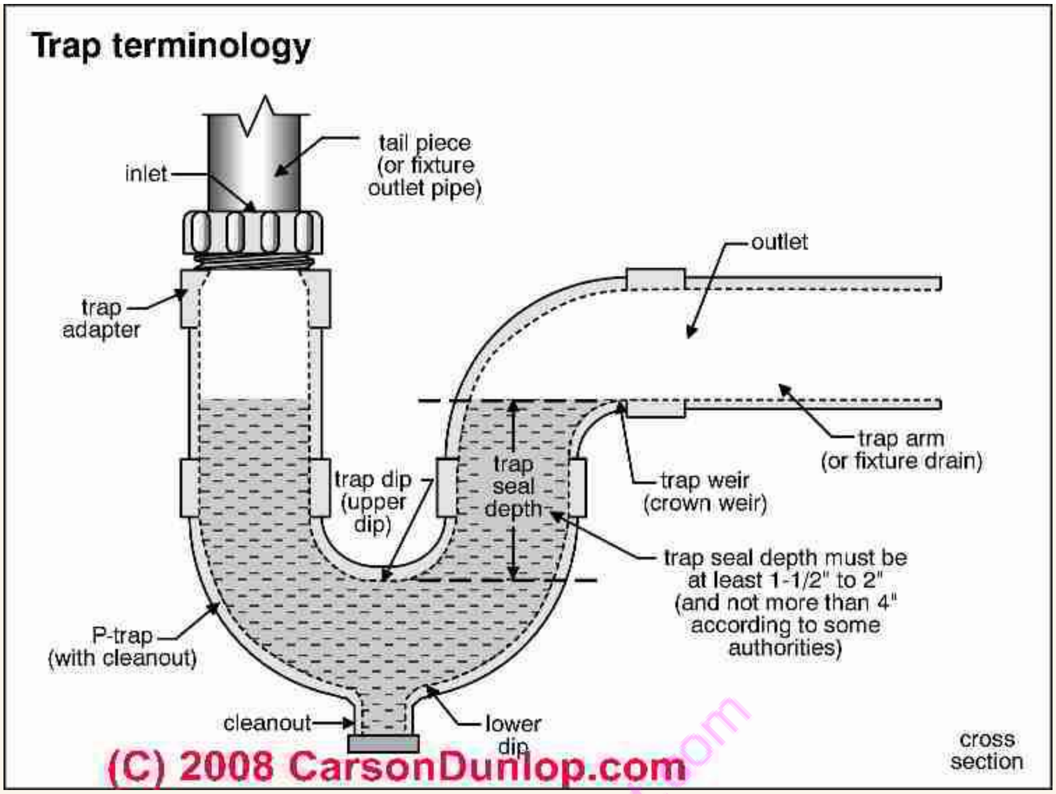
Section view is a view used on a drawing to show an area or hidden part of an object by cutting away or removing some of that object. ν The cut line is called a "cutting plane", and can be done in several ways. ν The following slides will help show the several methods or types of "section views".

What is a cutting plane?

The place where the building is cut away is called “cutting plane”and the location of the imaginary cutting plane is typically indicated by a cutting plane line that consist of long dashes set off by two shorter ones.

6 TYPES OF SECTIONAL VIEWS

1. **Full sections.** This is the most common section (called a full section) with the imaginary laser cutting a line across the entire construction, offering a view of a portion of the building with the rest of it put to one side.
2. **Half sections or views.** In this type of section, only half of the space or object is cut away. This allows you to see part of it in elevation, while the other part of the drawing gives a glimpse inside.
3. **Offset sections or views.** In an offset section, the cutting plane does not follow a straight line. This might be used, for example, if the architect or engineer wanted to show a section of one room but also the section of another that is located behind it. In other words, while the cutting planes are parallel, the one in one portion of the drawing may be some distance from the plane in another portion.
4. **Broken out sections or broken views.** With these drawings, only a small portion of the object or space is shown in section. Instead of a section line, the portion that is shown in section is indicated by an irregular cut line.
5. **Revolving sections or view.** With this type of section, a space or detail is shown with a cutting plane at an angle, and then the section is rotated so that the cutting plane faces the viewer.
6. **Removed sections.** With a removed section, only a portion of the drawing is shown in section, and this detail is removed to the side. The scale of the section will be different from the main drawing, providing a more detailed perspective.



Cross section.

Line drawing

Different Types of Lines in Engineering Drawing

A single drawing is composed of many basic elements, and different types of lines play distinct roles. A variety of line styles graphically represent physical objects, including visible, hidden, center, cutting plane, section, and phantom. Each style can be divided into different types. Let's see what types of lines used in engineering drawings.

A: **Continuous Thick Line**

This line is used to display the outline and edges of the main drawing, done with a pencil softer than HB.

Continuous Thick Line

B: **Continuous Thin Line**

This line is basically used for dimension, extension, projection, leader line, etc. A harder pencil should be used, such as a 2H pencil.

Continuous Thin Line

C: **Continuous Thin Free Hand Line**

This line is used to show short break or irregular boundaries.

Continuous Thin Free Hand Line

D: **Continuous Thin Zigzag Line**

This line is used to show long break.

Continuous Thin Zigzag Line

E: **Dashed Line**

This line is used to show hidden edges of the main object.

Dashed Line

F: **Chain Thin Line Long-Dotted (Dashed Thin Lines with Dots)**

This line is used to represent the center line for circles and arcs.

Chain Thin Line Long-Dotted

G: **Chain Thin with Thick Ends**

This line is used to represent the location of a cutting plane.

Chain Thin with Thick Ends

H: **Long Thin Dashed and Double Short Dashed Lines**

This line is located in front of cutting planes, outlines of adjacent parts, censorial Lines, and to state center of gravity.

Long Thin Dashed and Double Short Dashed Lines

Free hand drawing is also used to quickly present an idea in a graphical form to non-technical peoples.

Free hand sketching

It improves the communication between all the members of a team and also between the customer. Free Hand Sketching is such a drawing which is drawn without measuring instruments.This drawing is drawn with the help of pencil and eraser only.Such drawing is drawn before every type of actual drawing because it takes less time.After doing such drawing, it is pondered over, and necessary alterations are made in it if needed.Then the actual drawing is prepared.

Free-Hand Sketching Instruments.

Importance of Free Hand Sketching.

Free hand drawing has much importance in practical works because a draftsman has to check the drawings of every object from the engineer.

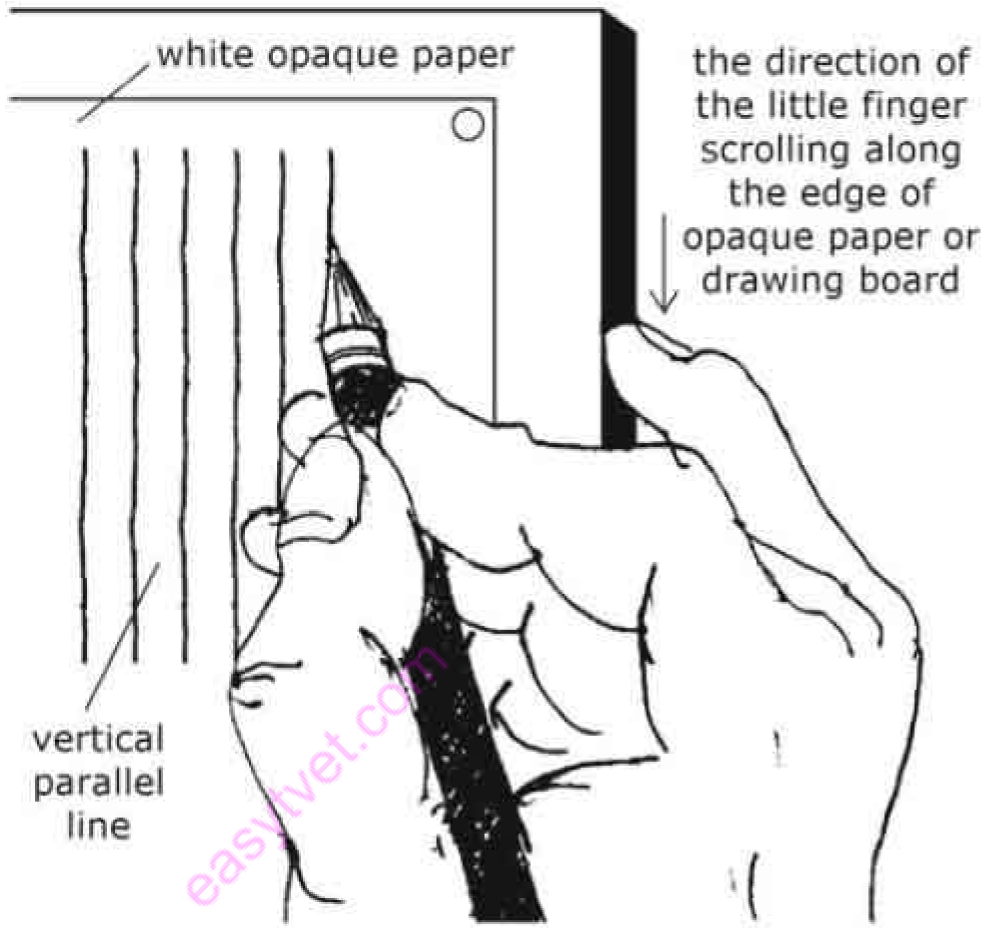
At the checking of complete drawing, much time is wasted on the alterations, if needed.

Sketching of Lines in Free Hand Drawing.

i). Sketching of Vertical Lines.

A vertical line is drawn from the top to the bottom of the drawing sheet.

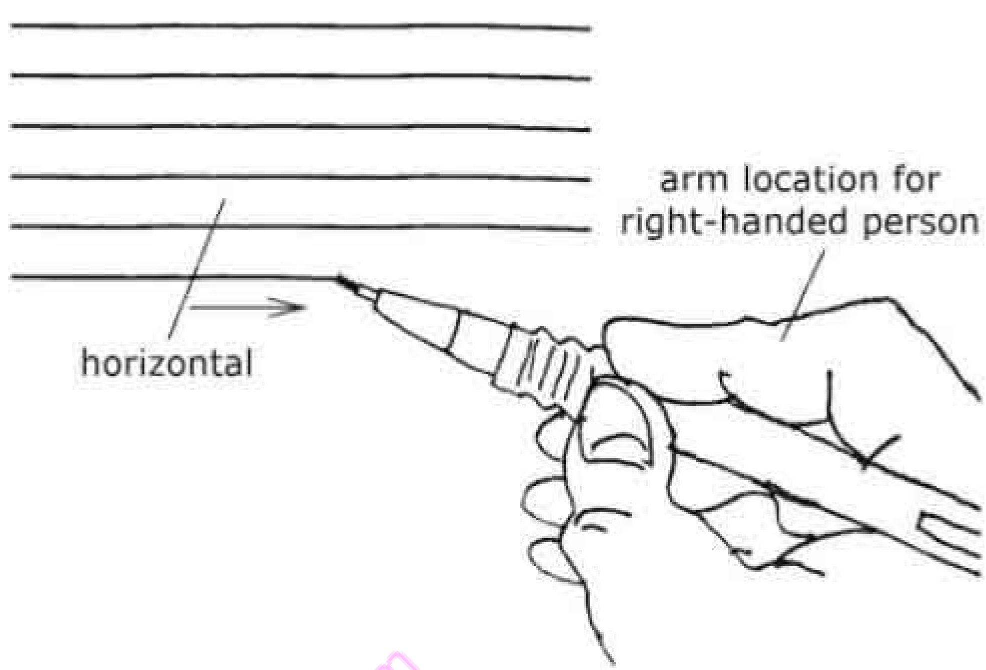
It takes a lot of practice to draw vertical lines.



Holding the pencil when drawing *vertical straight lines* [4]

(ii). Sketching of Horizontal Lines.

When sketching horizontal lines, your hand and forearm should turn at the elbow, and the edge of your hand should slide horizontally on the paper.



Freehand sketching of *horizontal parallel lines*

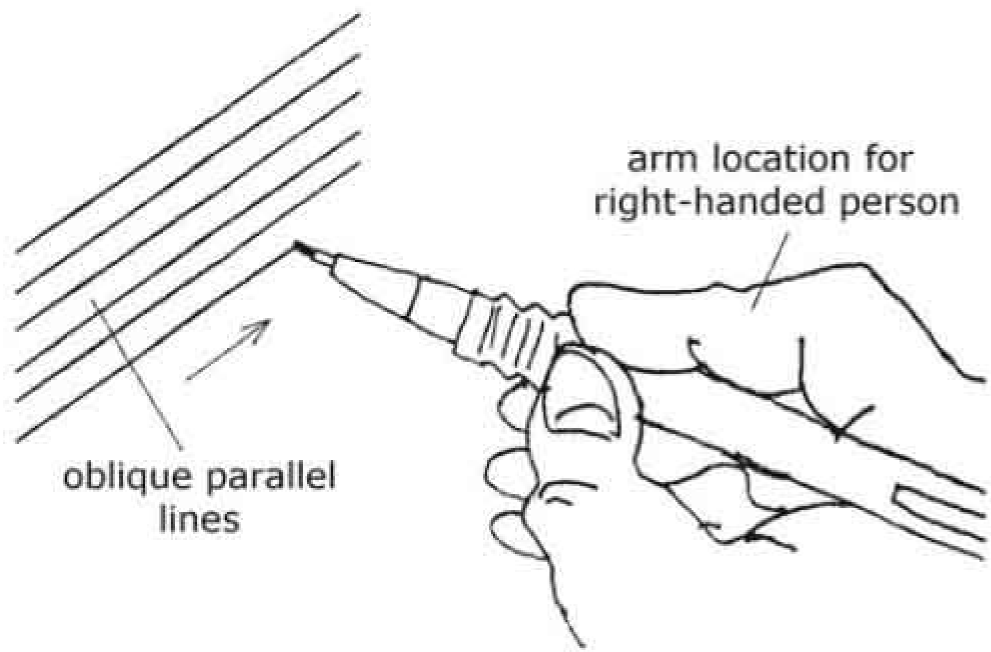
When drawing a horizontal line, you should first try drawing a line in the air to see how the line goes.

Then apply a little pressure on the pencil tip and draw a horizontal line lightly.

(iii). Sketching of Oblique Lines.

The oblique lines are drawn from the one corner of the page to the other diagonally.

Usually, the right-handed people draw sloping or oblique lines from the bottom left to the top right of the paper.

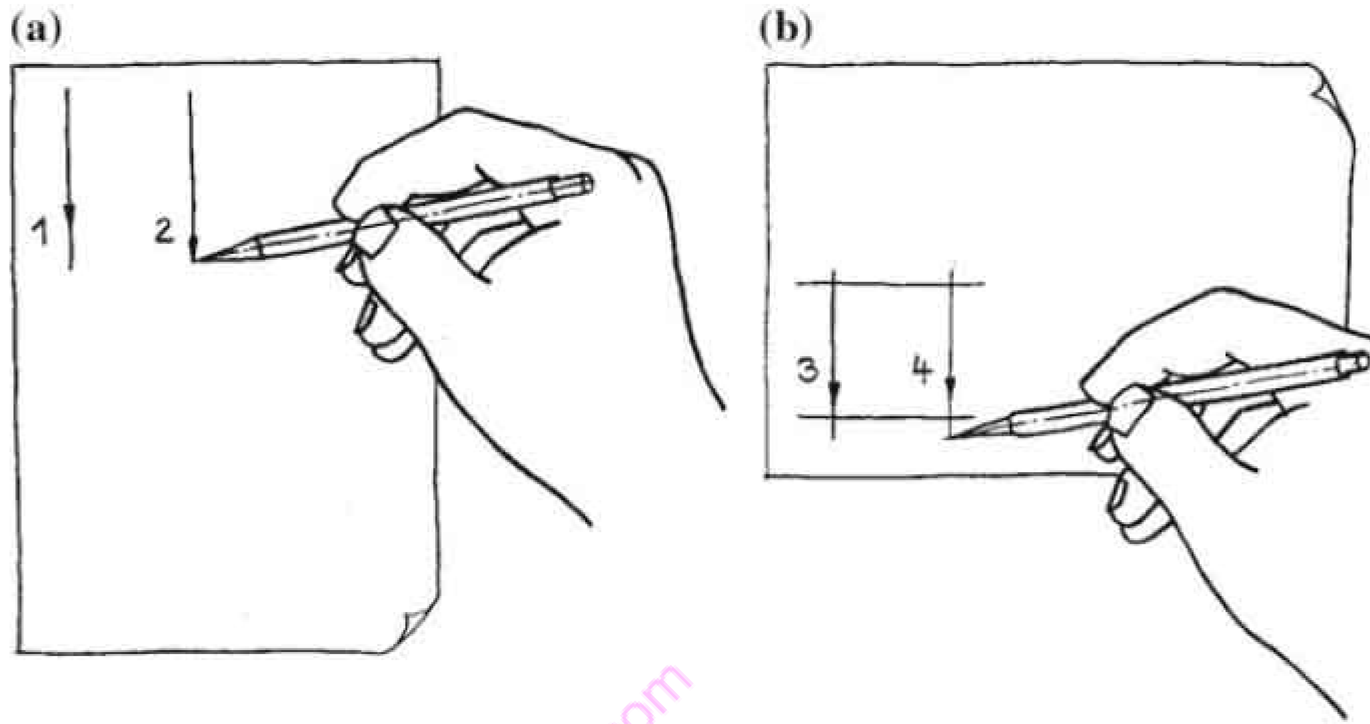


However, the sketching can be made much easier by just rotating the paper into a position where you are going to draw an oblique line.

2. Sketching of Rectangles.

A rectangle is a common shape in technical drawings. To draw rectangles via free hand sketching different techniques are used.

They can be drawn in several ways, but the easiest way to draw a rectangle is by drawing vertical or horizontal lines and rotating the paper at 90 degrees angle.

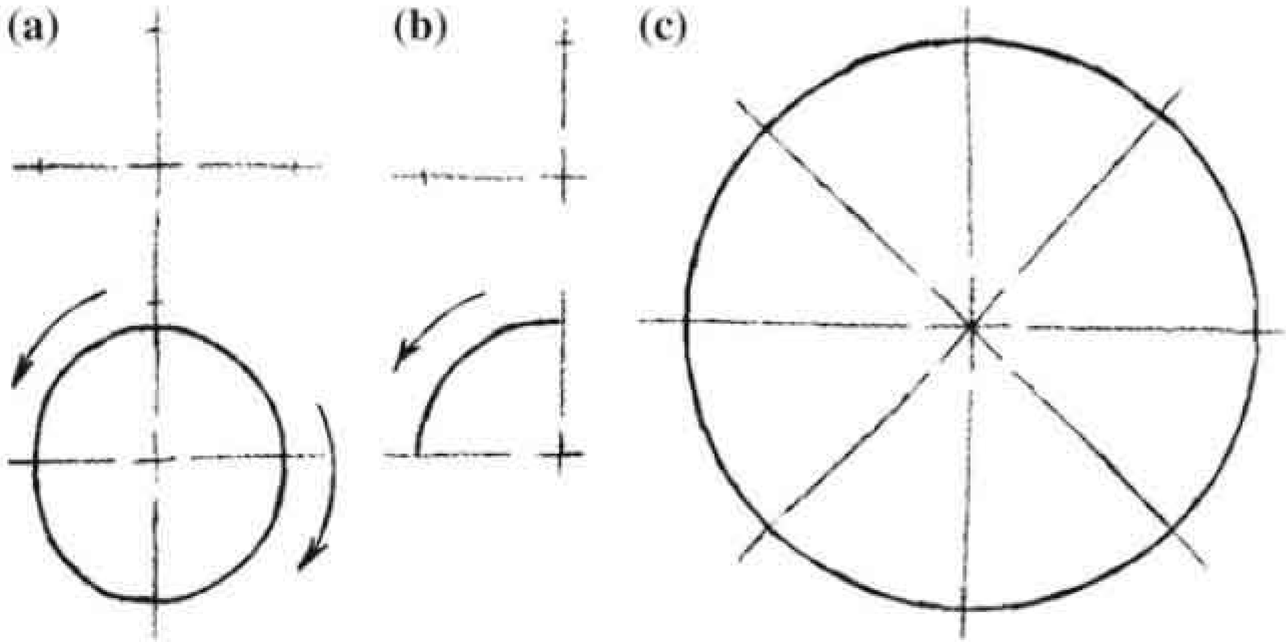


3. Sketching of Curved Lines.

Curved lines in the drawing can be arcs, circles, etc.

To draw a circle, first of all, you should draw a center line and mark it with radii.

Shape the radii points into a box, inside in which you can draw a circle.



Sketching a circle and an arc [19]. Principles: two arcs for small circle (a), sketchin
into clockwise direction (b), larger circle with eight arcs (45 degrees) (c)

First of all, sketch the top-left part of the circle (rotate the pencil in an anti-clockwise direction) then draw the bottom-right part of the circle (rotate the pencil in a clockwise direction).

Pictorial Drawing

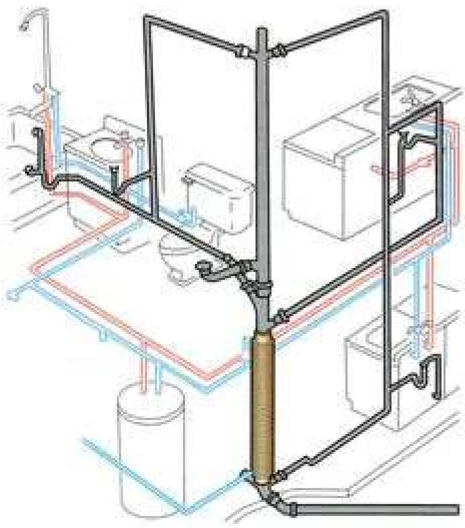
A Pictorial drawing provides a 3D image to help understand the shape of an object or to assist in interpreting a drawing. There are 3 main ways to draw a pictorial drawing,

1. Isometric, 2. Oblique, 3. Perspective.

(Other methods of Pictorial drawings include dimetric drawing, trimetric drawing)

1. Isometric drawing

Definition – An Isometric drawing is a pictorial representation of an object in which all three dimensions are drawn at full scale. The term isometric means “equal measurement”.



Isometric drawings

The isometric is one class of orthographic projections. (In making an orthographic projection, any point in the object is mapped onto the drawing by dropping a perpendicular from that point to the plane of the drawing.) An isometric projection results if the plane is oriented so that it makes equal angles (hence “isometric,” or “equal measure”) with the three principal planes of the object. Thus, in an isometric drawing of a cube, the three visible faces appear as equilateral parallelograms; that is, while all of the parallel edges of the cube are projected as parallel lines, the horizontal edges are drawn at an angle (usually 30°) from the normal horizontal axes, and the vertical edges, which are parallel to the principal axes, appear in their true proportions.

Stage 1: Construction

This should be done with a hard pencil (3H), used lightly, and the strokes with the pencil should be rapid. Slow movements produce wavy, uncertain lines. Since these constructed lines are very faint, errors can easily be erased.

Stage 2: Lining in

Carefully line in with a soft pencil (HB), following the construction lines drawn in stage 1. The completion of stage 2 should give a drawing that shows all the details and you may decide, particularly in an examination, not to proceed to stage 3

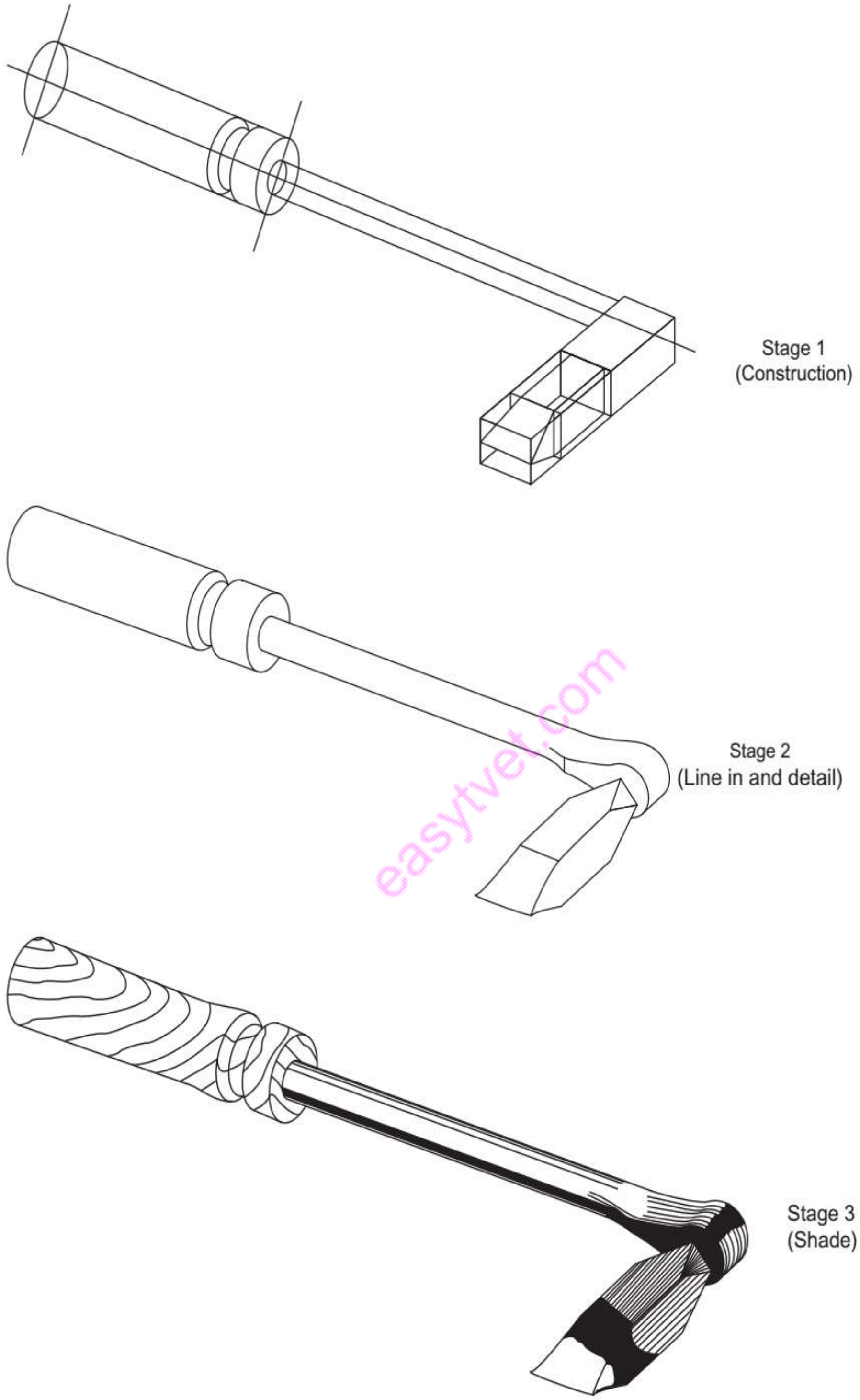
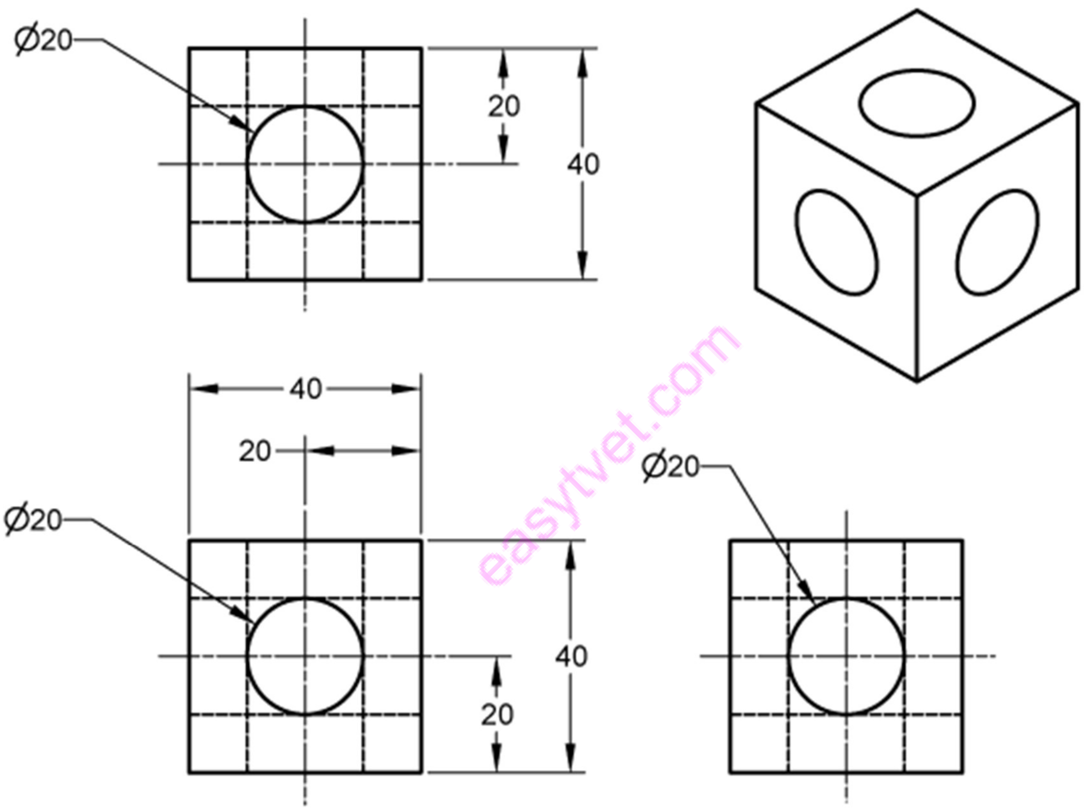


Figure 162 3 stages of freehand sketching

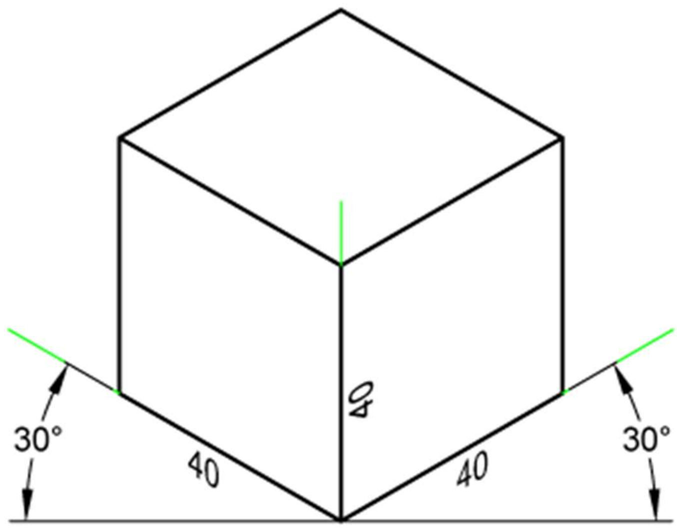
Stage 3: Shading

Drawing Circular Features

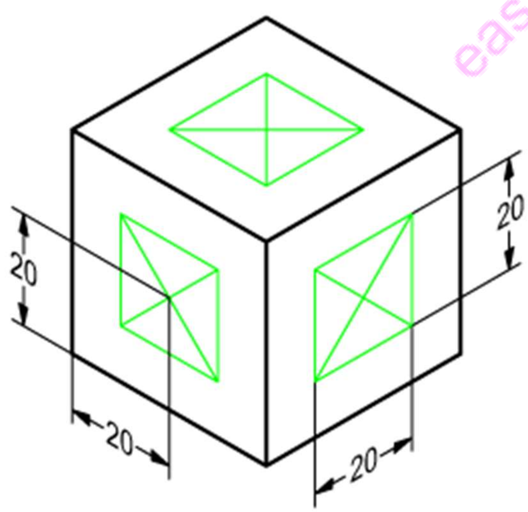
Circular features of an object appear as ellipses on an isometric pictorial.



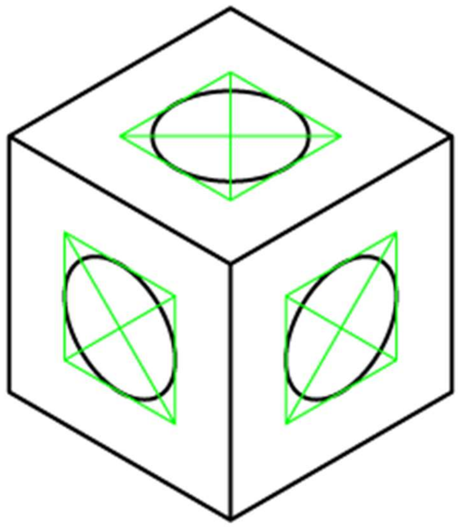
Step 1) Draw the linear features of the object using the procedure previously described.



Step 2) Draw a box whose diagonals meet at the center of the circle and the length of the sides are equal to the circle's diameter.



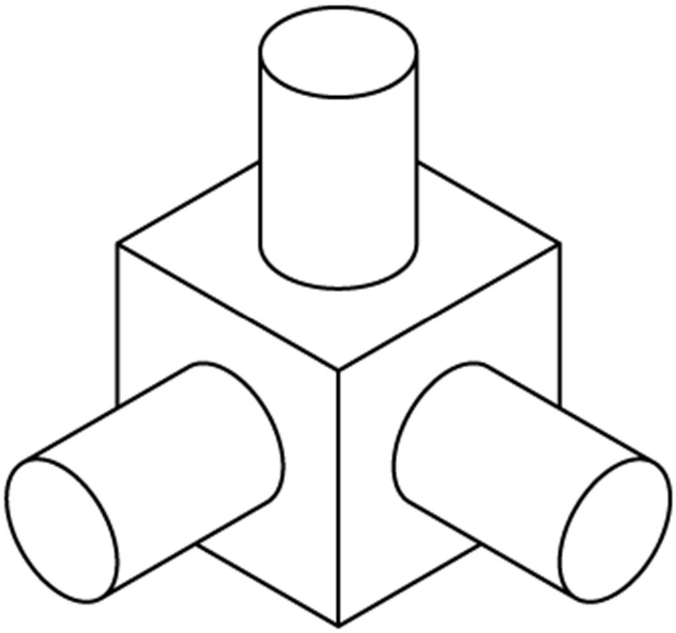
Step 3) Draw an ellipse in the box whose major axis is aligned with the long diagonal of the box. The ellipses touch the box at the midpoint of its sides.



The same procedure is used for creating radii except that the unwanted part of the ellipse is erased or trimmed.

Cylindrical Features

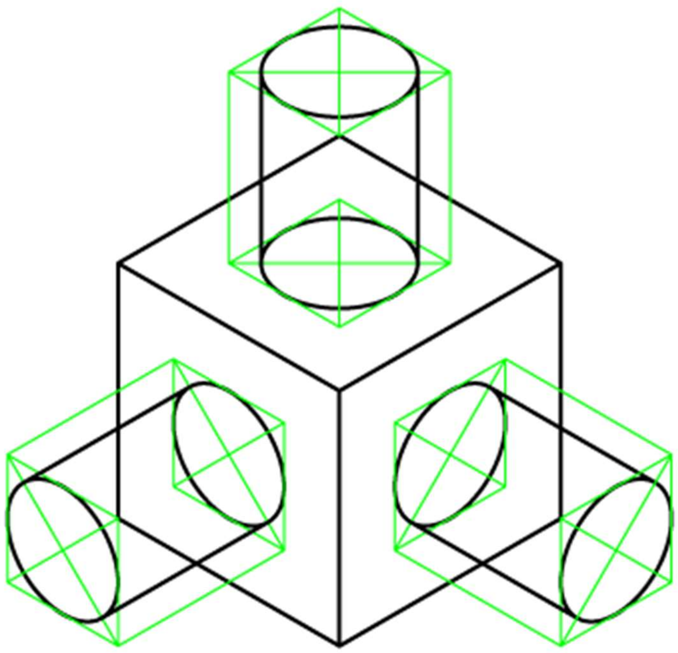
Drawing cylinders in an isometric pictorial is just a matter of drawing two circles and adding some connecting lines.



Step 1) Draw a defining box. The height is equal to the height of the cylinder and the width and depth are equal to the diameter of the cylinder.

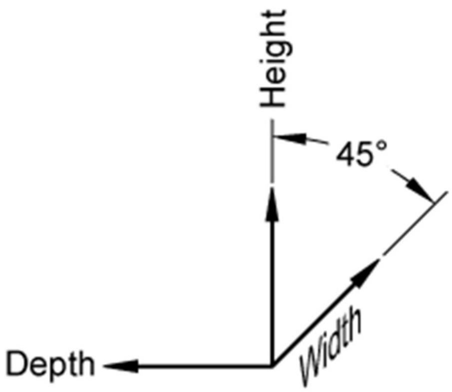
Step 2) Draw diagonals and ellipses in boxes that define the beginning and end of the cylinder.

Step 3) Draw two lines that connect the two ellipses. The lines will start and end at the intersection between the ellipse and the major axis diagonal.



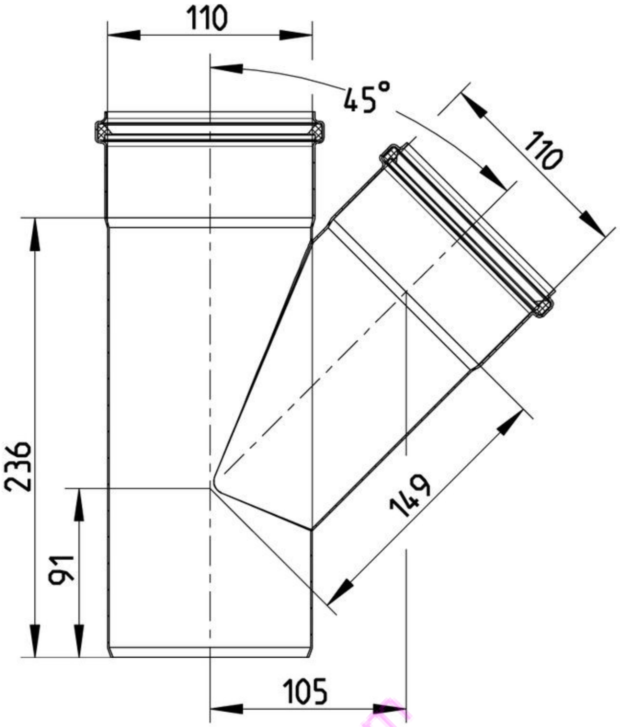
Oblique Axes

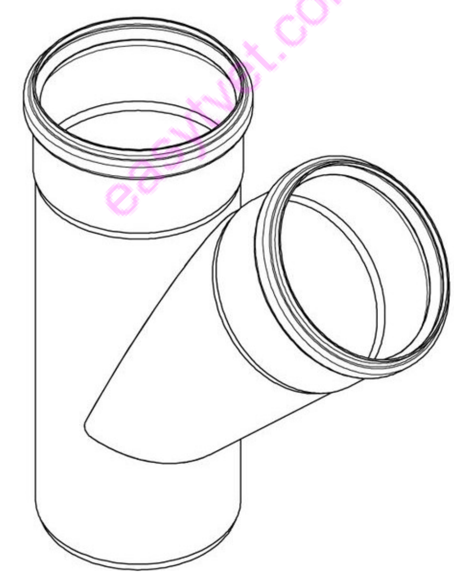
Oblique pictorials are drawn in a coordinate system where only one axis is at an angle from the horizontal. The angle of this axis may range between 0 and 90 degrees; however, the most commonly used angle is 45 degrees.



Oblique axes

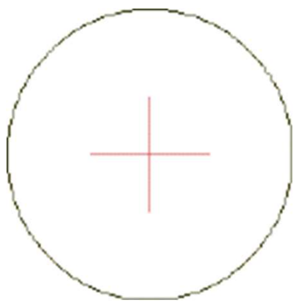
The features drawn on the plane defined by the vertical and horizontal axes are drawn at full scale and true shape. The linear features drawn on the angled axis may be full scale (cavalier projection) or may be drawn foreshortened. The most common, is half scale (cabinet projection, as shown in the figure).



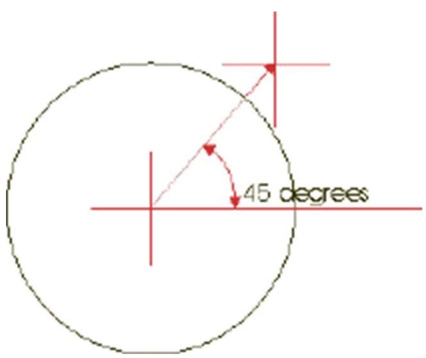


OBLIQUE PROJECTION - DRAWING CYLINDERS

Drawing cylinder in oblique projection ius quiet simple if the stages outlined below are followed.In comparison with other ways of drawing cylinders(for example,perspective and isometric)using oblique projectin is relatively easy.

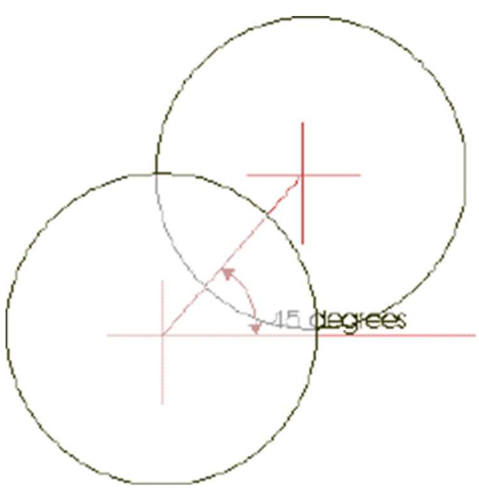


STAGE ONE: Draw a vertical and horizontal centre lines to indicate the centre of a circle, then use a compass to draw the circle itself.

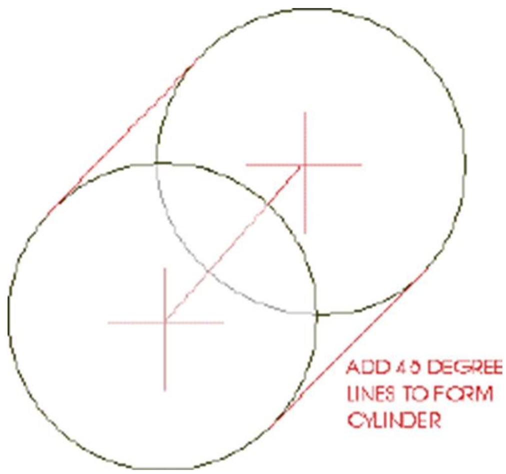


STAGE TWO: Draw a 45 degree line to match the length on the cylinder. At the end of this line draw vertical and horizontal centre lines.

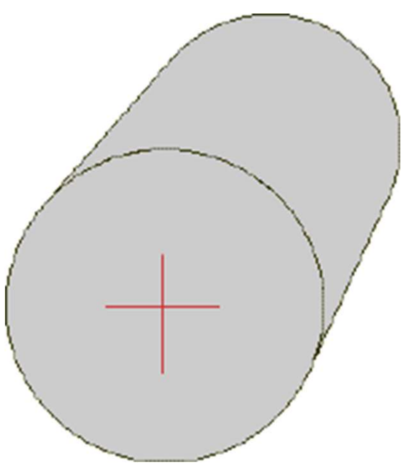
Remember the general rule for oblique is to half all distances projected backwards. If the cylinder is 100mm in length the distance back must be drawn to 50mm.



STAGE THREE: Draw the second circle with a compass.



STAGE FOUR: Draw two 45 degree lines - to join the front and back circles.



STAGE FIVE: Go over the outline of the cylinder with a fine pen or sharp pencil. Add shade - if required.

Isometric Pipework Drawings

Piping isometric drawing is an isometric representation of single pipe line in a plant. It is the most important deliverable of piping engineering. Piping fabrication work is based on isometric drawings.

Piping isometric drawing consists of three sections. Main graphic section consists of isometric representation of a pipe line route in 3D space, which includes following information:

i. Line number.
ii. Flow Direction.
iii. Support Tags and location.
iv. Piping Components location.
v. Weld Locations.

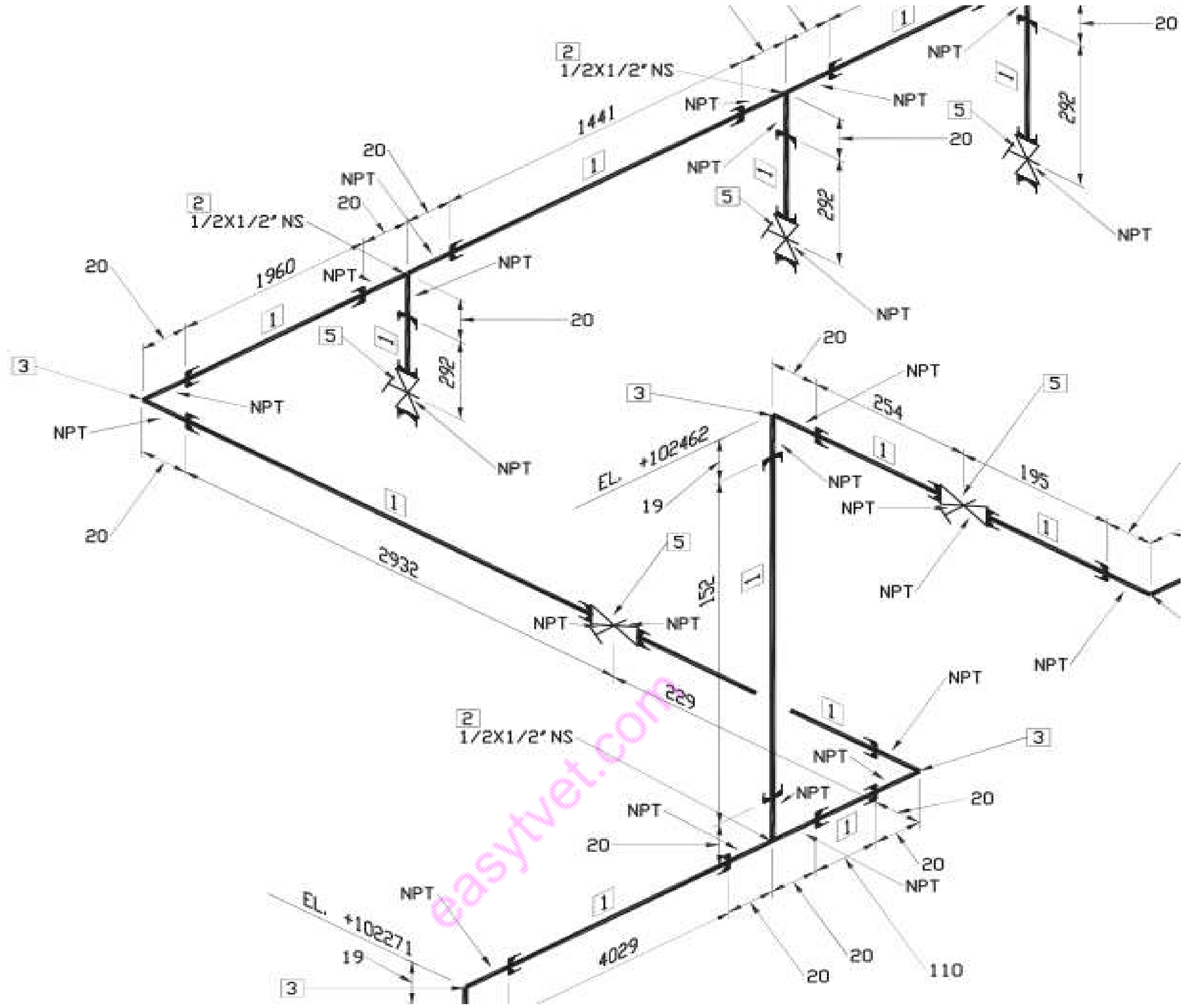
Section on left or right side of drawing consists of Bill of Material Section for the portion of line shown in isometric graphic. It includes following information for all components:

i. Component description.
ii. Component material code.
iii. Nominal size.
iv. Quantity.
v. Whether shop material or field material.
vi. Number of spools.

Title bar section at the bottom consists of following information:

- Project details such as client name
- Engineering office name
- Project name
- Project number

Figure 163: A pipework isometric drawing



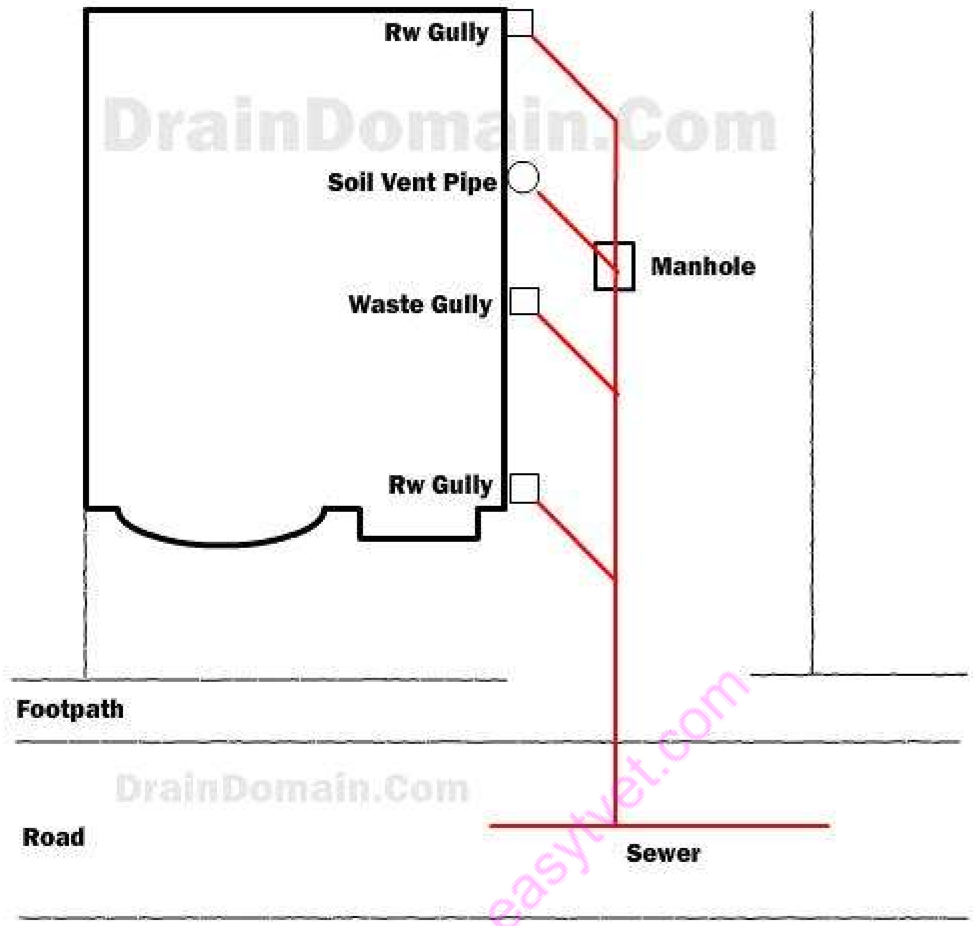
Perspective drawing

Perspective Drawing is a technique used to represent three-dimensional images on a two-dimensional picture plane.

There are three important tools for perspective drawing:

The horizon line; the horizon line appears to us as a clear separation between the ground and the sky.

Vanishing points and vanishing lines; is where all parallel lines intersect and is always on the horizon line.



Types of perspective drawing

There are typically three types of perspective drawing: one-point perspective, two-point perspective, and three-point perspective.

One-point perspective:

One-point perspective is often used for compositions that look at objects from the front. Lines extending from the foreground to the background gather (converge) at one point. The point of convergence is called the “vanishing point”.

The vanishing point will always be on the horizontal line, or “eye level” of the scene, which represents the height of the eye or camera of the observer.

Two-point perspective:

Two-point perspective is used for compositions that look at objects at an angle. As it is close to what the human eye normally sees, it is the most used perspective when drawing manga backgrounds and illustrations.

In one-point perspective, lines converged on one point from the background to the foreground. In two-point perspective, in addition to depth, lines representing width also converge.

Three-point perspective:

Three-point perspective is used for drawing compositions that are looking up at a large object or looking down from a high place.

3.2.1.4 Learning Activities

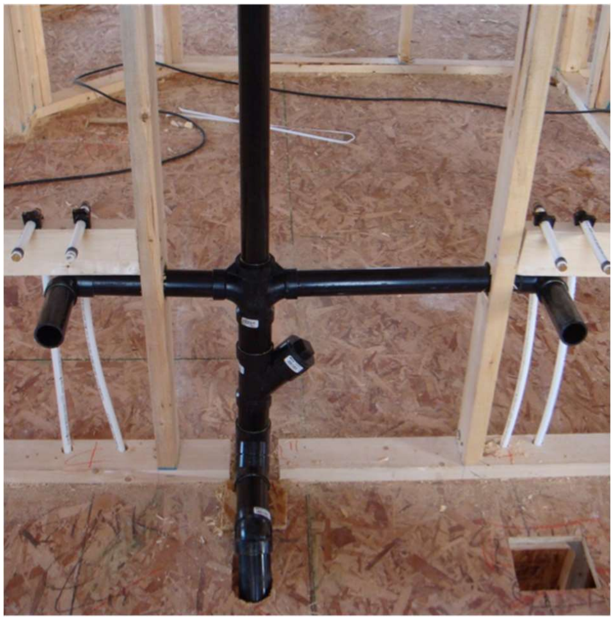
Create Piping Isometric Drawings

Have students create an isometric drawing based on an existing system of pipe. See below for sample pictures and drawings that could be created. As students gain skill, more complex systems could be shown and drawn.

Teacher Notes

- The shoulders of the fittings are drawn parallel to the opposing outlet.
- In terms of classroom management, it is likely easiest to show pictures of small systems on a projector rather than guiding students to draw isometrics in a lock-step format.

Below are sample piping arrangements and the isometrics that would represent them.



Materials Required

- Scale rule
- Pencils
- Eraser
- Drawing paper
- Drawing board
- T-square

3.2.1.5 Self-Assessment

1. Define the following;
   - **i.** Working drawings
   - ii. Bills of quantities
2. Which are the three types of perspective drawing?
3. There are 3 main ways to draw a pictorial drawing, name them.
4. List the instruments needed for the drawing of free hand sketching.
5. State where the following types of lines are used**;**
   - i. Continuous thick line
   - ii. Continuous thin line
   - iii. **Continuous Thin Zigzag Line**

3.2.1.6 Tools, Equipment, Supplies and Materials

May include but not limited to:

- i. Drawing boards
- ii. T squares
- iii. Set squares
- iv. Drawing sets
- v. Drawing paper
- vi. Protractors
- vii. Eraser Shield
- viii. Pencils
- ix. Erasers
- x. Masking tapes
- xi. Paper clips
- xii. Drawing curves
- xiii. Technical drawing software

3.2.1.7 References

- Mays, L., 2001. Water resources engineering. New York: Wiley.

- Cauldwell, R., 2005. Remodel plumbing. Newtown, CT: Taunton Press, pp.24-35.
- Blower, G., (2007). Plumbing. Welwyn Garden City: Pearson Education UK.
- Rendow Yee., (2002). Architectural drawings: a visual compendium of types and methods.
- Thompson., (2007). Architectural design procedures, Second Edition. Architectural Press
- https://en.wikipedia.org/wiki/Water_distribution_system

3.2.1.8 Model answers.

1. **Define the following;**
   i. **Working drawings -** A comprehensive set of drawings used in a building construction project.
   ii. **Bills of quantities**- is a measure or price of the amount of materials and labor and other items required for the building work.
2. Which are the three types of perspective drawing?
   i. **One –point perspective**
   ii. **Two-point perspective**
   iii. **Three –point perspective.**
3. There are 3 main ways to draw a pictorial drawing, name them.
   i. **Isometric**
   ii. **Oblique**
   iii. **Perspective**
4. List the instruments needed for the drawing of free hand sketching.
   i. **Soft Lead Pencil.**
   ii. **Eraser.**
   iii. **Sharpener.**
   iv. **Drawing Sheet.**
   v. **Graph Sheet.**
5. State where the following types of lines are used;
   i. **Continuous Thick Line**

This line is used to display the outline and edges of the main drawing, done with a pencil softer than HB.

ii. **Continuous Thin Line**

This line is basically used for dimension, extension, projection, leader line, etc. A harder pencil should be used, such as a 2H pencil.

iii. **Continuous Thin Zigzag Line**

This line is used to show long break.

3.2.2 Learning outcome 2: Quantify drainage materials

3.2.1.1 Introduction to the learning outcome

This learning outcome is important when selecting components and provides a description of the various types of pipes, fittings, and joining methods used in drainage systems. Then a detailed description is given of the components, including cleanouts, drains, interceptors, traps, and valves, which permits selection of the most appropriate components for a given installation.

3.2.1.2 Performance Standard

1. Drainage materials and supplies are identified based on the drawings and specifications.
2. Materials are estimated based on drawings and specifications
3. Materials cost estimates are calculated from the market rates
4. A schedule of materials is developed based on the drawing.

3.2.1.3 Information Sheet

Definitions of terms

- **Fittings** are any pipe parts used to join two sections of pipes.

- **A plumbing fixture** is an exchangeable device which can be connected to an existing plumbing system to enable a particular use.
- **Specification** is a precise description of the materials and methods of workmanship to be employed while carrying out the contract work
- **Schedules** give tables of information on ranges of similar item.
- **Bills of quantities-**is a measure or price of the amount of materials and labour and other items required for the building work.

Drainage Materials and Supplies

Materials for Drain Pipe

The materials used for manufacturing drain pipes are clay, concrete, and plastics. Important criteria for pipe quality and for selecting the most suitable type of pipes are: resistance to mechanical and chemical damage, longevity, and costs .Mechanical damage and chemical deterioration may occur during transport and handling, or after the pipe has been installed. In addition, the lifetime of the pipes should not be excessively shortened by deterioration in mechanical or chemical properties in the course of time. The costs are the total costs for purchase, transport, handling, and installation.

The selection of components and materials for pipes and fittings in drainage system installations depends on various factors which include;

- **Total installed cost**. This includes the cost of the pipe and fittings, assembly of the joints, handling, allowance for physical damage, and the cost of the support system for the piping.
- **Corrosion resistance of the pipe and fittings**. This is a measure of the ability of the pipe and fittings to resist both the internal corrosive effects of the effluent likely to flow through them and the effects of soils on their exteriors. Corrosion can be reduced or eliminated by the application of a suitable coating and lining.
- **Physical strength of the pipe and fittings**. This is a measure of the ability of the pipe and fittings to resist physical damage that may occur either during installation or after being placed in service.
- **Fire resistance of the pipe and fittings**. This is a measure of the ability of the pipe and fittings

a) to remain intact and not fail during a fire and

b) To retain the ability to carry water during a fire.

Drainage materials and supplies include;

1. **Pipes**

Pipes used in drainage systems can be either Metallic or Plastic pipes.

i. **Metallic Pipes**

a) **Cast-iron (Cl) Soil Pipe**

Also known as gray cast-iron pipe, is a pipe fabricated of an iron alloy containing carbon and It is manufactured in three classifications: service (standard) weight, extra heavy weight, and hubless. This pipe usually is lined internally with cement or coal-tar enamel and is coated externally with a variety of materials to reduce corrosion by soils. Cast iron is well suited for use in any part of a drainage and vent system.

Its advantages include the ability to withstand moderate external pressure (such as that resulting from burial in soil), good fire resistance, low flow resistance, and good corrosion resistance in most soils. Some piping of this type has been in use for over 100 years.

Disadvantages include brittleness (it is subject to breakage when roughly handled), low corrosion resistance in aggressive soils and to highly septic effluent, heavy weight, and high initial cost.

b) **Acid-Resistant Cast-Iron Pipe (AR)**

Acid-resistant cast-iron pipe, commonly called high-silicon iron pipe, is a gray cast-iron alloy containing between 4.25 and 15 percent silicon and small amounts of manganese, sulfur, and carbon. It is manufactured in the same dimensions as cast-iron pipe, but only in the extra heavy weight. It is available with two types of pipe ends: hub and spigot or hubless. The hub-and-spigot ends can be joined by caulking. Hubless pipe is joined by compression couplings. Acid resistant cast-iron pipe is used for drainage of corrosive liquids and in exposed or underground applications where it may be subject to physical damage.

c) Ductile-Iron Pipe

Ductile-iron pipe is fabricated of a cast-iron alloy in which graphite replaces the carbon that is present in cast-iron oil pipe.’ It is available for use either as a gravity sewer pipe or as a pressure pipe in sizes ranging from 3 to 54 in (8 to 135cm) as well as gravity sewer pipe. A cement or bituminous pipe lining can be provided to resist internal corrosion. This type of pipe can be assembled with mechanical joints, gasketed joints, or flanged joints.

The advantages of this type of pipe arc the same as those for cast-iron pipe. It has the additional advantage of a higher-pressure rating and higher external loadbearing capacity. It is not as brittle as cast-iron pipe, permitting rougher handling. Its initial cost is higher than that of cast-iron pipe, though.

d) Steel Pipe

Steel pipe is manufactured in a large number of alloys. It is produced either by extrusion (seamless) or by welding. It is available either plain (black) or galvanized (zinc-plated on the inside, outside, or both). Its wall thickness is expressed as a schedule, with thicknesses ranging from Schedule 10 (lightest) to Schedule 160 (heaviest). The relationship between schedule and wall thickness depends on the pipe diameter. Steel pipe can be obtained with threaded ends (for screwed fittings), plain ends, and beveled ends (for welding). Steel pipe is used for vent systems, for gravity drainage systems where human waste is not discharged, for indirect waste lines, and for pressure piping. Advantages of steel pipe include its availability in long lengths, its availability in varying pipe thickness to meet almost any design pressure, and high internal and external strength.

It has good flow characteristics, good fire resistance, and a low initial cost. A disadvantage is its low corrosion resistance, which results in the need for internal and external corrosion protection-galvanization being the most commonly used method of such protection.

e) Copper Tube

Copper tube used in drainage systems is classified as type DWV (drainage, waste, and vent). It is a seamless tube made from almost pure copper (99.9 percent) and is available only in drawn, or soft, form with plain ends. Joints for this pipe can be either soldered or brazed. Soldering provides adequate strength; it is also less. The pipe is available in diameters from 2 to 6 in (5 to 15 cm). It is primarily used in residential buildings for waste lines and in larger buildings, for local branch lines where human waste is not discharged.

Its advantages include light weight, ease of assembly, and a smooth interior. Its disadvantages include corrosive attack by ordinary sewage, poor fire resistance, and the need for dielectric connections to eliminate galvanic corrosion where this material is connected to iron piping.

f) Brass Pipe

Brass pipe is manufactured from an alloy containing 85 percent. copper and 15 percent zinc. For drainage systems, tubing having plain ends is used. Joints can be either screwed or soldered. Brass pipe is generally used in local branch drainage lines (where this alloy resists specific corrosive drainage effluent) and in alterations to match existing work. The advantages and disadvantages of brass pipe are the same as those for copper tubing, except that brass can be used as a drain pipe under pressure.

g) Lead Pipe

Lead pipe is made from 99.7 percent pig lead; various alloys also are available for special applications. This pipe is joined by wiped joints, burned joints, or flanged mechanical joints. Lead pipe is used for connections to floor-mounted water closets, for radioactive wastes, and for special laboratory corrosive wastes. It is rarely used in modern drainage systems.

1. PLASTIC PIPE

Plastic pipe is fabricated in a great variety of compositions, many of which are suitable for drainage and vent systems. The applicable code is usually the most important factor in determining the use and selection of plastic pipe for such purposes.

Plastic pipe is manufactured in two general types:

- thermoset (TS) and
- Thermoplastic (TP).

Thermoset piping (for example, epoxy and phenolic) is not affected by heat and will remain permanently rigid. It is more resistant to solvents than thermoplastics. Thermoplastic piping softens when subject to heat and rehardens

upon removal of the heat. This process of heating and subsequent rehardening affects the strength of the pipe. Therefore, the selection of plastic pipe must be closely coordinated with the pipe hangers and pipe support system. The advantages of plastic pipe in drainage and vent systems include;

- ✓ excellent resistance to a very wide range of sanitary and chemical effluents
- ✓ resistance to aggressive soils, availability in long lengths
- ✓ low resistance to fluid flow
- ✓ low initial cost.

Disadvantages include;

- ➢ poor structural stability (requiring additional support)
- ➢ susceptibility of some types of plastics to physical changes resulting from exposure to sunlight
- ➢ low resistance to solvents, poor fire resistance
- ➢ lowered pressure ratings at elevated temperatures
- ➢ Production of toxic gases which are released upon combustion of some types of plastic pipe.

a) Polyvinyl Chloride (PVC) Pipe

Polyvinyl chloride pipe (type TS) is available in Schedules 40 and 80 and in diameters up to 20 in (50 cm). Drainage fittings are made in diameters up to 8 in (20cm). Schedule 80 pipe can be joined either by threading or solvent welding, but Schedule 40 pipe can only be joined by solvent welding because it cannot be threaded. This pipe will not burn and is self-extinguishing. However, when subject to conditions of a fire, a toxic gas is developed. PVC is the plastic having the highest mechanical strength and is the plastic most widely used for plastic pipe, but it has very poor resistance to solvents.

b) Polypropylene (PP) Pipe

Polypropylene pipe (type TP) is available in Schedules 40 or 80 and in diameters up to 8 in (20 cm). Joining by heat fusion is recommended. This material is one of the more widely used plastics for drainage piping systems. It is capable of withstanding a wide range of both corrosive and sanitary waste. It is the most resistant to solvents of all the common plastic pipe materials and is only slightly less rigid than PVC..

c) Polyethylene (PE) Pip

Polyethylene (PE) PE pipes and fittings of numerous types and designs have been available for over forty years. The market requirements today have been refined to three general groupings, as follows:

i. **High-density PE** is available in a post-manufactured stress-relieved state (bestpractice PE), or as extruded product with no treatment. It is used mainly for drainage applications where it can withstand higher temperature discharges than PVC. To avoid ovality and installation problems when laying to grade the pipe is best used in straight lengths, normally up to 6 metres long. Jointing is achieved by electrofusion or

ii. **Medium-density PE** is more flexible than the high-density pipe. It has a slightly thinner wall thickness and is capable of withstanding higher internal pressure. It is the preferred material for long-distance drinking-water piping. Because of the application and the robust nature of the material it is generally available in coils of up to 200 metres (650 feet) length, depending upon the diameter. The method of jointing is the same as for high-density PE pipe. In colder climates coiled polyethylene piping can be very difficult to use and may be impractical.

iii. **Low-density PE** is suitable for the irrigation industry, where operating pressures are very low and a high degree of flexibility and low cost is required. Low-density PE pipe and fittings are not acceptable for use for connection to the water mains in many countries because of the low pressure rating of the material and its high leakage rate.

d) Acrylonitrile Butadiene Styrene (ABS) Pipe

Acrylonitrile butadiene styrene (type TP) is available in Schedules 40 and 80 and in diameters up to 12 in (35 cm). Drainage fittings are available only in diameters up to 6 in (15 cm). Joints are made by either solvent welding or threaded connections. Only Schedule 80 can be threaded. Acrylonitrile butadiene styrene (ABS) is slightly more rigid than PVC and is the least resistant to solvents of all the popular plastic materials.

Fittings in Drainage Systems

Codes require that any change in direction of piping in a drainage system be made with fittings. The bends in fittings used in drainage systems should have a radius of curvature large enough to prevent solids from accumulating

and to provide good hydraulic flow characteristics. Fittings that satisfy these characteristics are known as drainage-pattern fittings or sanitary-type fittings; they are required by code to be used in drainage systems.

a) Bends (Sweeps).

Is a fitting used to change the direction of a pipe. Fittings are available with changes at various angles. A bend is a 90^0 fitting; it is available as either a short or long sweep (i.e., short or long radius of curvature).

b) Wye.

A wye is a fitting used to connect a branch pipe into a straight run of piping at a 45" angle. Wyes are available with end connections that are of the same size or with various combinations of reduced pipe sizes in any direction.

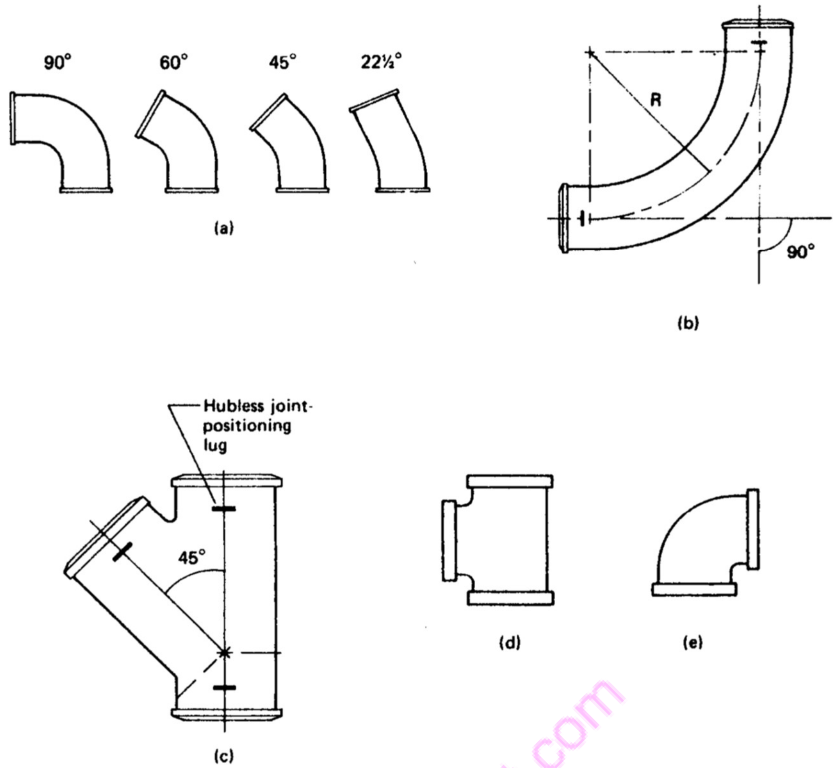
c) Tee.

A tee is a fitting used to connect a branch pipe into a straight run of piping at a right angle. Where flow characteristics are important, such as in the drainage system, codes require that a sanitary tee be used. Where flow is not a consideration, such as in a vent system, standard tees are permitted. They are available with end connections of all similar sizes or in various combinations of reduced pipe sizes in any direction.

d) Elbow.

An elbow is a fitting having a 90" change of direction with a very short radius. It is only suitable for use in vent systems.

***Fig 1.4:** Typical sanitary fittings. (a) 90'. 60°, 45', and $22^{1/2}$" bends; (b) 90' sweep; (c) 45' sanitary tee; (d) standard tee; (e) elbow.*



PIPE SCHEDULES

What are Pipe Schedules?

The schedule number on pipe products relates to the thickness of the wall on the pipe: as the number increases, the thicker the wall thickness becomes. Also, while the schedule number can be the same on different sized pipes, the actual wall thickness will be different. Here are a few

examples:

Pipe size 1.000” Schedule 40 – The actual wall thickness is 0.133”

Pipe size 2.000” Schedule 40 – The actual wall thickness is 0.154”

Pipe size 1.000” Schedule 80 – The actual wall thickness is 0.179”

Pipe size 2.000” Schedule 80 – The actual wall thickness is 0.218”

What we can see here is that the schedule number increases the wall size, and that the wall thickness changes based on the nominal pipe size (NPS).

The best way to see the relationship between pipe size, schedules and wall thicknesses is simply to refer to a conversion chart (below):

PIPE SCHEDULES & WEIGHTS					
		SCHEDULE 40		SCHEDULE 80	
NOMINAL PIPE SIZE	OUTSIDE DIAMETER	Wall Thick.	Wt. Per Ft.	Wall Thick.	Weight Per Ft.
1/8	0.405	0.068	0.245	0.095	0.315
1/4	0.540	0.088	0.425	0.119	0.535
3/8	0.675	0.091	0.568	0.126	0.739
1/2	0.840	0.109	0.851	0.147	1.088
3/4	1.050	0.113	1.131	0.154	1.474
1	1.315	0.133	1.679	0.179	2.172
1-1/4	1.660	0.140	2.273	0.191	2.997
1-1/2	1.900	0.145	2.718	0.200	3.631
2	2.375	0.154	3.653	0.218	5.022
2-1/2	2.875	0.203	5.793	0.275	7.661
3	3.500	0.216	7.576	0.300	10.250
3-1/2	4.000	0.226	9.109	0.318	12.510
4	4.500	0.237	10.790	0.337	14.980
5	5.563	0.258	14.620	0.375	20.780
6	6.625	0.280	18.970	0.432	28.570
8	8.625	0.322	28.550	0.500	43.390
10	10.750	0.365	40.480	0.500	54.740
12	12.750	0.375	49.560	0.500	65.420

There are several schedule numbers used on pipe, such as schedules: 5, 5S, 10, 20, 30, 40, 60, 80, 100, 120, 140, 160, STD, XS and XXS. The most common ones used are schedules 40 and 80

What does Nominal Pipe Size or NPS mean?

The NPS size represents the approximate inside diameter (not outside) of the pipe; if the schedule number on a set size is changed, it does effect the inside diameter (ID) but not the outside diameter (OD). In 1927 the American Standard Association replaced the previously used Iron Pipe Sizing (IPS) with Nominal Pipe Sizing (NPS). This North American standard is used on pipes for high or low pressures and temperatures. Example:

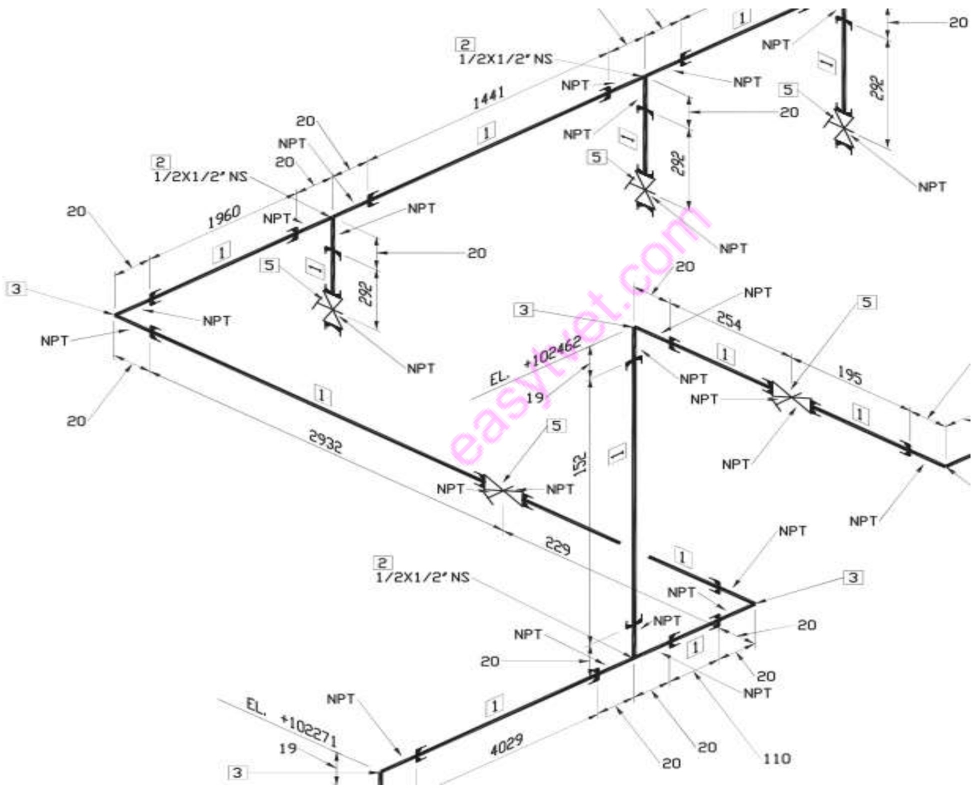
NPS	OD	Schedule #	Wall Thickness	ID
1.000”	1.315”	SCH 40	0.133”	1.049” (approx.)
1.000”	1.315”	SCH 80	0.179”	0.957” (approx.)

All pipes are specified using the NPS and schedule numbers. It is the schedule number that determines the approximate inside diameter

Estimation of Drainage Materials and Costing.

The required materials for the drainage system are estimated from the working plumbing drawing from which quantities are taken and the cost drawn out from the existing market.

Fig 1.5: An example of a working plumbing drawing



The Quantities are taken and cost estimates are made in the BQ.

Table 6: *A sample BQ for plumbing works*

ITEM	DESCRIPTION	UNIT	QTY.	RATE SHS.	AMOUNT SHS.
(II)	**INTERNAL PLUMBING**				
A	**PP-R PN20 Pipes:**				
(i)	25mm diameter pipe chased in walls/floors and in ducts	LM	20		
(ii)	20mm diameter Ditto	LM	12		
(iii)	15mm diameter Ditto	LM	12		
	Extra-over PP-R pipework for the following:				
B	**Bends/Elbows:**				
(i)	25mm diameter bends	No.	10		
(ii)	20mm diameter Ditto	No.	10		
(iii)	15mm diameter Ditto	No.	10		
C	**Tees:**				
(i)	25mm x 20mm diameter tees	No	10		

		.			
(ii)	20mm x 15mm diameter Ditto	No.	20		
D	**Sockets:**				
(i)	25mm diameter Sockets	No.	8		
(ii)	20mm diameter Ditto	No.	10		
(iii)	15mm diameter Ditto	No.	10		
E	**Reducers:**				
(i)	25mm x 20mm diameter Reducers	No.	10		
(ii)	20mm x 15mm diameter Ditto	No.	20		
F	**Valves;**				
(i)	25mm diameter PPRC gate valves	No.	3		
(ii)	20mm diameter Ditto	No.	3		
(iii)	15mm diameter Ditto	No.	3		
G	**Pipe clips;**				
(i)	25mm diameter Pipe Clips	No.	5		
(ii)	20mm diameter Ditto	No.	4		

(iii)	15mm diameter Ditto	No.	4		
H	**End Caps;**				
(i)	25mm diameter End Caps	No.	4		
(ii)	20mm diameter Ditto	No.	4		
(iii)	15mm diameter Ditto	No.	4		
I	**Male/Female Screwed adapter;**				
(i)	25mm diameter screwed adapters	No.	10		
	TOTAL CARRIED FORWARD TO NEXT PAGE				

3.2.1.4 Learning Activities

Practical activities

Quantify all the materials and supplies that are required to maintain the drainage system in your institution administration block.

Materials Required

- Pen
- Notebook

- Pencil
- Drawing sheets

3.2.1.5 Self-Assessment

1. What are Pipe Schedules?

The schedule number on pipe products relates to the thickness of the wall on the pipe: as the number increases, the thicker the wall thickness becomes.

Which are the three general grouping/categories of polyethylene (PE) pipes.

i. **High-density**
ii. **Medium-density PE**
iii. **Low-density**

3. Which are the five disadvantages of plastic pipes?
4. Which are the three types of plastic pipes?
5. Drainage system installations?

3.2.1.6 Tools, Equipment, Supplies and Materials

- Pen
- Notebook
- Pencil
- Drawing sheets

3.2.1.7 References

BS 6465: Sanitary installations; Part 7: 7984 Code of practice for scale of provision, selection and installation of sanitary appliances

BS 5503: Specification for vitreous china washdown WC pans with horizontal outlet; Part 1: 7977 Connecting dimensions; Part 2: 7977 Materials, quality, performance and dimensions, other than connecting dimensions

BS 5504: Specification for wall hung WC pans; Part 7: 7977 Wall hung WC pan with close coupled cistern. Connecting dimensions; Part 2: 1977 Wall hung WC pan with independent water supply. Connecting dimensions; Part 3: 7977 Wall hung WC pan. Materials, quality and functional dimensions other than connecting dimensions.

BS 1125: 1973 WC flushing cisterns (including dual flush cisterns and flush pipes)

3.2.1.8 Model answers

1. **What are Pipe Schedules?**

The schedule number on pipe products relates to the thickness of the wall on the pipe: as the number increases, the thicker the wall thickness becomes.

2. **Which are the three general grouping/categories of polyethylene (PE) pipes**.
    i. **High-density**
    ii. **Medium-density PE**
    iii. **Low-density**
3. **Which are the five disadvantages of plastic pipes?**
    - poor structural stability (requiring additional support)
    - susceptibility of some types of plastics to physical changes resulting from exposure to sunlight
    - low resistance to solvents, poor fire resistance
    - lowered pressure ratings at elevated temperatures
    - Production of toxic gases which are released upon combustion of some types of plastic pipe.
4. **Which are the three types of plastic pipes used in drainage?**

- Polyvinyl Chloride (PVC) Pipe
- Polypropylene (PP) Pipe
- Polyethylene (PE) Pipe

5. **What are four factors considered when selecting components and materials for pipes and fittings in drainage system installations?**

- Total installed cost.
- Corrosion resistance of the pipe and fittings
- Physical strength of the pipe and fittings.
- Fire resistance of the pipe and fittings.

3.2.3 Learning Outcome 3: Use drainage tools and equipment

3.2.3.1 Introduction to the learning outcome

This learning outcome enlightens the trainee on the tools and equipment used installing drainage systems as it involves in construction industry.

3.2.3.2 Performance Standard

1. Personal Protective Equipment is used in line with occupational safety and health requirements
2. Drainage tools and equipment are identified based on the requirements of the job.
3. Drainage tools and equipment are used based on manufacturer's instructions.
4. Drainage tools and equipment are cared for and maintained based on manufacturer's manual and workplace place policy.
5. Drainage tools and equipment are stored based on work place policies.

3.2.3.3 Information Sheet

Definitions of terms

- **Tool i**s anything which is held by hand and assists a person to do manual work.
- **Pipe** is a long hollow cylinder used chiefly to convey fluid.

- **Material** is the matter from which a thing is made.
- **Equipment** is a power tool usually run by a motor
- **Maintenance** is the act of keeping tools and equipment in good working condition
- **Repair** is the process of fixing tool or equipment to make it serviceable again.

Tools and Equipment Required

These tools can be broadly classified into two;

- Hand tools -Hand tools include anything from axes to hammers, and screwdrivers to wrenches
- Power Tools require a non-human power source to function properly e.g. External (electricity, compressed air, etc.) or Internal (battery pack, internal combustion engine, etc.).

The tools are further classified into six classes based on the job requirement namely;

1. **Measuring tools**
2. **Cutting tools**
3. **Boring tools**
4. **Driving tools**
5. **Testing tools**
6. **holding tools**

Measuring tools- are tools used to obtain dimensions or angles in a piece of work. They are marked in different units.

Table Table 7: Measuring tools

Name	Uses	Image
inside caliper	used to measure the internal size of a pipe.	
Outside caliper	used to measure the external size of a pipe.	
Steel square	primarily used to measure the accuracy of right angle (90˚ degrees) tried on any surface so as to check its straightness or correspondence to an adjoining surface.	
Pull-Push Rule	Use to measure lengths of pipe for installation	

Cutting tools- is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, plaining and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. Grinding tools are also multipoint tools.

Table 8: Cutting tools

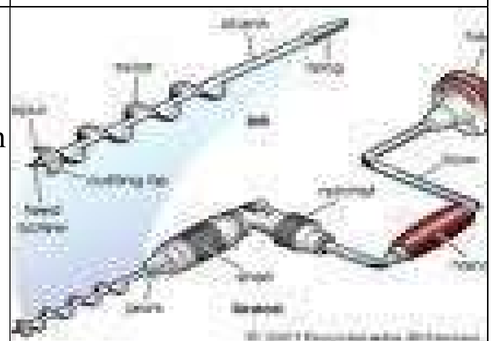
Name	Uses	Image
pipe cutter	used for cutting metallic pipes and tube	

pipe threader	Used for threading pipes.	 
Pipe reamer	used for cleaning the inside portion of the pipe and tube to remove the burst and chips.	
Hacksaw	Used for cutting metal or plastic pipe.	

Boring tools-boring is the process of enlarging a hole that has already been drilled by means of a single-point cutting tool, for example as in boring a cannon barrel. Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole.

Table 9: Boring tools

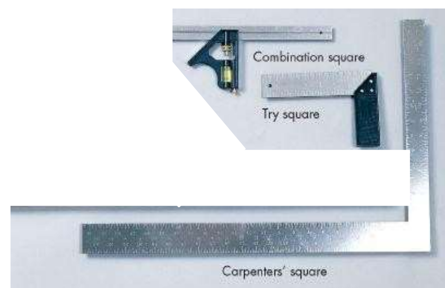
Name	Uses	Image

Electrical drill	Is a power tool that rotates a replaced drill bit to make a hole in wood, plastic or metal. Alternately, a screw driver tip can be installed to turn screw.	
hand drill	Used with drills or bits found around the tang. The tang is the end of the bit of which is held in the brace.	
cold chisel	a tool made from hexagon or octagon-shaped steel and is commonly called cold chisel steel. Its convenient size is for handling. One end is shaped for cutting operations.	

Testing tools-used in finding out the perpendicularity or levelness of the finished work.

Table 10: Testing tools

Name	Uses	Image

Plumb bob or plummet	Used for testing and surveying to position a point on the ground that is not readily visible. Plumb bob is a weight with a pointed tip at the bottom that is suspended from a string and used as a vertical reference line.	
Squares	Used for laying out angles. It has two edges that form a 90° angle.	
Levels	A level has tubes partially filled with colored liquid leaving a trapped air bubble. Used to level a pipe	

1. **Driving tools-**driving tools help hand tools and power tools work together, especially important for the variety of drilling tasks that get done in woodworking.

Table 11:Driving tools

Name	Uses	Image
crow bar	Consists of a metal bar with a single curved end and flattened points, often with a small fissure on one or both ends for removing nails.	
screw driver	Used to insert and tighten, or to loosen and removescrew. The screw driver comprises a head or tip which engages with a screw, a mechanism to apply torque by rotating the tip, and some way to position and support screw driver **types:** triple square, spanner head, torque, tri wing, obertson, hex allen, torx, pozidive, crosshead, flat	

2. **Holding tools-**tool for holding firmly any material that has to be cut.

Table 12: holding tools

Name	Uses	Image
Adjustable spanner/wrench	used to loosen and tighten a nut or bolt. It has a jaw of adjustable-size, which allows different sizes of nut and bolt.	
basin wrench	Is a specialized tool which allows one to reach tight spot under sink and basin. The jaw of the basin wrench can not only be adjusted to accommodate nuts of different sizes, but it can also be flipped over the opposite side to keep it turning without removing the wrench	

<table>
<tr><td>clamp</td><td>used to grip and hold an object firmly such as wood, paper, plastic and some metals for a short period time.</td><td>
</td></tr>
<tr><td>Pipe wrench</td><td>Is an adjustable wrench used for turning soft iron pipes fittings with a rounded surface. The design of the adjustable jaw allows it to rock in the frame such that any forward pressure on the handle tends to pull the jaw tight together</td><td></td></tr>
<tr><td>bench vise</td><td>Used for holding or clamping a work piece to allow work to be performed on it which uses an anchor. Bench vise or vice has one fixed jaw and another, parallel, jaw which is moved towards or away from the fixed jaw by the screw</td><td></td></tr>
</table>

Safety when using tools and Equipment

- Always wear eye protection.
- Wear the right safety equipment for the job.
- Use tools that are the right size & right type for your job.
- Follow the correct procedure for using every tool.
- Keep your cutting tools sharp and in good condition.

- Don't work with oily or greasy hands.
- Make sure each tool type has a separate compartment in ther toolbox, as this will help to stop them coming into contact with others that could damage them

Maintenance of tools

Here are some of the practices that enhance the lifespan of the tools and same time limit injuries to the user:

- Hand and power tools with adjustable parts need lubrication
- For storage maintain their optimum level of performance and to help fight rust development
- Only use tools in proper working order.
- Regular repair of broken parts.
- Clean your tools after use.

PPE used when carrying drainage systems installations

Face protection

Goggles and face protection must be used when workers are at risk from flying particles, liquid chemicals, acids or caustic liquids and chemical gases. Various goggles for face protection must meet certain design criteria for safety.

Foot Protection

Safety shoes with impact protection are used in work areas where heavy objects or tools could be accidentally dropped on the feet. Safety shoes with puncture protection are required when working around nails, wire tacks, scrap metals and other objects that could fierce the feet.

Hand Protection

Gloves are required to protect the hands of workers from cuts, scrapes, punctures, burns, chemical absorption, and exhaust temperatures. It is crucial that the type of glove being used is the right one for the job.

Hearing Protection

Appropriate **ear muffs or ear plugs** must be made available as a last resort if it is not possible to make the workplace less noisy. The requirement is a small part of the occupational noise exposure standard which requires employers to ensure that workers are exposed to less than 90 decibels of noise over an 8 hour period.

Respirators

Appropriate **respirators** must be worn as a last

resort if it is not possible to ventilate the work area properly.

Overalls

Overalls are a type of safety clothing made of tough cotton, denim or linen and usually used as protective clothing while working. It is a loose fitting pair of pants with supporting cross-straps, or a full or half sleeve shirt that is worn over regular shirts, vests and trousers to protect them from heat, cold, splashes, sparks, flames and flying debris etc. in the workplace.

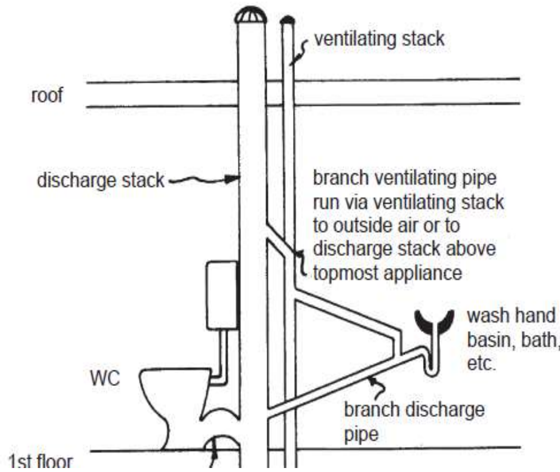
3.2.3.4 Learning Activities

Practical activities

You are required to undertake the following activities in from your institution's drainage system

a) Identify all the tools you would use to install the drainage system below
b) Highlight the use of each tool named in (a) above
c) Give 10 maintenance practices for the tools named above

Figure 164: Drainage system installation



Materials Required

- Pen
- Pencil
- Straight edge
- Notebook

3.2.3.5 Self-Assessment

Which safety measures would you observe when using plumbing tools and equipment?

1. Which four cutting tools would you use when installing a metallic pipe?
2. Which four PPE's would you use when installing an elevated steel tank?
3. Draw a pipe wrench.

5. Which are the two broad classes of tools?

3.2.3.6 Tools, Equipment, Supplies and Materials

- Pen
- Pencil
- Straight edge
- Notebook

3.2.3.7 References

Mays, L., 2001. Water resources engineering. New York: Wiley.

Cauldwell, R., 2005. Remodel plumbing. Newtown, CT: Taunton Press, pp.24-35.

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https://inspectapedia.com/plumbing/Building-Plumbing.php

3.2.3.8 Model Answers

1. **Which safety measures would you observe when using plumbing tools and equipment?**

    - Always wear eye protection.
    - Wear the right safety equipment for the job.
    - Use tools that are the right size & right type for your job.
    - Follow the correct procedure for using every tool.
    - Keep your cutting tools sharp and in good condition.
    - Don't work with oily or greasy hands.

2. Which four cutting tools would you use when installing a metallic pipe?

    - pipe cutter
    - pipe threader
    - Pipe reamer
    - Hacksaw

3.Which four PPE's would you use when installing an elevated steel tank?

- Gloves
- Boots
- Googles
- Overall

4. Draw a pipe wrench.

5. Which are the two broad classes of tools?
   - Power tools
   - Hand tools.

3.2.4 Learning Outcome 4: Set out Drainage systems

3.2.4.1 Introduction to the learning outcome

This learning outcome will help the trainee gain the competencies required in setting out drainage systems as it involves in construction industry.

3.2.4.2 Performance Standard

1. Measurements are transferred to the ground based on working drawings
2. Joint positions are identified based on the working drawings and standards
3. Invert levels are taken based on the gradient.

3.2.4.3 Information Sheet

Definitions of terms

i. **Levelling** is a process of determining the height of one level relative to another. It is used in surveying to establish the elevation of a point relative to a datum, or to establish a point at a given elevation relative to a datum

ii. **Datum:-** Datum plane is an arbitrarily assumed level surface or line with reference to which level of other line or surface are calculated.

iii. **Reduced level (RL)**:- Height or depth of a point above or below the assumed datum is called reduced level.

iv. **Bench mark (BM)**:- B.M. is a fixed reference point of known elevation. It may be of the following types.

v. **Boning Rods and Sight Rails** are tools as old as time but still important and extremely useful when setting out paving and drainage projects

vi. **Reduced level (RL)** is the height or depth of a point above or below the assumed datum.

Setting out the fall

The method used to ensure the pipe is laid to the correct gradient will depend upon the length of drainage run, and for short sections a gradient board, or incidence board, is used.
The gradient board is a plank of wood cut to the required gradient of a drain and used in conjunction with a spirit level. If a drain run is to have a fall of 1 in 40 the drop in depth over 1m would be ($1 \div 40 = 0.025$m) 25mm.

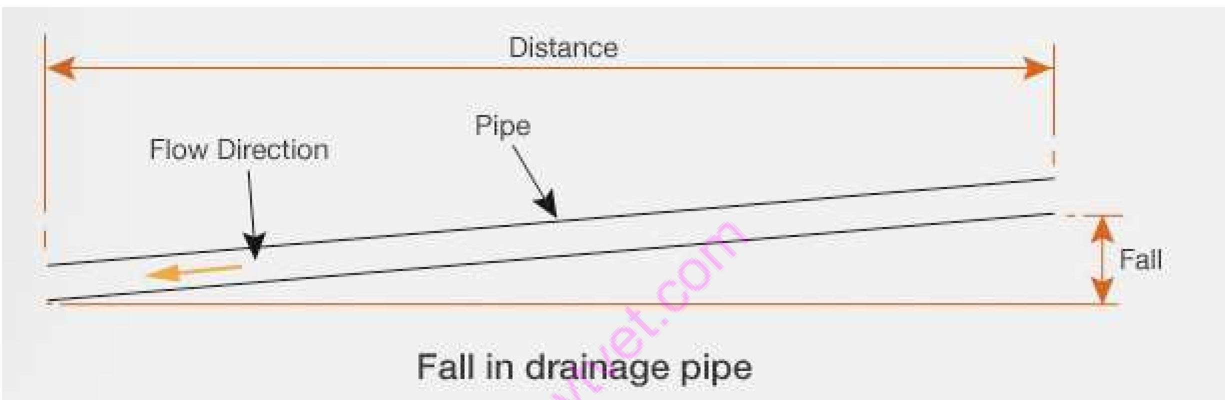
So, to make a simple gradient board, take a straight plank 1m long and cut it at an angle. Where a long drainage run is to be installed the method used to determine the fall should be carried out using sight rails and traveler (also called a boning rod). First the site rails are positioned at either end of a drainage run at different heights, the difference being that of the required gradient.
This process is done by a site surveyor, using a site level, or by using a water level to give an accurate transference of levels between each end of the drainage run. Then the trench is excavated to the required fall or backfilled as necessary. Two operatives are then used; one sighting his eye between

the site rails and instructing his partner to raise or lower the traveler by lifting or lowering the boning rod as necessary

Determining Drainage Levels

Falls

The fall in a pipe may be defined as the vertical amount by which the pipe drops over a distance. The distance can be between sections of pipe or between manholes. The diagram below shows pipe fall and distance.



FALL = GRADIENT X DISTANCE

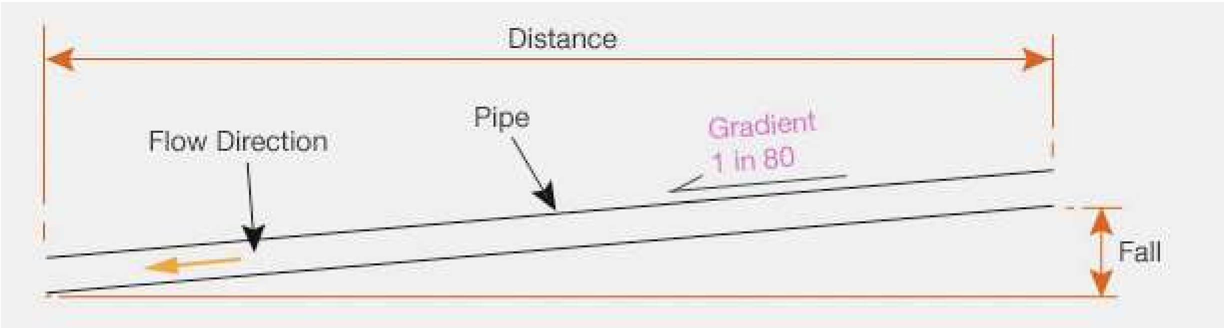
For example, calculate the fall in a 50 metre section of foul water pipe work if the gradient is to be 1 in 80.

A gradient of 1 in 80 is converted to a number instead of a ratio – 1 / 80 = 0.0125

Fall = 0.0125 x 50

Fall = 0.625 metres or 625mm.

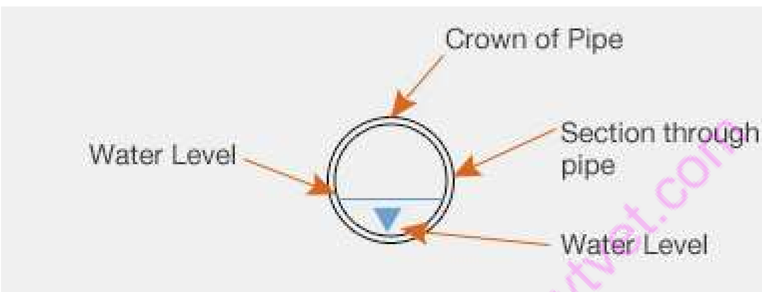
The previous diagram may be completed by adding a pipe gradient.



Fall & Gradient in drainage pipe

Invert Levels

The invert level of a pipe is the level taken from the bottom of the inside of the pipe as shown below.



Invert level of Pipe

The level at the crown of the pipe = the invert level + internal diameter of the pipe + pipe wall thickness. It may be necessary to use this in calculations when level measurements are taken from the crown of a pipe.

Table 13: Determining levels

Pipe Diameter (mm)	Recommended Fall
100	1 in 40
150	1 in 60
225	1 in 90

Drainage Calculations

To calculate the difference in levels of the two ends of a drain a simple formula is used which is:

Length of run ÷ Gradient

The gradient is always expressed as "1 in a given distance", e.g.:

1:40 means a drop of 1mm in 40mm or 1 metre in 40 metres

1:60 means a drop of 1mm in 60mm or 1 metre in 60 metres

Example: If a 100mm drain pipe 70m long is laid to a gradient of 1:40 what would be the difference in level of the two ends.

Length of Run

Gradient

= 70

40

= 1.75m or 1,750mm

Boning Rods

Boning rods - These are T-shaped and of a uniform height. They can be easily manufactured by nailing a wooden lath of approximately 80 cm long and 10 cm wide on another lath of approximately 150 cm long and 10 cm wide so that the end result looks like a "T" (figure 5). A simple stand can be manufactured so that the setting out can be done by two instead of three persons if necessary.

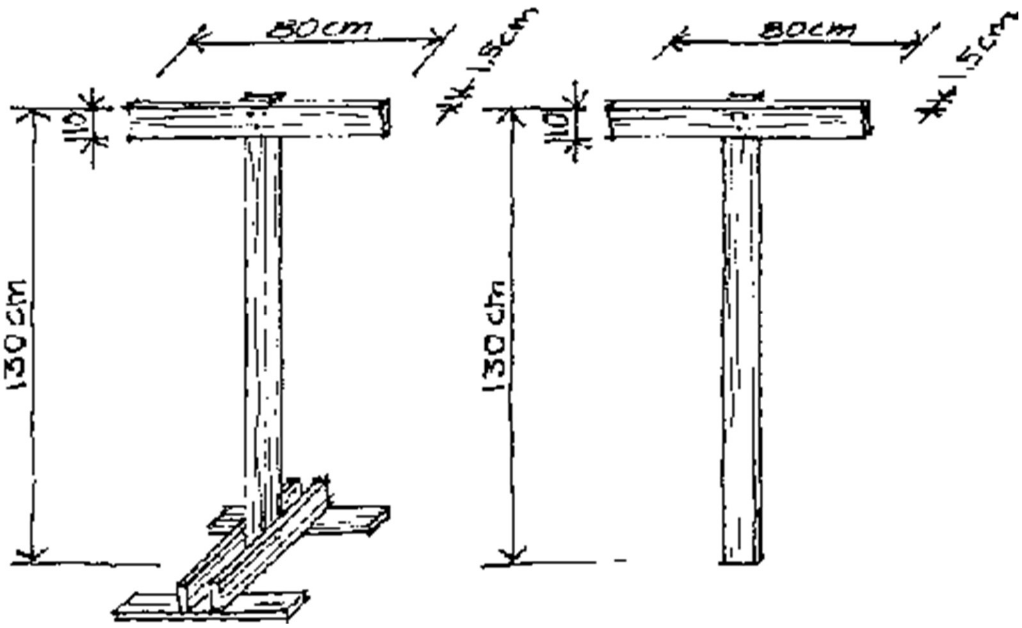
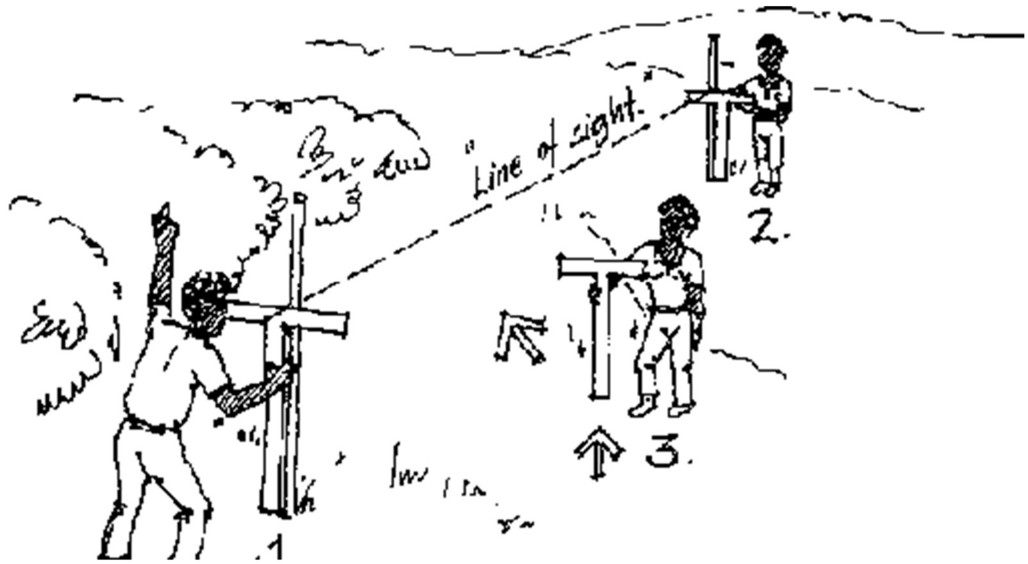


Fig. 5.

Paint the upper lath in a clearly visible colour. Different colours should be used for different boning rods.

When "level pegs" show two levels of the road "boning rods" can be used to establish a "line of sight", which enables you to find additional levels in between or beyond the level pegs. This "line of sight" is established by putting boning rods on top of the level pegs and looking over the top of the boning rods. Figure 6 shows how the new level is found:



This man can see that boning rod 3 is too low. When the man in the middle moves uphill his boning rod will come into the line of sight. He then moves his boning rod up (or down) until the top is at the correct height. The bottom of the boning rod is then at the required new level.

Note that this method should not be used to set out new alignments in hilly terrain, but only to find additional points between level pegs! Setting out in hilly terrain by an inexperienced person can cause excessive and unnecessary earthworks.

Use of boning rods

Boning rods are used to set out horizontal lines or lines with a constant slope. In particular they are used for setting out canal excavation works, but also for roads and dyke construction.

To be able to set out horizontal lines or lines with a constant slope, the elevation (or height) of two points on the line (preferably the starting and end points) must be known.

Dumpy level

A dumpy level (also known as a Builder's Level) is an optical instrument used to establish or check points in the same horizontal plane. It is used in archaeological surveying to measure horizontal levels, for example to demonstrate the difference in height at the top and base of a slope such as an excavated pit or a surviving earthwork.

Equipment

The level 'kit' consists of a level head (in box), staff and tripod.

The level head comprises an eyepiece, bulls eye spirit level, three levelling screws and a focus for the telescope lens; the base also incorporates a 360 degree compass.

The 5m staff is in sections. Each ‘block’ represents one centimetre, and each 'E' represents 5 centimetres. The 10 cm sections alternate back and forth and between black and white, and the colour alternates between black and red for each metre.

The tripod is composed of aluminum and plastic, with three extendable/lockable legs and a base plate with screw fitting with which to attach the level head. There is a canvas carrying strap and a belt to secure the legs together.

To set up a TBM: mark an easily identifiable permanent feature nearby – eg. a coloured brick in a wall, or a fence post; a wooden stake may also be used.

Setting up the level

- Find a benchmark location near the spot you want to measure. A benchmark location is a spot that you already know the height of thanks to previous land surveys.

If possible, set up in the centre of the area that you intend to survey, or somewhere that you can see all of the site as well as the back sight/Bench Mark, with the top plate relatively level.

Set your tripod up near the spot you want to measure. Place your tripod on a patch of flat, clear ground that sits between your benchmark location and the spot you want to measure. Then, undo the latches on your tripod's legs and extend each leg out. Adjust the legs until your tripod is completely level, then close each latch.

- Almost all tripods come with a built-in bubble level. You can use this to assess whether or not the tripod is level.
- To measure the area properly, make sure you set up in a spot that's slightly higher than your benchmark location.

Connect your device to the tripod and position it over 2 leveling screws. Screw your dumpy level onto the tripod's base plate, then connect the base plate to the main tripod body. Once the instrument is securely attached, turn the dumpy level's telescope so that it sits parallel with 2 of the device's leveling screws.

- If the dumpy level wobbles when tapped, tighten the leveling screws to better secure the device.

Level the device by adjusting the 2 leveling screws. Look for a traditional bubble level located somewhere on your device. When you find it, grab the 2 leveling screws that are parallel to the device's telescope and twist them in opposite directions. Do this until the bubble sits in the exact center of the level.

Turn your telescope 90 degrees and adjust the third leveling screw. After adjusting your first 2 leveling screws, turn your telescope approximately 90 degrees so that it sits parallel to the device's third leveling screw. Then, adjust this screw until the bubble once again sits in the center of the level

Check your level's calibration by turning it 180 degrees. After making your initial leveling adjustments, return your telescope to its starting position and check that the bubble still sits in the center of the level. If it does, turn the telescope 180 degrees and check the level again. You can focus the device once all 3 positions show the bubble in the center of the level.

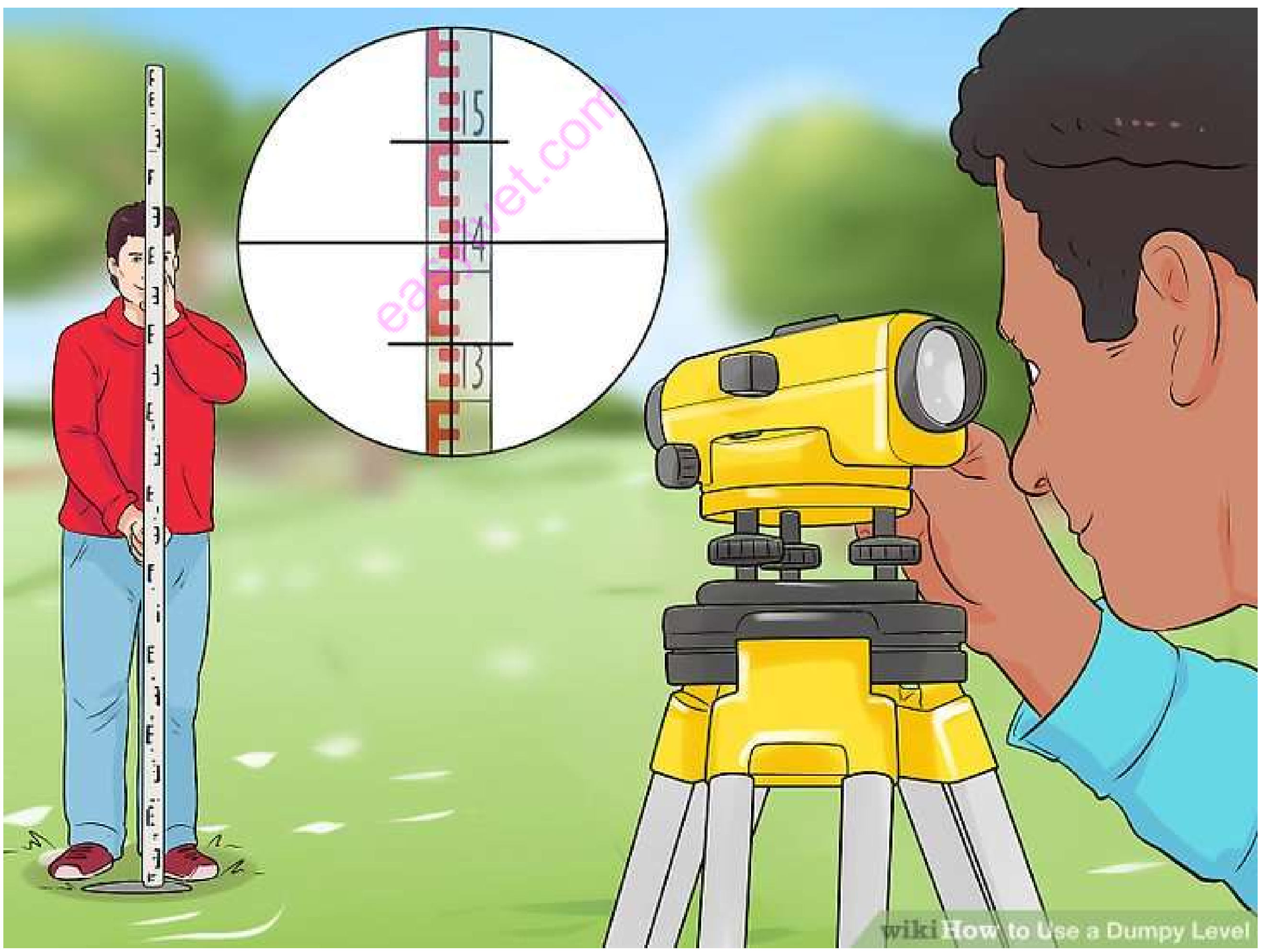
Focusing your level.

- Remove your dumpy level’s lens cap.
- Adjust the eyepiece until you can see the device’s crosshairs.
- Twist the device’s focusing knob until the image is clear.

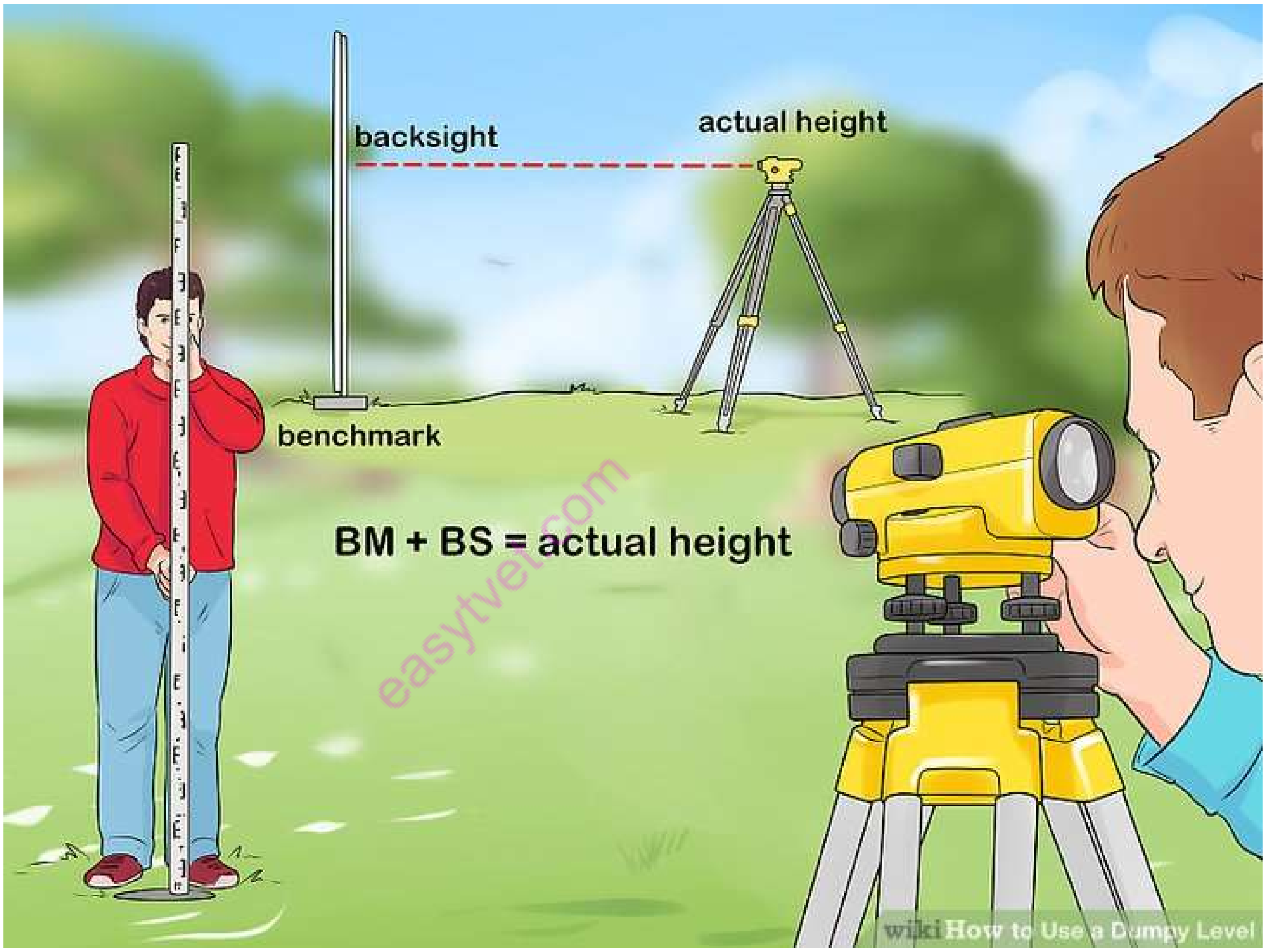
Taking measurements.

1. Position an E staff on top of your benchmark spot.

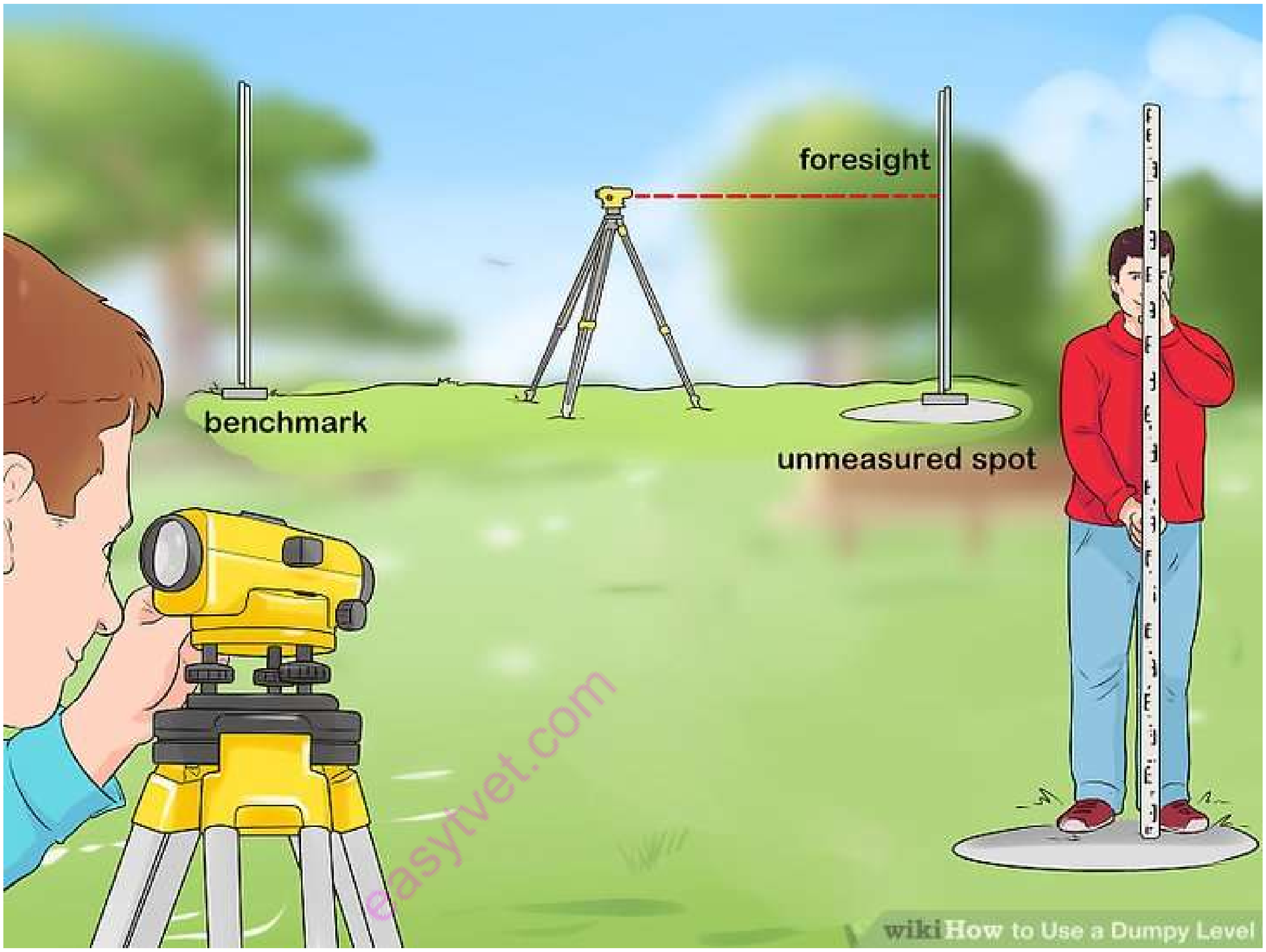
2. Find the height difference between your level and the benchmark spot. Look through your dumpy level’s telescope and locate the E staff. Then, record the measurement indicated by your device’s center, horizontal crosshair.

- This measurement is known as your backsight.
- Each numbered section of your staff represents 10 cm (3.9 in). Within these sections, every block indicates 1 cm (0.39 in) and every E indicates 5 cm (2.0 in).
- 

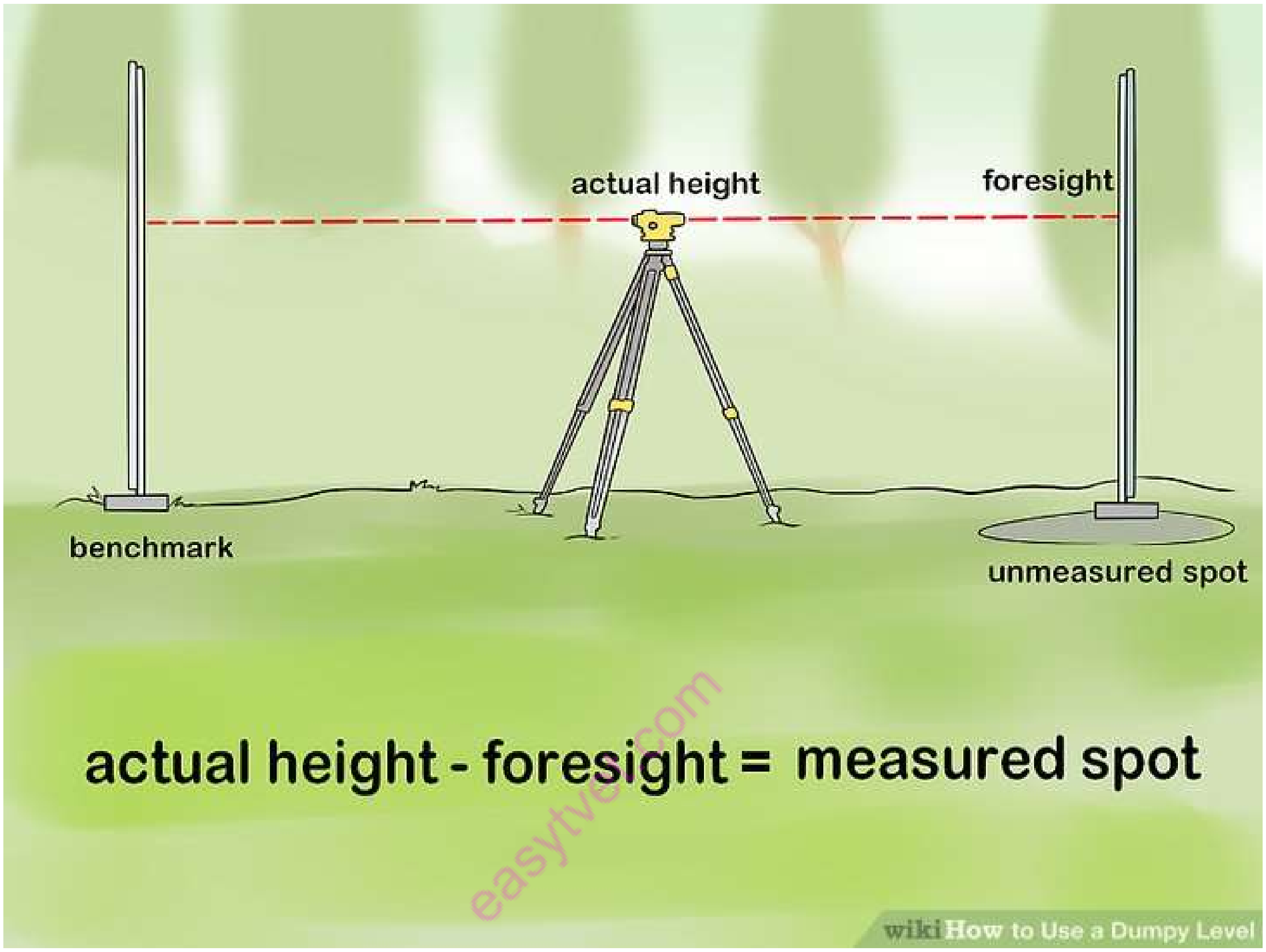
3. Calculate your level's actual height using the benchmark height. Once you have your backsight measurement, add it to your benchmark location's actual height. This will give you the current height of your dumpy level's telescope.

- Record this measurement so you can use it to find the height of your next spot.
- 

4. Find the height difference between your level and the unmeasured spot. Move your E staff so it sits directly on top of the spot you want to measure. Use your device's telescope to find the staff, then record whatever number the device's center, horizontal cross hair sits over



4. Calculate the spot's actual height using your level's height. Unlike with your previous calculation, you'll need to subtract your foresight measurement from your dumpy level's actual height. This will give you the height of the spot you measured.



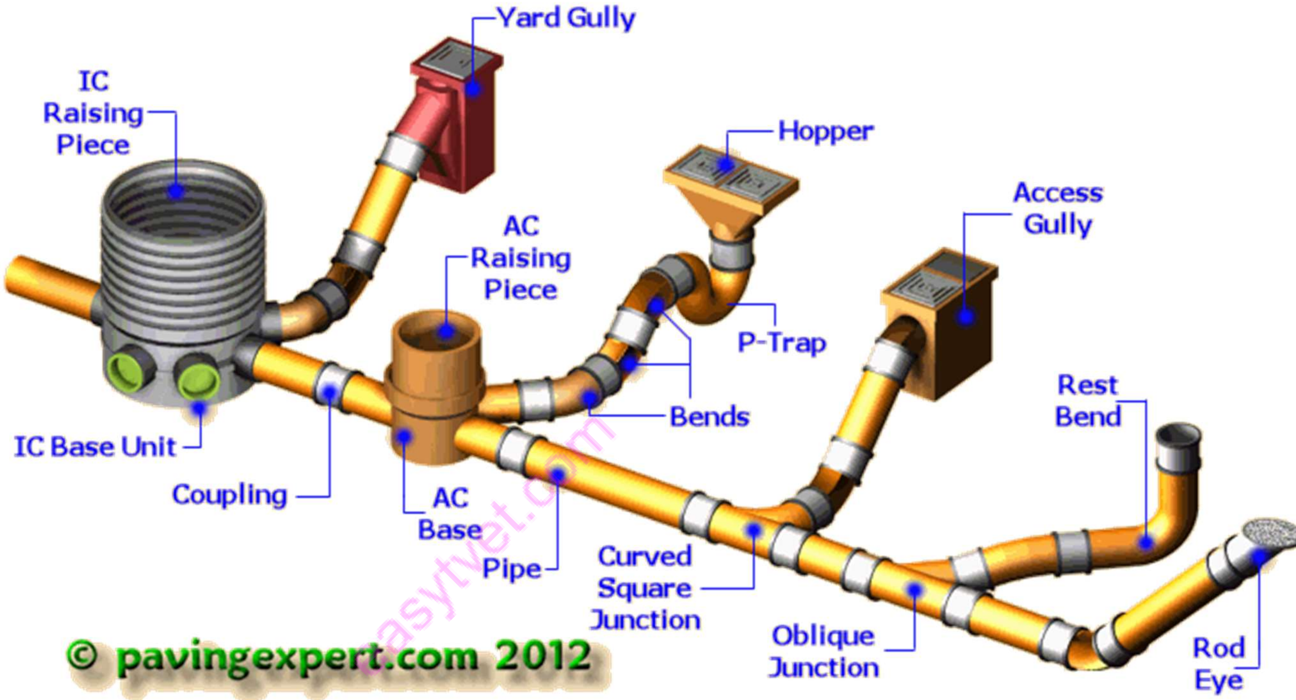
3.2.4.4 Learning Activities

Practical activities

Procedure

1. Assemble all tools and materials required
2. Set out the drainage system at a gradient of 1:40 as shown in the figure below.

Figure 165: Drainage system installation



Materials Required

- Measuring tools
- Levelling equipment's
- Mason trowels
- Mason square
- Spirit level
- Boning rods
- Floats
- Mallet

- Ball hammer
- Masonry chisel
- Pipes

3.2.4.5 Self-Assessment

1. What is the meaning of fall as used in determination of drainage levels?
2. Calculate the fall in a 70 meter section of foul water pipe work if the gradient is to be 1 in 60.
3. State two uses of boning rods.
4. What is a dumpy level used for?
5. What do you understand by the term **'reduced level?'**

3.2.4.6 Tools, Equipment, Supplies and Materials

- Measuring tools
- Levelling equipment's
- Mason trowels
- Mason square
- Spirit level
- Boning rods
- Floats
- Mallet
- Ball hammer
- Masonry chisel

3.2.4.7 References

Mays, L., 2001. Water resources engineering. New York: Wiley.

Cauldwell, R., 2005. Remodel plumbing. Newtown, CT: Taunton Press, pp.24-35.

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https://inspectapedia.com/plumbing/Building-Plumbing.php

3.2.4.8 Model answers.

1. What is the meaning of fall as used in determination of drainage levels?
   The fall in a pipe may be defined as the vertical amount by which the pipe drops over a distance.
2. Calculate the fall in a 70 meter section of foul water pipe work if the gradient is to be 1 in 60.

   Solution
   1 in 60 =1/60
   =0.01667
   Therefore fall =70 meters * 0.01667=1.1667
   Fall =1.1667 meters.

3. State two uses of boning rods.
   - **Are used to set out horizontal lines**
   - **Set out lines with a constant slope**
4. What is a dumpy level used for?
   - **A dumpy level is an optical instrument used to establish or check points in the same horizontal plane**
5. What do you understand by the term **'reduced level?'**

- **Reduced level (RL) is the height or depth of a point above or below the assumed datum.**

3.2.5 Learning Outcome 5: Install above ground drainage system

3.2.5.1. Introduction to the learning outcome

This learning outcome helps the learner to develop competency in installation of all pipework systems that is installed to convey the discharges of sanitary appliances down to the below-ground drainage system and the faults associated with the above ground drainage.

3.2.5.2. Performance Standard

1. Soil and waste water is identified based on the working drawings.
2. Setting out is carried out based on the working drawing.
3. Pipes are laid based on the levels.
4. Housekeeping is conducted based on workplace procedure
5. Safety and health practice are observed based on OSHA.
6. Functionality tests are conducted based on best practices
7. Faults in the system are corrected based on best practice.

3.2.5.3. Information Sheet

Soil and waste pipe systems should be designed to carry away the discharges from sanitary fittings quickly and quietly without the risk of injury to the health of the occupants of the building.

Definitions of terms

- ***Discharge Pipe-*** means any pipe which is intended to convey discharges from sanitary fixtures or sanitary appliances and includes a waste pipe, combined waste pipe, branch discharge pipe and discharge stack
- ***Drain*** - pipe normally laid below ground level including fittings and equipment and intended to convey foul water or surface water to an outfall.
- *Drain vent pipe* means any pipe which is intended to permit the movement of air into and out of a drain or sewer
- Waste water-used water which is not contaminated by soil water or trade effluent.

- ***Fixture discharge*** *pipe* - a discharge pipe which is used to convey waste from a single sanitary fixture or sanitary appliance to a branch discharge pipe, a discharge stack or directly to
- the drain
- ***Fixture vent pipe*** - a vent pipe which is connected to a fixture discharge pipe or the sanitary fixture itself
- ***Foul water drainage system* -** drains, joints. and fillings normally laid underground and used specifically for the conveyance of foul water from the plumbing system to an outfall
- ***Gully trap*** - a fitting designed to prevent foul air escaping from the drainage system and used to receive the discharge from waste pipes,
- ***Sanitary appliance*** - an appliance which is intended to be used for sanitation, but which is not a sanitary fixture.
- ***Sanitation*** - the activities of washing and/or excretion carried out in a manner so that adverse effects on health are minimized, with regard to dirt and infection.
- ***Sewe****r* - means a drain which is under the control of or is maintained by, a sewage disposal undertaking.
- ***Soil fixture*** - a sanitary fixture constructed to receive solid and/or liquid excreted human waste. It includes a bedpan disposal unit, slop sink, urinal, water closet pan and bidet.
- ***Vent pipe*** - a pipe which is open to the atmosphere at one end and acts as a pressure limiting device
- ***Waste pipe*** –a pipe which conveys waste water ,either alone or together only with rain water.
- ***Waste water fixture*** - a sanitary fixture used to receive wastes which is not a soil a fixture
- ***Water seal*** - the depth of water which can be retained in a water trap
- ***Water trap*** - a fitting designed to prevent foul air escaping from the plumbing system or foul water drainage system and entering a building

Introduction to Above Ground Drainage

The general perception of drainage systems is to remove human waste from a building with the least disruption and impact on our daily lives as possible. This perception is not completely wrong; however, the other main objective of a drainage system is to prevent foul dour ingress into the built environment and thus prevent the possibility of bacterial infection occurring.

Installation procedures

To ensure that the waste water is collected and discharged out of the building safely, during both the design and installation processes, the following areas need to be considered:

- Pipe sizing
- Ventilation system
- Pipework Materials
- Jointing
- Thermal Movement
- Gradients
- Access Pipework Testing

1. Pipe sizing

Drainage systems have many types of appliances discharging into them. To help the engineer correctly design the drainage system, Discharge Units (DUs) and Drainage Fixture Units (DFUs) have been determined using probability distribution law to take into account the probability of use and discharge of individual appliances. The total number of DUs required when incorporated into a mathematical formula will give an acceptable discharge flow rate that can be applied to a table to determine a suitable pipe size. The total number of DFUs can be applied directly to a table to determine a suitable pipe size.

2. Ventilation system

All drainage pipework systems are full of air until an appliance is discharged; once this occurs, the air within the pipework fluctuates. These pressure fluctuations, if not balanced, can adversely affect the water trap seals; therefore, to limit pressure fluctuations, vent piping is traditionally employed.

3. Pipework Materials

There are a number of metallic and plastic materials that can be used for internal drainage systems. Each type of material has its own advantages and disadvantages. The material used should be appropriate for the drainage system being designed.

Jointing There are a number of ways that drainage pipework can be jointed, ranging from solvent welded connections, push fit, fusion welded and mechanical connections. It is necessary to ensure that the jointing system adopted for the drainage system is suitable for the pipework material and the drainage system, along with the environmental conditions in which the pipework system is being installed.

4. Thermal Movement

All pipework materials will expand and contract with changes in temperature, both from ambient temperature and from the temperature of the waste discharge through the pipework. The co-efficient of linear expansion of differing pipework materials will vary; however, the cumulative effects of thermal movement on an installed system can be considerable.

5. Gradients

Any horizontal collector pipework should be designed and installed to the correct gradient and size to ensure that it is uniform, self-cleansing and efficiently carries away the maximum volume of matter which may be discharged into it. .

6. Access

It is essential that adequate provision is made for the testing and maintenance of the above-ground drainage system. Suitable accessibility via access covers, plugs and caps should be provided to enable all traps, discharge pipes and stacks to be tested, cleaned and cleared of any obstructions as and when necessary.

Access points must be;

- Air- and watertight
- Quick and easy to remove
- Fully accessible to facilitate cleansing.

Access points should be located:

- At the base of all soil and waste stacks above the spill-over level of the highest connection on a branch run, typically 1200mm above finished floor level

- At every change of direction, on vertical stacks and horizontal pipe runs
- At regular intervals on long horizontal runs, typically, - at 15m intervals on pipework up to110mm - at 24m intervals on pipework 160mm and above
- Where more than 1 wc is connected to a branch.
- On all appliances, either via the trap or adjacent to the trap
- On multi-story buildings at each floor level.

Types of pipes

Drainage pipes are required in any area to dispose of waste water from our homes and industrial areas. There are different types of drainage pipes for every purpose**. *A pipe that facilitates the transfer of water from one place to another is known as a drainage pipe***.

Corrugated Polyethylene Drainage Pipes

Corrugated drainage pipes are strong, durable and cost-effective solutions for good drainage systems. Moreover, polyethylene is a chemically inert plastic that is highly corrosive and abrasion resistant.

PVC Drainage Pipes

Polyvinyl chloride pipes are widely used in drainage systems, as they are cheap, durable and easy to assemble. PVC pipes account for about 75%, in the waste water mains.

Concrete Drainage Pipes

Concrete pipes need no introduction as they are most commonly used in building material. The local availability, effective cost, strength and durability make it the most commonly used drainage pipes.

Copper pipes

Were widely used for residential water and drainage lines. However, these pipes are being replaced by PVC or plastic, the reason being copper is now quite expensive and tends to rust over a period of time.

Types of appliances.

Sanitary appliances

Sanitary appliances are accessories that are designed to receive foul or waste water and then discharge

It through a system of sanitary pipework or directly to the drainage system where it will be disposed off..

Sanitary appliances are classified into:

a. Soil Appliances

b. Waste appliances

Soil Appliances

Soil appliances receive and dispose human excreta. They include bed pan washer, slop sinks, urinals and water closets.

I. Bed pan washer

These appliances are only found in hospitals, hospices and large hotels. They are used for emptying and Washing bed pans. A bedpan or bed pan is a receptacle used for the toileting of a

Bedridden patient in a health care facility, and is usually made of metal, glass, ceramic, or Plastic. A bedpan can be used for both urinary and fecal discharge.

II. Slop sinks

They are deep sink for filling and emptying scrub pails, washing out mops.

III. Urinals

These are appliances are fixed in buildings. They are designed for use by males. There many types of urinals.

a) Stall urinal

It is made in single units complete with floor channel and have sides provided privacy.

b) Slab urinal

They are built up to any required length but do not generally have the side's pieces except at the ends of the ends of the range.

c) Bowl Urinal

It consists of a wall – mounted bowl with optional separate screens fitted in range.

Wash – down Closets

The content of the pan is washed out by the action of the flushing water, which must be directed all Around the pan by a flushing rim.

The water trap seal is normally 50mm deep.

The trap seal is either an s or p – outlet with a diameter of 100mm (4inch).

A simple rubber push – fit connectors with are available to suit into soil pipe. (Waste pipe)

Squatting Closet

This floor – mounted closet is unlike other closet in that you do not sit on it but squat.

It is usually connected to the high level flushing cistern and directs water the closet**.**

Water closets (WC)

They are designed to receive excreta and to flush it into a drainage system. They are smooth and easily

Cleaned surfaces and be made in one piece one – piece wherever possible, with an integral water trap.

Waste Appliances

They receive water and dispose excreta from general washing purposes or food preparation.

They include; Basins, baths, bidets, drinking fountains, sinks and showers.

Drinking Fountains

They are normally install in factories and mines where heavy peak – time washing of hands is needed And a range of washing basins would not be sufficient.

They are usually manufactured as circular bowls with a central pillar through which several nozzles Spray water into the bowl.

They are fixed away from the walls so that people access water round the bowl.

Wash basin or Lavatory

They are used for hand washing and face washing.

They are available in various sizes but the commonest are between 600mm and 685mm wide and Between 400mm to 560mm deep to the back, with a bowl depth approximately 240mm deep.

Domestic basins are usually made of vitreous china and mostly supported pedestal of the same Material.

Baths

They are used for whole body washing and are usually rectangular or tub shaped, with sizes ranging From 1.68 – 1.83 m long, 0.71m – 0.74m wide and 0.43m – 0.45m deep.

Shower

A Shower can be installed to discharge into a bath or into a ceramic or plastic shower tray inside a Waterproof cubicle.

The shower are used for whole body washing and are hygienic than baths because you are not actually

Immersed in dirty water.

Sinks

They are usually fitted in kitchens and used for general household work, including washing and Preparing food.

Their sizes range from 450mm – 1200mm long, 380 – 600mm wide and 200mm – 300mm deep.

Materials like stainless steel enameled steel and plastic are more popular these days and can be

Manufactured in various shapes.

Types of pipework in above ground drainage.

Flow pattern and air pressure fluctuations when reference is made to pipes conveying discharges from sanitary appliances, two classifications of pipe were formulated with the older discharge systems:

- waste pipes: conveying water bound discharges from sinks, baths, showers, washbasins and bidets;
- soil pipes: conveying human discharges from WCs or urinals.

In modern disposal pipework systems these two classes of pipe are combined in a single system. In pipework design, consideration needs to be given to the development of pressure within the system. This pressure can take two forms: positive compression and negative suction. The strongest effects of pressure arise when the bore of the pipe is completely filled, and this is therefore a condition that should be avoided. Where a near-horizontal pipe has a bore completely filled by the flow the name given to the condition is a hydraulic jump formation.

Above drainage pipework connections

The fluid flow in sanitary pipes moves along like a liquid bullet, compressing and displacing the air in front of it and creating negative pressure (suction) behind. Therefore, when full-bore flow occurs in a vertical pipe the effect is termed a plug formation. The significance of these pressure variations is revealed by examination of their effect on the fixtures provided to sanitary appliances. These fixtures include;

a) Discharge Pipes

The primary function of discharge pipes is to convey discharges from appliances to the underground drains and they can be arranged in the three different ways: two-pipe, one-pipe and single-stack systems. An efficient system should satisfy the following requirements;

1. Effective and speedy removal of wastes;
2. Prevention of foul air entering building;

3. Ready access to interior of pipes, including provision of rodding eyes where necessary;
4. Protection against extremes of temperature;
5. Protection against corrosion and erosion of pipes;
6. Restriction of siphonage and avoidance of liability to damage, deposition or obstruction;
7. Obtaining economical and efficient arrangements, which are assisted by compact grouping of sanitary appliances.

b) **Traps**

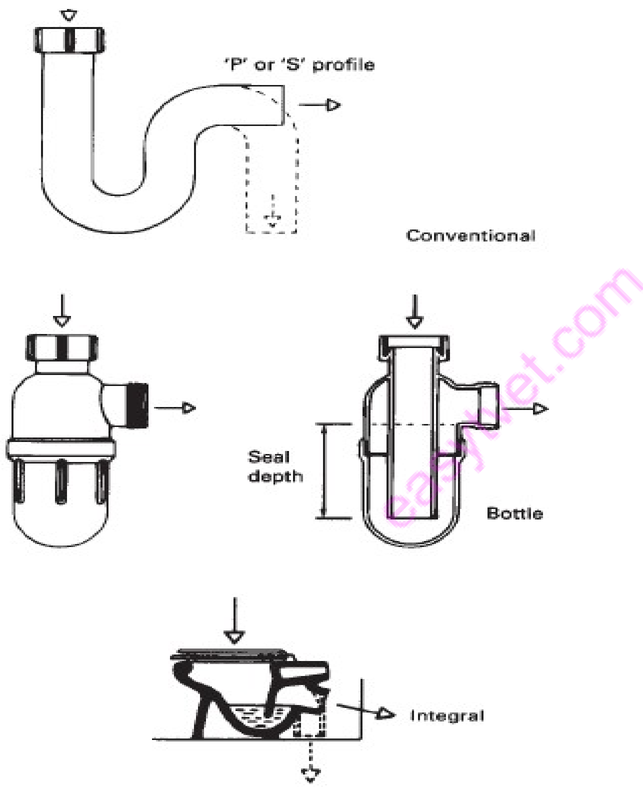
The primary function of the trap is to form a seal against foul air in the pipework system, thus preventing it from entering the building. The trap achieves this by retaining some of the liquid that is discharged by the appliance that it serves. Depths of liquid seal are generally 75 mm, the minimum being 50 mm. The arrangement for liquid retention provides the difference in the style of trap, and a range of types can be listed:

- Conventional;
- Bottle;
- Integral;
- Special.

- **Conventional traps** are formed from a series of bends in the pipe, and allow full pipe bore flow through the trap. This trap requires sufficient space to accommodate the various bends; these are arranged to give a 'P' or 'S' profile, depending on the direction of the trap outlet.
- The **bottle trap** is more compact: it provides excellent access for the clearance of debris, usually by simply unscrewing the base of the trap body. The working principle of the bottle trap does, however, cause disruption to the smoothness of the flow through the trap, which may prevent its use in certain situations for example, where sink grinders are to be used
- The WC has a trap in the body of the appliance itself, which is therefore classified as an **integral trap**. The shape of the outlet and trap provide the distinction between different WC types ('P' and 'S' trap washdown pans).

- **Special traps** provide a particular special function, such as resistance to siphonage action or perhaps the interception of components of a waste discharge such as may be needed for laboratory sinks. Foul air is prevented from entering the premises by the water seal in the trap, and careful thought needs to be given to the preservation of this liquid seal.

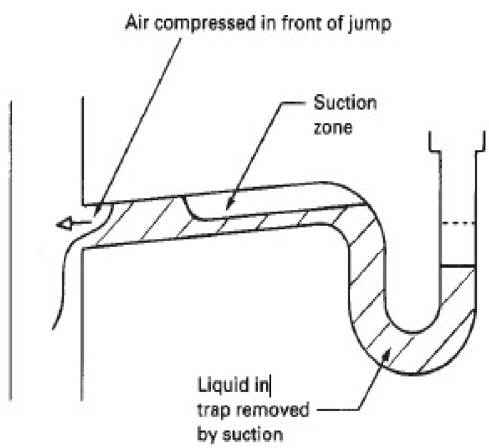
Figure 166: Types of Traps



The occurrence of undesirable discharge flow patterns in the form of hydraulic jump and plug formations may destabilize or even completely destroy the trap seal by the effect of pressure variations created by the flow leading to siphonage of the liquid trap seal resulting from the condition of self-siphonage.

Such an effect may be expected when the incorrect pipe diameter has been selected: for example, a 32 mm bore pipe to a bath rather than the minimum 38 mm needed.

Figure 167: Self siphonage in a waste pipe



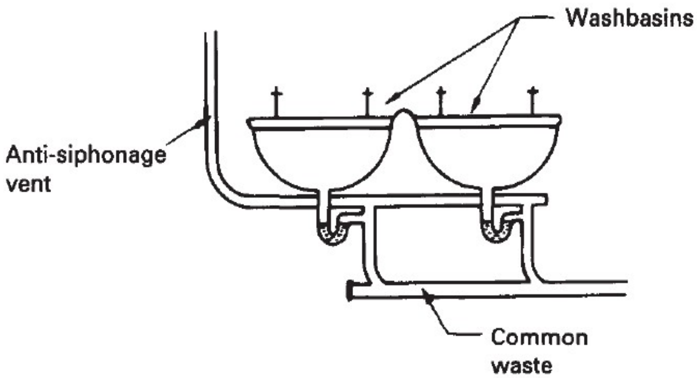
The development of suction is due to flows from other sanitary appliance discharges, which have entered
the vertical stack pipe further up the property. These discharges have caused a plug formation, which rushes past the waste branch to the affected appliance, compressing air in front of it and creating negative pressure in its wake. Such an effect is inducing disturbance of the appliance trap seal, and the description given to the condition is induced siphonage. A number of measures may be taken to avoid the effect of air pressure fluctuations on the liquid retained by traps. Self-siphonage may be avoided by using the correct pipe diameter to suit the appliance served. Induced siphonage may be prevented by using a stack of a diameter that discourages the creation of plug formations.

c) Anti-Siphonage Ventilation

The principle of anti-siphonage ventilation pipework works by connecting a ventilation source to the waste pipe between the stack and the trap, any suction effects can be nullified by drawing in air from the vent connection.

This will of course mean additional cost in the provision of the vent pipework, which sometimes extends through the building into the open air beyond roof level. Once the top floor is reached an alternative route for the ventilation may be by a loop connection to the stack. Special forms of bottle trap can also be used as a source of fresh air entry, to allow one-way movement of air through the trap. The seal against foul air entry to the building is preserved once the air pressure is stabilized by the injection of air. When appliances are connected to a vertical stack, there are often a number of connections to be made on one floor, and bathroom appliances tend to be grouped together.

Figure 168: Anti-siphonage ventilation



d) Waste and Soil Pipework Connections

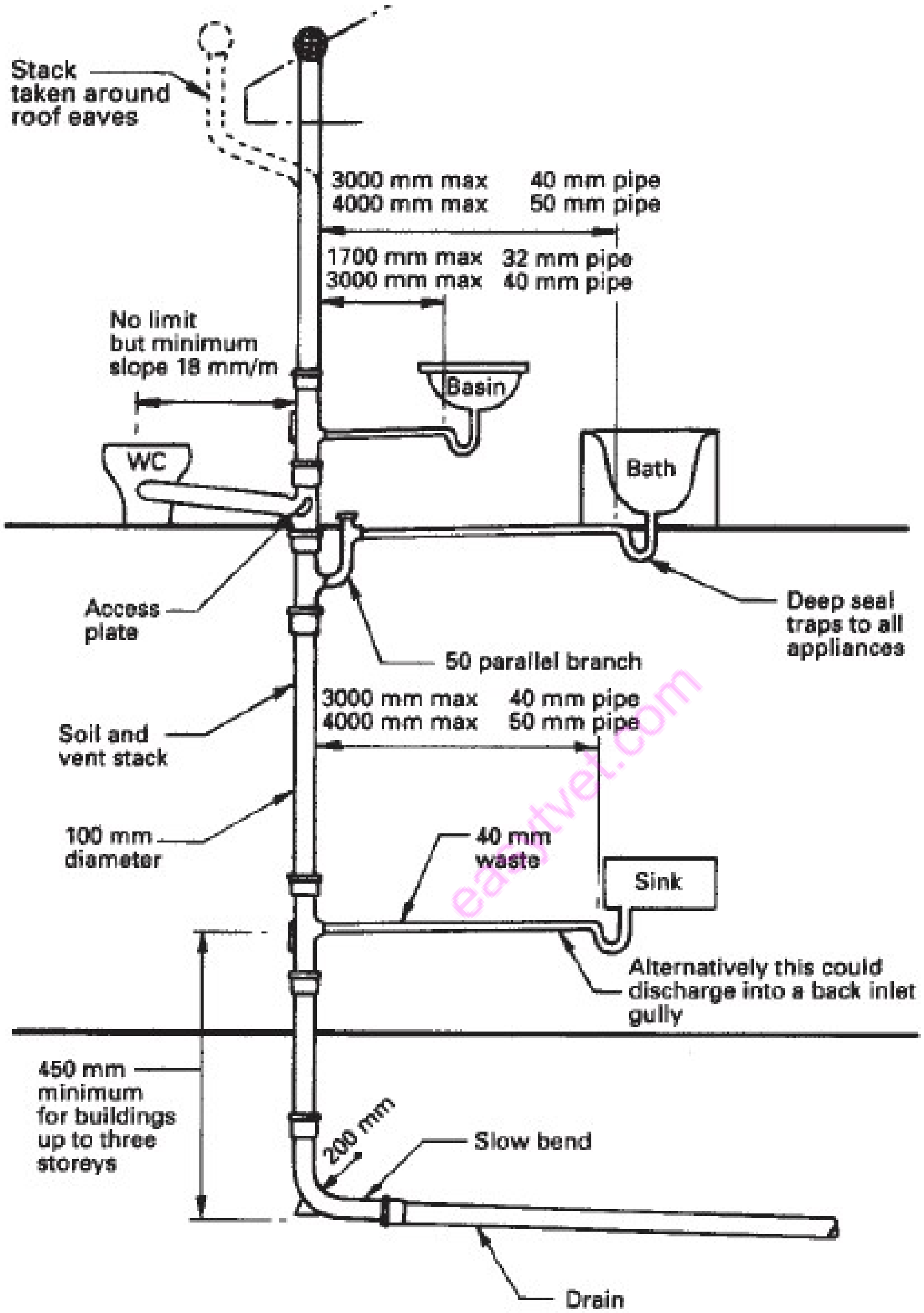
From the variety of different pipework arrangements possible for the collection of discharges from sanitary appliances, there are three major classifications:

- Single-stack system
- One-pipe system
- Two-pipe system.

i. Single stack

Single stack is a solution employed extensively in domestic housing, and a typical layout. The stack in this arrangement may be located inside or outside the external wall of the property, and terminates above roof eaves level with a cage or perforated cover. At this point the stack acts as a means of ventilating the below-ground drainage system, which commences at the base of the stack. Current Building Regulations require the discharge from the waste pipe to enter the gully below grating level but above the water retained by the gully. Other features of the single-stack system are deep seal traps on waste pipes (75 mm minimum seal) and restrictions on the length of waste and soil pipe connections to the stack.

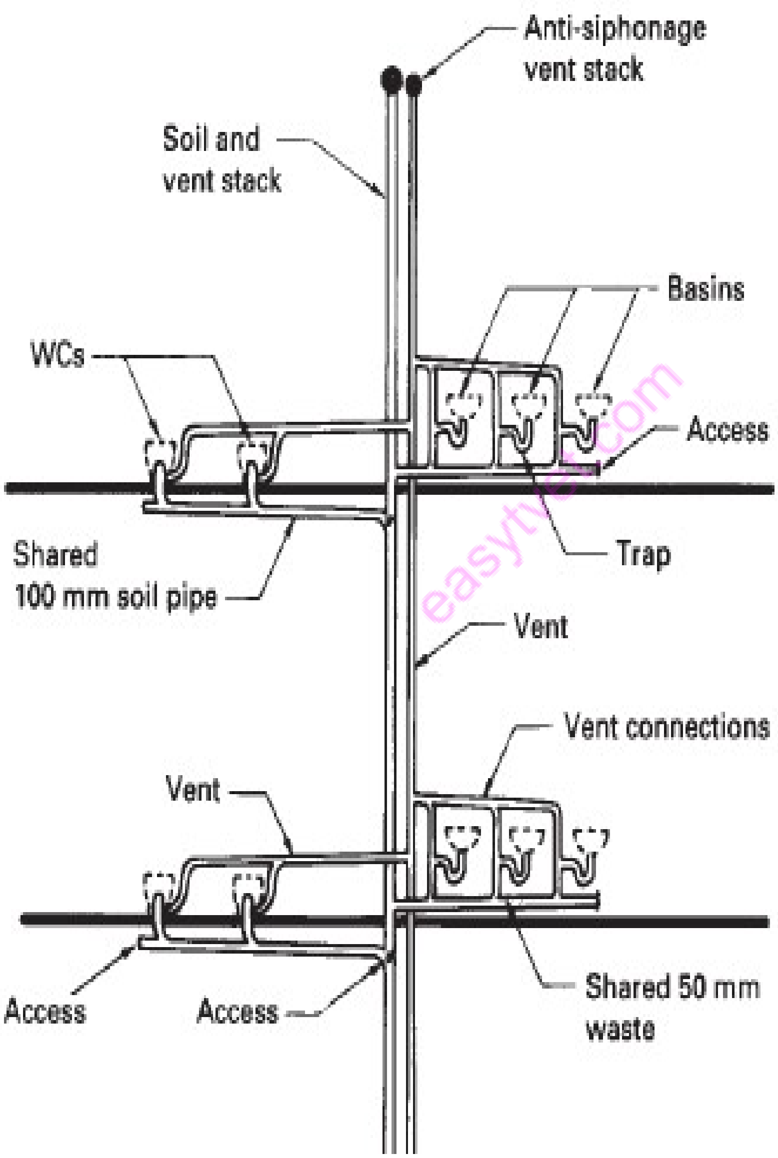
Figure 169: Single-stack disposal installation



ii. The one-pipe system

By contrast, is a fully ventilated arrangement Note the ant siphonage connections throughout. It is often said that the relatively large discharge from the WC is most influential in the development of air pressure fluctuations in the disposal installation, despite the fact that it is only a momentary discharge.

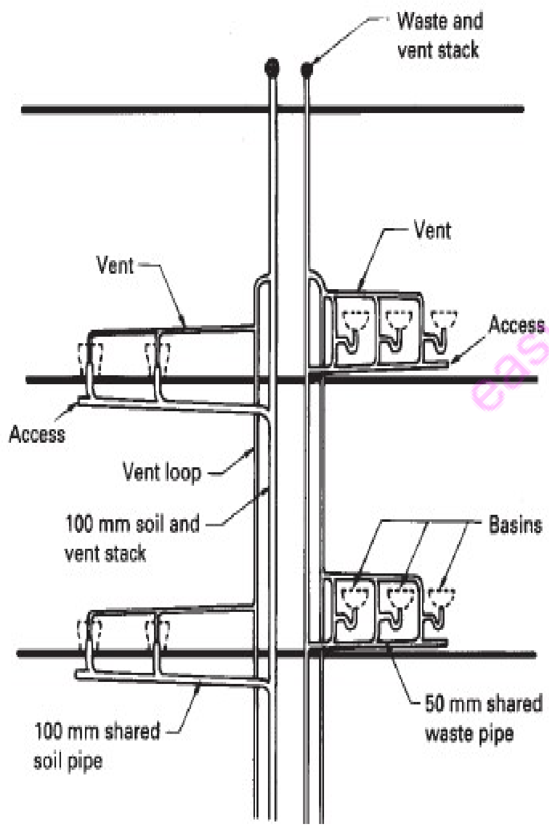
Figure 170: One-pipe disposal installation



iii. The two-pipe system

Separates the WC discharge by using two collecting stacks: a soil stack for collection of the discharges from the we, and a waste stack for collection of the water-bound waste discharges from the other appliances. Selection of one of the disposal arrangements in preference to another is usually based on a number of criteria, of which the proposed layout of the appliances on each floor and the distance of the
appliances to the stack are probably the most influential. Provided that careful design is employed and appliances are grouped around the stack, the economical single-stack system may be chosen for high-rise as well as low-rise structures.

Figure 171: Two-pipe disposal installation



Where the cumulative effect of discharges is such that siphonage effects could develop, and this is particularly the case for multi-story buildings, a one-pipe or two-pipe system may be preferable.

Tests for Above Drainage Systems

After the pipework has been installed it should be tested. The three main methods of testing for pipework soundness are:

- Water Tests.
- Air Tests.
- Smoke Tests.

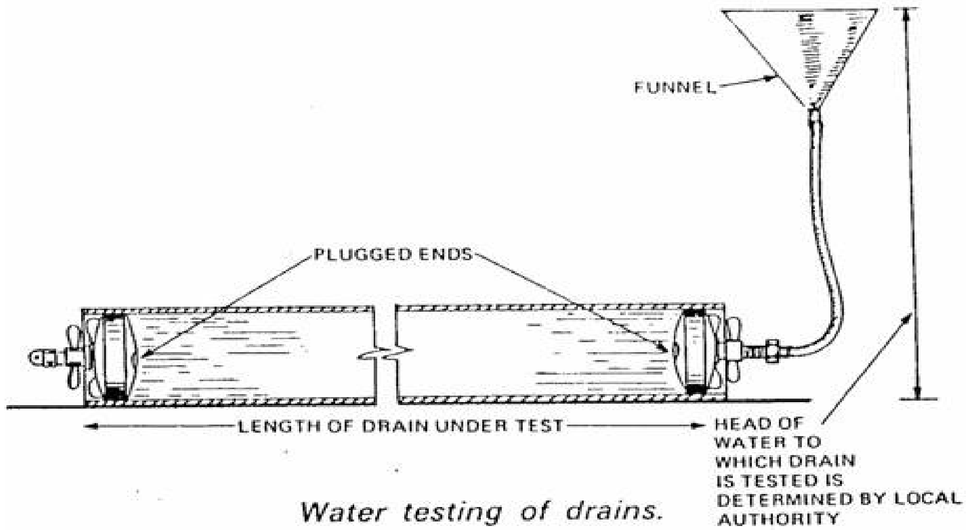
If any leak occurs, the defective pipe or joint should be rectified and once again tested.

Water Tests

- The stack should be filled with water, to give a test pressure equal to 1.5m of water above the soffit of the drain at the high end, but not more than 4m head of water above the soffit of the drain at the low end. Steeply grade drains should be tested in stages, so that the head of water at the lower end does not exceed 4m.
- The pipeline should be allowed to stand for two hours and topped up with water.
- After two hours the loss of water from the pipeline should be measured by noting the quantity of water needed to maintain the test head for 30 minutes. The fall of water needed in the vessel or stand pipe may be due to one or more of the following:

    - Absorption by pipes or joints;
    - Trapped Air;
    - Sweating of pipes and joints;
    - Leakage from defective pipes or joints;
    - Leakage from stoppers.

Figure 172: Water test



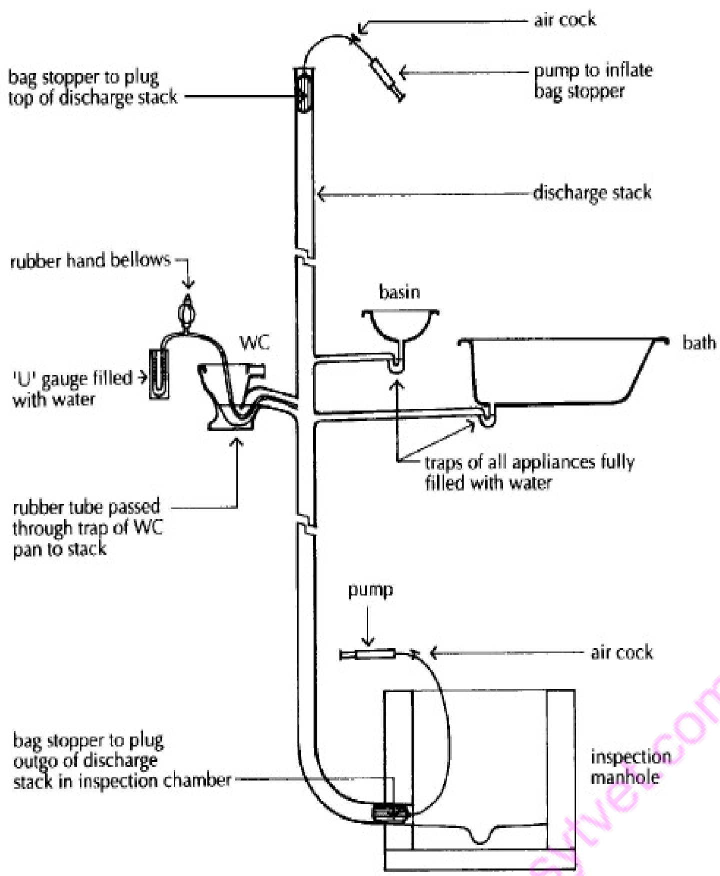
Water testing of drains.

Air Tests

An air test is usually applied if there is insufficient water available for testing, or if there is difficulty in its disposal on completion of the test. Air tests are usually pressurized to 100mm for 10 to 15 minutes, during which time the pressure drop on the gauge must not be more than 25mm.

An advantage with air testing is that all parts of the drain are subjected to the same pressure, unlike water testing where the lower end is at a higher pressure than the inlet. A tee piece with three valves is connected to a manometer (U-gauge), hand pump and a hose. The hose is passed through the seal of a Gulley Trap. With Valves A and C open and Valve B closed, air is pumped into the system. The air pressure is checked periodically by opening Valve B. When the test pressure is reached, Valve A is closed and Valve B is opened. The air pressure is now recorded on the U-Gauge. If the system is sound the difference in levels in the manometer will be retained. Should there be a leak the levels will return to zero.

Figure 173: Air Test



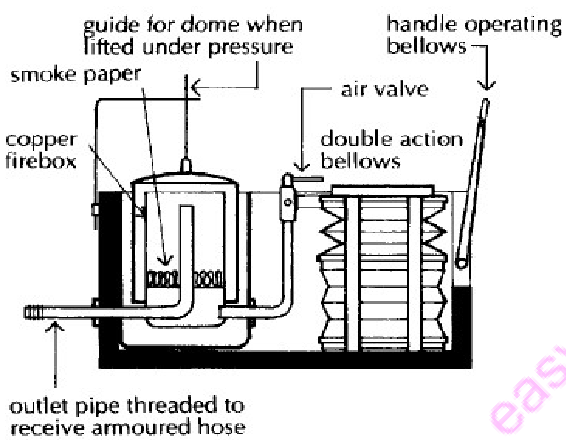
Smoke Tests

The smoke test is used both for testing the soundness of the system and for tracing a suspected leak. It can be used equally well for the testing of above ground soil, waste and vent pipes. All water seals must be charged with water and all branch drains and vents must be sealed except one. Smoke is then pumped into the system through a test plug which is fitted in the lowest point of the drain or stack.

The highest vent is left open until smoke begins to escape. At this point the vent is then sealed and pumping continues until sufficient pressure is built up inside the smoke machine to raise the dome approximately 50mm. Pumping now ceases and the system remains under test for 5 minutes. If the dome remains in the elevated position the system is sound. Should the dome fall or fail to rise a leak is indicated. Pumping is continued while the system is checked for smoke leakage.

This test should not be used on plastic systems, because of the detrimental action between the smoke and some types of plastic.

Figure 174: Smoke testing machine



Plumbing Faults in Drainage Systems and Corrections

Plumbing problems can spring up anytime in systems. Some of the issues are minor and can be fixed without any professional assistance. However, there are problems that only an expert plumber can resolve satisfactorily. Following are some of the common the plumbing defects that can arise in water storage and pumping systems after installation:

1. **Low water pressure**

Poor water pressure is generally caused by blocked joints and elbows. It can be corrected through repair and replacement of the affected joint

2. **Clogged pipes**

When a sticky or hard substance such as a stone or other foreign body passes through pipes it causes obstruction or partially closing the valves and pipes. There are many techniques used to clear the drain and sinks Using an appropriate chemical can fix the minor obstruction. However, chemicals are not always safe.

3. **Leaky pipes**

Can be caused by pipe joint damage, excessive water pressure, cracked pipes and incorrect pipe laying. This leaking water dampens the walls, making them look ugly and dirty. Damp or wet walls cause unpleasant earthy odor and mold growth. Fix pipe leakages using a shark bite, rubber and metal clamp or by sealing it with an Epoxy seal.

4. **Air locks**

It occurs in plumbing systems when pockets of air in a pipe trap the water in the pipe, not allowing the water to flow freely through the pipe. This problem usually occurs in hot water pipes, since the water pressure from the hot water tank won't force the air blockage out of the way.

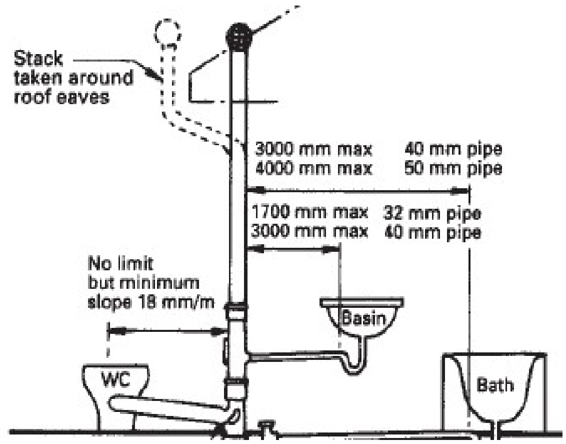
3.2.5.4. Learning Activities

Practical activities

Procedure;

1. Assemble all tools and materials required
2. Install the above ground drainage stack as shown below.
3. Carry out a water test for the system installed.
4. Correct the faults that arise after testing the system

Figure 175: Above ground drainage installation



Materials Required

- Measuring tools
- Levelling equipment's
- Mason trowels
- Mason square
- Spirit level
- Boning rods
- Floats
- Mallet
- Ball hammer
- Masonry chisel

3.2.5.5. Self-Assessment

1. What are the four types of traps?
2. What are the six primary requirements of an efficient system?
3. What are the three pipework arrangements for the collection of discharges from sanitary appliances?
4. Explain the working of an anti-siphon age ventilation trap.
5. What are the two classifications of pipe conveyance for sanitary appliances giving examples?

3.2.5.6. Tools, Equipment, Supplies and Materials

- Measuring tools
- Levelling equipment's
- Mason trowels
- Mason square
- Spirit level
- Boning rods
- Floats
- Mallet
- Ball hammer
- Masonry chisel

3.2.5.7. References

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3.2.5.8. Model answers.

1. What are the four types of traps?
    - Conventional
    - Bottle
    - Integral
    - Special.

2. What are the six primary requirements of an efficient system?
   - Effective and speedy removal of wastes;
   - Prevention of foul air entering building;
   - Ready access to interior of pipes, including provision of rodding eyes where necessary;
   - Protection against extremes of temperature;
   - Protection against corrosion and erosion of pipes;
   - Restriction of siphonage and avoidance of liability to damage, deposition or obstruction;
   - Obtaining economical and efficient arrangements, which are assisted by compact grouping of sanitary appliances.
3. What are the three pipework arrangements for the collection of discharges from sanitary appliances?
   - Single-stack system
   - One-pipe system
   - Two-pipe system.
4. Explain the working of an anti-siphonage ventilation trap.
   - The principle of anti-siphonage ventilation pipework works by connecting a ventilation source to the waste pipe between the stack and the trap, any suction effects can be nullified by drawing in air from the vent connection. This will of course mean additional cost in the provision of the vent pipework, which sometimes extends through the building into the open air beyond roof level. Once the top floor is reached an alternative route for the ventilation may be by a loop connection to the stack. What are the two classifications of pipe conveyance for sanitary appliances giving examples?
   - waste pipes: conveying water bound discharges from sinks, baths, showers, washbasins and bidets
   - soil pipes: conveying human discharges from WCs or urinals.

3.2.6 Learning Outcome 6: Install below ground drainage system

3.2.6.1. Introduction to the learning outcome

This learning outcome outlines on the different processes, activities and equipment involved when undertaking installation for drainage systems below the ground surface and the tests are applied to a newly constructed underground drainage system to ensure correct work free from defects.

3.2.6.2. Performance Standard

1. Excavation is carried out based on the layout.
2. Pipeline base is stabilized based on drawings.
3. Pipes are laid based on the levels
4. Pipe work is protected based on specifications
5. Inspection chambers, man holes and traps are constructed according to specifications.
6. Housekeeping is conducted based on workplace procedure
7. Functionality tests are conducted based on best practices
8. Faults in drainage system are corrected based on best practice.
9. Backfilling and making-good is carried out based on best practice.
10. Safety and health practices is observed according to OSHA and NEMA.
11. Above ground signage is placed based on best practice.

3.2.6.3. Information Sheet

The efficient disposal of foul and surface water from a building is of great importance to public health and is an essential part in building construction. If a drain is unsound and leaks, the escaping water may contaminate the water supply or air.

Definitions of terms

- ***Haunching*** - the concrete which slopes from the top of a drainage pipe down to the bedding
- ***Benching*** - the sloping sides constructed at the base on an inspection chamber to prevent the accumulation of solid deposits
- ***Invert*** -the lowest point of the internal surface of a drain, sewer or channel
- ***Soffit*** -the highest point of the internal surface of a pipeline at any cross-section
- ***Manhole*** – a chamber usually constructed of brick or concrete and designed to expose a section large enough to work in it.
- ***Below ground drainage system*** -This is a system of pipes which conveys surplus water or liquid sewage away from the building in the most speedy and efficient way possible to the sewer without any risk of nuisance or danger to health and safety.

Below Ground Drainage System

When designing any drainage system, one must observe the following principles:

1. Provide adequate access points.
2. Keep pipework as straight as possible between access points and for all bends over 45º and access point should be provided.
3. Ensure all pipework is adequately supported
4. Ensure the pipe is laid to a self-cleansing gradient
5. Ensure the drainage system is well ventilated
6. The whole system must be water tight including inspection chambers.
7. Drains should not be run under buildings, unless this is unavoidable or by so doing it would considerably shorten the route of pipework.
8. The minimum internal diameter of a foul water drain is 100mm.

There are three types of below ground drainage systems:

a) Combined system

In this case, as its name implies, both foul and surface water are discharged into the same sewer This system has the cheapest layout as it requires only one set of pipes, and during heavy rainfall both house drains and sewers are thoroughly flushed out.

Sewers are public authority drains to which private house drains are connected. This system has often been used in the past where raw sewage was disposed of without treatment, ie. discharged into the sea or a water course. There is a further disadvantage: in storms and periods of very heavy rainfall. Flooding and subsequent surcharging of the drains has been known to occur.

b) Separate system

This system requires the use of two sewers one carrying foul water to the treatment works, the other carrying surface water (which requires no treatment) to the nearest water course of river.

It is expensive to install, but from the local authorities' point of view it is the most economical to operate because the volume of sewage to be treated is far smaller than the discharge from a combined system.

The biggest danger is that cross-connections may accidentally be made, i.e. foul water may be connected to a surface water drain.

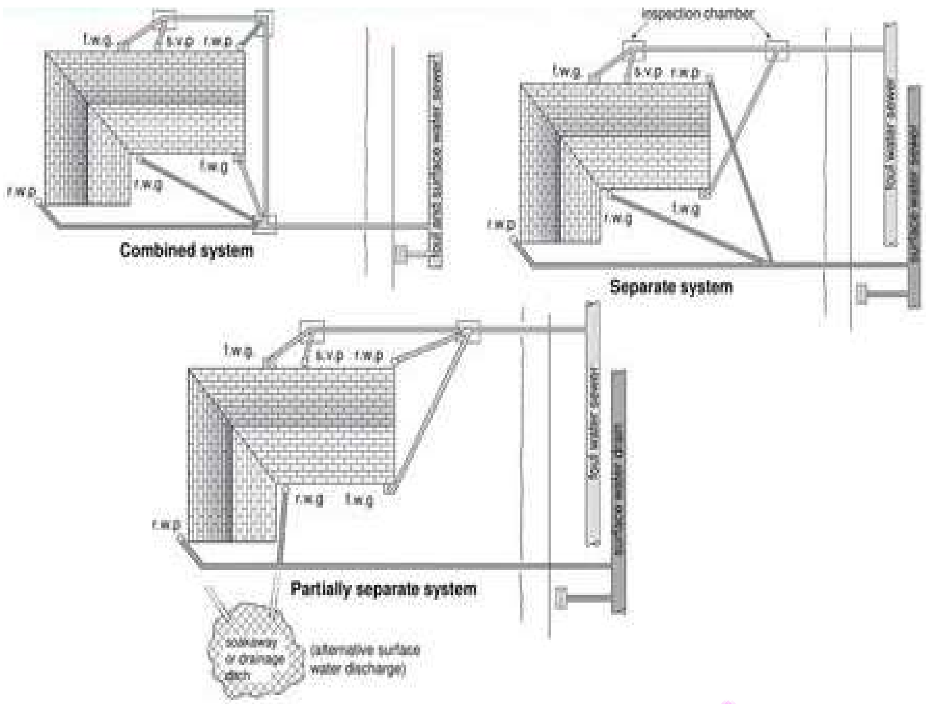
a) **Partially Separate System**

This system probably originated when towns began to grow in size and local authorities found it necessary to try to reduce the loading on the combined system, which in most cases had hitherto been employed. This is something of a compromise between the previously mentioned systems.

It requires two sewers, one carrying water from paved areas and part of the roof, the other carrying foul water and water from the remainder of the roof.

The disadvantage of this system are similar to those of the combined system, but to a lesser degree.

Figure 176: *Below ground drainage systems*



Measuring the gradient or slope while laying pipes.

Pipe slope / gradient: Slope or gradient may be defined as fall divided by the distance.

Gradient = Fall / distance

Sample Calculation of fall: If your drainage pipe length (L) is 15 metres, what is fall (F) required to

Attain gradient of 1:60?

Answer:

Slope of 1:60 means the slope will fall 1 meter for 60 meter length of pipe.

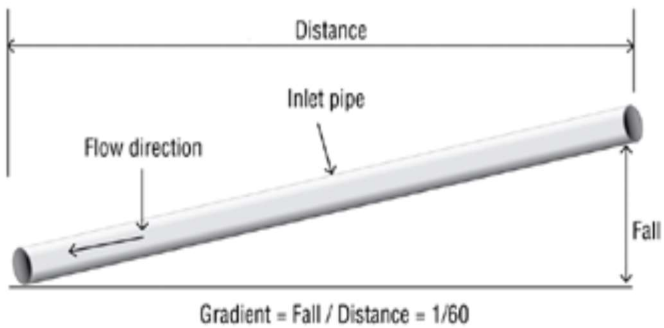
Our Pipe length (L) = 15 meters

So, Fall = Gradient * distance

Fall = 1/ 60 * 15 = 0.25 meters

Fall should be 0.25 m or 25 cm.

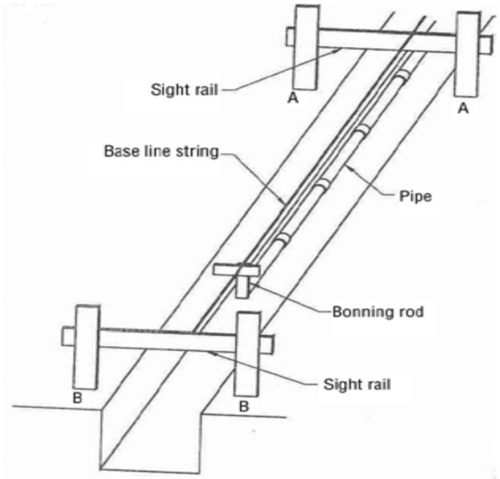
Figure 177: *Fall and gradient in drainage pipe*



Procedure to measure gradient for laying of sewerage pipe:

1. Mark the width of the trench on ground with chalk powder and start excavating to the required depth.
2. Drive two pegs on the side of the trench at the starting point at a distance of 600 mm from the trench mark.
3. Mark the level on both pegs using water level. Fix a sight rail at the mark.
4. Calculate required slope up to the end of the trench
5. Fix two more pegs at the end as done earlier.
6. Mark the level considering the slope required.
7. Fix a sight rail at mark.
8. Tie a string from sight rail at the starting point to the end tightly.
9. Check the bottom level of the trench using a boning rod.

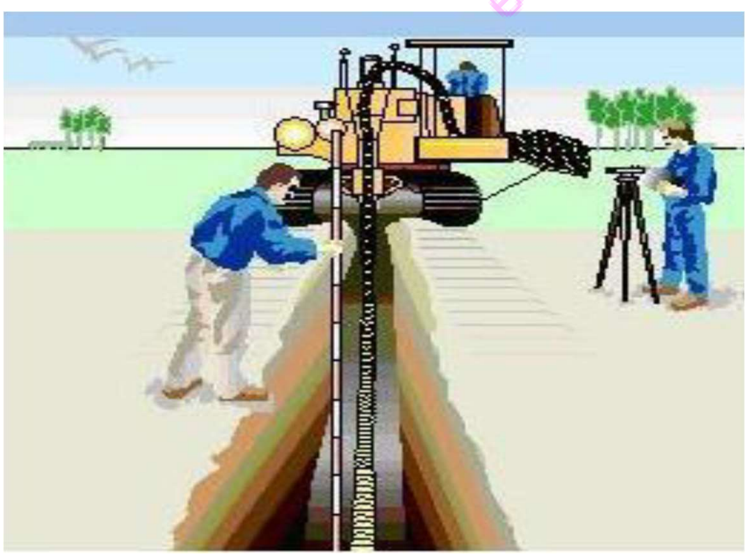
Figure 178: *Measuring gradient*



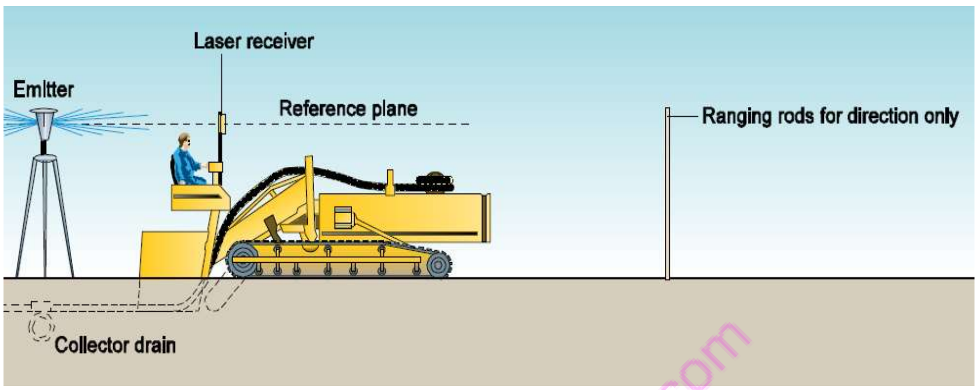
Steps in pipe drain installation

1. Setting out alignments and levels – Involves establishing vertical elevations on the ground surface where the drainage system will be installed. Usually, the difference between the levels of two nearby points is found and the level are reduced.
2. Grade control – Involves ensuring that the required measurements: depth and width and straightness are maintained throughout the excavation process. It is either done manually or by a laser machine

Manual inspection



Automatic grade control by laser



3. Excavating the trenches -it involves making vertical incisions into the ground called trenches to accommodate the pipes. The methods used are either excavation by manual means or mechanically by use of excavators.

An excavator digging up a trench

4. Placing the drain pipes also called pipe laying. It involves laying down drainage pipes on the excavated trenches. It is done by hand or machine.

Pipe laying

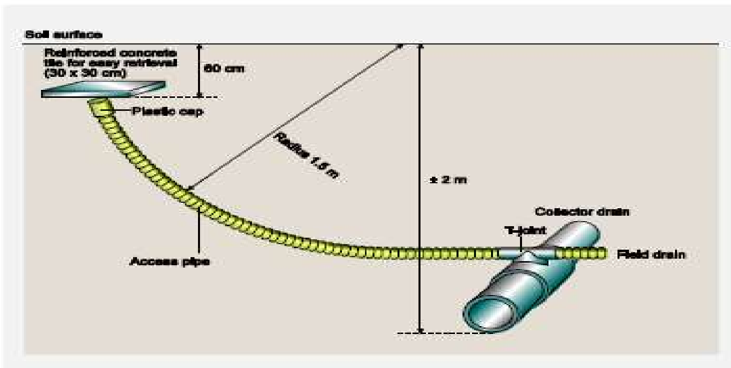
5. Placing the envelopes- done for the protection of the laid pipes either Manually or Mechanically: Synthetic and organic envelopes are prewrapped

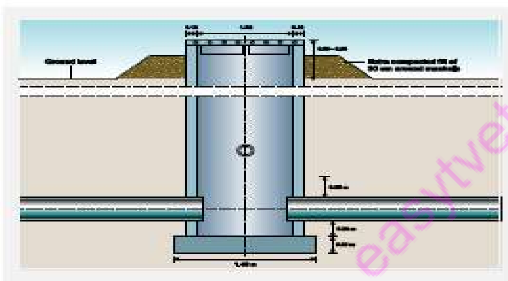
Manual Placing of envelopes

Mechanical placing of envelopes

6. Installation of the junctions/manholes – Manholes are established at identified intervals along the drainage lines for ease of inspection and repair of the drainage system.

Manhole





7.Backfill of the trenches- Involves restoring the surface that was excavated to its original state. Backfill is a three-step operation:

a) Blinding – involves application of a thin layer of soil to cover all the gaping holes
b) Backfill – Involves bringing back the subsoil that was excavated previously
c) Compaction – is the final operation that involves compactors moving on the backfilled portion in order to harden the surface to secure the underground pipes.

Fig 4.0: Mechanical backfilling

8. Site clean-up – it is the final step that involves making sure that the surface is clear from any debris, stones or dirt. The surface should be reinstated to its natural state.

Site clean-up in action

Access to Drains

Although a good drainage system (whether carrying surface water or foul water) should be designed to avoid the possibility of a blockage, circumstances arise, often due to misuse, where this happens. It is therefore very important that adequate provision is made so that obstructions can be cleared with the minimum of trouble.

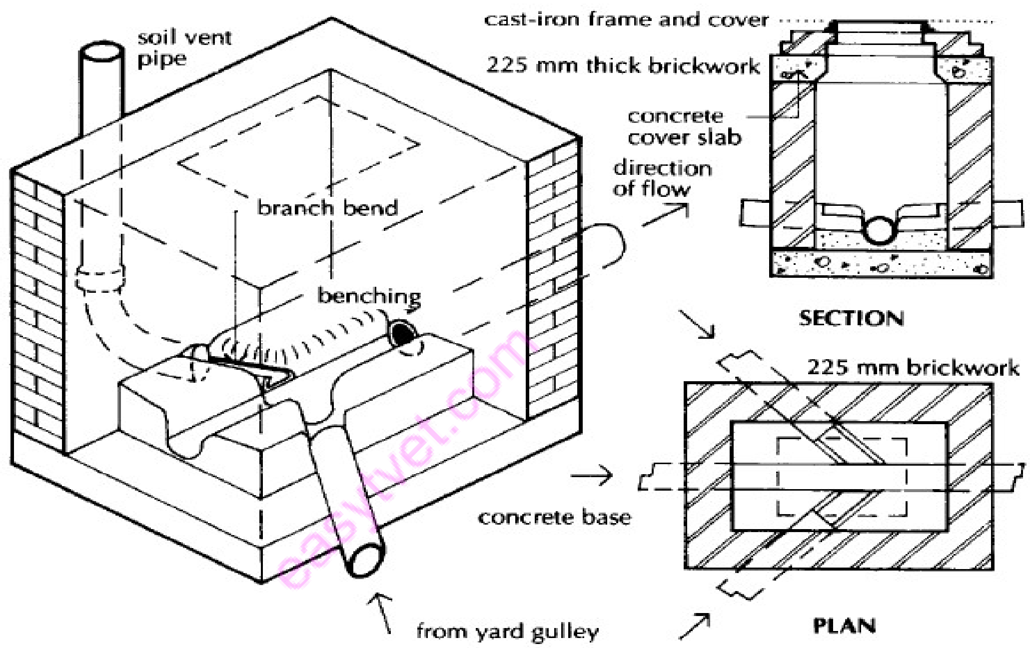
To enable internal inspection and testing of a drainage system or to provide a route in which the clearance of blockages can be achieved it is essential that sufficient provision is made for the internal access to the drain.
An access point should be provided at the following locations:

- At the highest point or head of the drain.
- At changes of gradient or direction (i.e. bends).
- At junctions or branches.
- At changes in pipe diameter.
- Between long drainage runs.

There are three types of access generally in use:

- **Rodding eyes:** A capped extension on the pipe where access can be gained to a drain or any discharge pipe for the purpose of cleaning with rods or inspection.
- **Access fittings:** A fitting, such as a bend, branch or gully, which has a cover fitted, usually bolted to the fitting, in order to gain access. The cover may be located above ground or at ground level such as in the case of a gully. It may be located below ground; in which case it will need to be incorporated into an inspection chamber or manhole.
- **Inspection chambers and manholes**: A chamber constructed of brick, concrete or plastic and designed to expose a section of open pipe, in the form of a channel at its base. The definition of an inspection chamber or manhole is based on size. If the chamber is large enough to work in it is identified as a manhole, which would certainly be the case in all chambers over 1m deep.

Section view of an inspection chamber



Drainage Installation methods

a) Manual installation

- Labour intensive
- Slow
- No special equipment needed
- Only drain depth < 1.0 m
- Only when water table > drain depth
- More costly

b) Mechanical Installation

- Specialized machines & equipment
- Automatic depth control

- Drain depth above & below watertable
- Only for large-scale projects

c) Combined manual & mechanical installation

- Digging trenches with hydraulic excavators
- Installing drains by hand

Tests for Below Drainage Systems

After the drain has been laid and before backfilling, or pouring concrete or granular material round the pipes, it should be tested. The three main methods of testing underground drains for soundness are:

- Water Tests.
- Air Tests.
- Smoke Tests.

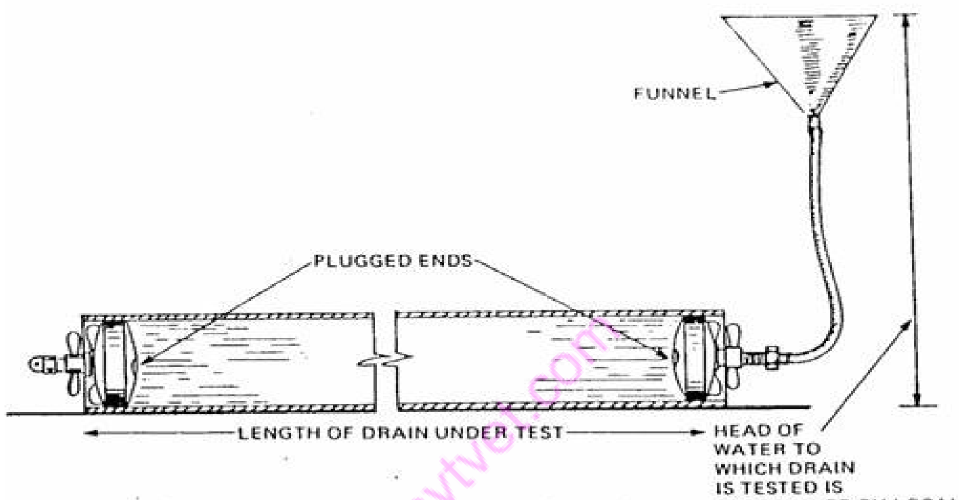
If any leak occurs, the defective pipe or joint should be rectified and the drain again tested. Wherever possible, testing should be carried out between the manholes and short branch drains tested along with the main drainage system. Long branch drains and manholes should be tested separately. The test before backfilling should be carried out as soon as is practicable and the pipe should be supported to prevent any movement of the drain during the test.

1. **Water Tests**

- The drain should be filled with water, to give a test pressure equal to 1.5m of water above the soffit of the drain at the high end, but not more than 4m head of water above the soffit of the drain at the low end. Steeply grade drains should be tested in stages, so that the head of water at the lower end does not exceed 4m.
- The pipeline should be allowed to stand for two hours and topped up with water.
- After two hours the loss of water from the pipeline should be measured by noting the quantity of water needed to maintain the test head for 30 minutes. The fall of water needed in the vessel or stand pipe may be due to one or more of the following:

- Absorption by pipes or joints;
- Trapped Air;
- Sweating of pipes and joints;
- Leakage from defective pipes or joints;
- Leakage from stoppers

Water test



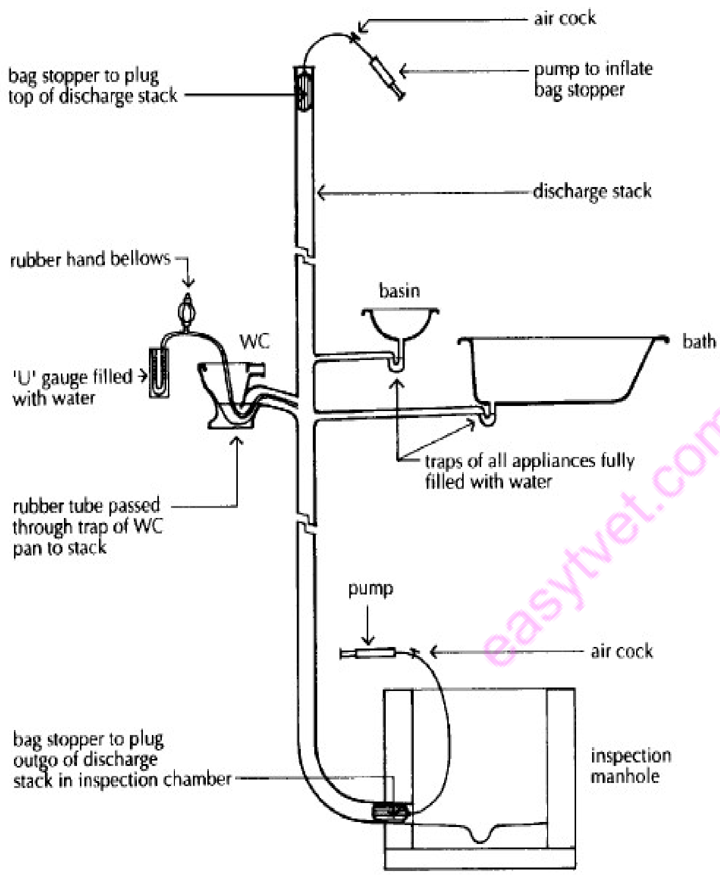
Water testing of drains.

2. **Air Tests**

An air test is usually applied if there is insufficient water available for testing, or if there is difficulty in its disposal on completion of the test. Air tests are usually pressurized to 100mm for 10 to 15 minutes, during which time the pressure drop on the gauge must not be more than 25mm.

An advantage with air testing is that all parts of the drain are subjected to the same pressure, unlike water testing where the lower end is at a higher pressure than the inlet.A tee piece with three valves is connected to a manometer (U-gauge), hand pump and a hose. The hose is passed through the seal of a Gulley Trap. With Valves A and C open and Valve B closed, air is pumped into the system. The air pressure is checked periodically by opening Valve B. When the test pressure is reached, Valve A is closed and Valve B is opened. The air pressure is now recorded on the U-Gauge. If the system is sound the difference in levels in the manometer will be retained. Should there be a leak the levels will return to zero.

Figure 179: *Air Test*



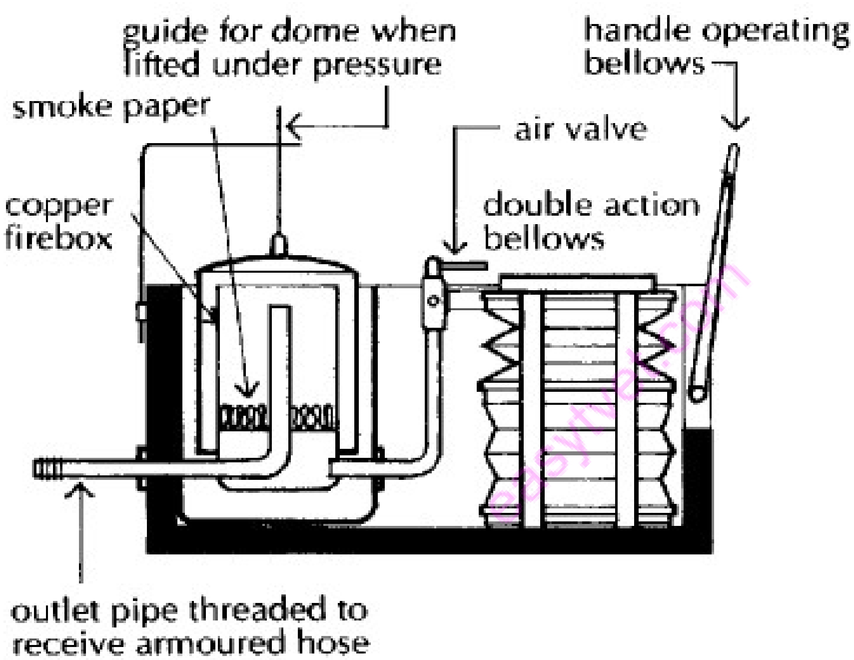
3. Smoke Tests

The smoke test is used both for testing the soundness of the system and for tracing a suspected leak. It can be used equally well for the testing of above ground soil, waste and vent pipes. All water seals must be charged with water and all branch drains and vents must be sealed except one. Smoke is then pumped into the system through a test plug which is fitted in the lowest point of the drain or stack.

The highest vent is left open until smoke begins to escape. At this point the vent is then sealed and pumping continues until sufficient pressure is built up inside the smoke machine to raise the dome approximately 50mm. Pumping now ceases and the system remains under test for 5 minutes. If the dome remains in the elevated position the system is sound. Should the dome fall or fail to rise a leak is indicated. Pumping is continued while the system is checked for smoke leakage.

This test should not be used on plastic systems, because of the detrimental action between the smoke and some types of plastic.

Figure 180: *Smoke testing machine*



Plumbing Faults in Drainage Systems and Corrections

Plumbing problems can spring up anytime in systems. Some of the issues are minor and can be fixed without any professional assistance. However, there are problems that only an expert plumber can resolve satisfactorily. Following are some of the common the plumbing defects that can arise in water storage and pumping systems after installation:

4. Low water pressure

Poor water pressure is generally caused by blocked joints and elbows. It can be corrected through repair and replacement of the affected joint

5. Clogged pipes

When a sticky or hard substance such as a stone or other foreign body passes through pipes it causes obstruction or partially closing the valves and pipes. There are many techniques used to clear the drain and sinks Using an appropriate chemical can fix the minor obstruction. However, chemicals are not always safe.

6. **Leaky pipes**

Can be caused by pipe joint damage, excessive water pressure, cracked pipes and incorrect pipe laying. This leaking water dampens the walls, making them look ugly and dirty. Damp or wet walls cause unpleasant earthy odor and mold growth. Fix pipe leakages using a shark bite, rubber and metal clamp or by sealing it with an Epoxy seal.

7. Air locks

It occurs in plumbing systems when pockets of air in a pipe trap the water in the pipe, not allowing the water to flow freely through the pipe. This problem usually occurs in hot water pipes, since the water pressure from the hot water tank won't force the air blockage out of the way.

Waterproofing to plumbing appliances and fittings can be done using:

- Cement Waterproofing.
- Liquid waterproofing membrane.
- Bituminous Membrane Waterproofing Method.
- Polyurethane Waterproofing
- Teflon tape
- Caulking

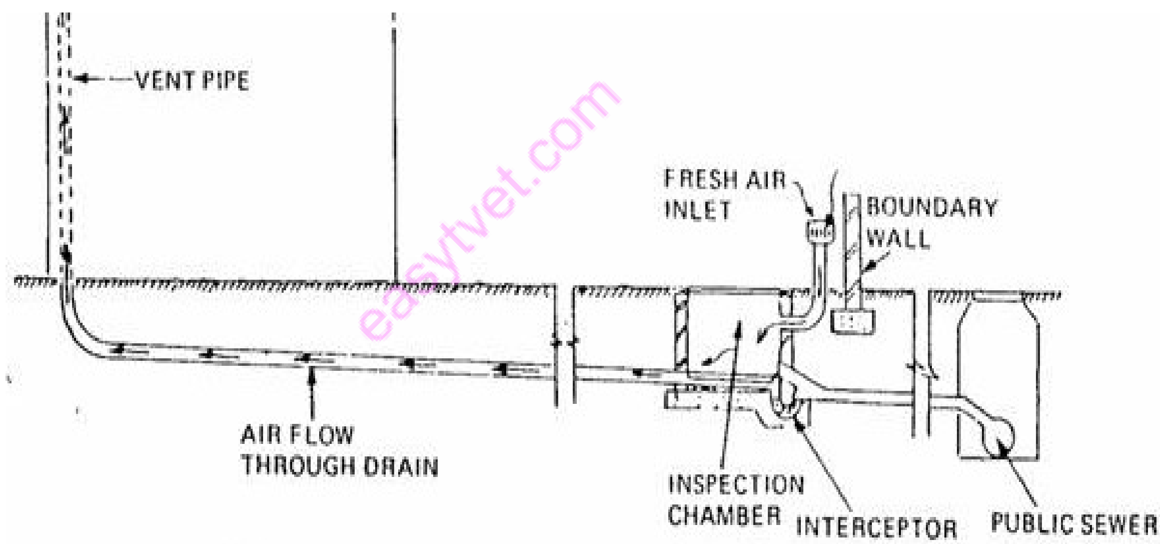
3.2.6.4. Learning Activities

Practical activities

Procedure

1. Assemble all tools and materials required
2. Set out the drainage system of a suitable depth as in the figure below.

Fig 4.6: Below ground drainage



Materials Required

May include but not limited to:

- Measuring tools
- Levelling equipment's

- Mason trowels
- Mason square
- Spirit level
- Boning rods
- Floats
- Mallet
- Ball hammer
- Masonry chisel

3.2.6.5. Self-Assessment

1. Which four tests would you apply when testing the functionality of a plumbing system?
2. What are the five disadvantages of manual installation for underground drainage?
3. Which three waterproofing material would you use to correct a leaking elbow?
4. What are the guiding principles when designing any drainage system?
5. How would you undertake the smoke test for below water drainage?

3.2.6.6. Tools, Equipment, Supplies and Materials

- Measuring tools
- Levelling equipment's
- Mason trowels
- Mason square
- Spirit level
- Boning rods
- Floats
- Mallet
- Ball hammer
- Masonry chisel

3.2.6.7. References

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3.2.6.8. Model Answers

1. Which four tests would you apply when testing the functionality of a plumbing system?
    - Water
    - Smoke
    - Air
    - Peppermint
2. What are the five disadvantages of manual installation for underground drainage?
    - Labour intensive
    - Slow
    - Limited depth. Only drain depth < 1.0 m
    - Limited to tough ground surfaces
    - More costly

3. Which three waterproofing material would you use to correct a leaking elbow?
    - Cement Waterproofing.
    - Bituminous Membrane
    - Teflon tape
    - Caulk

4. What are the guiding principles when designing any drainage system?

- Provide adequate access points.
- Keep pipework as straight as possible between access points and for all bends over 45º and access point should be provided.
- Ensure all pipework is adequately supported
- Ensure the pipe is laid to a self-cleansing gradient
- Ensure the drainage system is well ventilated

5. How would you undertake the smoke test for below water drainage?

- The smoke test is used both for testing the soundness of the system and for tracing a suspected leak. It can be used equally well for the testing of above ground soil, waste and vent pipes.
  All water seals must be charged with water and all branch drains and vents must be sealed except one. Smoke is then pumped into the system through a test plug which is fitted in the lowest point of the drain or stack.

CHAPTER 4: SANITARY APPLIANCES

Unit of learning code: CON/CU/PL/CR/04/5/A

Related Unit of Competency in Occupational Standard: Install Sanitary Appliances

4.1 Introduction to the unit of learning

This unit specifies the competencies required to install sanitary appliances. It involves preparing simple working drawings, quantifying and costing sanitary appliances, fixing sanitary appliances and testing and commissioning working of sanitary appliances. It is applied in the construction industry

4.2 Summary of Learning Outcomes

1. Prepare working drawings
2. Quantify sanitary appliances
3. Fix sanitary appliances
4. Test and commission working of sanitary appliances

4.2.1 Learning Outcome 1: Prepare working drawings

4.2.1.1 Introduction to the learning outcome

This learning outcome specifies the different working drawings that a plumber will encounter when carrying out sanitary installations. The plumber will be able to interpret and understand how to fit various components from the information contained in the working drawings and specifications. Preparing simple working drawings,

4.2.1.2 Performance Standard

1. Drawings are identified and selected based on the job.
2. Scale of the drawing is determined based on the ***specifications*.**

3. Measurements are converted based on scale.
4. Symbols are identified based on best practices.
5. Sanitary appliances are identified based on the drawing
6. Simple working drawings are Prepared based on specifications
7. Isometric working drawings are drawn based on best practices.
8. Manufacturers drawing of sanitary appliances are interpreted as presented.
9. Assembling of sanitary appliances is identified and interpreted as per manufacturers' drawing.

4.2.1.3 Information Sheet

Definitions of terms

- ***Working drawings*** - A comprehensive set of drawings used in a building construction project. They include architectural, structural and other engineering drawings.
- *Symbol* is a simplified image of component or things they represent.
- *Blueprint* is a reproduction of a technical drawing or engineering drawing using a contact print process on light-sensitive sheets.
- *A plan* a view from above showing the arrangement of spaces in building in the same way as a map, but showing the arrangement at a particular level of a building
- *An elevation* is a view of a building seen from one side, a flat representation of one front of a building
- *Block plan* used in identifying the site and locate the outline of the building in relation to the surrounding.
- *Cross section,* also simply called a section, represents a vertical plane cut through the object, in the same way as a floor plan is a horizontal section viewed from the top
- *Detail drawings* show a small part of the construction at a larger scale, to show how the component parts fit together.

- *Specification* is a precise description of the materials and methods of workmanship to be employed while carrying out the contract work
- *Schedules* give tables of information on ranges of similar items
- *Bill of Quantities* is a measure or price of the amount of materials and labor and other items required for the building work.
- *Ancillary equipment* is machines and other technical things which are used with the main items of equipment to create a complete system.

Types of Drawings

At the design stage, sketch drawings and preliminary drawings will be used to show the designer's intentions. Sketch drawings are also often used by site supervisors and craftsmen to show other operatives how a particular problem might be resolved or how a component can be fabricated on site. Once the design is accepted, production of the working drawings can be done.

These drawings are used in a range of fields namely;

- Mechanical drawings - show information about heating, ventilating, air conditioning and plumbing details in a building.
- A structural drawing includes a plan or set of plans and details for how a building or other structure will be built. They are generally prepared by registered professional engineers, and based on information provided by architectural drawings.
- Architectural drawings are an illustration of what the final product will look like plus an instructional tool on how to achieve it. Architectural drawings can be devoted to depicting an overview of the building i.e., an elevation or they can focus on a particular detail.
- A plumbing drawing, a type of technical drawing, shows the system of piping for fresh water going into the building and waste going out, both solid and liquid. It also includes fuel gas drawings. Mainly plumbing drawing consist of water supply system drawings, drainage system drawings, irrigation system drawings, storm water system drawings.

Scales in Drawings

Scaling is used to enlarge or reduce a drawing in size while keeping the proportions of the drawing the same. Scales are generally expressed as ratios and the most common scales used in furniture drawing are 1:1, 1:2, 1:5, and 1:10 for reducing and possibly 2:1 for enlarging.

Scaling is used to either:

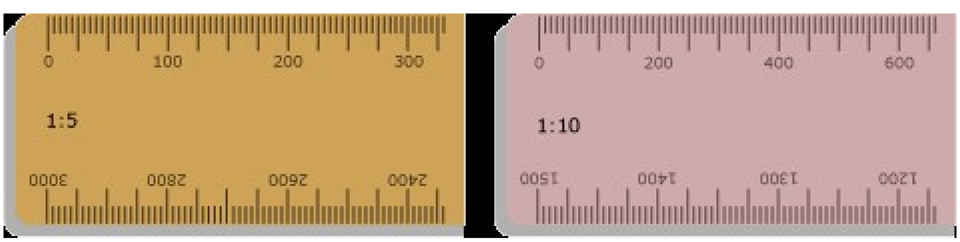
i. reduce the drawing in size so that it will fit onto the page, or
ii. enlarge the drawing in size so that all required details are clearly visible.

Scale rules allow us to directly set out measurements onto a drawing without having to convert them to their scaled sizes by using a calculator first.

The whole process is made easier because these conversions are already made for us. On a scale rule which has divisions of 1:5, each division represents 5mm and the measurements on the rule indicate this.

Scale rulers.

On a scale rule which has divisions of 1:10 each division represents 10mm and the measurements on the rule indicate this.



Conversions of Measurements Based on Scale

Making a measurement smaller or larger is known as scale conversion and requires a common scale factor, which can be used to multiply or divide all measurements by.

To scale a measurement to a smaller measurement, for instance when making a blueprint, simply divide the real measurement by the scale factor. The scale factor is commonly expressed as 1: n or 1/n, where n is the factor.

For example, if the scale factor is 1:8 and the real measurement is 32, divide 32 ÷ 8 = 4 to convert.

To convert a measurement to a larger measurement simply multiply the real measurement by the scale factor.

For example, if the scale factor is 1:8 and the measured length is 4, multiply 4 × 8 = 32 to convert.

Reducing the Scale Factor

The methods above to convert a measurement assume the scale factor is in the form of 1: n or 1/n, which means some additional work is needed if the ratio is 2:3, for example. When the scale factor is not in an even 1: n ratio it will need to be reduced to 1: n. Use our ratio calculator to reduce a ratio. A ratio can also be reduced by dividing both the numerator and the denominator by the numerator.

For example: 2/3 can be reduced by dividing both numbers by 2, which would be 1/1.5 or 1:1.5.

2 ÷ 2 = 1

3 ÷ 2 = 1.5

scale factor = 1:1.5

Plumbing symbols

Plumbing symbols are used when drawing house plans and isometric plumbing drawings. The purpose of these symbols is to indicate where the different elements of the plumbing system are positioned.

Table 14: Plumbing symbols for sanitary appliances

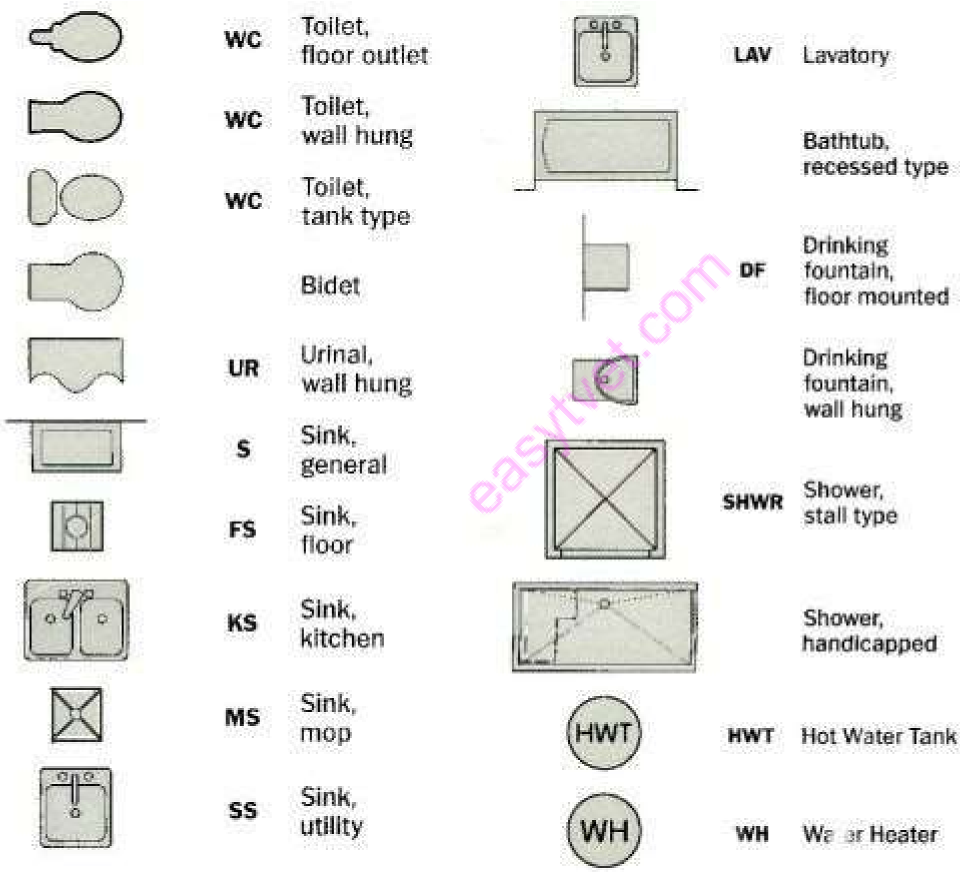


Table 15*: plumbing symbols*

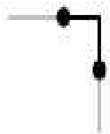
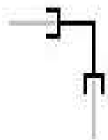
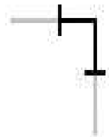
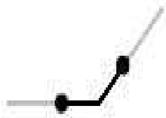
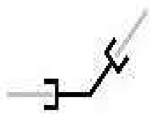
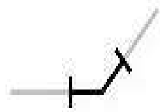
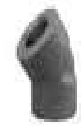
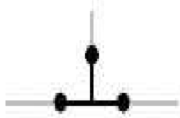
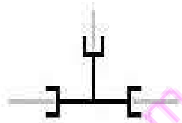
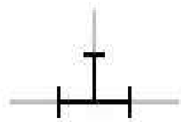
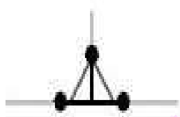
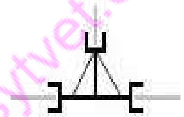
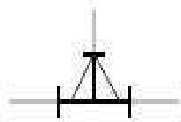
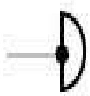
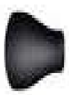
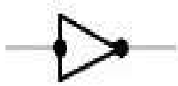
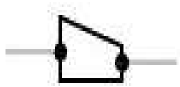
Image	Fittings	Butt weld Symbol	Socket Weld Symbol	Threaded Symbol	Fittings	Image
	Elbow 90°				Elbow 90°	
	Elbow 45°				Elbow 45°	
	Tee equal				Tee equal	
	Tee reducing				Tee reducing	
	Cap				Cap	
	Reducer concentric		....	...	Reducer concentric	...
	Reducer eccentric		....	...	Reducer eccentric	...
Image	Fittings	Butt weld Symbol	Socket Weld Symbol	Threaded Symbol	Fittings	Image

Image	Valves	Butt weld Symbol	Flanged Symbol	Socket or Threaded Symbol	Valves	Image
	Gate				Gate	
	Globe				Globe	
	Ball				Ball	
	Plug				Plug	
	Butterfly			...	Butterfly	
	Needle				Needle	
	Diaph	...			Diaph	
	Y-type				Y-type	
	Three way				Three way	
	Check				Check	
	Bottom	...		...	Bottom	
	Relief	...		...	Relief	
	Control straight	...		...	Control straight	
	Control angle	...		...	Control angle	
Image	Valves	Butt weld Symbol	Flanged Symbol	Socket or Threaded Symbol	Valves	Image

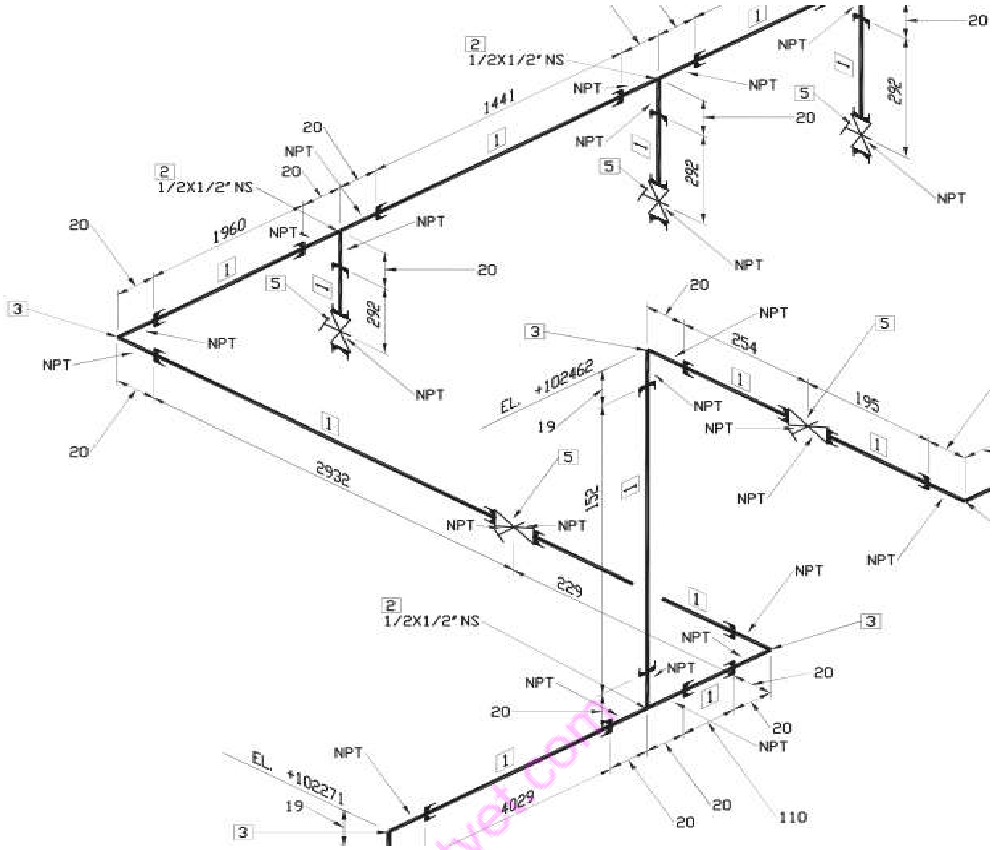
Isometric Pipework Drawings

Piping isometric drawing is an isometric representation of single pipe line in a plan. It is the most important deliverable of piping engineering. Piping fabrication work and assembly is based on isometric drawings.

Piping isometric drawing consists of three sections. Main graphic section consists of isometric representation of a pipe line route in 3D space, which includes following information:

vi. Line number.
vii. Flow Direction.
viii. Support Tags and location.
ix. Piping Components location.
x. Weld Locations.

Example of a pipework isometric drawing



Section on left or right side of a Plumbing drawing consists of a schedule of Material Section for the portion of line shown in isometric graphic. It includes following information for all components:

vii. Component Description.
viii. Component Material Code.
ix. Nominal Size.
x. Quantity.
xi. Whether shop material or field material.
xii. Number of Spools.

Title bar section at the bottom consists of following information:

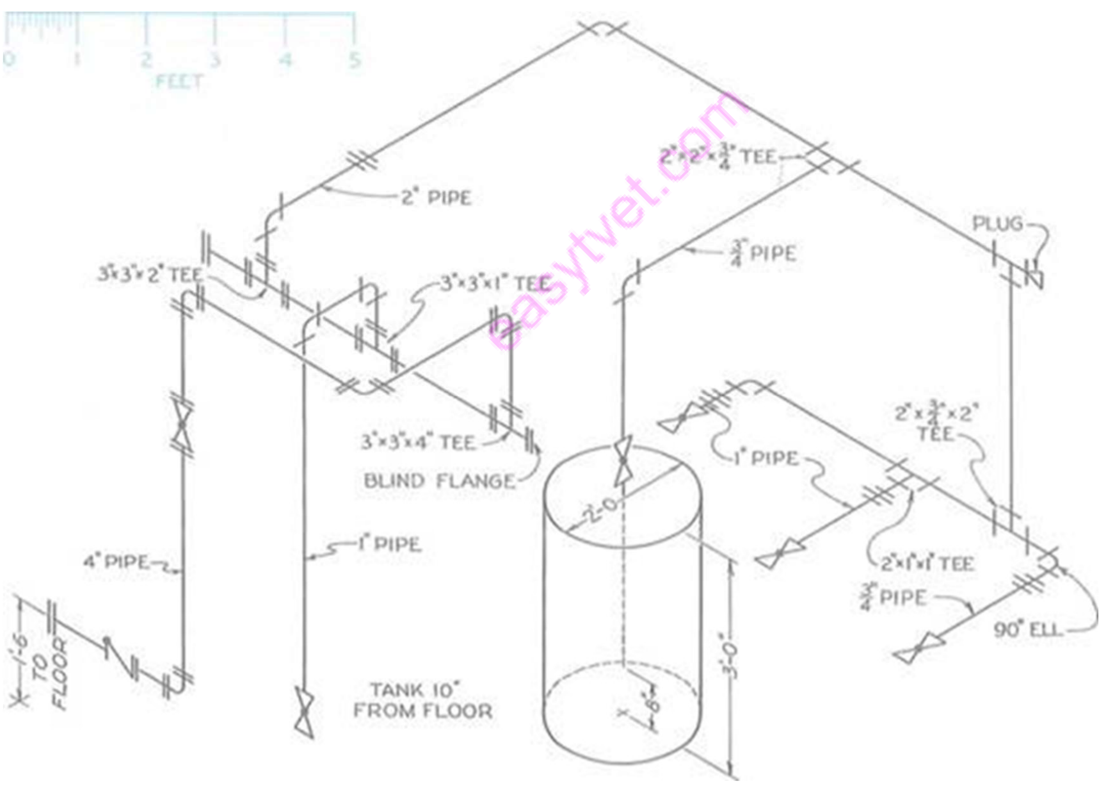
- Project details such as client name

- engineering office name
- project name
- project number

4.2.1.4 Learning Activities

Produce a freehand sketch of the isometric pipework diagram shown below.

isometric pipe drawing



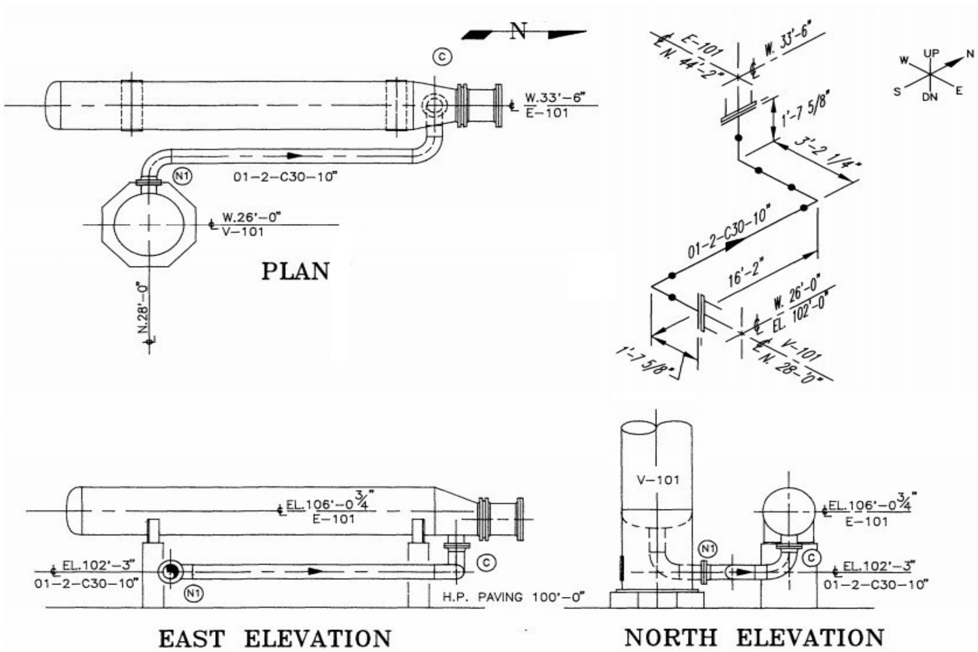
Materials Required

- Scale rule
- Pencils
- Eraser
- Drawing paper
- Drawing board
- T-square

4.2.1.5 Self-Assessment

1. What does a 1/2 scale mean?
2. Draw a free hand sketch of the isometric pipework drawing shown below.

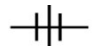
isometric pipework drawing



Match column A with column B.

Table 16: Plumbing symbols questions

A	B
Symbol	
1. Tee	A. WC
2. Elbow 90º	B.
3. Wye	C.
4. Union	D. LAV
5. Elbow 45º	E.
Abbreviation	
6. Water Closet	F. UR
7. Shower	G. SH

8. Lavatory	H. 
9. Floor Drain	I. 
10. Urinal	J. FD

Convert the following measurements as required in the given.

a. 64 cm ---------------------------- inches

b. 59 yards------------------------------- feet

c. 95.5 dm ------------------------------meter

d. 19 inches ----------------------------centimetre

e. 47 feet ------------------------------ inches

f. 4 m -------------------------cm

g. 9 yards feet

h. 5.5 dm ---------------------------- meter

i. 9meters ----------------------------centimetre

j. 7 feet -----------------------------inches

4.2.1.6 Tools, Equipment, Supplies and Materials

- Scale rule
- Pencils
- Eraser
- Drawing paper
- Drawing board
- T-square

4.2.1.7 References

Mays, L., 2001. Water resources engineering. New York: Wiley.

Cauldwell, R., 2005. Remodel plumbing. Newtown, CT: Taunton Press, pp.24-35.

Blower, G., (2007). Plumbing. Welwyn Garden City: Pearson Education UK.

Rendow Yee., (2002). Architectural drawings: a visual compendium of types and methods.

Thompson., (2007). Architectural design procedures, Second Edition. Architectural Press

4.2.1.8 MODEL ANSWERS

1. What does a 1/2 scale mean?
    - Half scale is 1:2. One unit on the drawing equals two units on the object. This means the drawing of the object is twice as large as the object itself.
2. Identify the symbols on this pipework isometric drawing.
    - Pipe
    - Flow direction
    - Coupler
    - Nipple

3. A. Identification

i. Prints
ii. Specifications
iii. Symbols
iv. Abbreviation

B.Matching Type

1. C
2. E
3. H
4. I
5. B
6. A
7. G
8. D
9. J
10. F

C. Units conversion

1. $64\ \text{cm} \times \dfrac{1\ \text{inch}}{2.54\text{cm}} = 25.20\text{inch}$

2. $59\ \text{yards} \times \dfrac{3\ \text{ft}}{1\ \text{yard}} = 177\text{ft}$

3. $95.5\ \text{dm} \times \dfrac{1\text{m}}{10\text{dm}} = 9.55\text{m}$

4. 19 inches x 2.54

cm = 48.26cm

1 inch

5. 47 feet x 12 inches = 5.64 inches

6). 4 m ----------------------400cm

7). 9 yards --------------------- 27 feet

8). 5.5 dm---------------------- .55meter

9). 9meters -------------------- 900centimetre

10). 7 feet ---------------------- 84inches

4.2.2 Learning outcome 2: Quantify sanitary appliances

4.2.2.1.Introduction to the learning outcome

This learning guide helps the trainee to identify the supplies and materials required for installation of sanitary appliances.

4.2.2.2.Performance Standard

1. Materials and Supplies required for fixing are identified based on requirements of the job.
2. Schedule of sanitary appliances is prepared based on the drawing.
3. Materials and supplies required are measured and estimated based on working drawings and specifications
4. Sanitary appliances are costed based on best practice

4.2.2.3.Information Sheet

Definitions of terms

- *Discharge Pipe*- means any pipe which is intended to convey discharges from sanitary fixtures or sanitary appliances and includes a waste pipe, combined waste pipe, branch discharge pipe and discharge stack
- *Drain* - pipe normally laid below ground level including fittings and equipment and intended to convey foul water or surface water to an outfall.
- *Drain vent pipe* means any pipe which is intended to permit the movement of air into and out of a drain or sewer
- *Fitting or Fixture* -any article which is intended to remain permanently attached to and form part of a building
- *Fixture discharge pipe* - a discharge pipe which is used to convey waste from a single sanitary fixture or sanitary appliance to a branch discharge pipe, a discharge stack or directly to
- the drain
- *Fixture vent pipe* - a vent pipe which is connected to a fixture discharge pipe or the sanitary fixture itself
- *Foul water drainage system* - drains, joints. and fillings normally laid underground and used specifically for the conveyance of foul water from the plumbing system to an outfall

  Gully trap - a fitting designed to prevent foul air escaping from the drainage system and used to receive the discharge from waste pipes,

  Sanitary appliance - an appliance which is intended to be used for sanitation, but which is not a sanitary fixture.

Sanitary Appliances

Sanitary Appliances are referred to as sanitary fittings and include all fixed appliances in which water is either used for flushing foul matter away or in which water is used for cleaning, culinary and drinking purposes.

They are divided into two classes namely;

a) Soil appliances – which includes WCs and urinals. The discharge is directed to the soil. The type of waste discharged is in the form of fluids with solid matter.

b) Waste appliances – includes wash-basins, baths, showers, sinks and bidets. The discharge from these appliances is described as waste water. The type of waste discharged is in the form of soapy or oily water.

1. Soil appliances

a) WC (Water Closet)

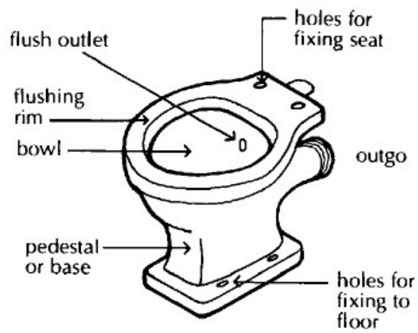
They include the WC (Water closet) and the urinal. The WC is a small room in which the early soiled water pans were enclosed when they replaced the original earth closets. A WC pan is a ceramic or metal bowl to take solid and liquid excrement, with an inlet for flushing and a trapped outlet. The seat is usually a plastic ring secured to the back of the pan. The ususal flushing appliance is a cistern designed to discharge water rapidly into the pan through a flush pipe for cleaning and disposal of contents

Types of WC

i. Pedestal WC

The pan is secured to the floor with screws through holes in the pedestal base to timber plugs in solid floors. The flushing rim is designed to spread the water which discharges through the flush outlet around the pan to wash down the side of the bowl. Spigot end connections for the waste pipe are moulded integrally with the pan.

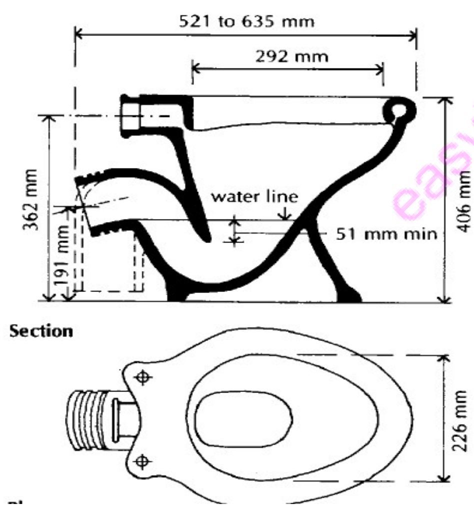
Pedestal WC



ii. Washdown WC

The flush water runs around the rim to wash down the bowl and then overturns the water seal to discharge the contents.

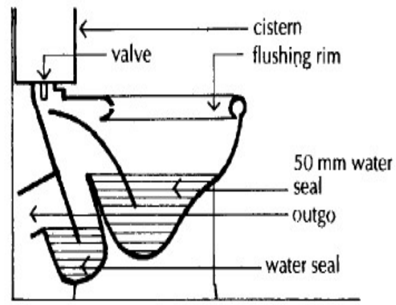
Washdown WC



iii. Siphonic WC

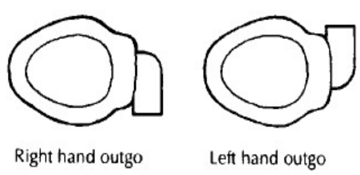
The flush water washes the sides of the bowl and causes a water trap or traps to overturn and create a siphonic action which discharges the contents. The purpose of this arrangement is to effect a comparatively quiet flush and discharge of contents. The trap is the 51 mm minimum projection of the pan into the water lying in the base of the pan to seal against any foul smells that might rise from the drains.

Siphonic WC



Majority of WC have discharge outgo that is near horizontal with a small slope down and is a standard arrangement used for simplicity in production and consequent economy.

dischargo outgo



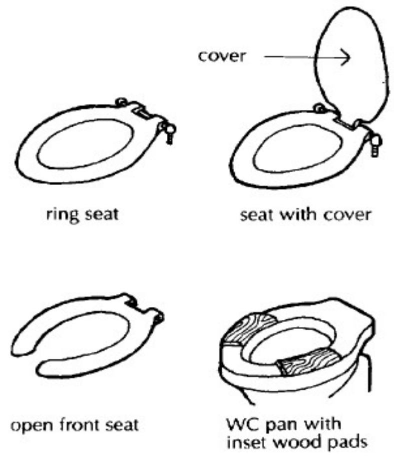
WC have seats in the form of a moulded plastic ring that fits the top of the WC pan. The back of the seat is bolted to pillars and a rod so that the seat is secured in position and can be lifted. They include;

The ring seats and lift up covers – they are moulded from plastic and finished in a small range of colors.

The open fronted lift up seat is used in male toilets to minimize fouling.

The inset wood pads fixed to one WC pan have been used in communal toilets to avoid damage that occurs to lift-up seats in general use

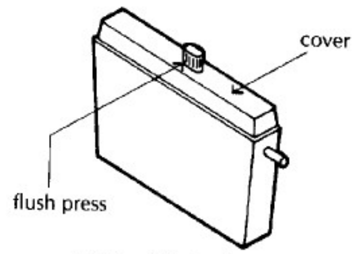
WC seats



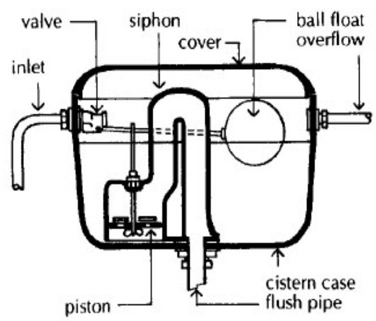
Flushing WC cisterns

Flushing cisterns are made of enameled or galvanized pressed steel or plastics or vitreous china. The cistern is used for low level WC suites and is made into two pieces: the body and a lift-up cover or lid for access to the flush apparatus inside. Perforations for water supply, overflow pipe, operating lever or push and flush pipe are provided. These cisterns discharge water in one operation through a flush pipe or directly to the pan by a siphonic action. The cistern is filled through a valve operated by a ball float and arm. An air gap exists between the highest level of water in the cistern and the outlet of the float valve. The plastic siphon is operated by a lever which raises a piston to force water over the siphon bend and the siphonic action causes the water in the cistern to follow through perforations in the piston.

WC cistern



7.5 litre 'Slimline'
polystyrene WC cistern



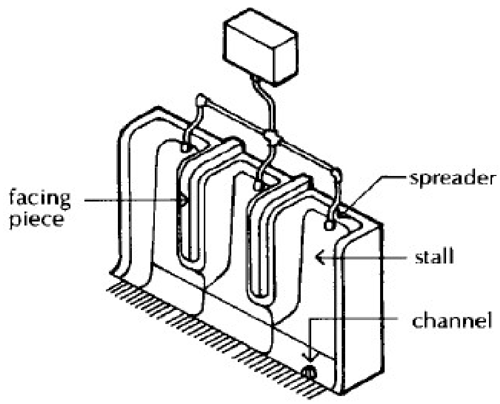
b) Urinals

There are three types namely; Stall, Slab and Bowl.

i. Stall urinal.

Consists of heavy, individual stoneware stalls with either a salt glazed finish, each stall having its own integralchannel. The stalls are set in place on a solid floor against a wall. The junction between individual stalls is covered with salt glazed or white glazed rolls or facing pieces to serve as a finish to the joint between the stalls and afford some privacy to the users.

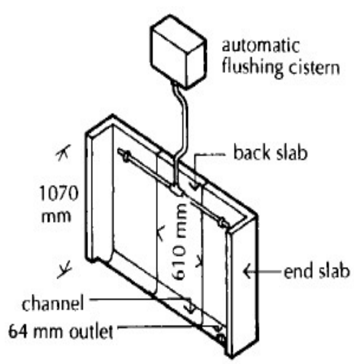
Stall urinal



ii. Slab urinal.

Are less heavy constructions largely taken over from stall urinals for use in public lavatories. Consist of flat white glazed ceramic slab and white glazed ceramic channels bedded in cement and sand against the wall with projecting end slabs to each side.

Fig 2.2 : Slab urinal

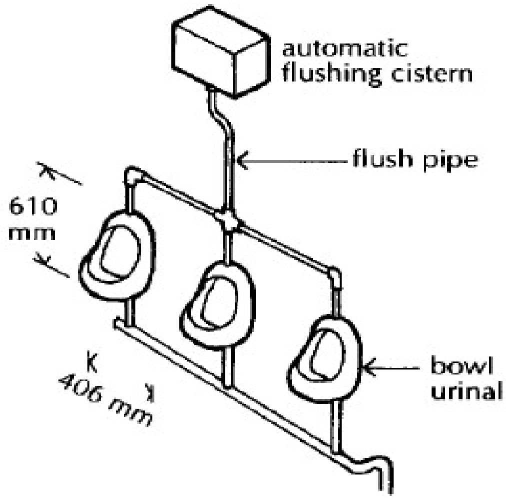


iii. Bowl urinals

Are individual white glazed ceramic bowl urinals fixed to a wall. They are easy to clean and offer privacy to the user. They are bolted to the wall or support and bedded in cement and sand and joints finished with silicone sealing compounds.

Urinals are flushed by automatic flushing cisterns fixed above the urinal and discharging through a flush pipe, spreaders or sparge pipe.

Bowl urinal



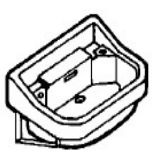
2. **Waste Water Appliances.**

Include basins, baths, sinks and bidets.

a) Wash basins

Designed for washing the upper part of the body supported by wall brackets or by pedestal secured to the floor. Usually made of vitreous china

Wash basin



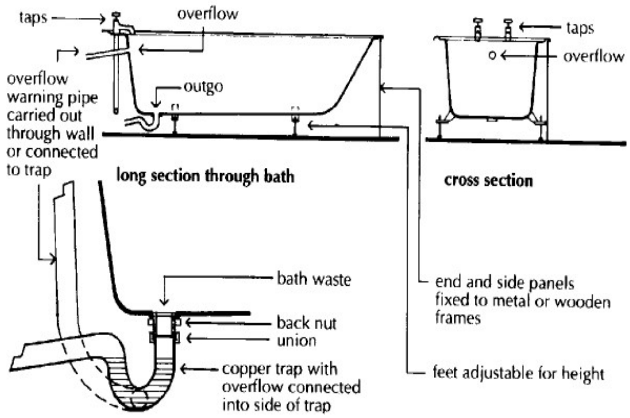
Wash basin fixed on wall brackets

Wash basin on pedestal

b) Baths

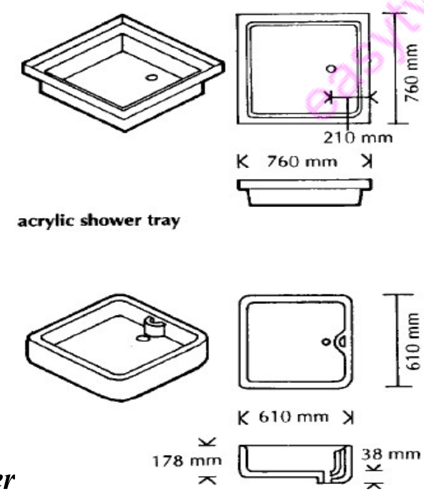
The most used is the standard Magna square ended bath. They are made of porcelain-enameled cast iron or enameled pressed sheet steel or plastic. They are used for body washing.

Bath



c) Shower

Consists of a shower tray or receiver of glazed ceramic, enameled cast iron or plastic to collect and discharge water with a fixed or hand-held shower head or rose and a valve. Showers are either fixed in a wall recess or may be free standing with enameled metal or plastic sides. The walls around fixed showers are lined with some impermeable materials such as tiles and an open side fitted with a waterproof curtain.

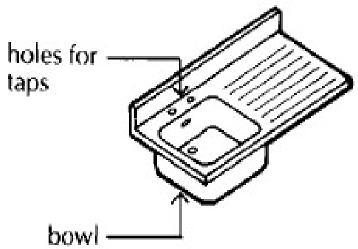


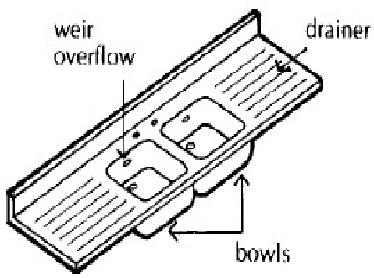
Shower

d) Sinks

Is a stainless steel appliance designed to fit into the kitchen unit made with a single bowl and drainer or double bowl and double drainer. They are finished in the natural colour of stainless steel from which they are pressed.

Sink

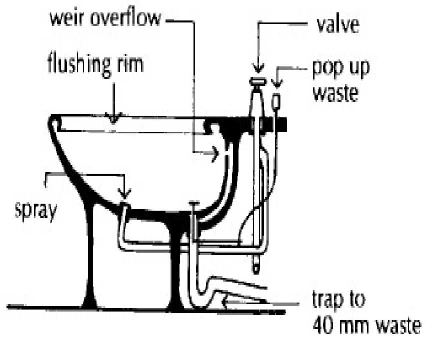




e) **Bidet**

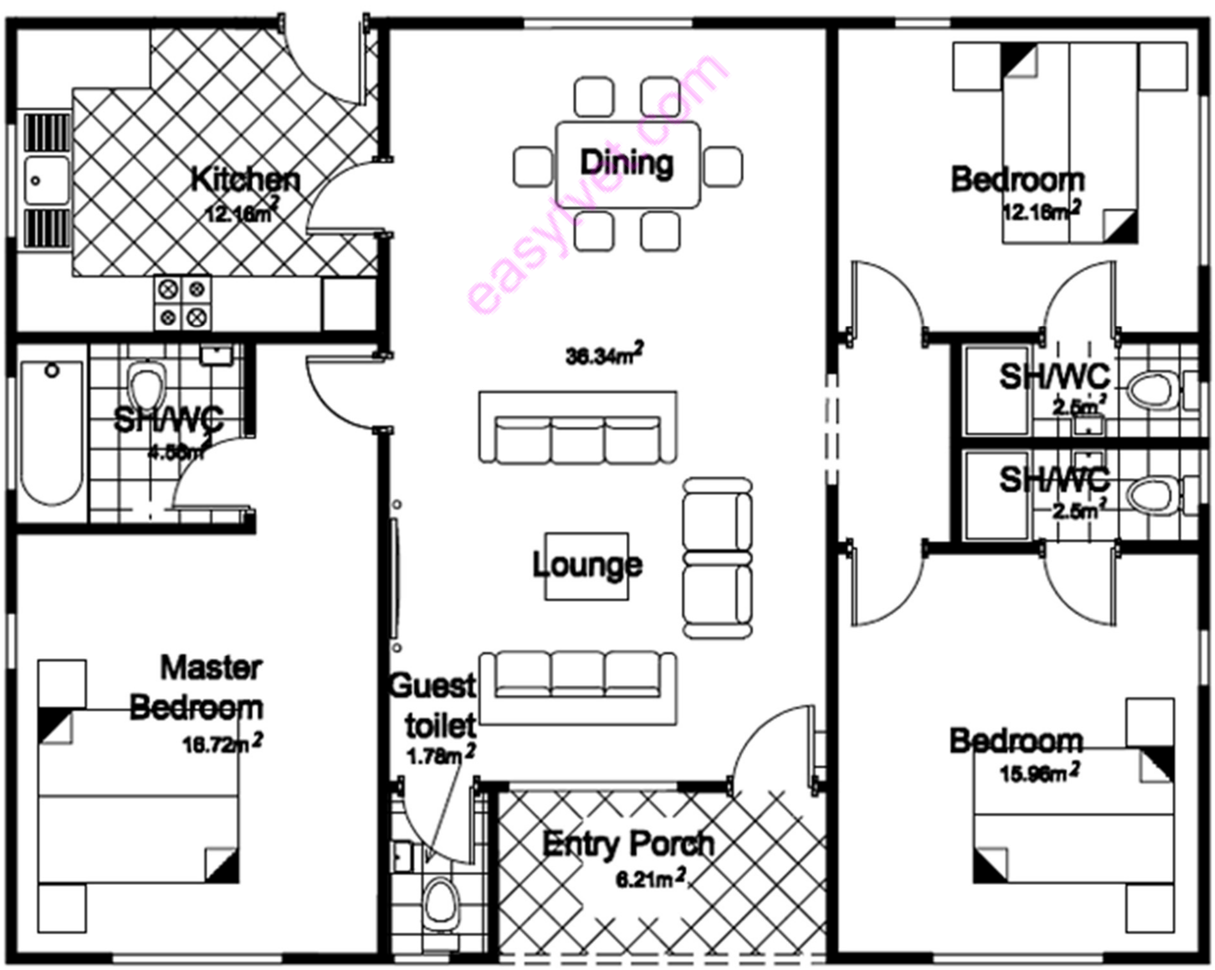
These are appliances used for washing excretory organs. It consists of a glazed ceramic pedestal bowl which is secured to the floor usually backing on to a wall or partition. May be white glazed or finished in a limited range of pastel colours to match other bathroom appliances.

Bidet



Estimation of Sanitary Appliances

Before the fixing of appliances is done, the plumber must first identify the type and number of appliances to be installed. This is clearly visible from the Plumbing working drawings (House Plans).



The type and Number of appliances are then identified from the drawing and the information presented in a tabular form.

NO	DESCRIPTION	QUANTITY
1	Single sink, Double Drain (Stainless Steel)	1
2	Bath-Tub	1
3	Water Closets (Ceramic)	4
4	Shower Heads	2
5	Shower Trays	2
6	Wash Hand Basin	4

The Schedule of materials will then be used to order for the appliances. The cost of purchase will depend on the specifications of the appliance, quality and the manufacturer.

NO	DESCRIPTION	QUANTITY	@
1	Single sink, Double Drain (Stainless Steel)	1	
2	Bath-Tub	1	
3	Water Closets (Ceramic)	4	
4	Shower Heads	2	
5	Shower Trays	2	
6	Wash Hand Basin	4	
	TOTAL		

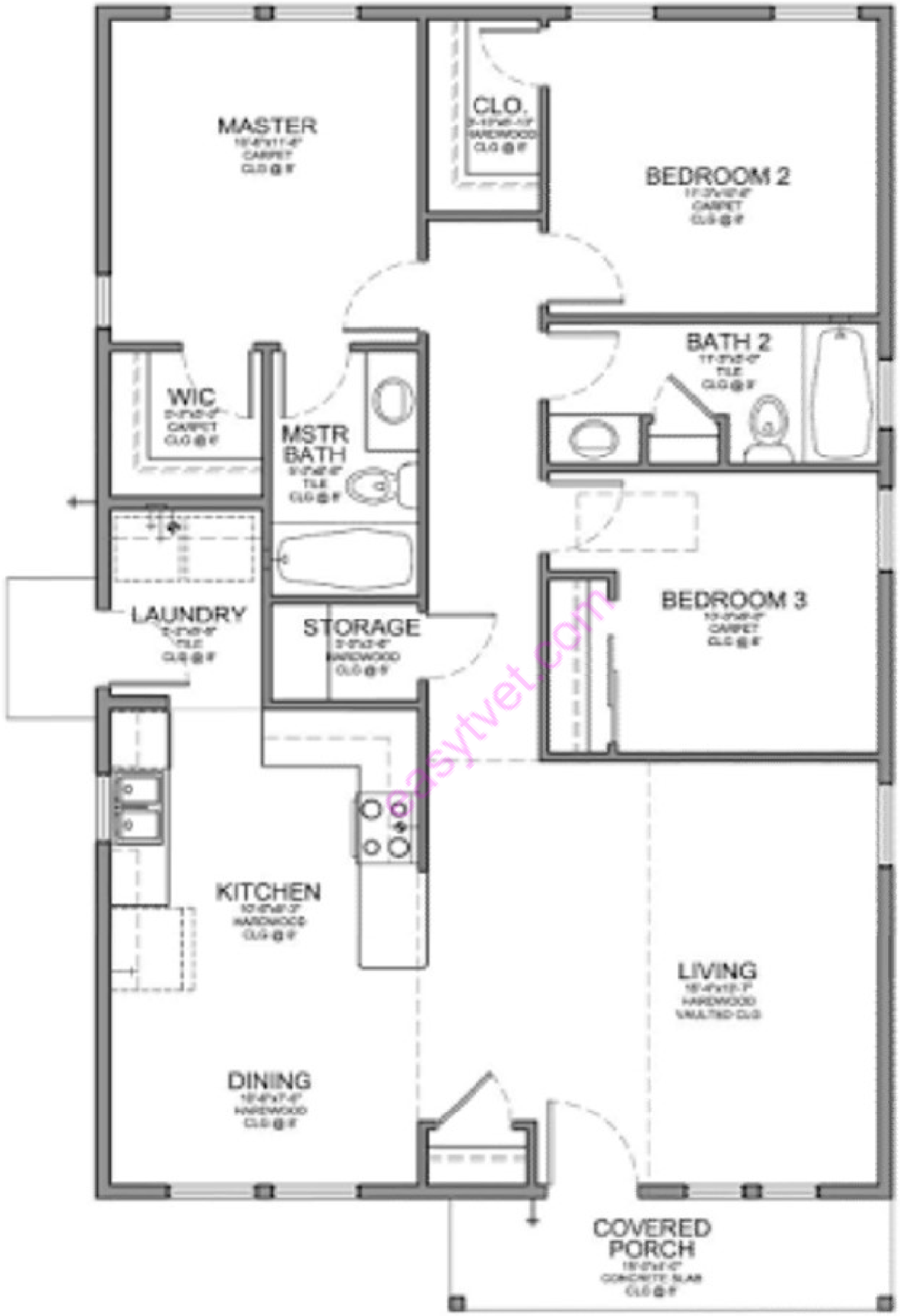
The sum total cost of installation will be inclusive of cost of purchase of materials, cost of labor, cost of profits and cost of overheads. These are charged as a percentage of the cost of appliances.

4.2.2.4.Learning Activities

Practical activity

Task 1

Identify the correct type and number of appliances shown on the plan


MASTER
CLO.
BEDROOM 2
BATH 2
WIC
MSTR BATH
BEDROOM 3
LAUNDRY
STORAGE
KITCHEN
LIVING
DINING
COVERED PORCH
easytvet.com

4.2.2.5.Self-Assessment

Prepare a schedule of materials that will be used to order for the supplies for the plan given in the practical activity

4.2.2.6.Tools, Equipment, Supplies and Materials

- Pipe wrench.
- Simple water storage system
- Pipe threading equipment.
- Pipe cutter.
- Hacksaw.
- Steel rule.
- PPE
- Sink auger
- Toilet auger
- Flange plunger
- Cup plunger
- Teflon tape
- Screws.
- Adhesives.
- Pipes.
- Traps.
- Caulking materials.
- Fittings.
- Water

4.2.2.7.References

P. S. Gahlot., 2006, Building repair and maintenance management, first edition.

Antonio Curado et al,. New materials and technologies in building water piping systems. India.

S. M. Patil,. 2004. Building services.

Deolalikar, S. G,.2013, Plumbing design and practice. 21st reprint. New Delhi.

4.2.2.8.MODEL ANSWERS

Schedule of materials

NO	DESCRIPTION	QUANTITY	@	TOTAL
1	Bath Tub	2		
2	Double sink double drain kitchen sink	1		
3	Wash Hand basins	2		
4	Water Closets	2		
TOTAL				

4.2.3 Learning Outcome 3: Fix sanitary appliances

4.2.3.1.Introduction to the learning outcome

This learning outcome specifies on the the procedures followed when carrying out installation works for sanitary appliances and the tools used for the operation. It also outlines the protective gear that should be worn during such operations.

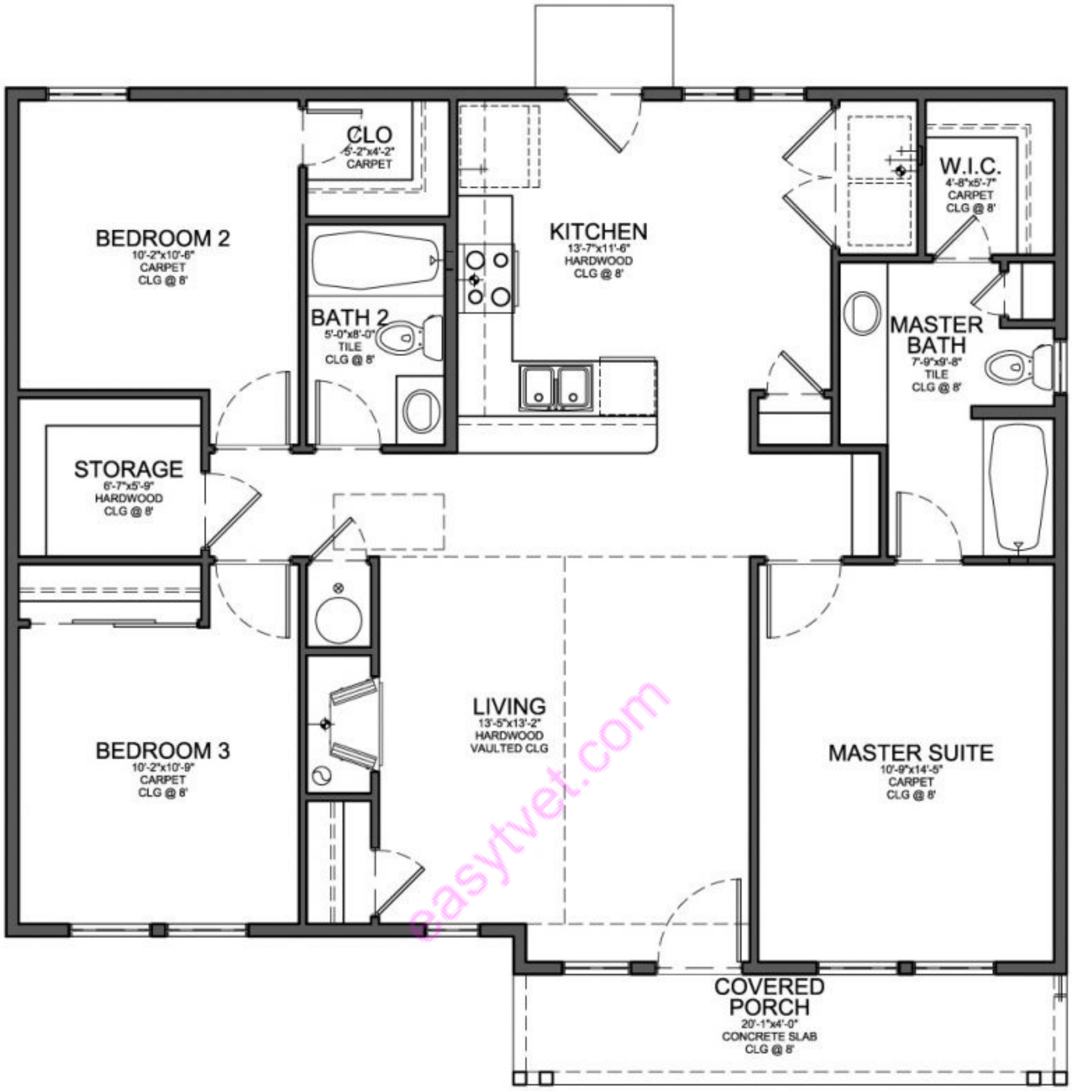
4.2.3.2.Performance Standard

1. Tools and equipment needed for fixing appliances are identified based on the type of sanitary appliance.
2. Appliance positioning is determined based on working drawings.
3. Tools and equipment are used based on best practices.
4. Support for sanitary appliances is put in place based on manufacturers' instructions.

5. Sanitary appliances are mounted based on best practices.
6. Parameter checks are done in accordance to industry standards.
7. Housekeeping is conducted based on best practice.
8. Personal Protective Equipment is used in line with occupational safety and health regulations.
9. Safety and health practices are observed based on OSHA.

4.2.3.3.Information Sheet

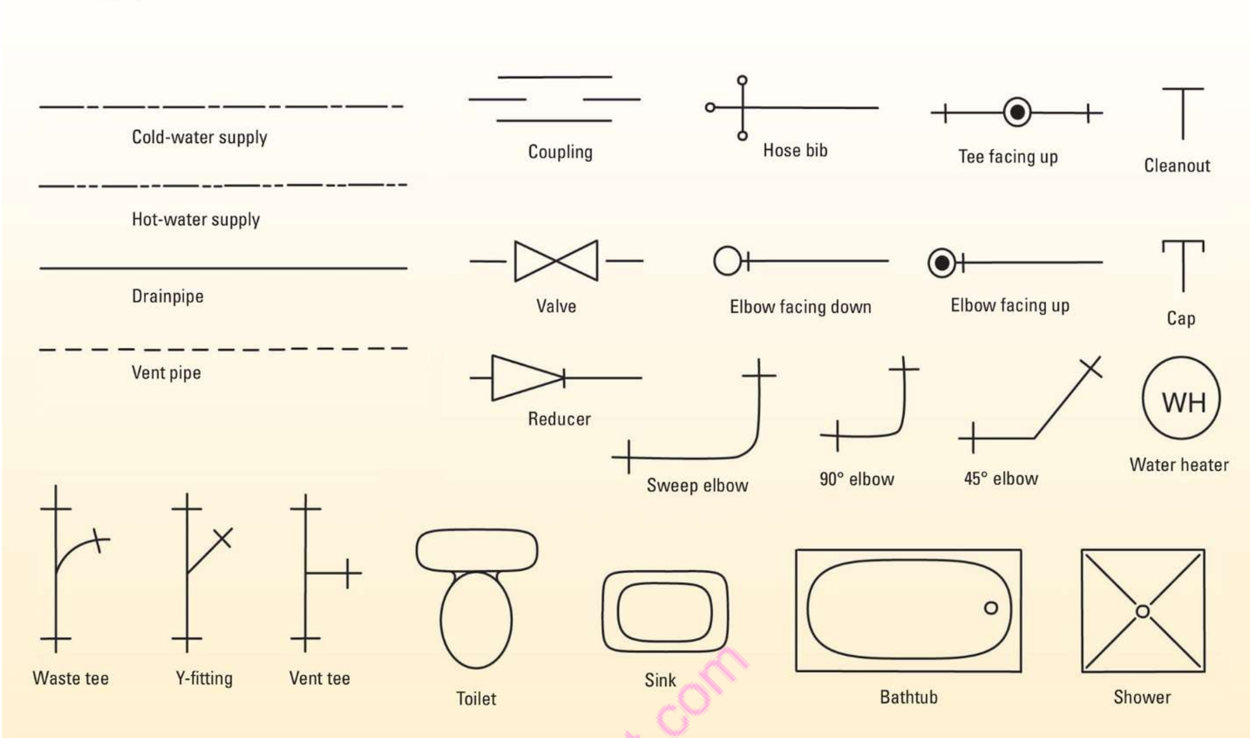
Before installation of sanitary appliances begins, one is first supposed to identify the type and number of appliances from the architectural and plumbing working drawings.



This can be correctly identified if there is prior knowledge on the Plumbing symbols

Sample of Plumbing Symbols

Plumbing symbols



PROCEDURE FOR INSTALLATION OF APPLIANCES

WC INSTALLATION

AN OLD WC

Disconnect the Supply Line

After turning off the water at the shutoff, flush the toilet to remove most of the water from the tank and bowl. A little water will be left in the bowl. Use a force-cup plunger to force it down the drain line. Remove the remaining water from the tank with a sponge and a bucket. Disconnect the supply line from the base of the tank.

Remove the Old Toilet

To remove the old toilet, pop off the trim caps at the base of the toilet. Next, loosen and remove the nuts and washers on the closet bolts securing the bowl to the floor. If the nuts are rusted, you may need to cut them off with a hacksaw.

Install a New Wax Seal

Use a putty knife to pry up and remove the old wax seal

Inspect the flange beneath the seal to make sure it's not cracked. Once you've inspected the flange, remove the rag from the hole.

Attach the Tank and Bowl

With the closet bolts and seal in place, you can attach the tank and bowl to assemble the new toilet. Slide the tank bolts through the opening in the bottom of the tank. Line up the shank of the bolts with the holes in the bowl, and drop the tank into place. Secure the tank to the bowl by tightening a nut onto each tank bolt. Evenly tighten all the nuts until the tank rests firmly on the bowl.

Secure the Toilet and Finish Installation

Set the assembled toilet onto the flange assembly, making sure that the closet bolts protruding from the floor line up with the holes in the base. Lightly press the toilet in place to form a good seal with the wax ring.

Place a couple of washers and a nut on each bolt. Secure the nuts with a small wrench, but don't over tighten them. If the bolts extend too far over the top of the washers and nuts, cut off the excess with a hacksaw.

Pop the trim caps in place to cover the ends of the bolts.

Secure the new seat and lid to the bowl with mounting bolts.

Use slip-joint pliers to reconnect the supply line to the bottom of the tank.

WC INSTALLATION FOR A NEW WC

Installation Procedures & Details for Toilets

Before installing a toilet, examine it for manufacturing defects that can cause leaks or prevent it from sealing fully to the closet flange. Occasionally the inlet where the tank connects to the bowl, or the outlet (horn) at the bottom of the bowl that seals to the closet flange, is deformed enough to cause problems.

Also make sure the base (foot) of the toilet is flat or it will have a tendency to rock and break the seal, leading to odors and leakage.

Next, make sure the floor framing where the toilet will be mounted is adequate. Ideally the toilet should sit between two joists set no more than 12 inches on-center, with blocking nailed on either side of the drain to reinforce the area around the closet flange. This will limit any movement in the fixture that could break the seal at the wax ring.

Toilet rough-in dimensions locate the toilet waste pipe and flange assembly in the building rough and finished floor so that the toilet will be spaced a proper distance from the wall. The toilet rough-in dimension shows the standard distances to the waste line center from the finished wall and side wall.

- 12" from finished wall behind toilet to center of waste line - may vary by toilet model
- 15" from center of toilet to nearest side wall
- 24" clear space in front of the toilet (or more)

- 6" from flushometer to highest fixture part (for flush-o-meter toilets)

The hole in the subfloor cut to fit the toilet waste line should be just a bit larger than the drain. Also, it is best if the toilet sits on top of the finished flooring rather than having a dirt-trapping joint where the finished floor abuts the fixture.

Next, install the closet flange and secure it to the subfloor with brass or stainless-steel screws. With vinyl flooring, the flange can sit directly on the subfloor. With tile, use a plywood spacer to raise the flange to the height of the tile.

NB

To insure longevity, use brass closet bolts, nuts, and washers rather than the plated steel that is often packaged with the toilet.

Toilet Setting Tips : Some plumbers use two wax rings. The first is pushed onto the bottom of the toilet bowl around its drain opening, pushing the wax ring thoroughly into recesses and making sure that the stick wax seals thoroughly to the bowl bottom and that it does not protrude into (and thus block) the bowl drain opening**.**

A second, thin wax ring is then placed onto and gently pushed against the toilet flange ring on the floor. Alternatively you can buy an "extra thick" toilet base wax ring seal.

Now as the toilet is set and pushed down onto the toilet flange, rotate the toilet left and right slightly an inch or two to seal the two wax rings together. This approach can provide a more thorough seal and plenty of wax to minimize the risk of future leaks around the toilet base.

- **Gradually tighten the nuts on the closet bolts**, alternating from one side to the other until it is snug without over tightening.
- **Finally, apply a bead of silicone caulk** around the sides and front of the toilet foot, leaving the back unsealed. This will allow leaks to be spotted before serious damage develops.

INSTALLATION FOR A Wash Hand Basin (W.H.B)

1. Get the necessary tools for the job. You can install a new sink with basic tools and new components that match the valves already installed in your plumbing. Make sure you have:

- Silicone caulking
- Plumbers' wrenches, either pipe wrench or slip-joint pliers
- Basin wrench
- Set of plumbing sockets

2. Turn off the water supply valves. Typically located beneath the sink, it's critical that you shut off the water supply to the sink before you remove it. If the valves are not beneath the sink, then you'll have to turn off the main water supply. This is typically located on a lower level or the basement near the water meter.

- To test, turn on the hot and cold water on your sink and make sure no water comes out before proceeding.

3. Remove the old WHB, if necessary. If you're replacing a WHB, you'll obviously need to remove the WC that's in place before installing the new one. Disconnect the supply and drain lines from the faucet, using locking pliers or a crescent wrench. A small amount of water may leak out when you do this, which is normal. Just use a bucket or a towel to handle the water that leaks out.

- Locate the large nut that connects the sink to the drain and disconnect it. This metal or plastic nut will be located either in the wall or the floor. Use your hands or locking pliers to unscrew the nut.
- Remove the current sink by sliding the edge of a putty knife around the perimeter of the bathroom sink, loosening any caulk that connects it. Pull it loose.
  Measure the new sink to make sure it fits the space. All new sinks should come with a template of the mounting opening, marking the location of the faucet holes, including a cutout for the sink. You can use the template to make sure the sink fits in the desired location. If it doesn't, you may need to do some trimming or, or cut the entire opening if you're installing a sink in a house under construction.
- Most new sinks come with clips and screws that are used to hold the sink in place. If you buy a faucet, sometimes it'll come with the drain and tailpiece for the sink. If it isn't included, get one

before you start. The supply lines for the faucet need to correspond to the faucet and valves under the sink, so make sure they match before you get started.

MOUNTING THE NEW SINK

1.Put the sink in place and caulk it. Put a thin bead of silicone around the bottom lip of the sink and set it into the hole. Clean up any excess silicone or smooth a line. Depending on the design of the sink and the opening where it connects to the plumbing lines, you may need to caulk in any number of different places.

- For under mount sinks, put a bead of silicone under, have someone hold the sink in place, and install the connecting clips included with the sink.
- You might have to pre-drill holes with a diamond carbide tip if you're installing the sink in a granite/stone counter.

2. Secure the sink with clips. Connective clips are often included with new sinks to help anchor the units into place, in addition to the sealing caulk. The design of this varies, and will depend on the type of sink and the design, but they usually act like a lever to hold the sink in place. Follow the instructions included with the new sink and defer to the manufacturer's guidelines.

3. Install the faucet. New faucets usually screw onto the faucet assembly in a clockwise direction. Some faucets will have a rubber gasket around the base, and screw on easily, while others will recommend using silicone sealant to secure to the sink or counter. You can anchor the faucet by reaching up underneath and using lock nuts that are included with the installation kit.

- Sometimes it may be easier to install the faucet before the sink, depending on the design of the counter and the fixtures. Make sure the space for the faucet matches the location of the sink, using the template to measure before you install anything

4. Install the tailpiece and drain kit. Drop the tailpiece through the sink and screw on the tailpiece nut from underneath. Some sinks come with gaskets that go between sink and tailpiece.

If it doesn't, use non-hardening plumbers' putty or silicone to create the seal. Install the gasket, the included cardboard washer, and the locknut to secure the tail piece

PPE used when carrying out during installation / fixing of appliances

A. Face protection

Goggles and face protection must be used when workers are at risk from flying particles, liquid chemicals, acids or caustic liquids and chemical gases. Various goggles for face protection must meet certain design criteria for safety.

B. Foot Protection

Safety shoes with impact protection are used in work areas where heavy objects or tools could be accidentally dropped on the feet. Safety shoes with puncture protection are required when working around nails, wire tacks, scrap metals and other objects that could fierce the feet.

C. Hand Protection

Gloves are required to protect the hands of workers from cuts, scrapes, punctures, burns, chemical absorption, and exhaust temperatures. It is crucial that the type of glove being used is the right one for the job.

D. Hearing Protection

Appropriate **ear muffs or ear plugs** must be made available as a last resort if it is not possible to make the workplace less noisy. The requirement is a small part of the occupational noise exposure standard which requires employers to ensure that workers are exposed to less than 90 decibels of noise over an 8 hour period.

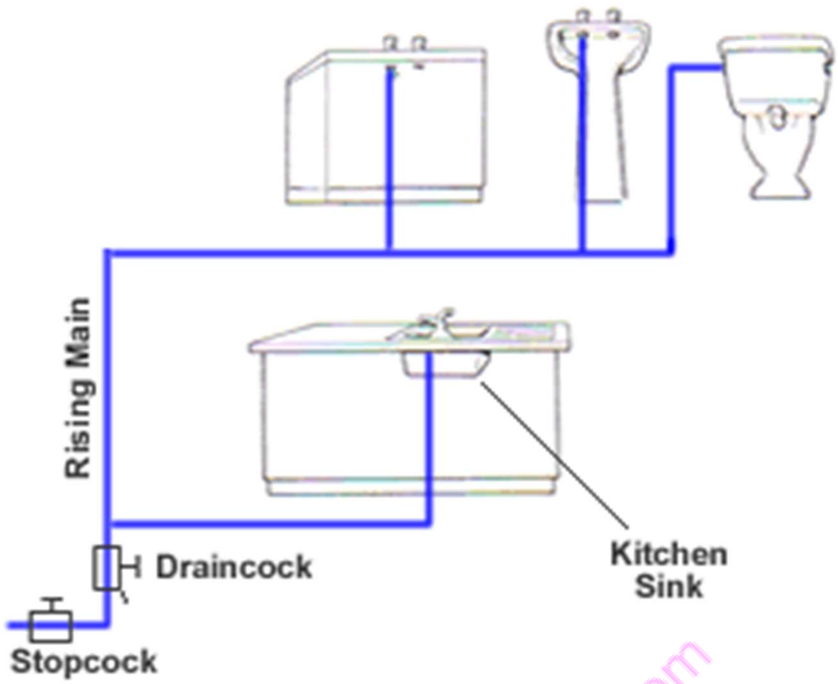
E. Respirators

Appropriate **respirators** must be worn as a last resort if it is not possible to ventilate the work area properly.

4.2.3.4.Learning Activities

Practical Activities

With assistance from your trainer, install the appliances as shown on the isometric drawing



4.2.3.5.Self-Assessment

1. Sketch THREE types of Urinals
2. Outline the procedure to follow in installing a WC
3. Outline the procedure for installing a Wash Hand Basin

4.2.3.6.Tools, Equipment, Supplies and Materials

- Simple water storage system
- Pipe threading equipment.
- Pipe cutter.
- Hacksaw.
- Vise bench.
- Files.
- Steel rule.

- PPE
- Screws.
- Adhesives.
- Pipes.
- Traps.
- Caulking materials.
- Pipe wrench.
- Fittings.
- Water

4.2.3.7.References

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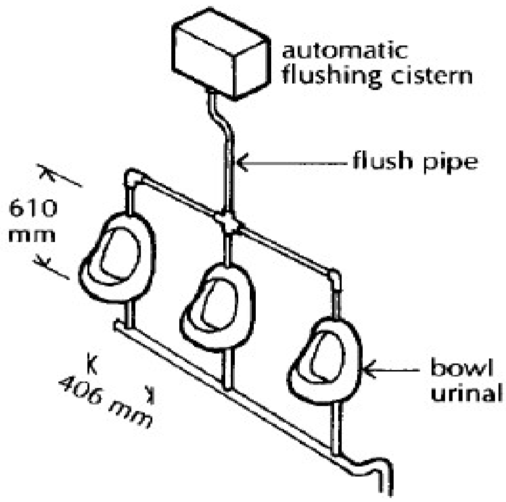
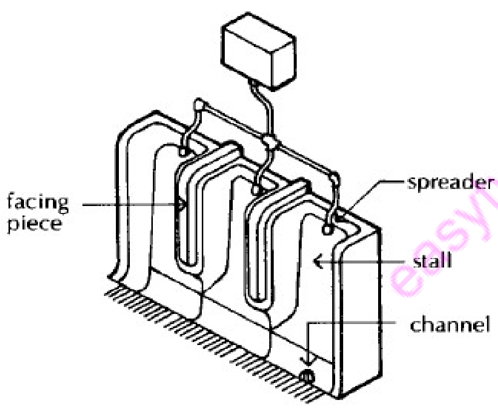
4.2.3.8.MODEL ANSWERS

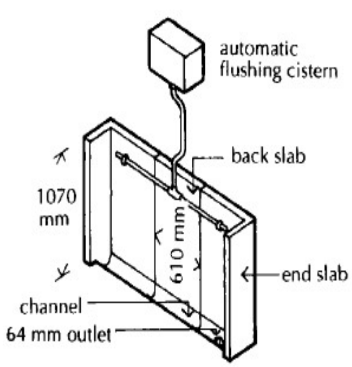
1. Bowl Urinal



Stall urinal



Slab Urinal



2. Outline the procedure to follow in installing a WC

Examine the WC it for any manufacturing defects that can cause leaks or prevent it from sealing fully to the closet flange.

Check to ensure the base (foot) of the toilet is flat or it will have a tendency to rock and break the seal, leading to odors and leakage.

Ensure the floor framing where the toilet will be mounted is adequate. Ideally the toilet should sit between two joists set no more than 12 inches on-center, with blocking nailed on either side of the drain to reinforce the area around the closet flange.

locate the toilet waste pipe and flange assembly in the building rough and finished floor so that the toilet will be spaced a proper distance from the wall. The toilet rough-in dimension shows the standard distances to the waste line center from the finished wall and side wall.

- 12" from finished wall behind toilet to center of waste line - may vary by toilet model
- 15" from center of toilet to nearest side wall
- 24" clear space in front of the toilet (or more)
- 6" from flushometer to highest fixture part (for flush-o-meter toilets)

The hole in the subfloor cut to fit the toilet waste line should be just a bit larger than the drain. Also, it is best if the toilet sits on top of the finished flooring rather than having a dirt-trapping joint where the finished floor abuts the fixture.

Next, install the closet flange and secure it to the subfloor with brass or stainless-steel screws. With vinyl flooring, the flange can sit directly on the subfloor. With tile, use a plywood spacer to raise the flange to the height of the tile.

Gradually tighten the nuts on the closet bolts, alternating from one side to the other until it is snug without over tightening.

Apply a bead of silicone caulk around the sides and front of the toilet foot, leaving the back unsealed. This will allow leaks to be spotted before serious damage develops.

3. Outline the procedure for installing a Wash Hand Basin

1. Put the sink in place and caulk it. Put a thin bead of silicone around the bottom lip of the sink and set it into the hole. Clean up any excess silicone or smooth a line. Depending on the design of the sink and the opening where it connects to the plumbing lines, you may need to caulk in any number of different places.

- For undermount sinks, put a bead of silicone under, have someone hold the sink in place, and install the connecting clips included with the sink.
- You might have to pre-drill holes with a diamond carbide tip if you're installing the sink in a granite/stone counter.

2. Secure the sink with clips. Connective clips are often included with new sinks to help anchor the units into place, in addition to the sealing caulk. The design of this varies, and will depend on the type of sink and the design, but they usually act like a lever to hold the sink in place. Follow the instructions included with the new sink and defer to the manufacturer's guidelines.

3. Install the faucet. New faucets usually screw onto the faucet assembly in a clockwise direction. Some faucets will have a rubber gasket around the base, and screw on easily, while others will recommend using silicone sealant to secure to the sink or counter. You can anchor the faucet by reaching up underneath and using lock nuts that are included with the installation kit.

- Sometimes it may be easier to install the faucet before the sink, depending on the design of the counter and the fixtures. Make sure the space for the faucet matches the location of the sink, using the template to measure before you install anything

4. Install the tailpiece and drain kit. Drop the tailpiece through the sink and screw on the tailpiece nut from underneath. Some sinks come with gaskets that go between sink and tailpiece.

If it doesn't, use non-hardening plumbers' putty or silicone to create the seal. Install the gasket, the included cardboard washer, and the locknut to secure the tail piece

4.2.4 Learning Outcome 4: Test and commission working of sanitary appliances

4.2.4.1. Introduction to the learning outcome

This learning outcome enlightens the trainee on how to test the functionality of an installed sanitary component or system before it is commissioned for use.

4.2.4.2. Performance Standard

1. Functionality of the appliance is tested based on best practices.
2. Faults in appliance functionality are corrected based on best practices
3. The works are commissioned in accordance to job requirements

4.2.4.3. Information Sheet

Introduction to testing of Plumbing Systems

Definitions of terms

- ***Test -*** a procedure intended to establish the quality, performance, or reliability of a system before it is taken into widespread use.
- *Functionality* - the quality of being suited to serve a purpose well
- *Fluid* - a substance, as a liquid or gas, that is capable of flowing and that changes its shape at a steady rate when acted upon by a force tending to change its shape.
- *Fault/defect* - unsatisfactory feature in a piece of work.
- *Workplace policy* - course of action adopted by an organization.
- *Leakage* - escape of liquid or gas through a hole or crack.
- *Outcome – the end result of an operation*
- *Commission* - bringing a newly constructed system into working condition

- *Waterproofing* - applying a physical barrier to pipes and appliances to prevent moisture penetration into a structure.
- *Caulking* – applying a waterproof filler and sealant building work and repairs

TYPES OF TESTS DONE ON PLUMBING SYSTEMS

Plumbing tests are usually done for the purpose of ensuring correct work, free from defects arising after installation of components and systems. There are four different methods of testing the plumbing systems which include;

1. water test
2. air test
3. peppermint test
4. smoke test

Of these, the water, peppermint, and smoke tests are most commonly used. The water and air tests are chiefly used as the first test on new work. When it comes to the final test, either the peppermint or smoke test may be applied. Each is thorough when properly applied.

Before the final test is applied, all fixtures should be in position and the system entirely complete, and the traps filled with water.

1. WATER TEST

Is applied on new work where any defective leaks in joints will be readily detected when the system is filled with water. The mode of applying the water test is to close up all openings in pipes, either by soldering the ends shut or by plugs with caps. These plugs are made in different forms to suit all the uses for which they may be called upon in testing a job. The water supply for testing may be connected to the end of the test plug where capped, with a stop-cock to shut off when necessary; and then the system is ready for filling. The filling should be done slowly, and any leaks found should be immediately fixed. Where a leak occurs in a lead joint which only requires a little more caulking, the water may be shut off until this is done.

Water test

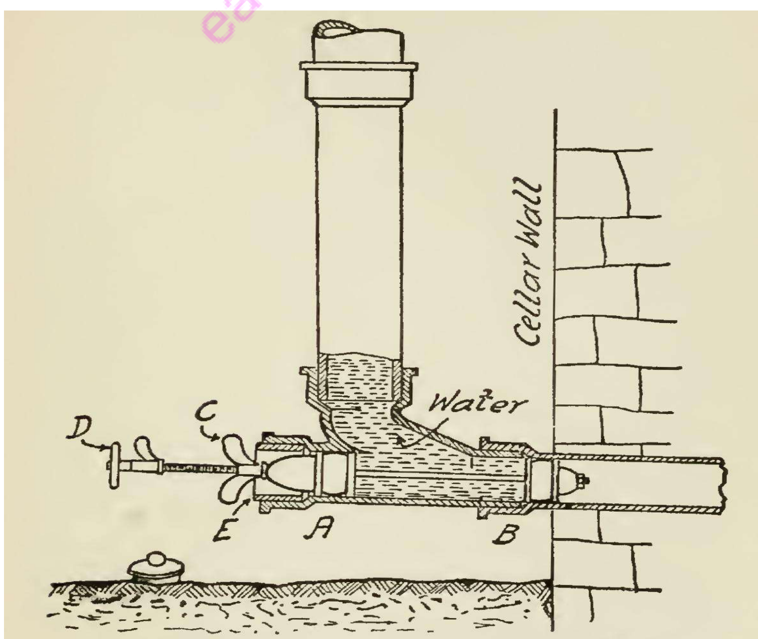


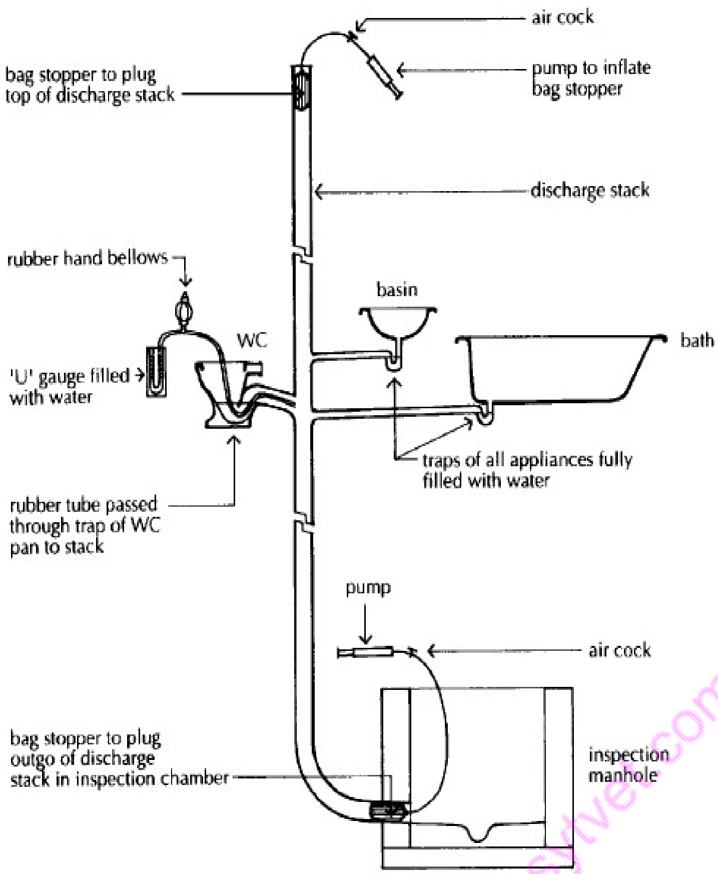
Fig. 48. Illustrating Use of Test Plug in Water Test.

2. AIR TEST

The air test shall be made by attaching an air compressor testing apparatus to any suitable opening, and after closing all other inlets and outlets to the system, forcing air into the system until there is a uniform gage pressure of five (5) pounds per square inch (34.5 kPa. The pressure shall be held without introduction of additional air for a period of at least fifteen (15) minutes.

The air test subjects all parts of the system to the same uniform pressure, while the pressure in the water test varies from zero pressure at the top to a pressure at the bottom depending upon the height of the stack. In applying the air test, all openings are closed. Through any convenient plug, a gas pipe is connected, to which a mercury gauge is attached, and hose connection made to the force pump. The air pumped into the system exerts a pressure on the mercury, forcing it upward in the tube about two inches for each pound of air pressure.

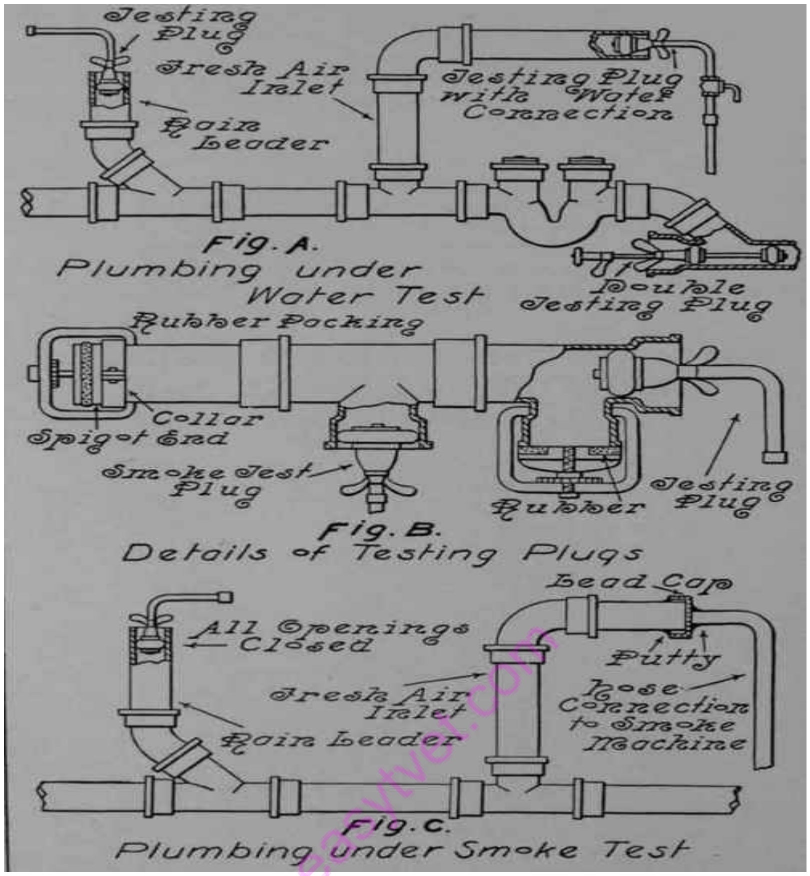
Air test



3. **SMOKE TEST.**

The smoke test is another test that can be applied to roughed-in new work. It is used most frequently, however, in testing old work, or in testing new work after the fixtures have been set. The manner of applying a smoke test is to close all openings, the same as for the water test, and also the openings at the roof. The testing machine, which is made especially for this purpose, is then connected to the piping system, and the smoke turned into the pipes.

Smoke test



4. **PEPPERMINT TEST.**

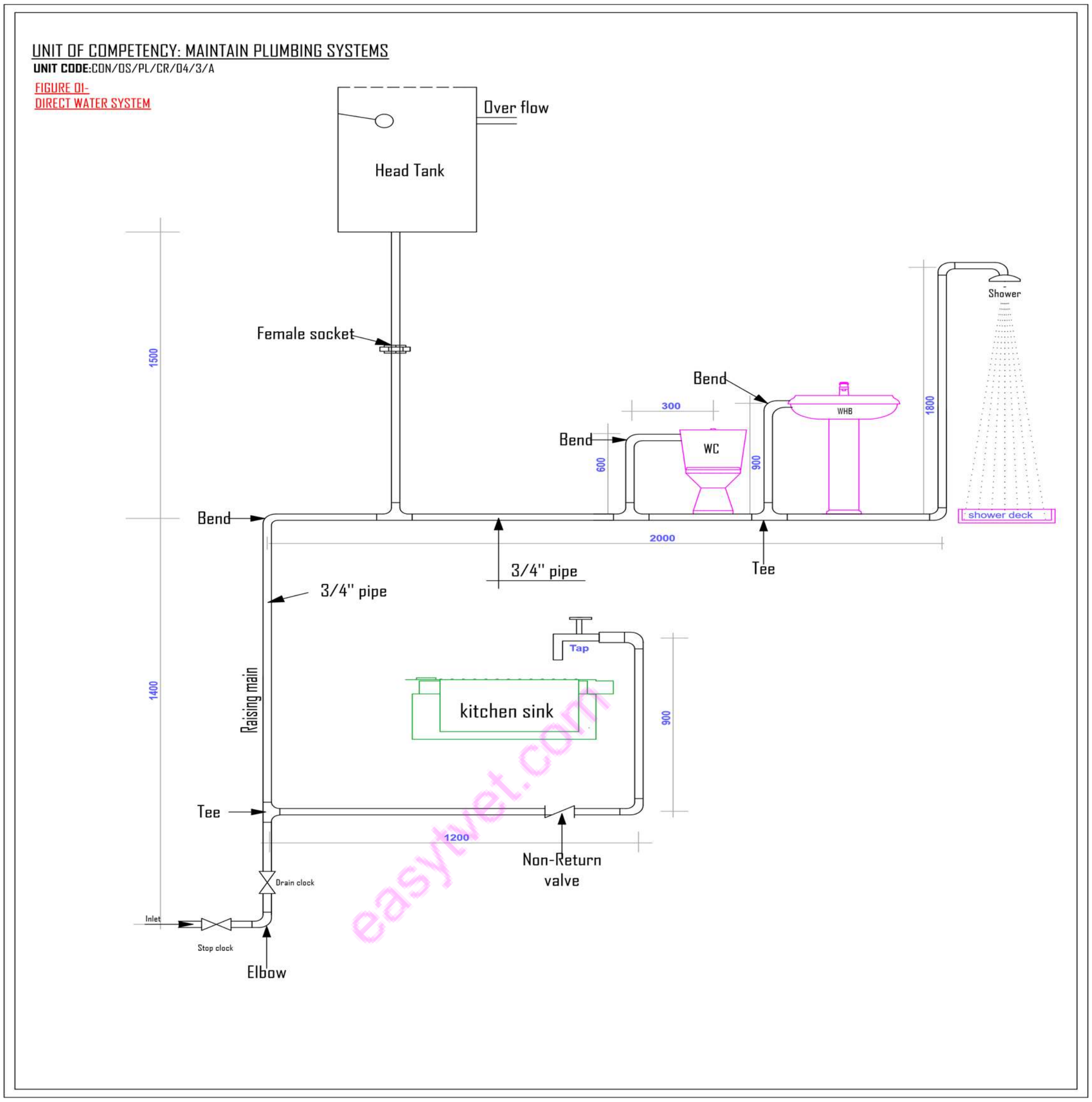
The peppermint test is applied by putting about two ounces of oil of peppermint into the system at the roof, after all openings have been closed as with the other tests, and pouring about a gallon of hot water into the piping, immediately closing the opening with a plug kept at hand for the purpose. The fumes of the peppermint are supposed to travel throughout the system of piping, and to penetrate any existing leaks, the presence of which can then be detected from the characteristic smell. There being no pressure applied in this test, there is a possibility of the odor not escaping through very small leaks; and this test, therefore, is not so reliable as the water or smoke tests.

4.2.4.4.Learning Activities

Practical activity

Instruction:Assemble a sanitary water system as shown in the diagram and Test its functionality using the water test.

Sanitary water system



Materials Required

- Simple water storage system
- Pipe wrench
- Pipe threading equipment.
- Pipe cutter.
- Hacksaw.
- Vise bench.

- Files.
- Steel rule.
- PPE
- Screws.
- Adhesives.
- Pipes.
- Traps.
- Caulking materials.
- Fittings.
- Water

1.4.3.4.1 A case study

With the assistance of your trainer, conduct a Field visit to a nearby facility with a well-established plumbing system and fill in the field visit notebook indicating the key areas listed

Visit Objective/Aim	Indicators	Special Instruction
To identify the established plumbing systems in use.	A list of plumbing systems	Must correctly identify the available plumbing systems
To identify the possible faults of the systems identified.	A list of faults	Must indicate the function possible faults for each
To assess the functionality of the plumbing systems	Functionality table	Must fill in the table for each system.

4.2.4.5.Self-Assessment

1. Which four tests would you apply when testing the functionality of a plumbing system?
2. Which three waterproofing material would you use to correct a leaking elbow?
3. What are the four causes of pump failure?
4. What causes clogging in pipes?.
5. Why do pipes leak?

4.2.4.6.Tools, Equipment, Supplies and Materials

- 200 litre plastic tank
- 100 litre plastic tank
- PPR threaded union
- Rigid PPR pipe
- PPR bend
- Flexible PPR pipe
- Pipe threading machine
- Pipe cutter
- Pipe wrench
- Adjustable spanner
- Seal tape
- Timber
- Claw hammer
- Saw
- Spirit level
- Plumb bob
- Tape measure
- Hose pipe
- Tap

- File
- PPE (Gloves, safety boots, dust coat, goggles, helmet)
- Gate valve
- Ball valve
- Centrifugal pump

4.2.4.7.References

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4.2.4.8.Model Answers

1. Which four tests would you apply when testing the functionality of a plumbing system?
    - Water
    - Smoke
    - Air
    - Peppermint
2. Which three waterproofing material would you use to correct a leaking elbow?
    - Cement Waterproofing.
    - Bituminous Membrane
    - Teflon tape
    - Caulk
3. What are the four causes of pump failure?

a) Stuck switches
b) An overwhelming amount of water
c) Clogged pipes
d) Improper pump installation

4. What causes clogging in pipes?

Sticky or hard substance such as a stone or other foreign body passes through pipes it causes obstruction or partially closing the valves and pipes.

5. Why do pipes leak?

- joint damage
- excessive water pressure
- cracked pipes
- incorrect pipe laying

CHAPTER 5: WATER STORAGE SYSTEMS

Unit of learning code: **CON/CU/PL/CR/05/5/A**

Related unit of competency in occupational standard: Install water storage systems and auxiliary fittings

4.1 Introduction to the unit of learning

This Unit describes the competencies required to install water storage systems and auxiliary fittings. It involves preparing water storage drawing, quantifying and costing storage and auxiliary fittings supplies, install storage systems and auxiliary fittings and testing and commissioning storage and auxiliary fitting. It applies in the construction industry.

4.2 Summary of Learning Outcomes

1. Prepare water storage drawings
2. Quantify and cost materials
3. Install storage systems and auxiliary fittings
4. Test and commission storage and auxiliary fittings

5.2.1 Learning outcome 1: Prepare water storage drawings

5.2.1.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to prepare water storage drawings. It includes definition of terms and concepts, symbols, design and construction of water storage facilities, storage fittings and storage capacity.

5.2.1.2 Performance Standard

1. Drawings are identified and selected based on the job.
2. Scale of the drawing is determined based on the specifications.

3. Measurements are converted based on scale.
4. Symbols are identified based on best standard practices.
5. Simple working drawings are Prepared based on specifications
6. Isometric working drawings are drawn based on best practices

5.2.1.3 Information Sheet

Terms and Concepts

Piping: It is a system of pipes used to convey fluids (liquids and gases) from one location to another.

Valves: is a type of fitting that allows for regulation, control, and direction of fluids passing through a pipe.

Adapter: An adapter has male and female ends, the male having threads on the outside and the female on the inside.

They're used to connect different sized pipes, or even turn a male pipe into a female, and vice versa.

Nipple: It connects pipes to appliances such as water heaters, and connects two straight pipe runs.

Union: Union fittings are made up of three parts: a nut, a female end, and a male end. They're designed to connect two pipes with the possibility of being detached without damage or deformation to the pipes. They're conveniently used in maintenance or cases of planned replacements in the future.

Couplings: can be used to connect two pipes of the same size and diameter. They're also commonly used to change pipe sizes; a bell reducer is a common coupling used to do this since it connects a big pipe to a smaller one.

Cross: crosses are four-way fittings, a combination of two tees (see below). They consist of one inlet and three outlets, and these often have a solvent-welded socket or female-threaded ends.

Tees: They look like a coupling with an outlet in the middle. They're short pipes with a 90-degree "branch" at the center.

Wyes: They look like the letter "Y." They're generally used in drainage fittings and have a 45-degree branch.

Elbow: They are curved and are mainly used to change flow directions. These are mostly produced in 45 and 90-degree angles and can be sweated or threaded.

Bushing: It looks like small screws. They're mainly used to connect pipes of different sizes, reducing a large fitting to a small pipe. These can be threaded on the inside and outside; however, this is not always the case.

Bushing fittings are smaller than unions and couplings, and are, therefore, often used in the same situations.

Reducer: It is designed to reduce flow.

SYMBOLS

Piping **Valves**

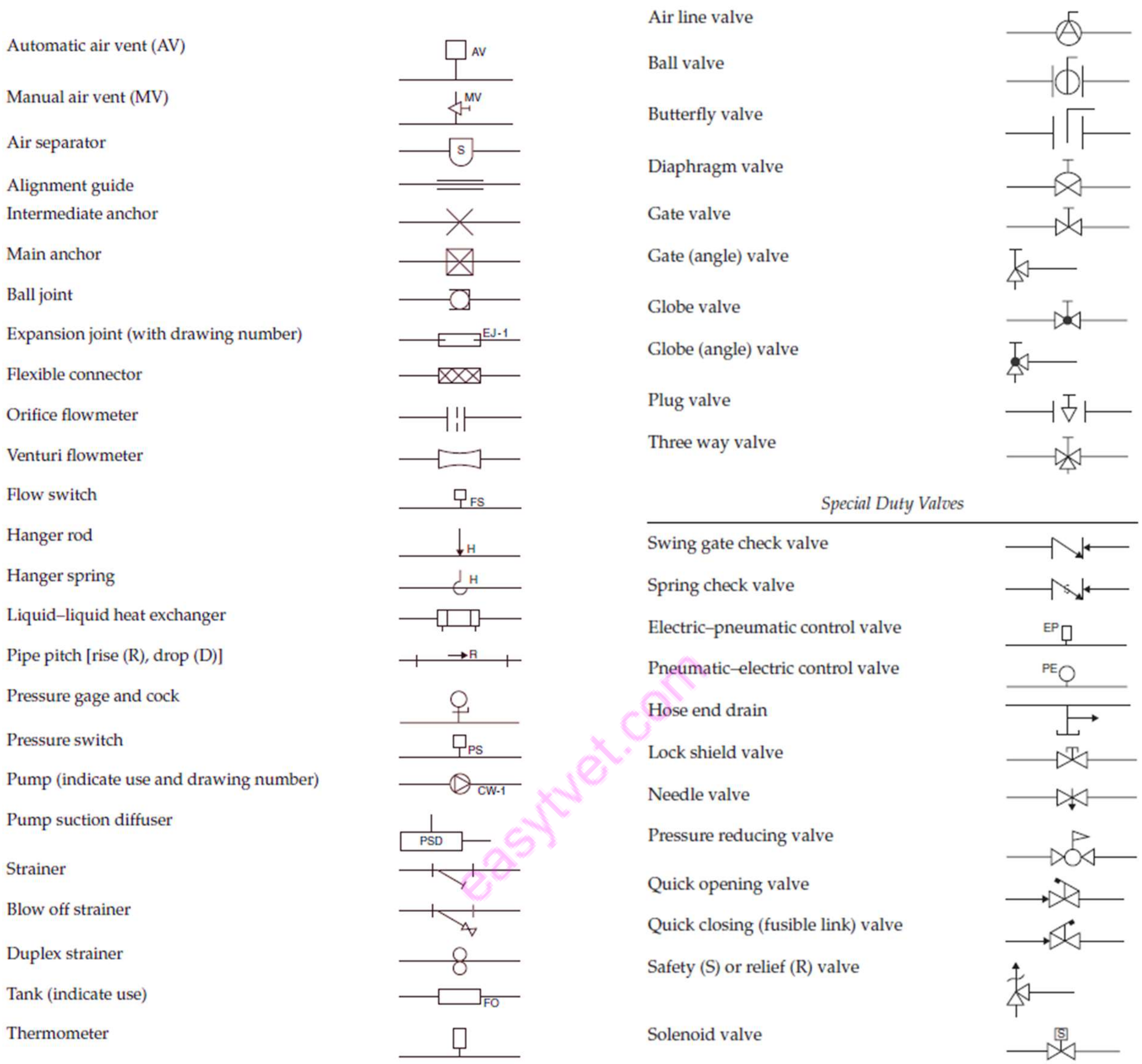
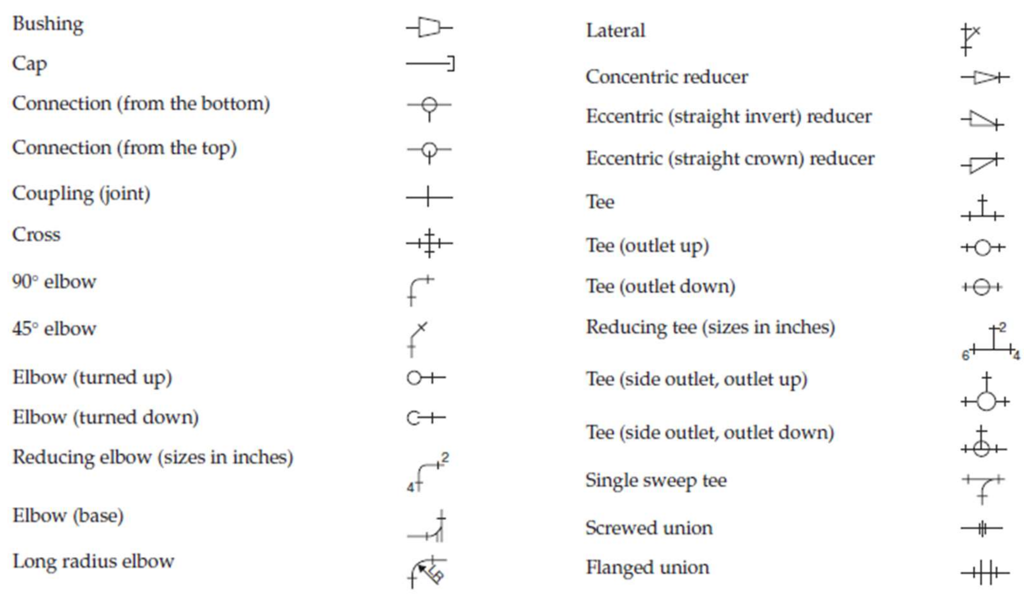


Figure 181: piping and valve symbols

Fittings



Fittings

DESIGN AND CONSTRUCTION OF WATER STORAGE FACILITIES

1. Capacity:

As a rule of thumb, the storage tank volume should be at least equal to one-fourth (25%) of average day demand of the community. The formula is:

$$Cr = \tfrac{1}{4}\,(ADD)$$

Where:

Cr	=	reservoir capacity in litres
ADD	=	average day demand in liters per day

2. Site of the Storage Tank

In the selection of the site for storage tanks, first priority should be given to natural elevated places. If the elevated storage tank is to be constructed in a flat area, it may be built central to the distribution system or opposite the source. This is to avoid long and consequently large-diameter service mains.

3. Structural Design

The structural design of reservoirs must meet the standards set by the National Structural Code of the Country. The reservoirs must be strong enough to withstand all loads, such as hydrostatic pressure, earth pressure, wind loads, seismic loads and other dead or live loads. The reservoir should be covered to avoid pollution and growth of algae.

RESERVOIR APPURTENANCES

1. Inlet Line

The size of the inlet line is determined by the supply and demand requirements. The inlet line on all reservoirs must have a shut-off valve located adjacent to the reservoir.

2. Outlet or Discharge Line

Like the inlet line, the size of the outlet line is determined by the supply and demand requirements. The upstream-end of the outlet pipe is usually installed at least 5 cm, above the floor of the reservoir to create a dead volume of water. This dead volume of water at the bottom of the reservoir acts as settling zone, where particles are allowed to settle and kept from entering the water distribution line.

These dead volumes of water are drained via a drainage pipe. The outlet line must also have a shut-off valve located adjacent to the reservoir.

In floating-on-the-line reservoirs, there is only one inlet and outlet line.

3. Drain Line

This is provided for draining and cleaning the reservoir. Draining could be done through the inlet–outlet line by shutting off the valve controlling the flow in the main line and opening the drain valve. To facilitate cleaning, the floor of the reservoir is sloped towards the drain.

4. Ventilation facilities

These are provided in reservoirs to allow the air to escape fast enough to prevent pressure from building up inside the reservoir during filling, and to prevent a vacuum from forming when water is being drawn out. The ventilation facilities should be designed to keep rain and surface water from entering, and they should be screened to keep out insects. Overflow and drainage pipes should be designed with a valve chamber to prevent rodents from entering the reservoir.

5. Overflow Line

Reservoirs should be provided with an overflow line large enough to allow the maximum anticipated overflow (pump or spring capacity) and should be properly screened and covered like an air vent.

6. Water Level Indicators

These are used to indicate the water level inside the reservoir. Depth gauges using a float and wires are usually used.

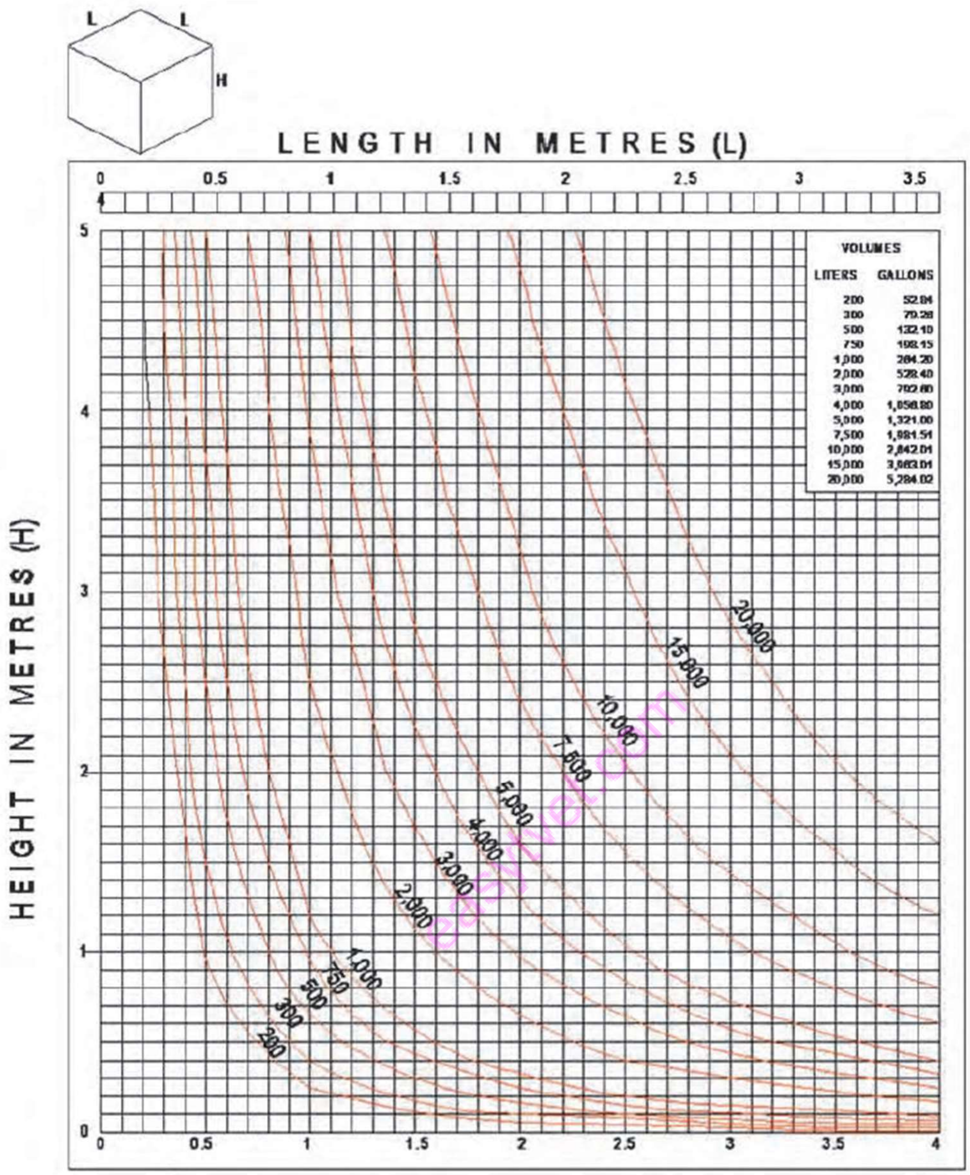
7. Control Valves:

The use of reservoir control valves will depend on the type of controls and means of operation to be employed for the system. The flow into the reservoir may be stopped manually or automatically by a float valve, pressure switch or equivalent device.

SAMPLES OF RESERVOIR DESIGN

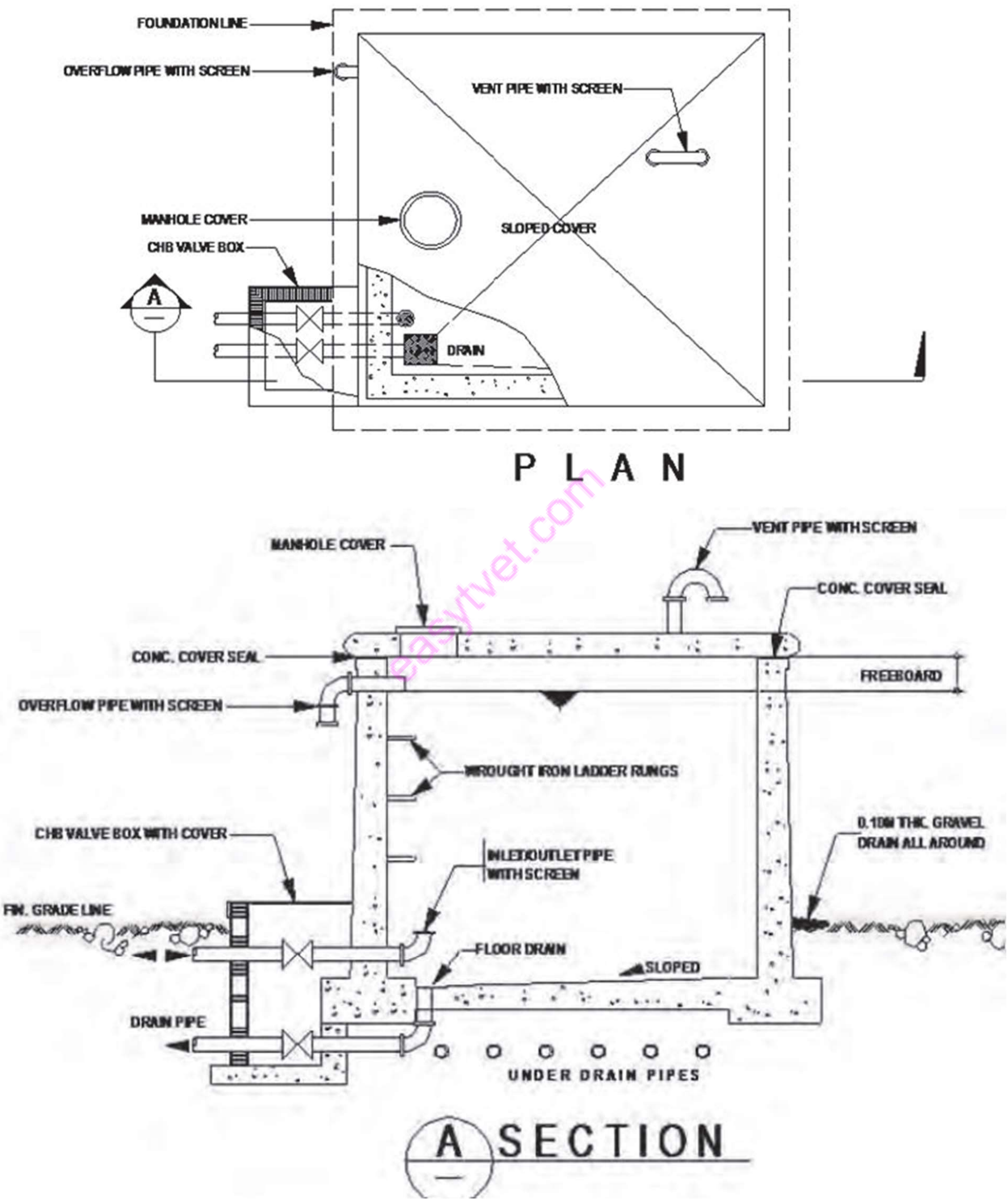
The figure below provides a quick method of determining prismatic tank dimensions.

Prismatic Tank Volume.



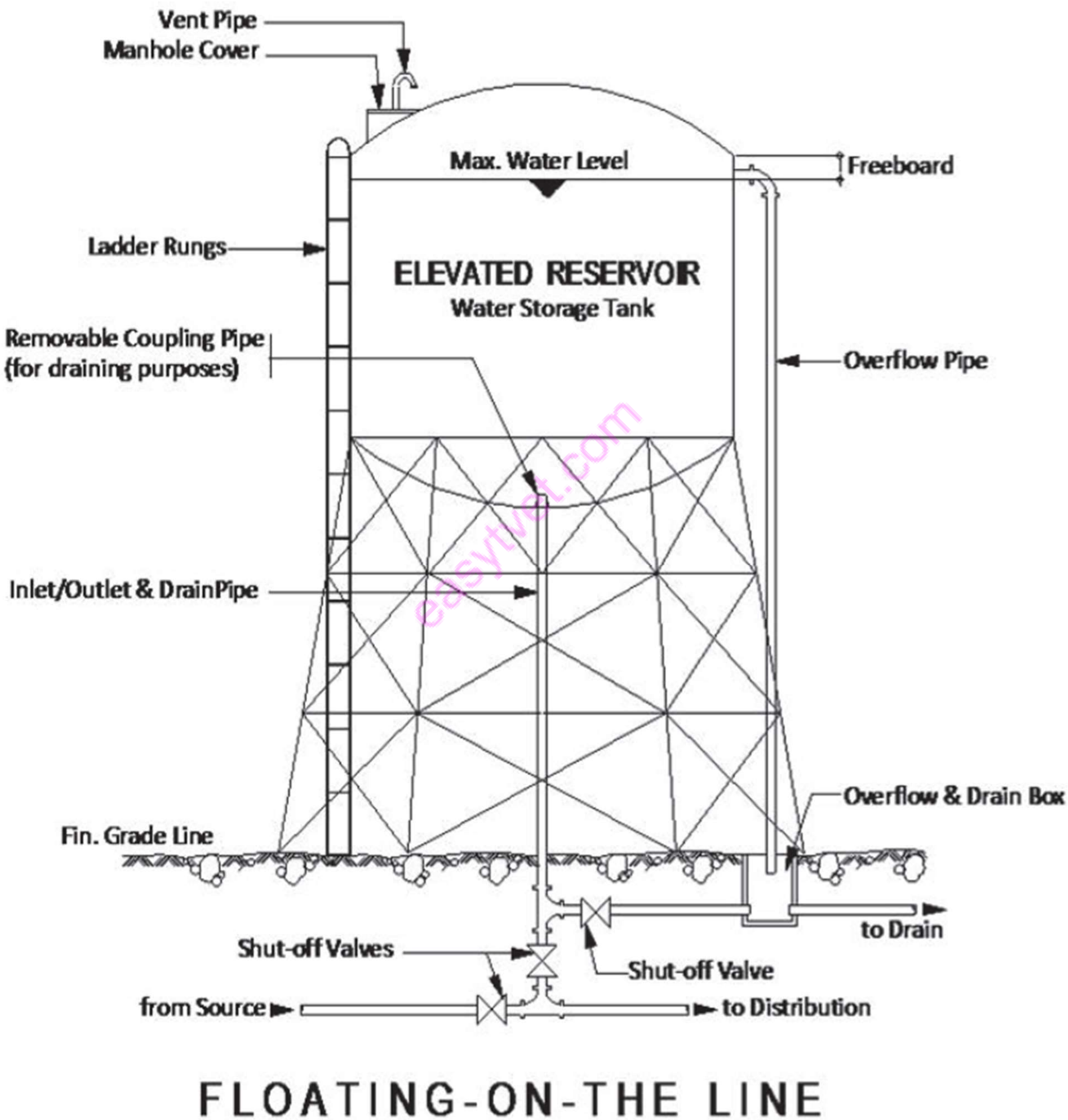
Tank Volume prismatic tank volume

Design of ground level reservoirs



Ground Level Concrete Reservoir

An elevated Reservoir



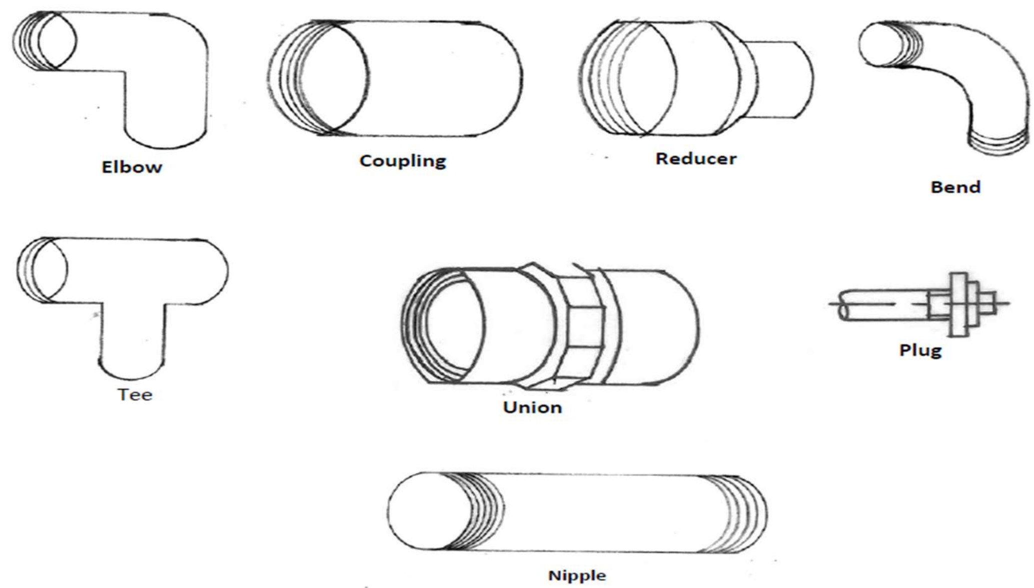
An elevated Reservoir

Storage fittings

Type of Pipe Fittings

Pipe fitting are important component of pipelines as they connect pipes and control pipe leakages. Various pipe fitting are used for distribution piping system. Choose the diameter of the fitting based on the size of pipe. These fitting are available with threading, mainly for metallic pipes. For PVC pipes, non-threaded fittings are normally used for smaller diameter pipes. For HDPE pipe fitting special flanged fittings are available for joining pipes.

a. Socket or coupling - It is used to connect two straight lengths of pipes. The outer diameter of pipe will be equal to inner diameter of socket after threading.
b. Elbow – It connects two pipes of same diameter at an angle, normally 90 degrees.
c. Tee - it will fit two straight pipes and will have an outlet at right angle.
d. Union - It is used for joining the ends of two pipes which cannot be rotated. They are used in long stretches of straight pipes in the beginning of a pipe system and near all appliances along stop valves.
e. Reducer - It is used to connect two pipes with different size (diameter) to reduce the size of pipe. Reducer can be a socket, elbow or a tee as per required distribution network requirement.
f. Nipple - it is tubular pipe fitting, mainly in 300 mm length. It is used for extending pipeline.
g. Plug - It is used to plug the flow of water at dead ends.



STORAGE CAPACITY

Determination of storage capacity required

Water Demand

Water demand is the volume of water requested by users to satisfy their needs. A simplistic interpretation considers that water demand equals water consumption. However, conceptually, the two terms cannot be equated because, in some cases, especially in rural parts of Africa, the theoretical water demand considerably exceeds actual consumptive water use.

Calculating Demand

Calculating the water needs of the user is relatively easy and involves a simple formula which includes the average daily consumption of water from the tank per person (or livestock), the number of days in the dry season, and the numbers of people using the tank.

Studies have shown that rural people with tanks next to their houses often use about 20 to 40 litres of water per person per day. This is high compared to people who must walk long distances for water who may use less than 10 litres per family per day. As an average, assume that each person will take 20 litres per day if it is a household tank, and 5 litres per day if it is a school or health centre tank.

The formula is;

Demand (litres) = Total dry days x water required per person x total number of consumers

It is good to note that if the consumption is higher than estimated, the tank will run dry before the next rainy season.

Volume of storage structure

This is calculated differently depending on the shape of the tank. The general formula adopted for all shapes is the prismoidal formula expressed as follows:

$$\mathbf{V = (A + 4M + B)^{d/6}}$$

where:

V = volume

A = top area of excavation (area of water surface when full)

B = bottom area of excavation (area of floor)

M = area at ½ depth

d = depth

For convenient calculating, the following derivations of the prismoidal formula can be used for each particular excavation shape:

Circular:

$$\mathbf{V = \pi\,[R^2 + (R \times r) + r^2]^{d/3}}$$

Rectangular:

$$\mathbf{V = [(L \times W) + (lf \times wf) + [(L \times lf) + (W \times wf)]]^{d/6}}$$

Square shaped tank:

The design volume is calculated with the following equation:

$$\mathbf{V = [L^2 + (L \times lf) + lf^2]^{d/3}}$$

where in all formulae:

V = volume (m^3)

R = radius of water surface (m)

r = radius of floor (m)

d = depth (m)

π = *Pi* or 22÷7 or 3.14159

L = length of water surface (m)

W = width of water surface (m)

lf = length of floor (m)

wf = width of floor (m)

d = depth of water from surface to floor (m).

Cold water storage data is provided to allow for up to 24-hour interruption of mains water supply.

Building purpose	Storage/person/24 hrs
Boarding school	90 litres
Day school	30
Department store with canteen	45 (3)

Department store without canteen	40 (3)
Dwellings	90 (1)
Factory with canteen	45
Factory without canteen	40
Hostel	90
Hotel	135 (2) (3)
Medical accommodation	115
Office with canteen	45
Office without canteen	40
Public toilets	15
Restaurant	7 per meal

1. 115 or 230 litres min.
2. Variable depending on classification.
3. Allow for additional storage for public toilets and restaurants.

At the design stage the occupancy of a building may be unknown.
Therefore, the following can be used as a guide:

Building Purpose	**Occupancy**
Dept. store	1 person per 30 m² net floor area
Factory	30 persons per WC
Office	1 person per 10 m² net floor area
School	40 persons per classroom
Shop	1 person per 10 m² net floor area

E.g., A 1000 m² (net floor area) office occupied only during the day therefore allow 10 hours emergency supply.

1000/10 = 100 persons x 40 liters = 4000 liters (24 hrs.)

= 1667 liters (10 hrs.)

5.2.1.4 Learning Activities

Design a Reservoir

Data:

Design Population: 600

Average Day Demand: 600 × 80 *lpcd* (level II/III) = 48,000 LPD

PF1, found at the remotest of the system

Friction Head Loss in Pipeline: F1 = 4m

Elevation of PF: E1 = 2m

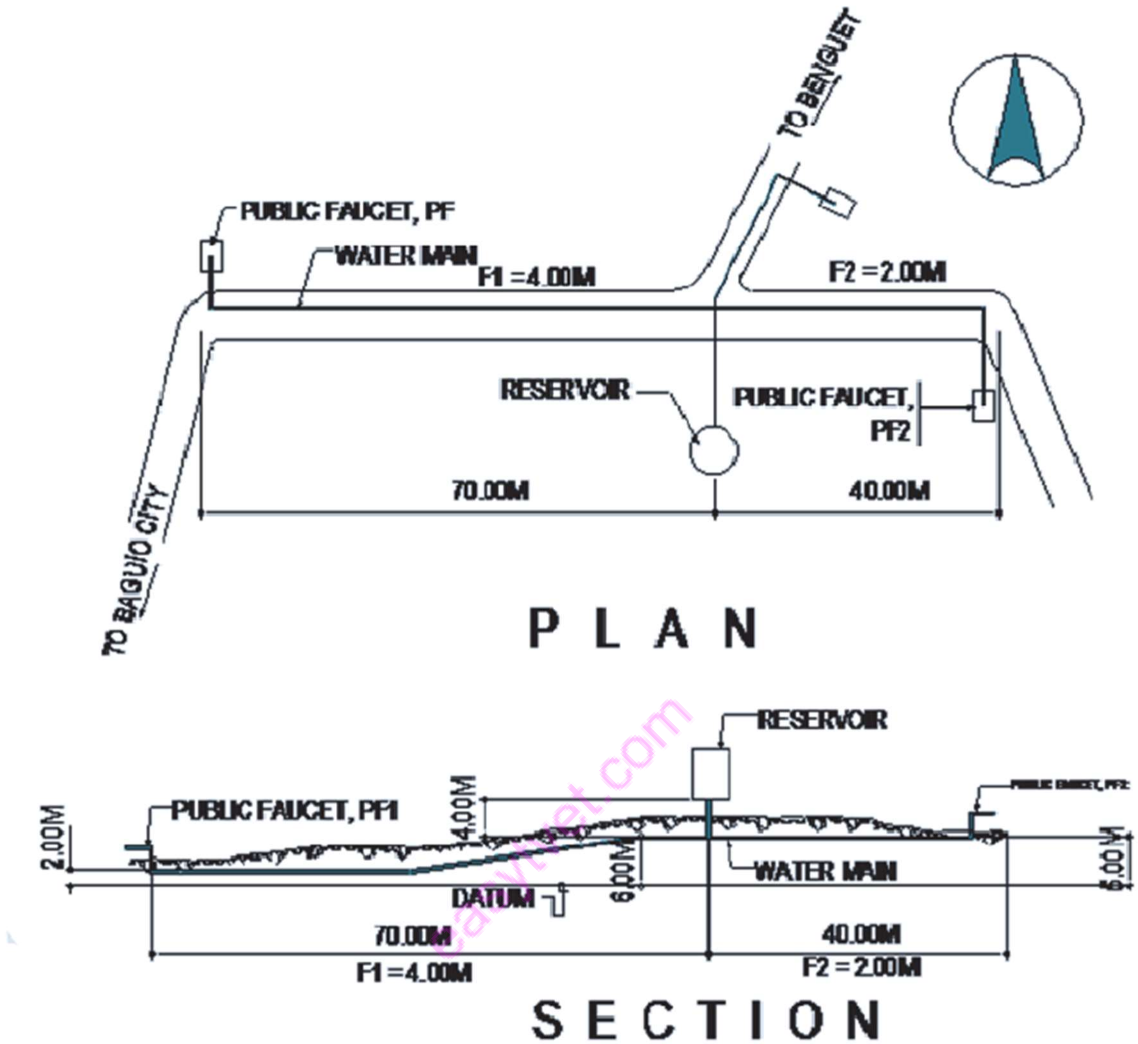
PF2, found 40 m from the storage tank

Friction Head Loss in Pipeline: F2 = 2 m

Elevation of PF: E2 = 5 m

Elevation of the location of Storage Tank: E3 = 6 m

Using an elevated tank, calculate tank capacity and height of the minimum water level.



5.2.1.5 Self-Assessment

1. While planning a water supply reservoir the design yield should be kept ___________________
    a. Higher
    b. Lower
    c. Equal
    d. Lower or higher as per designer's discretion

2. Yield of a water tank represents ____________________
    a. The inflow into the tank
    b. The capacity of the tank
    c. The outflow demand on the tank
    d. The optimum value of catchment yield

3. As the reservoir elevation increases, the outflow discharge increases.
    a. True
    b. False

4. What do you understand by the following terms?
    a. Valves
    b. Union
    c. Tees
    d. Valve

5. Draw the symbols of the following items:
    a. Cross
    b. 90^0 Elbow
    c. 45^0 Elbow
    d. Coupling

6. What is the function of the following pipe fittings?
    a. Socket or coupling
    b. Elbow
    c. Reducer
    d. Nipple
    e. Plug

7. Using an elevated tank, calculate the capacity and height of the required minimum water level given the data below:

5.2.1.6 Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:

Tools and Equipment

- Pipe wrench
- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vice - Bench
- Pliers
- Tap and Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Mallet
- Ball hammer
- PPR machine / Heat Fusion equipment
- Pipe bender
- Sealant gun

Supplies and Materials

- Fittings
- Back nuts
- Cisterns
- Valves
- Sealant
- Water proofing agents

5.2.1.7 References

Fred Hall & Roger Greeno., 2009., Building services handbook incorporating current building & Construction regulations., 5th Edidition

David V. Chadderton., 2007., Building Services Engineering., 5th Edition

Nissen Peterson., 2007., Water storage

Julie fryer., 2011., The complete guide to water storage

5.2.1.8 Model Answers

1. While planning a water supply reservoir the design yield should be kept

   ____

e. Higher

f. Lower

g. Equal

h. Lower or higher as per designer's discretion

2. Yield of a water tank represents ___________________

e. The inflow into the tank

f. The capacity of the tank

g. The outflow demand on the tank

h. The optimum value of catchment yield

3. As the reservoir elevation increases, the outflow discharge increases.

c. True

d. False

4. What do you understand by the following terms?

- **Valves:** is a type of fitting that allows for regulation, control, and direction of fluids passing through a pipe.
- **Union:** Union fittings are made up of three parts: a nut, a female end, and a male end. They're designed to connect two pipes with the possibility of being detached without damage or deformation to the pipes. They're conveniently used in maintenance or cases of planned replacements in the future.
- **Tees:** They look like a coupling with an outlet in the middle. They're short pipes with a 90-degree "branch" at the center.
- **Valve:** It is used to regulate or stop the flow of gas or liquid. Valves are generally categorized by application.

5. Draw the symbols of the following items:

- Cross
- 90^0 Elbow

- 45^0 Elbow
- Coupling

6. What is the function of the following pipe fittings?
   - Socket or coupling - It is used to connect two straight lengths of pipes. The outer diameter of pipe will be equal to inner diameter of socket after threading.
   - Elbow – It connects two pipes of same diameter at an angle, normally 90 degrees.
   - Reducer - It is used to connect two pipes with different size (diameter) to reduce the size of pipe. Reducer can be a socket, elbow or a tee as per required distribution network requirement.
   - Nipple - it is tubular pipe fitting, mainly in 300 mm length. It is used for extending pipeline.
   - Plug - It is used to plug the flow of water at dead ends.

7. Using an elevated tank, calculate the capacity and height of the required minimum water level given the data below:

   Minimum Pressure at the remotest public faucet (PF) = 3 m

   Average Day Demand (ADD) = 43,440 lpd

   Friction head loss from tank to remotest PF = 3 m

   Solution:

   Using Elevated Tank,

   Calculate the Reservoir Capacity

   Capacity = ¼ × 43,440 = 10,860 liters, say 11,000 liters

If Shape of Reservoir = Cylindrical

Assumed Height = 3 m

From Figure 13.4, Diameter = 2 m*

The diameter was determined using Figure 13.4. Locate the height =3 m in the figure and move horizontally to intersect V = 11,000 and then move down on the abscissa to find the diameter, D = 2.09 m.

Use D = 2.0 m

Calculate the Height of Minimum Water Level, H

H =Minimum Pressure at the remotest PF + Friction Head Loss in pipeline from tank to remotest PF,

H = 3 + 3 = 6 m

5.2.2 Learning Outcome 2: Quantify and cost materials

5.2.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to Quantify and cost materials. It includes, definition of terms and concepts, types of storage, types of auxiliary fittings, quantify materials and supplies and estimation of quantities and costs.

5.2.2.2 Performance Standard

1. Materials required for installing storage and auxiliary fittings are identified based on requirements of the job.
2. Supplies required for installation of storage and auxiliary fittings are identified based on requirements of the job.
3. Types of storage and types of pumps required are enumerated based on the drawing.

4. Materials and supplies required are measured and counted based on working drawings and specifications
5. schedules of storage and pumps are prepared based on working drawings

5.2.2.3 Information Sheet

Choice of building materials for tanks

The choice of building materials can be decided by considering the following:

1. Where coarse river sand is expensive, tanks should be built of either burnt bricks or soil compressed bricks to reduce cost.
2. Where coarse sand is cheap, tanks should be built of ferro-cement if trained builders are available.
3. Where coarse river sand, pebbles, stones and hardcore (larger stones) are in plenty, it is most economical to use concrete in formwork (in situ) or concrete blocks.
4. The cost of making concrete blocks can be reduced by compacting rubble stones into the concrete in the steel mould. Such blocks, as seen in the photo are called rubble stone blocks.

TYPES OF TANKS

Plastic tanks (PE)

Spherical ground tanks are manufactured of seamless polyethylene. Spherical tanks are placed on a 2000 mm concrete slab in the bottom of a cylindrical excavation.

The space around the tank is back-filled with pea gravel or sand, while the tank is filled with water to the same level to avoid localized stress concentrations.

Cylindrical tanks are also made of two seamless layers of polyethene; the inner layer being white and the outer being black.

A cylindrical tank

Cylindrical tanks are also made of two seamless layers of polyethene; the inner layer being white and the outer being black. The tanks are UV stabilized and will not break down under harsh outdoor weather conditions.

A cylindrical tank

Steel tanks

Storage tanks come in a wide variety of types, shapes and materials. Every steel storage tank design must be specific to its task, be it underground or on-surface storage tasks. Steel tanks are among the most commonly preferred storage tanks due to their effectiveness and durability. Because of these traits they have found wide use in residential, commercial and industrial establishments.

Factors Considered During the Designing and Building of Steel Storage Tanks

There are number of important factors to consider when designing and building these storage tanks. They mainly involve the specific application and the intended method of usage for which the tank is being built.

Some of the main factors are;

- **Materials**: This mainly relates to the tank's application, simplicity and installation, regulations and codes, and the tank's cost.
- **Size and Shape**: Depends on the application, regulations and standards.
- **Strength**: Here designers and engineers decide on the thickness of the tank walls, and the vertical, horizontal and cross ribs depending on its application and usage.
- **Location**: Whether the tank will be aboveground, underground or partially buried also influences the design and the construction of the steel storage tank.
- **Accessibility**: Considering the accessibility during the initial designing of the tank helps facilitate the needed tank's and installed components internal inspection and maintenance.
- **Mobility**: Whether the tank will be fixed or mobile helps in deciding its size and weight, and the suitable way to assemble and disassemble for moving from one point to another.
- **Others**: There are a number of other design calculations that may be factored in such as on seismic load, snow load and wind load among others.

Types of Steel Tanks

Steel tanks come in many different types, with each fabricated to standards that will be effective to a specific type of application.

Some of the most common types of these tanks include:

- **Steel portable water tanks** – They can be used in schools, hospitals, rural developments and for emergency water.
- **Corrugated steel tanks** – These can be used for rainwater collection, storing irrigation water, freshwater, and fire suppression.

- **Steel rainwater collection tanks** – They are used for rainwater collection and water storage. They can also be used in fire sprinklers applications.
- **Double walled steel storage tanks** – For storing heating fuel, residual fuel oils, and for fuel storage and containment.
- **Mobile steel tanks** – For construction sites, agricultural sites, pipelines, and power utilities.
- **Steel fire protection tanks** – Used for fire sprinklers, storing water, and in commercial and industrial applications.
- **Above ground lube tanks** – They are designed to store lube oil, motor oil, class III B liquids, and emergency fuel
- **Underground steel tanks** – These can be used to store livestock liquid waste, wastewater, greywater, or for landfill collection among other applications.
- **Underground steel fuel tanks** – Storage of petroleum, chemical, and flammable liquid.
- **Diesel fuel tanks** – Used for fuel storage and in industrial locations

Advantages of steel storage tanks

i. Longevity

The resistance of steel to a number of environmental factors makes steel tanks withstand the test of time. Stainless steel tanks are rust-resistant, fire-resistant, U.V rays resistant and long lasting even without painting.

ii. Cost effectiveness

Steel storage tanks are more cost effective as compared to tanks made from other materials considering the low amount of maintenance they require.

iii. Versatility

Steel is a versatile material. Its resistance to corrosion and durability allows it to be used in a number of different storage applications when used to make steel tanks. This guarantees strength, resistance to corrosion, and durability.

Concrete tanks

Any water that is stationary will eventually become stagnant and undrinkable. How water is stored and its temperature will determine how long the water stays healthy and drinkable. Spring water is often considered as the best water you can drink and storing your water in an underground concrete tank maintains its value.

Why is concrete the best material to store water in

The very nature of water itself is that it wants to balance out to a neutral ph. and a concrete tank is the only man-made storage system that will allow this to happen. To neutralize itself, water will absorb some of the minerals out of the concrete and will generally settle in a slightly alkaline state.

An in-ground concrete water tank will keep the water at the temperature that it fell out of the sky at and if the area gets mostly winter rain, that cold water will remain cold all summer.

Even above ground, light cannot penetrate through the concrete walls of a concrete and into the water.

All of this become very important, because roof harvested rain water picks up all sorts of dust, bacteria, and bugs and even after being pre-filtered some always gets through.

Water that is alkaline, cold and removed from light will not support the growth of any bacteria that makes its way into your tank, thus allowing this water to stay clean and drinkable for years.

Masonry tanks

Masonry tanks are a low-cost option for storing water gained through water harvesting. They are cheaper than ferro-cement tanks and easier to build.

In clay areas, be sure to build the tank robustly enough to resist cracking. Ground tanks should always be designed as either hemispherical (half ball shape) or cylindrical because those shapes equalize the pressure of water and soil whether the tanks are full or empty (square or rectangular tanks will always crack).

Suitable conditions:

- The area should be suitable for **rooftop rainwater harvesting**. Volumes can be 0.5 to 30 m³.
- Tanks should not be located near a pit latrine/toilet or rubbish or on an ant hill.
- Avoid building the tank next to a tree as the roots may undermine the foundation and dry leaves will block gutters.
- The height of the gutters should be higher than the proposed tank height.
- Do not site tanks where heavy vehicles will pass close to tank foundations.

Rubber tanks

Various materials are used for the construction of tanks.The majority of such vessels are, however, made of mild steel or cast iron, particularly the former, and it has become almost standard practice to line them with rubber or ebonite, materials which give protection in respect of a wide range of corrosive chemicals.

Fibre Reinforced Plastics (FRP)

FRP storage tanks are made with resins, but they are manufactured using resins that match the specific liquid material. So, when storing drinking water, your tank is made with resin suited and approved for potable (drinking water)

GRP, or glass-reinforced plastic, is composed of strands of glass. The glass fibres are very fine, and they are woven to form a flexible fabric. When layered with resin and catalyst and allowed to cure, the resulting material is extremely strong and lightweight.

Insulated tanks

Tank base insulation system has the following benefits:

- Reducing energy loss

- Protect the structural concrete base material against high temperatures. This means that the reinforced concrete foundation can be installed more cost efficiently.
- Helps protect against chemical attacks from the content of the tank in the event of a major spill or leakage which can put workers in danger.
- Provide adequate compressive strength suited for the tank's design. Insufficient compressive strength in high load bearing situations can lead to settlement and loss of thermal performance, which may result in viscosity increase or product solidification.
- Resist corrosion and mitigate deterioration of the vessel. Throughout its lifespan, a typical storage tank may be used for different purposes, or operate under cyclic temperatures, creating an environment where corrosion under insulation (CUI) becomes an issue if the tank is not properly insulated.

A tank base insulation system should always be included in the initial design when new multi-purpose tanks are being built.

Using non-flammable insulation will limit potential fire and smoke hazards inherent in storage tanks.

Moreover, it is critical for the insulation materials to be available in high load bearing grades that have been specially designed for tank base applications and can deliver a compressive strength up to 240 t/sqm without any compression.

In the case of high temperature tanks, insufficient insulation compressive strength can lead to settlement, loss of thermal performance, destabilisation of the processing environment, reduced viscosity control and possible solidification of the contents.

QUANTIFY MATERIALS AND SUPPLIES

Supplies

Various types of taps

1. Pillar Taps

They are mounted on a basin or a bath, with separate taps for hot and cold water. Pillar taps usually have a lever or a mechanism that enables you to turn the water supply on and off. These types of taps are available in a wide range of styles and designs.

pillar tap

2. Mixer Taps

Mixer taps are a traditional style of tap and they comprise two pillar taps joined, sharing one spout for the hot and cold water to come out together instead of separately. The improved water control can help you achieve the perfect, consistent temperature mix.

You can also get single-lever mixer taps besides the two pillar taps. With a single lever, you can turn the hot and cold water on and off, and mix them in the same way as the independent tap models. You can mostly find those in kitchen sinks and baths, and we recommend replacing your taps with mixer ones for your peace of mind.

mixer tap

3. Wall Mounted Taps

As the name implies, wall-mounted taps are fitted to the wall, protruding from it over the basin or bath. In essence, they are easier to clean, but there is a downside, and this relates to plumbing. Since the pipes are inside the walls, repairs are more difficult and costly.

wall mounted taps

4. Monobloc Taps

Monobloc taps are a type of tap that has a single spout for both hot and cold water. You can operate it with a lever that's adjustable. It allows choosing the temperature of the water with a single shift of the lever to the right or to the left. These are a more modern alternative to the taps discussed above and can be a beautiful choice for your bathroom or kitchen.

5. Washer Taps

Well-suited for DIY work, washer taps, otherwise known as compression washer taps, have a pillar tap that operates with a twisting handle. As the name suggests, the washer inside controls the amount of water released.

6. Ball Type Taps

A common problem with ball taps is that they are prone to leaks more easily. Apart from this downside, they are very easy to control because of the ball that sits inside the tap mechanism. It allows you to switch between hot and cold water easily, and control the amount of water that comes out of the tap.

7. Cartridge Taps

This is a combination type, and it comes with a tap lever. Moving it left-to-right controls the temperature of the water, while moving it from top to bottom enables you to control the water flow. You can choose from heavy flowing to completely off

8. Disk Type Taps

Similar to a monobloc tap type, this tap gets its name from the ceramic disks inside the tap mechanism. The disks control the amount of water that is released and flowing out of the tap. The disks have small holes and are fit in aligned order, which allows the water to pass through. Sometimes, however, dirt and grime can get captured in between. So, this type of tap may need replacement or repairs regularly.

Various type of Valves

A valve is a device that regulates, controls, or directs the flow of a fluid by opening, closing, or partially obstructing fluid flow.

Gate valve

A gate valve is the most common type of valve in any process plant. It is a linear motion valve used to start or stop fluid flow. In service, these valves are either in a fully open or fully closed position. Gate valves are used in almost all fluid services such as air, fuel gas, feedwater, steam, lube oil, hydrocarbon, and all most any services. The gate valve provides a good shutoff.

Globe Valve

Globe valve is used to stop, start, and regulate the fluid flow. Globe Valves are used in the systems where flow control is required and leak tightness is also necessary. Globe valve provides better shut off as compared to the gate valve and it is costlier than a gate valve.

Check Valve

The check valve prevents backflow in the piping system. The pressure of the fluid passing through a pipeline opens the valve, while any reversal of flow will close the valve.

Plug valve

Plug valve is a Quarter-turn rotary motion Valve that uses a tapered or cylindrical plug to stop or start the flow. The disk is in plug shape, which has a passage to pass the flow. Plug valve used as on-off stop valves and capable of providing bubble-tight shutoff. Plug valve can be used in a vacuum to high-pressure & temperature applications.

Ball Valve

A Ball valve is a quarter-turn rotary motion valve that uses a ball-shaped disk to stop or start the flow. Most ball valves are of the quick-acting type, which requires a 90° turn of the valve handle to operate the valve. The ball valve is Smaller and lighter than a gate valve of the same size and rating

Butterfly Valve

A Butterfly valve is a quarter-turn rotary motion valve, that is used to stop, regulate, and start the flow. The butterfly valve has a short circular body. Butterfly Valve is suitable for large valve applications due to Compact, lightweight design that requires considerably less space, as compared to other valves.

Needle Valve

Needle valves are similar to a globe valve in design with the biggest difference is the sharp needle-like disk. Needle valves are designed to give very accurate control of flow in small diameter piping systems. They get their name from their sharp-pointed conical disc and matching seat.

Pressure Relief Valve

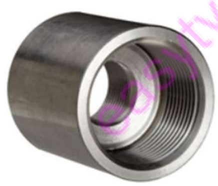
A pressure Relief valve or pressure safety valve are used to protect equipment or piping system during an overpressure event or in the event of vacuum. This valve releases the pressure or vacuum at a pre-defined set pressure.

Fittings

Elbows: Such pipe fittings are used to change the direction of the flow. They are majorly available in two standard types - 90- and 45-degree angles owing to their high demand in plumbing. The 90-degree elbow is primarily used to connect hoses to water pumps, valves, and deck drains, while the 45 degree elbow is mostly used in water supply facilities, electronic and chemical industrial pipeline networks, food, air-conditioning pipelines, garden production, agriculture, and solar-energy facility.

Fitting

Couplings: A coupling is a pipe fitting used to stop leakages in broken or damaged pipes. The pipes to be connected should be of the same diameter. The two kinds of couplings used in plumbing are regular coupling and slip coupling. The regular coupling is arranged between the two pipes to prevent further leakages with the help of rubber seals or gaskets on the both sides. The slip coupling itself contains two pipes to repair the damaged lengthy pipes.



Coupling

Union: This type of pipe fitting is almost similar to coupling in terms of functions, but just with a difference, i.e. a union can be removed easily any time while the coupling cannot. A variety of dielectric unions are used to join pipes made of different materials to avoid any kind of galvanic corrosion between them. These pipe fittings comprise of a nut, female and male ended threads.

Union

Adapters: Adapters are connected to pipes to either increase their lengths or if pipes do not have appropriate ends. These pipe fittings make the ends of the pipe either male or female threaded as per the need. This permits unlike pipes to be connected without any need of extensive setup. They are mostly used for PVC and copper pipes.

Adapter

Nipple: This is a short butt of a pipe that works as a connection between two other fittings having male threads. A close nipple is a type of pipe fitting having continuous threading on them. They are mostly used in hoses and plumbing.

Nipple

Reducer: This pipe setting is used to reduce the flow size of the pipe from the bigger to smaller one. There are two kinds of reducers- concentric reducer and eccentric reducer. Reducer the former one is in the shape of a cone used for gradual reducing of the size of the pipe. The latter one has its one edge facing the mouth of the connecting pipe reducing the chances of air accumulation.

Reducer

Tee: This T-shaped pipe fitting used in the plumbing system has one inlet and two outlets arranged at an angle of 90 degrees to the main pipe. This kind of fitting is used to connect the two pipes and make their flow direction as one. If all the three sides of this fitting are same in size, it is called equal tee, otherwise unequal tee.

Tee

Cross: This type of pipe fitting contains four openings in all thefour major directions. This fitting is adjoined to four pipes meeting at common point. There is either one inlet and three outlets or vice-versa to flow water or any other liquid in four different directions. These kinds of pipe fittings are commonly used in fire sprinkler systems.

Cross

Flanges: A flange is another pipe fitting used to connect pipes, pumps, valves, and other components to form a full-fledged piping system. They come with a flexibility of easily cleaning or inspecting the whole system from within. They are fixed to the pipes using welding, threading or screwing techniques and then finally sealed with the help of bolts. They are used in residential pump systems and majorly for industrial purposes.

Flanges

Caps & Plugs: Both these pipe fittings are used to close the ends of the pipe either temporarily or permanently. The plugs are fitted inside the pipe and threaded to keep the pipe for future use. There are a good number of ways a cap can be applied to the pipe like soldering, glue, or threading depending on the material of the pipe.

Caps and Plugs

Bushings: These pipe fittings are used to combine pipes of different sizes together by decreasing the size of the larger fitting to the size of the smaller pipe. Bushings are not always threaded inside out and occupy very little space in comparison to a union or coupling used for the same purpose.

Bushings

Wyes: Such type of pipe fittings are used in drainage systems and have a branch line at 45 degrees to keep the flow of water smooth. When the sanitary tees fail to work in a horizontal connection, such cases needs a wye.

Wyes

Valves: Valves are used in the plumbing system to stop the flow of gases or liquids. There are of three types – throttling, isolation, and non-return. The isolation valves are used to disconnect a part of the piping system temporarily for maintenance or repair. The throttling valves are used to regulate the amount of pressure of a liquid in a pipe; they can also withstand the stress caused by this process.

Valves

Barb: A barb is another useful pipe fitting used in the plumbing system that connects flexible tubing to pipes. It has a male-threaded end on one side that connects with the female threads, and the other end has a single or a multi-barbed tube that is inserted in the flexible tubing.

Barb

Diverter tee: This kind of a tee-shaped pipe fitting is commonly used in the pressurized hydronic heating systems to redirect a part of the flow from the main line to the side branch connected to a heat exchanger.

Fig 1.28: diverter tee

Gaskets and O-rings

Gaskets

A gasket is a flat piece of material that sits between to flat surfaces. The gasket's material whether neoprene, rubber, silicone or another flexible substance prevents liquid or air (or sometimes both) from leaking in or out of an area.

O-Rings

O-rings are circular, ring-shaped pieces that sit in a groove between two (usually cylindrical) parts. The compression of the two parts creates the airtight and liquid-tight seal.

O-rings can be made from many flexible materials, like rubber, neoprene, or polyurethane. While the ring-shape is a staple characteristic of o-rings, the height and thickness of the ring can vary based on your design.

Difference between a Gasket and O-Ring

Both perform the same basic function of stopping liquids or gasses from ingressing or egressing.

1. The shape of the seal is one key criteria where the difference between an O ring and a gasket becomes very clear. In some applications, only a gasket will work because the shape of the joint makes it difficult or impossible to design a good seal using an O ring, which requires a groove to sit in.
1. The other key factors are temperature and pressure. The material used to make the seal is a critical factor with regards to operating temperature. While both O rings and gaskets can perform well in a wide temperature range, gaskets have the edge in extreme temperatures. O rings, however, are the superior choice in applications with extreme pressure. Under pressure, an O ring's performance will improve while a gasket's effectiveness will decrease

Caulking agents

It is a sealant but differs from plumbers' putty. A big difference in both is that a silicone caulk cannot be replaced.

It is a sticky material and is an adhesive one. It is hard enough that you can use it everywhere. It also has a rubbery touch to it that keeps it elastic for quite some time. It can be so tight after applying, you would need a scrapping tool to remove this sealant.

Sealant and glue

Silicone sealants are a form of liquid adhesive commonly used in building, bonding, and repairing many materials, including finishing joints and filling seams or other gaps. Since they are waterproof and offer durable elasticity and stability in both high and low temperatures, silicone sealants work particularly well as plumbing sealants.

Water proofing agents

Concrete is the main building material used in all civil constructions and it is prone to shrinking. Concrete hence requires protection due to porosity, cracks & potential to reaction with atmospheric gases such as CO_2. Apart from that, the structures have various joints & connections which need to be considered & given extra protection.

Estimation of quantities and costs

Bill of Quantities and cost for a 5 cu.m. tank of concrete in situ

Description	**Unit**	**Quantity/ Days**	**Unit cost Ksh**	**Total cost Ksh**
Labour cost	Artisans	1 x 8 days	400/day	3,200
Artisan	Labourers	2 x 8 days	200/day	3,200
Labourers				**6,400**
Cost of labour				
Materials				
Cement	50 kg bags	12	600	7,200
River sand	Tonnes	3	200	600
Crushed stones	Tonnes	3	600	1,800

Burnt bricks 4” x 6” x 10”	Units	50	5	250
Water	Oil-drums	8	100	800
Weld mesh 2.4 x 1.2 m	Sheets	4	370	1,480
Barbed wire 20 kg rolls, g	Kg	1	3,000	3,000
12.5	Rolls	2	3,000	6,000
Chicken mesh, 3’ x 90’ x 1”	Kg	5	100	500
Nails, 2”	25kg	1	400	400
Lime	Lengths	1	400	400
uPVC, 2” sewage pipe	Metres	0.5	420	210
G.I pipe, 1½”	Metres	0.9	200	180
G.I pipe, ¾”	Units	4	500	2,000
G.I fittings, ¾” tap, elbow	Sq.m.	1	200	200
etc	6 mm x 25 mm	6	20	120
Galvanized coffee mesh	Centimetres	200 x 20	Free	Free
Circular bolts	Metres	30	75	2,250
Circular metal ring	Kg	5	80	400
Timber, 6” x 1”				**27,790**
Nails, 3”				
Cost of materials				
Transport of materials				
Hardware lorries	3 tonnes	1 load	3,000	3,000
Tractor trailer loads	3 tonnes	5 loads	900	4,500
Cost of transport				**7,500**
Total cost of a 5 cu.m. tank built of concrete in situ				**41,690**

Bill of Quantities and cost of a 90 cu.m. ground tank

Description	Unit	Quantity	Unit cost Ksh	Total cost Ksh
Labour cost				
Artisan	Artisans	3 x 14 days	400/day	16,800
Labourers	Labourers	4 x 20days	200/day	16,000
Cost of labour				**32,800**
Materials				
Cement	50 kg	73	600	43,800
Lime	bags	2	400	800
River sand	25 kg	17	200	3,400
Crushed stones	bags	1	600	600
Burnt bricks, 4” x 6” x 10”	Tonnes	1000	5	5,000
Water	Tonnes	45	100	4,500
Weld mesh, 2.4 x 1.2 g.8	Units	25	370	9,250
Chicken mesh 25mm, 0.9m	Oil-drums	100	110	11,000
Twisted bars, Y12	Sheets	5	60	300
Barbed wire g12.5	Metres	100	150	15,000
G.I pipe, 1½”	Metres	4	420	1,680
G.I elbow, 1½”	Kg	1	80	80
G.I pipe, ¾”	Metres	9	200	1,800
G.I tap, elbow, socket, nipple,	Unit	1	700	700
¾”	Metres	5	133⅓	670
uPVC, 4” sewage pipe	Tap unit	1	200	200
Galvanized coffee mesh	Metres	0.5	100	50
Mosquito mesh	Sq.m.	60	75	4,500
Timber, 6” x 1”	Sq.m.	60	75	4,500
Timber, 2” x 3”	Metres	12	40	480
Poles	Metres	12	50	600

Bolt 6 x 120mm	Units	48	Free	Free
Oil-drums, discharged	Units	50	30	1,500
Plastic bag	Units	16	120	1,920
Angle iron 25 x25mm	Units	1	100	100
Plastic basin	Units	3	70	210
Sisal twine	Units	3	80	240
Nails 3”	Kg			**112,880**
Cost of materials	Kg			
Transport of materials				
Hardware lorries	7 tonnes	1 loads	5,000	5,000
Tractor trailer loads	3 tonnes	14 loads	900	12,600
Cost of transport				**17,600**
Total cost a 90 cu.m. ground tank built of ferro-cement				**163,280**

5.2.2.4 Learning Activities

With the help of your trainer, Quantify and cost for materials and supply for the water storage system given

5.2.2.5 Self-Assessment

1. What factors are considered during the designing and building of steel storage tanks?

2. Which of the following is not a type of steel tanks?
    a. Steel portable water tanks
    b. Corrugated steel tanks
    c. Steel fire protection tanks
    d. Above ground tank

3. What are some of the signs that a septic tank is not working properly?

4. Of the following, which one is not a tank base insulation system benefit?
    a. Increases energy loss
    b. Protect the structural concrete base material against high temperatures.
    c. Helps protect against chemical attacks from the content of the tank.
    d. Resist corrosion and mitigate deterioration of the vessel.

5. How does a septic tank work?

6. Which of the following are suitable conditions for the construction of a masonry storage tanks?
    a. Tanks should not be located near a pit latrine/toilet or rubbish or on an ant hill.
    b. Avoid building the tank next to a tree as the roots may undermine the foundation
    c. The height of the gutters should be lower than the proposed tank height.
    d. Do not site tanks where heavy vehicles will pass close to tank foundations.

7. What factors are considered in the choosing of building materials for tanks.

5.2.2.6 Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:

Tools and Equipment

- Pipe wrench
- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vice - Bench
- Pliers

- Tap and Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Mallet
- Ball hammer
- PPR machine / Heat Fusion equipment
- Pipe bender
- Sealant gun

Supplies and Materials

- Fittings
- Back nuts
- Cisterns
- Valves
- Sealant
- Water proofing agents

5.2.2.7 References

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Art Ludwig., 2006., Builder's Greywater Guide

5.2.2.8 Model Answers

1. What factors are Considered During the Designing and Building of Steel Storage Tanks
    - **Materials**: This mainly relates to the tank's application, simplicity and installation, regulations and codes, and the tank's cost.
    - **Size and Shape**: Depends on the application, regulations and standards.
    - **Strength**: Here designers and engineers decide on the thickness of the tank walls, and the vertical, horizontal and cross ribs depending on its application and usage.
    - **Location**: Whether the tank will be aboveground, underground or partially buried also influences the design and the construction of the steel storage tank.
    - **Accessibility**: Considering the accessibility during the initial designing of the tank helps facilitate the needed tank's and installed components internal inspection and maintenance.
    - **Mobility**: Whether the tank will be fixed or mobile helps in deciding its size and weight, and the suitable way to assemble and disassemble for moving from one point to another.
    - **Others**: There are a number of other design calculations that may be factored in such as on seismic load, snow load and wind load among others.

a. Which of the following is not a type of steel tanks?

   Steel portable water tanks

b. Corrugated steel tanks

c. Steel fire protection tanks

d. Above ground tank

- What are some of the signs that a septic tank is not working properly? The sewage in the toilet or the liquid waste from other fixtures flows away very slowly
- Liquid waste overflows from the disconnector trap
- Wet areas are seen at the top of the septic tank
- There is a strong unpleasant smell near the septic tank
- The grass around the tank is very green and growing well

2. Of the following, which one is not a tank base insulation system benefit?
   a. **Increases energy loss**
   b. Protect the structural concrete base material against high temperatures.
   c. Helps protect against chemical attacks from the content of the tank.
   d. Resist corrosion and mitigate deterioration of the vessel.

3. How does a septic tank work?

   A septic tank must be filled with water before it is used. The water helps start the treatment of the sewage by the bacteria.

   The sewage treatment by the bacteria turns the waste matter into **effluent** (wastewater) and a solid substance called **sludge**. The effluent gets carried to the leach drain, French drain or lagoon.

   The material in the septic tank gets covered by a hard crust known as a **scum blanket.** This blanket acts as an **air seal** keeping air away from the sewage. The lack of air helps in the breakdown of the sewage by the bacteria.

The sludge gathers at the bottom of the tanks. Eventually there will be too much sludge in the tank and it must be pumped out and the sludge disposed of correctly.

By having two tanks or a rectangular tank divided into two sections, most of the sludge stays in the first tank or section. In the second tank or section, the sewage undergoes further treatment to remove solid matter.

The effluent is then piped to the effluent disposal system, such as the lagoon.

4. Which of the following are suitable conditions for the construction of a masonry storage tanks?
    a. Tanks should not be located near a pit latrine/toilet or rubbish or on an ant hill.
    b. Avoid building the tank next to a tree as the roots may undermine the foundation
    c. The height of the gutters should be lower than the proposed tank height.
    d. Do not site tanks where heavy vehicles will pass close to tank foundations.

5. What factors are considered in the choosing of building materials for tanks.
    - Where coarse river sand is expensive, tanks should be built of either burnt bricks or soil compressed bricks to reduce cost.
    - Where coarse sand is cheap, tanks should be built of ferro-cement if trained builders are available.
    - Where coarse river sand, pebbles, stones and hardcore (larger stones) are in plenty, it is most economical to use concrete in formwork (in situ) or concrete blocks.

- The cost of making concrete blocks can be reduced by compacting rubble stones into the concrete in the steel mould. Such blocks, as seen in the photo are called rubble stone blocks.

5.2.3 Learning Outcome 3: Install storage systems and auxiliary fittings

5.2.3.1.Introduction to the learning outcome

This learning outcome specifies the content of competencies required to Install storage systems and auxiliary fittings. It includes, terms and concepts, tools and equipment, PPEs, types of storages systems, pumping systems, types of pumps, their installation and supports, positioning, housekeeping and occupational safety and legal requirements

5.2.3.2.Performance Standard

1. Tools and equipment needed for fixing storage and ancillary fittings are identified based on the job requirements.
2. Tools and equipment are used based manufacturer's manuals.
3. Location of Storage and auxiliary fitting is determined based on drawings.
4. Support for Storage and auxiliary fitting are put in place based manufacturers' manual.
5. Storage and ancillary fittings are mounted based job requirements and manufacturer's installation manual.
6. Personal Protective Equipment is used in line with occupational safety and health regulations.
7. Housekeeping is conducted on work area based on work place procedure
8. Safety and health practices are observed based on OSHA.

5.2.3.3.Information Sheet

INSTALL STORAGE SYSTEMS AND AUXILIARY FITTINGS

Tools and Equipment

- Pipe wrench

Pipe wrench size should be selected such that its opening exactly pits the pipe and should not be used for bending, raising or lifting pipe.

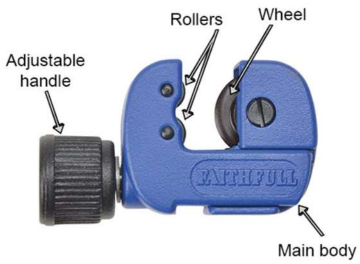
It is used for:

- screwing and unscrewing small pipes.
- tightening of nut and bolts, fixing of small taps, valves etc in pipelines.

Pipe Wrench

- Pipe cutter

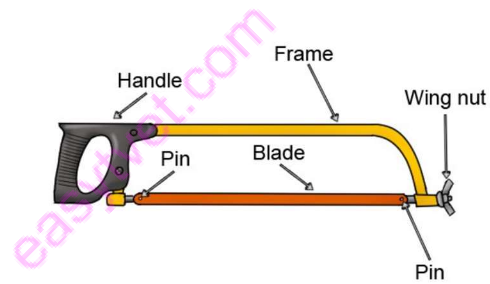
It is used for cutting of pipes. It is placed around pipes and tightens so that it holds the pipe tight. However, over tightening may damage pipe. The cutter is rotated around the pipe one to two times and then the pipe is tightened again. The process is repeated unless the pipe is cut. Pipe cutters are available for cutting of pipes from 25-150 mm.



Pipe Cutter

- Hacksaw

It is used for cutting pipes of smaller diameters (15-25 mm). It consists of frame, handle, prongs, tightening screw and nut. The frame may be fixed type or adjustable type. Blade is fixed in position by means of tightening screw. The direction of the cutting teeth of the blade is to be in the forward direction.



Hack Saw

- Pipe Threading Equipment

It is used for threading external taper threads of pipe. Pipe is fixed in the pipe vice and threading is done with help of the die set as per pipe size requirement.

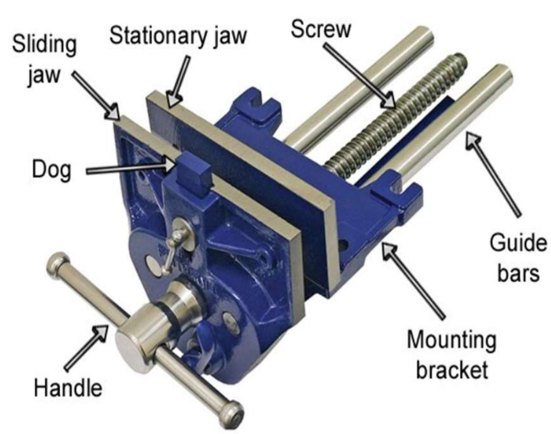
Pipe Threading Equipment

Using instructions:

a. Take required size of pipe threading die.
b. Fix the pipe in the pipe vice tightly.
c. Cut the pipe to required size at right angle.
d. Hold the die in right angle of the pipe and put some oil on pie.
e. Cut the thread on the pie with die rotating in clockwise direction. Rotate the die in anti clockwise direction so that the cut material will come out.
f. Clean the chips or burr.

- Bench vice

It is used for holding pipes in position rigidly for cutting and threading. Pipe vices are available in market in various sizes for holding pipes starting from 37 mm diameter.



Bench Vice

1. The Base

The base of the vise is the part that holds everything together. It is truly the life of the party. The base of the vise is fastened to the bench and it comes in different designs. Some can be clamped in place; the others can be bolted. There are also swivel and vacuum bases available for different purposes.

2. The Jaw

This is where everything stays. The jaw is jaw-like and clamps everything in place. It comes in two different parts. Considering the nature of the job, the jaws can take the form of wood, plastic, or metal.

The sliding jaw: this part of the jaw moves when the handle is turned. It also applies pressure on the object being clamped. If you are new to clamping, it’s pretty easy to spot out which part of the clamp is the sliding jaw, since it’s the part that allows motions and has a handle sticking through.

The static jaw: this part is fixed. This is the vise that enforces solidity. The sliding jaw backdrops in this component applying pressure for its immovability. You can identify the static jaw by its size.

3. The Slide

This part moves when the handle is turned, applying pressure to the object. It is attached to the sliding jaw.

4. Main Screw

The force applied to the handle is transformed into the movement of the sliding jaw, which moves towards the static jaw. This jaw is conspicuously attached to the handle and extends through the vise.

The main screw is an essential part. It is so vital that if the main screw is not manufactured based on the type or comes with flaws creating weaknesses, the vise will not hold well at all.

5. Handle

The handle has a lever attached to it.

Applying too much force on the handle can be tempting. But if done out of proportion, it can lead to explosive results. The power applied to move the handle multiplies and gets accompanied by the actions of the main screw. While clamping, if any material observes a bend, it’s best to stop and reverse the handle to release the pressure level.

6. The Anvil

This can come in handy form when light-shaping of materials.

7. Serrated Jaws

This is the actual point where the vise meets with whatever it is you are fastening. Take precautions with anything other than metal. The jaws can do a ‘damage job’ when too much pressure is applied.

8. Pipe Jaws

These pipe jaws can be found inside the sliding and static jaw. They allow you to hold pipes and other oddly shaped objects in place, and present you with the prerogative to cut them easily.

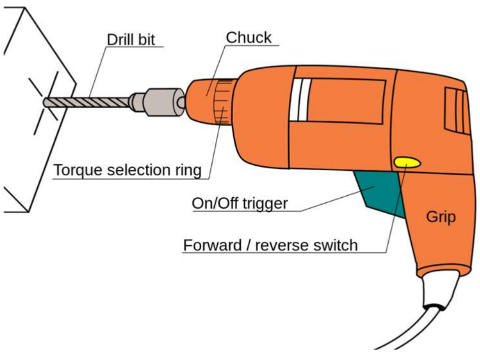
- Spanner

Spanner is used for fixing and opening nuts and bolts. Different types of spanners and size are available as per requirement of pipe size.

Spanner

- Drill with various sizes of bits

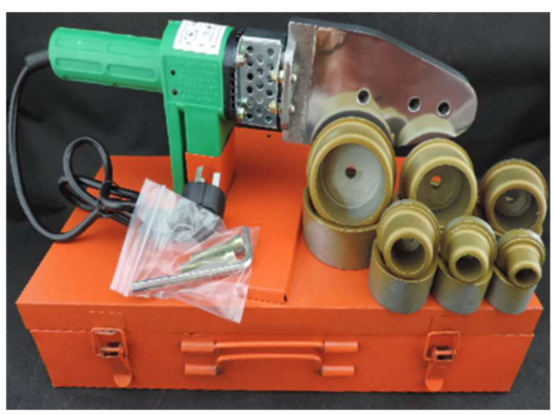
It is a tool primarily used for making round holes or driving fasteners. It is fitted with a bit, either a drill or driver, depending on application, secured by a chuck. Some powered drills also include a hammer function.



Drill and Bits

- PPR machine / Heat Fusion equipment

It is a pipe welding machine set used for welding plastic pipes.



Ppr Machine

- Pliers

These are used everyday by plumbers. Easily tighten or loosen nuts and bolts that wrenches can’t grab onto.

Pliers

- Pipe bender

It is used for bending pipes. Fix wooden stopper to one end of the pipe. Fill the pipe with sand completely. Fix wooden stopper from other side of pipe. Fix the pipe in the machine. Location of the bend should be in center of pulley. Tight the screw. Bend the pipe with help of lever till required bend. Remove stopper and sand from pipe.

: Pipe Bender

PPES

Plumbing Safety Tools

PPE can be defined as safety gear that protects plumbers against safety or health risks when handling the job. The main objective of a protective gear for a plumber is to reduce plumber exposure to hazards related to plumbing.

Below are essential PPE for plumbers commonly used on plumbing and their benefits.

PPEs

1. Face and Eye Protection

Spectacles, safety goggles, and full-face shields are essential protective gears a plumber should consider using when handling the task. This safety gears are commonly used when handling power tools. This safety equipment helps the plumber to effectively and efficiently complete the task.

2. Head Protection

Protective helmets are important in a plumbing site because they prevent injuries from flying or falling objects. Recently, due to advanced technology, some hard hats are equipped with accessories, such as earmuffs and shields. A plumber should consider buying a well-fitted protective helmet to prevent inconveniences. Too small or too large hard hats are inappropriate to use. Falling or flying objects might lead to severe head injuries.

3. Hand and Skin Protection

Plumbing projects typically require the use of hands. Recently, there have been many reported cases of hand injuries resulting from lack of hand protective gear. Also, a plumber can suffer from various occupational skin diseases, such as skin cancer, dermatitis, and other severe skin injuries.

Hand gloves are essential because they lower the risk of hand and skin diseases. There are different types of gloves that can be used as PPE for plumbers. These types include cut-resistant gloves, rubber gloves, heat-resistant gloves, chainsaw gloves. Gloves are essential when a plumber is handling tasks that involve hot materials, electricity, and slippery objects.

4. Respiratory Protection

Production of toxic substances is common in plumbing sites. Respiratory protection gears, such as respirators, are designed to protect a plumber from fumes, dust, and other dangerous substances that could lead to respiratory problems. Respiratory protection gears are important in areas where there’s air contamination.

5. Hearing Protection

Noise pollution in plumbing sites can lead to permanent hearing impairment. Earplugs and earmuffs are the common hearing protection equipment in plumbing projects. Note that earplugs are effective in reducing low-frequency noise, whereas earmuffs are effective in preventing high-frequency noise.

Water Pumping

Pumping Machinery is used for transfer of water from one place to another and pumping of water from water source. Pumping is required for

a. Lifting water from the source (surface or ground) to purification works or the service reservoir.
b. Transfer of water from source to distribution system.
c. Pumping water from sump to elevated/ground surface tanks.

Pump house (civil works) is constructed for installation of pumping machinery.
Pump House is designed for life of at least 30 years, while pumping machinery is designed for at least 15 years lifespan.
Pumping Machinery consists of 3 major components:
a. Pump for lifting of water
The function of pump is to transfer water to higher elevation or at higher pressure. Pumps are driven by electricity or diesel or even solar power. They are helpful in pumping water from the sources, that is from intake to the treatment plant and from treatment plant to the distribution system or service reservoir.

b. Electric/diesel/solar powered motor
For pumping, 3 phase electric connection is required.

c. Panel board
Panel board consists of circuit breaker or switch and fuse, starter level controls etc. for transmission of electric supply.

PUMPING SYSTEMS

i. Total Dynamic Head

In order to accurately predict the performance of a pump in a specific application, the total head losses must be considered. These losses include, but are not limited to:

- Total static head;
- Losses due to pipe size, length, and material;
- Losses due to pipe appurtenances.

ii. Friction Losses in Conduits

When water moves through a closed conduit, the flow creates heat due to the friction of the two surfaces (water against conduit). A steel pipe will produce more friction than will any plastic pipe.
Friction increases with the increased length of pipe or hose, and also with a deceased diameter of pipe or hose. Increased friction slows down the water, effectively decreasing the discharge capacity and actual discharge of a given pipe.

iii. Suction Head

Atmospheric pressure at sea level limits the suction head of centrifugal pumps to 10.3 m (33.9 feet). However, this head would only be obtained if a perfect vacuum could be created in the pump. In reality, the suction head of centrifugal pumps is limited to about 7.9 m (26 feet).

Pump performance (capacity or pressure) is highest when the pump is operated close to the water's surface.
Increasing the suction head will decrease the discharge head and consequently the discharge capacity of the pump. Very importantly, suction head should be kept to the smallest value possible to reduce the likelihood of cavitation10. Cavitation can also occur if the suction pipe is restricted. A suction hose with a smaller diameter than the suction port should not be used as cavitation can quickly damage a pump.

iv. Discharge Head

As the pump discharge head increases in height, the pump capacity decreases and the available pressure at the end of the discharge pipe also decreases. At maximum head, the capacity of a pump drops to zero and no pressure is available at the end of the discharge line. The pump performance curves show the relationship between discharge capacity and total head.

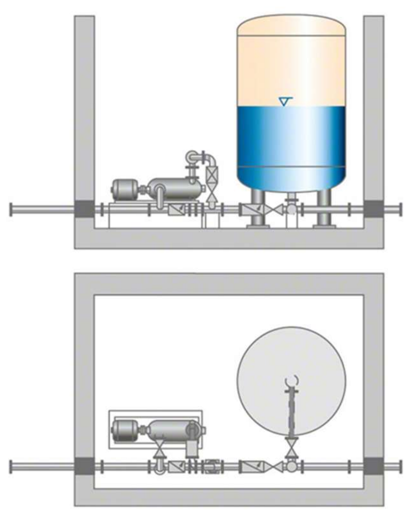
v. Pipe Restrictions

When water hits any restriction (valve or a reducer), only a partial amount of the flowing water is be allowed to pass through. Restrictions increase the friction and decrease the discharge capacity at the end of the pipe.

Pressure booster system

If the standard pressure of an existing water supply system is unable to ensure supply to consumers located at higher elevations, e.g. in high-rise buildings or elevated residential areas, it is necessary to boost the water pressure. This is accomplished by installing one or more booster pumps in a bypass line to the main water supply pipe.

In order to prevent any pumping in a closed circuit, a check valve is fitted in the main water supply pipe between the booster pumps' suction and discharge connections.



Booster Pump

Pressure booster system: Pump installed in bypass line with lift check valve and accumulator

Advantages of the Booster Pump System

- It requires the least floor space.
- It generally has the lowest initial cost.
- It is the most flexible system in terms of available flow and pressure to meet a variety of distribution requirements.
- The installation does not impose a large weight on the building structure.

Disadvantages of the Booster Pump System

- It has the highest operating cost.
- It has the the highest maintenance cost.
- Its control system is sophisticated and requires a knowledgeable maintenance
- It has couplings and variable-speed drives that require considerable maintenance.
- It will shut down the water supply for the entire building if there is an electrical power failure.
- The instantaneous fluctuations in water pressure during normal use may begreater than in the other systems.

- Direct pumping

Direct Inline Pumping (DIP) is a pumping methodology that can carry gravity-fed effluent away from the point of entry without requiring a wet-well.
Direct supply is simulated with two parallel pumps, one running at a constant speed (CSP) while the second, a variable speed pump (VSP) is fed by a variable frequency driver that during the simulation is adjusted to provide 20 m at the less favorable node avoiding over pressures at any time.

- Indirect pumping

In a case of indirect excitation, the absorption / pumping band is significantly shifted to shorter wavelengths and several processes of energy transfer.
Indirect supply, the pump is controlled by the tank's water level and, in order to avoid as much as possible pumping during on-peak hours, by the time as well.

- Zoned system

Zoned pumping system can be accomplished in one of two ways:

i. Multiple circulator pumps
ii. A single circulator pump and zone valves.

Multiple zones can be implemented using either multiple, individually controlled circulator pumps or a single pump and multiple zone valves.
Each approach has advantages and disadvantages.

Multiple pump system
Advantages:

- Lower total cost of ownership when zone valve failure and repair costs are taken into account.
- More robust and reliable system.
- Simple mechanical and control design ("SPST thermostats")
- Redundancy: If one zone pump fails, the others can remain working
- Far superior method of linking multiple heat sources. Such as gas and solid fuel in one system.

Disadvantages:

- Higher initial installation cost. Circulator pumps cost more than zone valves
- Higher power consumption. Operating circulators draw more power any time the zone is actively heating. Zone valves, by comparison, draw little power at any time and many designs only draw power while in transition from open to close or vice versa.

Zone valve system

Advantages:

- Lower initial installation cost.
- Lower power consumption.
- Ease of maintenance certain models.

Disadvantages:

- Zone valves are inherently more unreliable and prone to a very high failure rate. Zone valves operated by electric timing motors aren't "fail safe" (failing to the "open" condition).
- No inherent redundancy for the pump. A zone-valved system is dependent upon a single circulator pump. If it fails, the system becomes completely inoperable.
- The system can be harder to design, requiring both "SPDT" thermostats or relays and the ability of the system to withstand the fault condition whereby all zone valves are closed simultaneously.

Classification of Pumps.

Classified by use, pumps are called:

- Low service
- High service
- Deep well, booster
- Sewage, sludge
- Boiler feed
- Chemical
- Proportional feeders
- Air blowers

Low-service pumps operate at low discharge heads to lift water from sources of supply to water-treatment works.

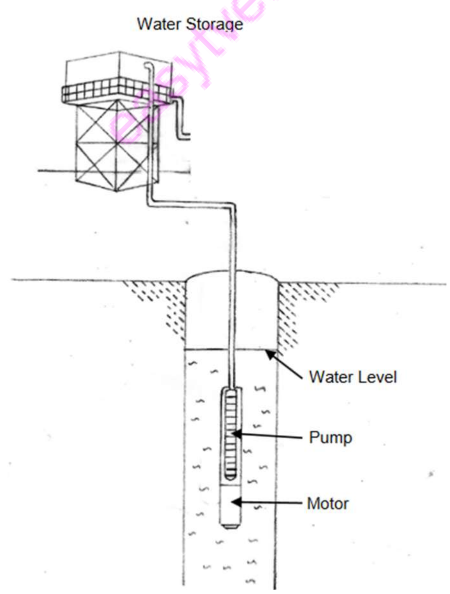
High-service pumps operate at high discharge heads to deliver water to distribution systems. Proportional feeders are used for dosage of solutions of chemicals or liquid chemicals.

The standard classification of pumps may be divided into four general classes with a section devoted to each class.

TYPES OF PUMPS

1. Turbine Pump (Deep well)

The principle of a pump used as turbine: When water flows back through a pump, the impeller will run in reverse and the pump will function as a turbine. The energy recovered from pressure differences, heads or flow can be fed back into the system or into the mains. Turbine pumps are mainly used in elevation of water from ground level storage to elevated areas/storage or pumping from deep wells/tube wells. If the water requirement is large and there is a large source of falling water (head and flow rate) nearby, turbine-pump sets can provide the best solution.



Turbine Pump

2. Sump pumps

Sump pumps move water from your basement out of your home. A sump is a naturally constructed pit, usually a hole carved below the main surface of your basement floor. This pit, known as a **basin**, holds the sump pump.

The pump is equipped with valves that sense escalating water levels or pressure. When the water gets too high, sump pumps automatically pump excess water out of the basement and away from your property using a discharge line. This line, called an **effluent**, connects the sump pump to a designated drainage area.

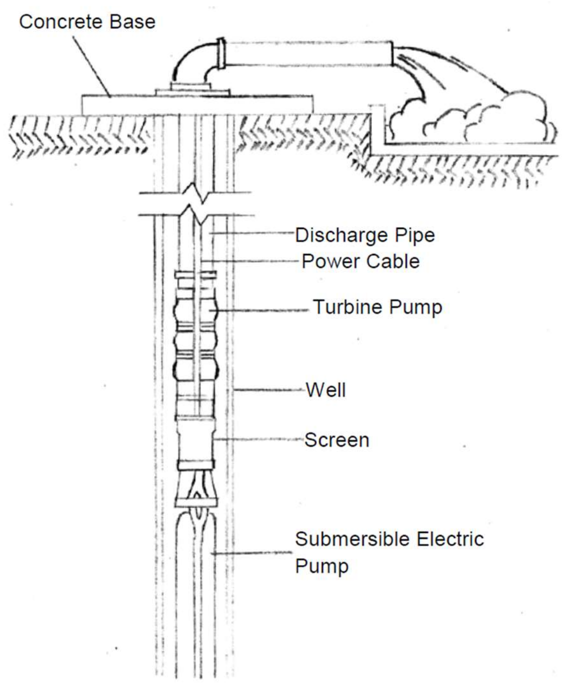
Two main types of sump pumps exist:

a. Submersible sump pumps, which are totally hidden in your sump basin
b. Pedestal sump pumps, which are mounted above floor level on columns that protrude out of the sump basin

a. Submersible pumps

It is designed such that it can be introduced into a well casing and lowered to the bottom of the well. It is highly used for pumping from bore well and underground sumps. Such pumps are used for water yield of 100 liters per minute.

It is driven by an electric motor, which is directly attached to the pumping element and therefore totally submerged. This pump type is mainly used where electric power is available or ideally in combination with a Solar Pumping System.



Submersible Pump

The main parts of a submersible pump are:

- Electric motor enclosed in a stainless-steel sleeve.
- Pump body with multiple impellers, foot valve and strainer.
- Rising main of GI or stainless-steel pipes connected with sockets or PVC- hose. If a hose is used, the motor with connected pump body has to be hung from the top of the well by a stainless-steel cable.
- Electrical cable for connecting the motor to the starting panel (power source).
- Starting panel.

Submersible pump have high efficiency and durability, low operation cost and high resistance to sand content.

b. Pedestal pumps

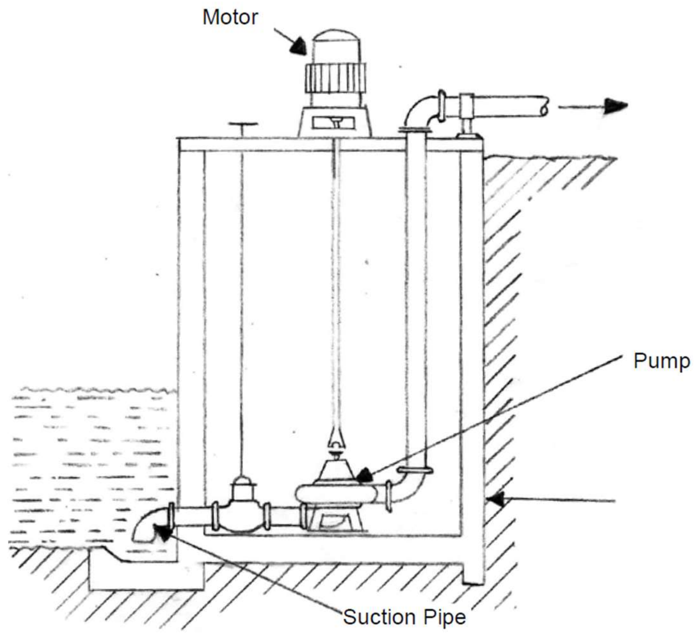
Pedestal sump pumps drain water in smaller-diameter sump pits that cannot accommodate submersible sump pumps. They have the pump motor above the sump pit and are mounted on top of a long tube sitting at the bottom of the sump pit. The pump impeller on the inside of the tube turns to transfer the water. Pedestal sump pumps (also known as upright sump pumps) have a long rod with a float on the end to turn the switch on and off, though the switch may sometimes be turned on in a different way.

Pedestal Pump

3. Centrifugal pump

It is used for pumping water from well/sump. It is a type of velocity pump where water is moved through continuous application of power. These type of pumps are used widely in water supply schemes containing sand, silt etc.

Centrifugal force is made use of in lifting water. Electrical energy is converted to potential or pressure energy of water. The pump consists of following parts: Casing, Delivery Pipe, Delivery Valve, Impeller, Prime Mover, Suction Pipe, Strainer and Foot Valve.



Centrifugal Pump

The pump consists of an Impeller which is enclosed in a water tight casing. Water at lower level is sucked into the impellor through a suction pipe. Suction pipe is air tight.
A strainer foot valve is connected at the bottom of the suction pipe to prevent entry of foreign matter and to hold water during pumping. Suction pipe is kept larger in diameter than delivery pipe to reduce cavitations and losses due to friction.

4. Booster pumps

A water booster pump helps increase the pressure and volume of water that flows from your faucet or shower head. A booster pump increases low water pressure and flow. It provides the extra boost needed to bring your water pressure to the desired level. A water booster pump provides pressure to move water from a storage tank or throughout a whole house or commercial facility.

Most water booster pumps, have the following core components:

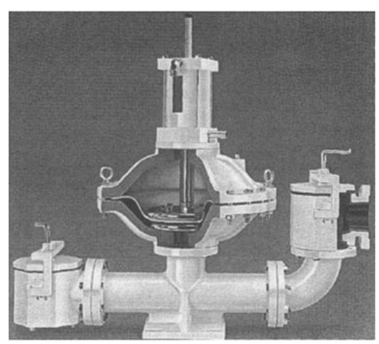
- Motor
- Impellers

- Inlet and outlet
- Pressure or flow sensing device

5. Reciprocating pump

Reciprocating pumps are a type of positive displacement pump which use alternating force and suction – using a piston or diaphragm – to create a steady, pulsing flow, with one or more check valves to regulate and direct flow through the system. The pump chamber is repeatedly expanded and contracted to draw the fluid through an intake valve and force it out through the other end. They are able to generate high pressures.

These pumps range from small, hand-powered pumps, to big pumping systems. Due to the broad range of pumps that are classed as reciprocating pumps, they play an integral role in a number of sectors including private, public and commercial/industrial sectors in applications such as irrigation, public water supplies, fire safety systems and where viscous liquids need to be moved.



Reciprocating Pump

The key components used in reciprocating pumps are

- **Piston, Plunger or a diaphragm:** All these parts have the basic functionality of moving the liquid inside the cylinder. The piston is a lubricated sliding shaft which moves inside the cylinder and pushes the liquid in forward and backward motion, creating a cavity and a high volume pressure at the outlet. In a diaphragm pump, the diaphragm is used to avoid leaking of the liquid since it completely seals the liquid to penetrate outside, and hence they are especially useful when the liquids are dangerous or toxic. In a plunger pump, there is a high-pressure seal which is stationary and a smooth cylindrical plunger slides through the seal.
- **Crank and Connecting rod:** Crank is a circular disk attached to the motor and used to transfer the rotary motion of the motor to the piston. Piston, in turn, moves in a reciprocating motion with help of a connecting rod.
- **Suction pipe:** Liquid flows from this pipe into the cylinder. One side of the pipe is immersed in the liquid and the other end is connected to the cylinder.
- **Delivery pipe:** This can be understood as an outlet pipe. One end is connected to the cylinder while the other is towards the discharge/Outlet.
- **Suction and Delivery valve:** It adjusts the rate of the flow of liquid at the suction and discharge points.

Reciprocating pumps are different from Centrifugal pumps on basis of its working, features, applications etc. The main difference is that Impellers are used in Centrifugal pumps whereas in reciprocating pumps piston is used to move the liquid. Centrifugal pumps continuously discharge the liquid, unlike reciprocating pumps. They are used for high viscous fluid and are lighter in weight, less expensive as compared to reciprocating pumps.

We look at the most common types of reciprocating pumps below.

Types of reciprocating pumps

1. Piston pumps

Piston pumps (also known as well service pumps, high pressure pumps or high viscosity pumps) use one or more reciprocating pistons to move fluid through a cylindrical chamber which are usually driven by an electric motor, internal combustion engine or other power source through a crankshaft or connecting rod.

These pumps have contracting and expanding cavities that move in a reciprocating motion rather than a circular (rotary) motion, alternately drawing the fluid in and then pushing it out under pressure.

These pumps can be single acting where the piston moves in both directions to complete a full pumping cycle, or doubling acting where there are two sets of check valves (one on each side of the piston) with fluid on both sides of the piston and a full pumping cycle being completed each time the piston moves from one end to the other.

Piston pumps are commonly used as hydraulic pumps to power heavy machinery or in smaller applications such as paint sprayers..

2. Plunger pumps

Plunger pumps operate in the same way as piston pumps, but rather than using pistons, they use plungers to move fluid through a cylindrical chamber, typically driven by electric motors, but steam and hydraulic drives are also used.

These pumps work with the drive moving one or more plungers back and forth inside the cylinder. This cylinder comes with packing rings to prevent the fluid from leaking past the plunger as it moves. At the end of the cylinder there is a pumping chamber with two check valves located at the inlet and outlet which stop the fluid from reversing direction as it passes through. Fluid is drawn into the chamber as the plunger moves away from it, creating a vacuum, and the fluid is pushed out of the chamber and into the system as the plunger moves towards it.

Plunger pumps can come with one or more plungers and sets of check valves. Where there are two, it is known as a duplex pump; where there are three, it is called a triplex pump; and where there are five, it is known as a quintiplex pump. Triplex and quintiplex versions are commonly used.

These pumps produce high pressures, and due to the reciprocating plunger they are also capable of producing pulsations, with the fewer plungers in the pump, the higher the pressure pulsations it is able to produce. Many systems include a pulsation dampener at the pump discharge that absorbs pulsations to significantly reduce the pressure pulsations further downstream.

As they can generate high levels of pressure and tend to be sturdily built, they are commonly used in applications where highly viscous or heavy fluids such as oil need to be moved. Smaller, lighter duty versions are used in applications such as pressure washes.

3. Diaphragm pumps

Diaphragm pumps use a flexible diaphragm to create a vacuum at the chamber inlet to draw the fluid in, with the volume of the pumping chamber decreasing and forcing the fluid out of the discharge as the diaphragm moves in the opposite direction.

Like piston and plunger pumps, diaphragm pumps have check valves at the inlet and outlet of the pump to prevent the fluid from moving backwards.

These pumps are highly reliable as they have no internal parts that rub against each other, and contain no sealing or lubricating oils within the pump head which eliminates the chance of oil vapour leakage or contamination of the pumped fluid.

They are highly reliable because they do not include internal parts that rub against each other. They also contain no sealing or lubricating oils within the pumping head, meaning there is no chance of oil vapor leakage or contamination of the handled media

Diaphragm pumps can be classed as one of four types depending on the drive mechanism:

- *Mechanically actuated* types use a gear set or other mechanical mechanism to transfer the rotation of the motor to move the diaphragm. Flow can be varied by changing the stroke length or pump speed
- *Hydraulically actuated* types use an intermediate hydraulic fluid on the non-product side of the diaphragm. The fluid is pressurised by a plunger in order to flex the diaphragm. This is the main difference between this type and mechanically actuated types where the plunger is attached to the diaphragm in order to flex it. Flow is varied in this type by adjusting the pump speed or the amount of contained hydraulic fluid
- *Solenoid* types have an electric motor that controls the solenoid by alternately energising and de-energising it which causes the diaphragm to flex. Flow is varied by changing the pump speed
- *Air operated double diaphragm (AODD)* types are a double acting pump which have two sets of check valves and use two diaphragms which are driven by compressed air alternately between the diaphragm via a shuttle valve. Flow can be adjusted by varying the air pressure supplied to the pump

These pumps can be further divided into single or double acting types depending on the number of diaphragms and how many sets of valves there are.

- Single acting types have one diaphragm and one set of valves, and are characteristic of mechanical drive type pumps
- Double acting types (or double diaphragm) have two diaphragms and two sets of valves, with AODD type pumps an example of this type

Diaphragm pumps are used in a number of applications including commercial, industrial, municipal and science. They are commonly used as metering pumps to deliver precise volumes of fluid for treating water (for example drinking water, wastewater, boiler water and swimming pool water), and process applications where high pressures, metering of fluids or a seamless pump is required or beneficial. AODD pumps in particular are used where fluids containing solids need to be moved but where no electricity is available.

4. Bladder pumps

Bladder pumps are non-contact, pneumatically operated pumps. They have a flexible, squeezable bladder in a rigid outer casing, which expands and contacts to displace fluids. Hydrostatic pressure is used to draw the fluid into the bladder and pass it through a check valve at the bottom of the pump. The check valve closes when the bladder is full to prevent backflow, and fluid is pumped up to the surface via injected gas pressure which squeezes the bladder. When the bladder is empty, gas pressure is reduced and the check valves opened again to restart the process.

These pumps are easy to operate, portable, small in diameter and can pump large volumes of fluid relative to their size.

Bladder pumps come in a range of sizes, materials and models, including models for deep wells, narrow or obstructed casings, and small volume models for low yield wells.

Criteria for Pump Selection for water supply

- Type of pumping required, i.e., whether continuous, intermittent or cyclic.
- Present and projected demand and pattern of change in demand.
- The details of head and flow rate required.
- Type and duration of the availability of the power supply.
- Selecting the operating speed of the pump and suitable drive/driving gear.
- The efficiency of the pumps and consequent influence on power consumption and the running costs.
- Ease in installation.

INSTALLATION

How to Install a General Water Storage Tank

The following are the most basic steps for installing the most common types of water storage tanks.

1. Build a Base or Foundation

Regardless of the kind of tank being installed, a flat and level base will be needed for the tank to stand on. Concrete is mostly used for the foundation, or a more affordable method of spreading a thick layer of compacted construction material. The point is to create an even surface that is wider than the tank itself.

2. Install Overflow Drainage (for rain harvesting)

When installing a water harvester, an overflow spout will be needed. Some tanks come with an overflow assembly already installed; others may require a technician to install one. The installer only needs to drill a hole; attach a gasket and, if necessary, a filter; and then drill some screws in place to secure the fixture. This will make sure that any excess water has a place to escape to and does not erode the concrete foundation due to overflow water dripping on it.

3. Connect to a Water Source

If the water source for the tank is a well, a pressure tank will be needed to direct the well water to the storage tank. Getting this network of pipes and fittings level and properly pressurized is a challenge and should be handled by a plumber or contractor with the right expertise.

If the water tank is intended for harvesting rainwater, then some sort of rain catcher of drainage system will be needed to direct the rain to the tank. In most cases this is just a roof gutter system with a downspout and some fill piping that runs to the tank's inlet.

This is typically called a "dry" delivery system. A "wet" delivery system is a bit more complicated and is often used when the storage tank is far from a collection source like a gutter downspout. These systems direct harvested rainwater through underground pipes and rely on gravity and pressure to direct the water up into the tank inlet. Wet systems are generally more secure, efficient, and aesthetically pleasing since much of the piping is buried underground.

Whether wet, dry, or collected from a well, a storage tank is going to need filters. If the water is only being used for irrigation purposes then only hard matter and leaf debris will be needed to be kept out, but if it is harvested for drinking water then a more sophisticated filtration system will be required. That, too, may require the help of a professional.

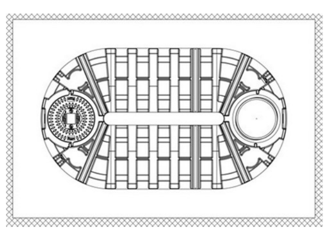
If the tank is being placed underground, there is need to install risers to elevate the inlet and gaskets to an aboveground access point. This is where water directed from a well or collection source will be directed. Once the risers are attached, the excavated land will be filled with backfill. As storage tanks are vulnerable to warping under pressure, the hole must be filled in evenly and in layers of compacted material. This is another complicated step that may require a professional.

4. Install Pressure System (for Well Water Systems)

Any sort of pressurized plumbing system will require extra hardware. In most cases, what will be needed at the very least is, a check valve, a pressure tank, a relief valve, a pressure switch, and a boiler drain. These tools help regulate the amount of pressure applied to the water line that runs from the well (or other source) to the storage tank inlet. Pressure systems are complicated as is, and those fixed to underground water storage tanks will only require greater professional expertise to install.

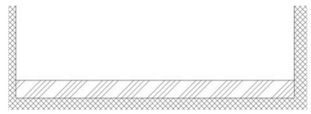
Installation Guide for Underground Water Tanks:

1. Excavate - Measure the length and width of the tank. Add 18" - 24" on both ends and sides of the tank and mark those dimensions on the ground. Excavate to a depth that will provide a minimum of 6" and a maximum of 48" of cover over the top of the tank.



2. Prepare Base - Remove any roots and rake the bed flat. The preferred tank bedding material is well packed pea gravel with minimums of 6" in soil terrain and 12" in rock

terrain. Sand or native soil can be used but it must be flowable, compactable and free from rock. After measuring and filling in the pea gravel base, compact and level before setting the tank



3. Tank - Place the tank in the middle of the hole. Begin pushing the tank back and forth to allow the pea gravel base to fill in the ribs along the bottom of the tank.

4. Install Connections - Install bulkhead fittings in tank. You must plumb with a flexible hose directly from the bulkhead fitting. This prevents any movement that could break the fitting and put extra stress on the tank. Extra fittings that are installed in this tank are the responsibility of the owner.

5. Add Risers - Remove lid and gasket that is supplied with the tank. These components are used in step (d).
   a) Silicone around tank and screw on the first riser.
   b) Bolt the riser to the tank using the 2 supplied bolts and nuts.
   c) Repeat steps (a) and (b) with additional risers.
   d) Add lid and gasket to the top riser installed.

6. Backfill - First, begin filling in the center of the tank with pea gravel or recommended material and compact. Make sure all gaps under the tank are completely filled. Backfill with 12” layers and compact each layer before the next layer is added. Always compact evenly around the entire tank. Make sure to compact backfill under pipes.

SUPPORTS

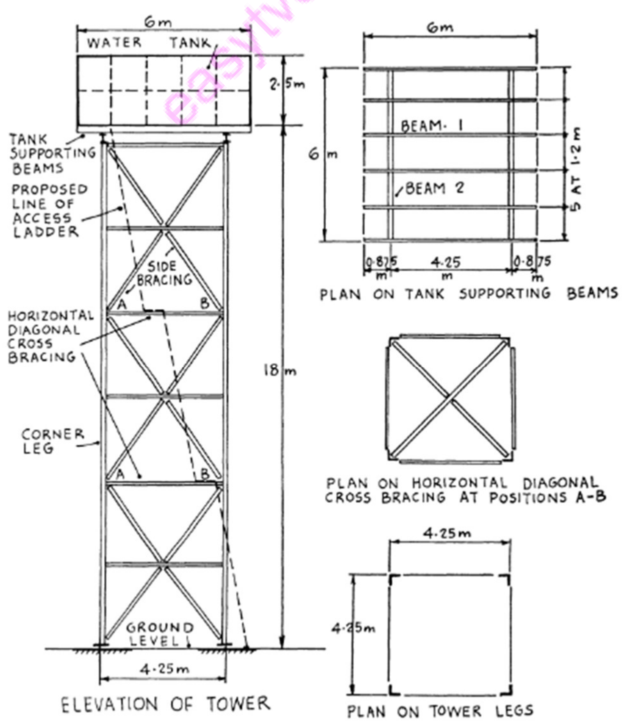
- Steel Pipes

Steel water tank support frames are suitable for raising the tank, allowing pump sets or other equipment to be positioned underneath.

a. Tank-supporting steel pipes.
   The spacing of the steel pipes will depend upon the size of the units from which the tank is built.

b. Corner legs. A suitable spacing for the corner legs must be decided. It is desirable that the legs should be spaced as far apart as possible to give a good width of base to resist overturning. Alternatively, it may be considered advisable to narrow the spacing of the Legs to allow the tank-supporting beams to cantilever over the sides of the tower.

DESIGN OF BRACED TOWER



Braced Tower

- Concrete

It is more expensive but will last the longest if constructed correctly. It looks neat and tidy. You may need to install drains depending on which way the water flows or how close it is to your house.
Flat concrete plinth- ensuring the plinth is level and that it extends 150mm beyond the tank internal length and width dimensions.

- Timber

Where tanks are to be supported by trussed rafters, the size type and position of the tank needs to be clearly indicated.

- Masonry

The elevated storage tank or reservoir offers advantages because it provides a reserve supply of water which is quickly available and also because it is adapted to intermittent windmill pumping.
A masonry silo provides a desirable support for an elevated water supply tank.

- Compact Earth

Pea Gravel: A solid option. Comes at a reasonable price and holds itS shape a lot better than sand. Pea gravel also needs to be supported so it doesn't degrade over time. This option filters water a lot better than sand. I highly recommend this.
Dirt/Clay: This is similar to using sand. If not supported correctly, it can run away very quickly during a storm or heavy rain.

Positioning (location)

Underground

Sump: Sump is used as additional storage at village/town level or cluster level. It is not used for direct distribution of water. Rather, it is used as intermediate or contingency storage, to store water before it is pumped to ESR/GSR.

The underground storage tank in circular shape with dome line covering is called sump. Generally, the capacity of sump is more (one and half to two times) than ESR or GSR or two to five days water requirement, so that if the supply is disturbed for that time, the water is available for the people.

Advantages of sub-surface tanks:

- Underground tanks offer a cheaper to install due to its lower cost of reinforcements needed
- during construction, as compared to surface tanks. This is due because ground support
- provides the strength needed to hold the water
- They are appropriate in places where space above ground is limited; and they can be made
- larger than surface tanks
- The water is sometimes cooler
- Larger volumes of water can be stored.

Disadvantages:

- Pump or some kind abstraction device (such as rope and bucket) is required to lift the water. Except where the ground gradient permits and where gravity outlets are constructed.
- Higher possibility of contamination and sedimentation sediment inflow.
- They cannot be easily drained for cleaning.
- If not well managed e.g. properly covered, they pose danger to children and small animals.
- Leaks or failures are more difficult to detect
- Tree roots can damage the structure from beneath
- Flotation of the tank may occur if groundwater level is high, and
- Heavy vehicles driving over a tank or other weight can damage the structure.

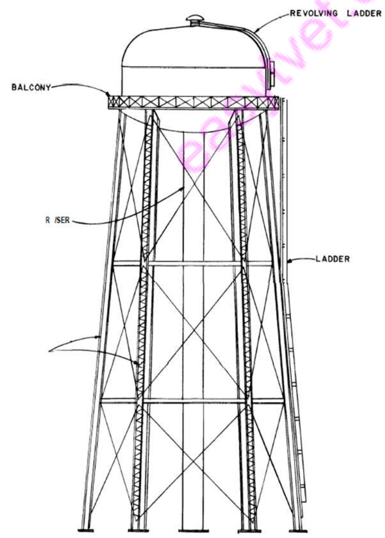
On-ground

Ground Service Reservoir (GSR): GSR is ground level or plinth level storage tank. The plinth level is generally not more than 3 m.

Storage capacity of the service reservoirs is estimated based on pumping hours, demand and hours of supply, electricity available for pumping. Systems with higher pumping hours require less storage capacity. Normally, such reservoirs are calculated to store half to one day daily water requirement.

Above ground (elevated)

Elevated Surface Reservoir (ESR) or elevated storage tank: ESR is constructed, where water is to be supplied at elevated height (less than the level of ESR) or where the distance is large and topography is undulating. Generally, ESR is at height more than 15m. Water can be distributed directly from this storage tank by gravity or pump.



Elevated Storage Tank

Advantages:

- Cheaper to install – Tanks installed aboveground are a lot cheaper and easier to install than underground tanks. There's no need to reinforce the tank or excavate the land around it, as you would have to with an underground tank, and you don't have to worry about leveling the backfill so that it holds the tank in the right place.

- Easier to maintain – Compared to underground tanks, aboveground tanks are easier to monitor for scratches and breaches. They're also much easier to fix, since there's no need to dig down to the source of a leak.

Disadvantages

- Aboveground tanks are more vulnerable to extreme weather that could create cracks or holes
- Theft or vandalism.

Housekeeping

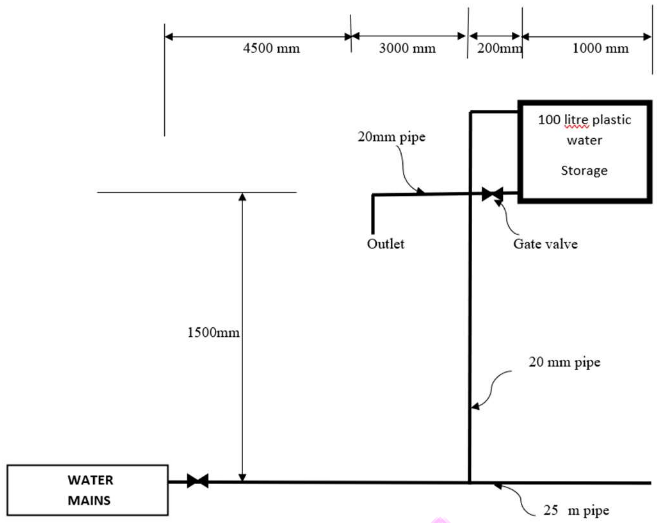
The following aspects need to be considered:

- Protecting existing works and sanitary appliances
- Clearing work area
- Cleaning work area
- Keeping work area tidy

5.2.3.4.Learning Activities

In this assessment, the candidate will be required to carry out practical tasks on:

a) installing a water storage tank, 100litres at a 1.5m distance from the ground and installing a centrifugal pump in the system mains and conducting a water test on the pipe appliance as shown on the diagram below



b) In this assessment, the candidate is required to complete the following tasks:

i. Collect all the required resources and materials
ii. Clearing and levelling the ground area
iii. Constructing steel supports
iv. Positioning the tank
v. Fixing the water tank fittings
vi. Measuring and cutting the pipes to the correct dimensions
vii. Installing the water pump
viii. Positioning the pipes
ix. conducting water test on the setup
x. Perform housekeeping operations

5.2.3.5.Self-Assessment

1. What are some personal safety habits practiced when installing storage tanks?

2. What is the purpose of a valve?

3. Which of the following is the correct classification of pumps?
   a. Physical principle of operation
   b. Mechanical principle of operation
   c. Chemical principle of operation
   d. Biological principle of operation

4. Displacement pump is classified on the basis of _____________
   a. Mechanical operation of principle
   b. Type of power
   c. Type of service
   d. Efficiency

5. Which of the following pump is classified based on the type of service?
   a. Displacement pump
   b. Centrifugal pump
   c. Deep well pump
   d. Electric driven pump

6. Which of the following pump is based on the type of power?
   a. Low lift pump
   b. High lift pump
   c. Air lift pump
   d. Steam engine pump

7. A booster pump is based on _____________
   a. Mechanical operation of principle
   b. Type of power
   c. Type of service

d. Efficiency

8. Consider the following statements.
    i. Capacity of the pump
    ii. Number of pump units
    iii. Discharge condition

The selection of a particular type of pump depends on which of the following?
    a. i, ii, iii
    b. i only
    c. ii, iii
    d. i, iii
9. The centrifugal pump has a ______ flow.
    a. Variable
    b. Uniform
    c. Continuous
    d. Constant

10. The maximum efficiency of a centrifugal pump is _____________
    a. 50%
    b. 60%
    c. 85%
    d. 100%

11. What controls the inlet of water into storage tanks and where should it be located
12. A water storage and pipe network is called a distribution system. This refers to the tanks and pipes used to get water from a source and/or the treatment plant to a house, building or other place of use. What are the distribution system components?

13. What are the uses of the following tools:

   i. Pipe reamer,
   ii. pipe wrench

14. What is the importance of having storage tanks?

15. How do we ensure that the ground to install the storage tanks is levelled?

5.2.3.6.Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:

Tools and Equipment

- Pipe wrench
- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vice - Bench
- Pliers
- Tap and Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Mallet
- Ball hammer
- PPR machine / Heat Fusion equipment
- Pipe bender
- Sealant gun

Supplies and Materials

- Fittings

- Back nuts
- Cisterns
- Valves
- Sealant
- Water proofing agents

5.2.3.7.References

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Nissen-Petersen, E. 1990. Water Tanks with Guttering and Hand-pump. Manual No. 1 of Harvesting Rainwater in Semi-arid Africa. Danida, Kenya.

Julie fryer., 2011., The complete guide to water storage

5.2.3.8.Model Answers

1. What are 3 personal safety habits practiced when installing storage tanks
    - **Wearing protective garments**
    - **Using the correct tools and equipment for the correct task**
    - **Safety goggles**
    - **Always working on a safe platform**
    - **Wearing helmets,**
    - **Storing all tools appropriately**

2. What is the purpose of a valve?

- **control the flow rate of fluid into distribution system**

3. Which of the following is the correct classification of pumps?
    a. Physical principle of operation
    b. Mechanical principle of operation
    c. Chemical principle of operation
    d. Biological principle of operation

4. Displacement pump is classified on the basis of _____________
    a. Mechanical operation of principle
    b. Type of power
    c. Type of service
    d. Efficiency

5. Which of the following pump is classified based on the type of service?
    a. Displacement pump
    b. Centrifugal pump
    c. Deep well pump
    d. Electric driven pump

6. Which of the following pump is based on the type of power?
    a. Low lift pump
    b. High lift pump
    c. Air lift pump
    d. Steam engine pump

7. A booster pump is based on _____________
    a. Mechanical operation of principle
    b. Type of power

c. **Type of service**
d. Efficiency

8. Consider the following statements.
    i. Capacity of the pump
    ii. Number of pump units
    iii. Discharge condition

   The selection of a particular type of pump depends on which of the following?
   a. i, ii, iii
   b. i only
   c. ii, iii
   d. i, iii

9. The centrifugal pump has a ______ flow.
   a. Variable
   b. Uniform
   c. Continuous
   d. Constant

10. The maximum efficiency of a centrifugal pump is _____________
    a. 50%
    b. 60%
    c. 85%
    d. 100%

11. What controls the inlet of water into storage tanks and where should it be located
    Float-operated valve: Installed close to the top of the tank

12. A water storage and pipe network is called a distribution system. This refers to the tanks and pipes used to get water from a source and/or the treatment plant to a house, building or other place of use. What are the distribution system components?
    - **Storage tanks.**
    - **Reservoirs.**
    - **Pumps.**
    - **Meters.**
    - **Pipes.**
    - **Valves.**

13. What are the uses of the following tools:
    i. Pipe reamer,
        - **used to remove internal burrs from steel or copper pipes**
    ii. pipe wrench
        - **tightening or loosening fittings and pipes**

14. What is the importance of having storage tanks?
    - **Storage is particularly important where the supply water is treated before distribution to consumers, because it means the treatment plant does not need to be sized to treat the peak flow that consumers require. The storage reservoir provides a buffer between the treatment plant and the consumers.**
    - **Storage can also help to maintain pressure levels by evening out the flow in a network. The most extreme example of this is in restricted-flow systems where every customer has their own tank, which is topped up by a small constant flow from the distribution pipe network.**

- **The storage can be used to provide chlorine contact time for the inactivation of micro-organisms and as a reserve of treated water in the event of a power cut or treatment plant malfunction.**

15. How do we ensure that the ground to install the storage tanks is levelled?

- **Use dumpy level**
- **Use theodolite**
- **Use spirit levels**

5.2.4 Learning Outcome 4: Test and commission storage and auxiliary fittings

5.2.4.1.Introduction to the learning outcome

This learning outcome specifies the content of competencies required to Test and commission storage and auxiliary fittings. It includes, types of tests and faults in storage and auxiliary fittings.

5.2.4.2.Performance Standard

1. Functionality of the Storage and auxiliary fittings are tested based on manufacturer's manual and requirements.
2. Faults in Storage and auxiliary fittings are corrected based on best practice.
3. Commission the storage system as per the client's/ contract requirements.

5.2.4.3.Information Sheet

TEST AND COMMISSION STORAGE AND AUXILIARY FITTINGS

Objectives of the Testing and Commissioning Works

The objectives of the T&C works are:

a. To verify proper functioning of the equipment/system after installation

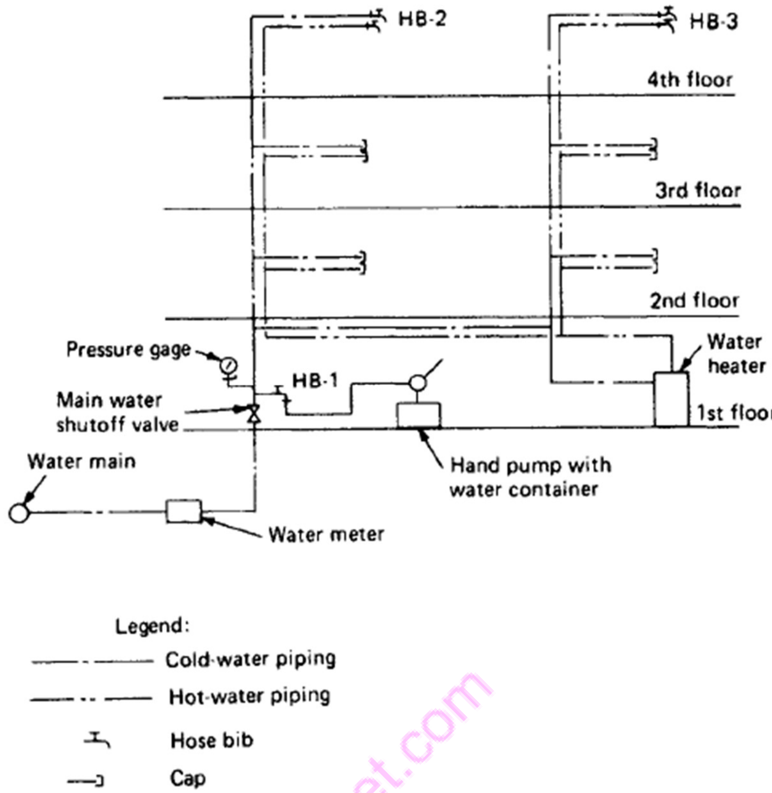
b. To verify that the performance of the installed equipment/systems meet with the specified design intent through a series of tests and adjustments
c. To capture and record performance data of the whole installation as the baseline for future operation and maintenance.

Testing the Rough Piping Installation

The following steps should be taken in testing the piping system before the fixtures, faucets, trim, and final connections are made to the equipment:

1. Install hose bibs for filling the piping system with water and to permit the evacuation of air from (i.e., venting) the system.
   There should be a hose bib (or similar device) at the bottom of the piping system for filling the system with water and at least one more at the highest point of the system for venting.
   Depending on the size and piping layout, several other hose bibs may be required for venting the system.

2. Cap all openings.
   All connections to future fixtures must be capped so they are watertight. Temporary caps will be removed after the pressure test, described below, is completed.



Piping Layout

3. Fill the system with potable water.

   With the bib at the top of the piping system in the open position, fill the system with water through the hose bib located at the bottom position. Air will then be forced out of the piping through the top bibs.

   During the time the piping system is being filled, all hose bibs for venting must be open. When water emerges from all the open hose bibs, all air in the system has been displaced by water. Then all hose bibs must be tightly closed.

4. Attach a pump and a pressure gauge to the piping system.

   Depending on the size of the piping system, the pump (used to create pressure in the system) may be a manual pump or a centrifugal pump activated by an electric motor.

In general, a manually operated pump is satisfactory for most applications. Water should then be pumped into the system until the pressure gage indicates the pressure desired for the test.

5. Subject the piping system to a hydrostatic test. The magnitude of the test pressure that is required by various codes or jurisdictions is different, but it is usually recommended that test pressure be equal to or higher than the following:
    a. % times the pressure at which the piping system will operate. Water pressure of existing water supplies can be obtained from the local water department.
    b. 125 psi (862 kPa).
6. Sustain the maximum pressure for a period of at least 3 h.
   After the test pressure is attained, close hose bib HB-1. Maximum pressure should be sustained for this period of time without any loss of pressure, as determined from readings of the pressure gage. If pressure is maintained, the system is watertight. If the pressure decreases, there is a leak in the system. The pipes should then be inspected to determine the location of the leaks. The leaks should be repaired and a new pressure test performed. This process must be repeated until it is shown that the maximum pressure is maintained without pressure loss for at least 3 h.

7. If during the testing procedure, the water supply system may be subject to freezing, an air test may be substituted for the hydrostatic test of Step 6.
   The air test is carried out as follows. First replace the water pump with an air compressor.
   Then raise the air pressure to 40 psi (276 kPa). At this pressure, check for leaks by applying liquid soap to the joints and connections. When all leaks appear to have been corrected, raise the air pressure to a value equal to 1% times the water pressure to which the system will be subjected. With the air compressor turned off and the hose bib HB-1 shut off, the pressure must be maintained within the system for a period of at least 2 h. If this is not the case, then previously undetected leaks must be found and repaired and the entire system retested.

Testing the Complete Plumbing System

After the rough piping installation has been shown to be watertight and has been accepted, then the following steps should be taken:

1. Install and connect all faucets, fixtures, hose connections, trim, and valves.
2. Connect the water piping system to the water supply.
3. Subject the entire system to the hydrostatic test of Step 5, above. Check for leaks. When all leaks have been detected and repaired, proceed with the operation test of the next step.
4. All bibs, fixtures, flush valves, pumps, tanks, and other appurtenances should be activated to show that the water quantities required for proper operation are adequate and that their operation is satisfactory.

DISINFECTING THE WATER SUPPLY SYSTEMS IN BUILDINGS

After the above testing has been completed, all aerators, filters, and strainers should be cleaned (after disinfection, they must be replaced), and the entire system should be flushed with portable water to rid it of impurities and debris.

Water should be run through the piping by opening the various faucets and valves until, by visual inspection, the water appears to be running clean, and no impurities such as sand, rust, and similar small particles are observed in the bowls of the plumbing fixtures.

The following procedure, performed by approved applicators or qualified personnel, is recommended:

1. One of the following chemicals, all of which add chlorine to the water, may be used to disinfect water:

- chlorine gas

- chlorine liquid
- sodium
- hypochlorite
- calcium hypochlorite

2. Inject a disinfecting agent through the hose bib located at the water service entrance. The injection should take place at a slow and even rate. The flow of this disinfection agent into the main connected to the public water supply is prohibited. Therefore, during disinfection, either the water supply connection should be disconnected or the main water valve should be effectively shut off to prevent any contamination from entering the main water supply.

3. Allow the disinfecting agent to flow into the system by opening hose bibs or faucets in each branch until the chlorine residual concentration is not less than 50 ppm of available chlorine. Then close all valves and accessories. Allow the chlorinated water to stand in the system for a period of not less than 24 hr.

4. After the 24-hr period of retention, the residual chlorine should not be less than 5 ppm. If it is less, the above process must be repeated.

5. If the concentration of residual chlorine is 5 ppm or greater, flush the system thoroughly with portable water before it is put in service.

6. The flushing should continue until;

   i. the residual chlorine in the system, as measured by orthotolidin tests, is not greater than that in the main water supply
   ii. biological tests show that there is absence of coliform organisms. Such water samples should be taken from faucets located at the highest floor and farthest from the main water supply.

7. If it is impractical to disinfect the water storage tank by the above means, then the entire interior of the tank should be swabbed with a solution containing 200 ppm of available chlorine and allowed to stand for at least 3 hrs before flushing.

8. After final flushing of the system has been completed, at least one water sample should be obtained from the cold-water line and the hot-water line. Water samples must be submitted to a state laboratory which should certify that the water does not contain organisms in excess of standards for potable water.

TYPES OF TESTS

Plumbing system inspection and tests

These tests are for the purpose of ensuring correct work, free from defects arising in construction and manufacture. There are three different methods of testing the plumbing system - the water test, air test and peppermint test or smoke test. Of these, the water, peppermint, and smoke tests are most commonly used.

The water and air tests are chiefly used as the first test on new work. When it comes to the final test, either the peppermint or smoke test may be applied.

On old work in residences and other finished and occupied buildings, the water test cannot be applied, owing to the damage that might result. Under these conditions, either the peppermint or smoke test should be used.

- Water test

Most plumbing codes allow air or water to be used for preliminary testing of drainage, vent, and plumbing pipes. After the fixtures are in place, their traps should be filled with water and a final test made of the complete drainage system.

Procedure:

The water test shall be applied to the drainage and vent systems either in its entirety or in sections. If applied to the entire system, all openings in the piping shall be tightly closed, except the highest opening, and the system filled with water to a point of overflow.

If the system is tested in sections, each opening shall be tightly plugged except the highest opening of the section under test, and each section shall be filled with water, but no section shall be tested with less than a ten (10) foot (3m) head of water.

In testing successive sections, at least the upper ten (10) feet (3m) of the next proceeding section shall be tested, so that no joint or pipe in the building (except the uppermost ten (10) foot (3m) of the system) shall have been submitted to a test of less then a ten.(10) foot (3m) head of water. The water shall be kept in the system, or the portion under test, for at least fifteen (15) minutes.

- Air test

An air test is made by sealing all pipe outlets and subjecting the piping to an air pressure throughout the system. The system should be tight enough to permit maintaining this pressure for at least 15 min without the addition of any air.

- Smoke test

The smoke test is another test that can be applied to roughed-in new work. It is used most frequently, however, in testing old work, or in testing new work after the fixtures have been set. The manner of applying a smoke test is to close all openings, the same as for the water test, and also the openings at the roof. The testing machine, which is made especially for this purpose, is then connected to the piping system, and the smoke turned into the pipes.

Oily waste or rags are placed in the machine and lighted, thus generating a heavy smoke which will entirely fill the pipes, and escape through any leaks that may exist—which are thereby easily detected. The smoke test is preferred by many, as it is cleaner than the water test, should any leaks develop, and there is no wetting down of the building.

- Peppermint test

The peppermint test is applied by putting about two ounces of oil of peppermint into the system at the roof, after all openings have been closed as with the other tests, and pouring about a gallon of hot water into the piping, immediately closing the opening with a plug kept at hand for the purpose. The fumes of the peppermint are supposed to travel throughout the system of piping, and to penetrate any existing leaks, the presence of which can then be detected from the characteristic smell. There being no pressure applied in this test, there is a possibility of the odour not escaping through very small leaks; and this test, therefore, is not so reliable as the water or smoke tests.

The person who puts the peppermint in the piping should not try to look for leaks, as he will carry the odour around with him through the building, and is apt to imagine that he smells leaks where in reality they do not exist.

- Building sewer test

  Building sewers shall be tested by plugging the end of the building sewer at its point of connection with the public sewer or private sewer disposal system and completely filling the building sewer with water from the lowest to the highest point thereof, or by approved equivalent low pressure air test, or by another test as may be prescribed by the Administration Authority. The building sewer shall be watertight at all points.

- Water piping

Upon completion of a section or of the entire hot and cold water supply system, it shall be tested and proved tight under a water pressure not less than the working pressure in which it is to be used.

The water used for tests shall be obtained from a potable source of supply. A fifty (50) pound per square inch (344.5 kPa) air pressure may be substituted for the water test. In either method of test, the piping shall withstand the test without leaking for a period of not less than fifteen (15) minutes.

5.2.4.4.Learning Activities

Practical task

You are required to:

i. carry out carry out testing on a piping system for leaks.
ii. Identify the leakage
iii. Repair the leakage

Scenario:

You are finished with the installation of an elevated water tank that is to supply water to your client's residence. The client is very happy with your work, his only concern is whether the system is 100% airtight.

In his opinion, a small leakage, although undetected might lead to significant water damage at a later stage. How would you test for the tightness of the system?

5.2.4.5.Self-Assessment

1. This condition is the result of low pressures within a pump, which creates boiling water and vapor bubbles.
   a. Air Lock
   b. Water Hammer
   c. Cavitation
   d. Plugging

2. What are some of the problems associated with pipe work?

3. How do we carry out the water method of testing a piping system for leaks?
4. Which of the following is suitable for testing a piping system for leaks?
    a. Air
    b. Water
    c. Smoke
    d. Gas

5. A final air test is a test of the plumbing fixtures and their connections to the sanitary drainage system
    a. False
    b. True

6. For some installations, several plumbing systems can be tested and inspected simultaneously, such as the building sewer and water service when they are installed in the same trench
    a. False
    b. True

7. An air test is a plumbing system test in which inlets and outlets to the system are sealed and air is forced into the system until a uniform air pressure of 5 psi is reached and maintained for 15 min without additional air being added to the system
    a. False
    b. True

5.2.4.6.Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:

Tools and Equipment

- Pipe wrench

- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vice - Bench
- Pliers
- Tap and Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Mallet
- Ball hammer
- PPR machine / Heat Fusion equipment
- Pipe bender
- Sealant gun

Supplies and Materials

- Fittings
- Back nuts
- Cisterns
- Valves
- Sealant
- Water proofing agents

5.2.4.7.References

Fred Hall & Roger Greeno., 2009., Building services handbook incorporating current building & Construction regulations., 5th Edidition

David V. Chadderton., 2007., Building Services Engineering., 5th Edition

Julie fryer., 2011., The complete guide to water storage

5.2.4.8.Model Answers

1. This condition is the result of low pressures within a pump, which creates boiling water and vapor bubbles.
    a. Air Lock
    b. Water Hammer
    c. Cavitation
    d. Plugging

2. What are some of the problems associated with pipe work?
    Leakages
    Blockages
    Air lock
    Water hammer

3. How do we carry out the water method of testing a piping system for leaks?
   close all the opening then allow water to run through the system under pressure in case of any leak in the system, the water already will try to ooze out of the leaking area.

4. Which of the following is suitable for testing a piping system for leaks?
    a. Air
    b. Water
    c. Smoke
    d. Gas

5. A final air test is a test of the plumbing fixtures and their connections to the sanitary drainage system
    c. False
    d. True

6. For some installations, several plumbing systems can be tested and inspected simultaneously, such as the building sewer and water service when they are installed in the same trench
   c. False
   d. True

7. An air test is a plumbing system test in which inlets and outlets to the system are sealed and air is forced into the system until a uniform air pressure of 5 psi is reached and maintained for 15 min without additional air being added to the system
   c. False
   d. True

CHAPTER 6: FIRE CONTROL SYSTEMS

Unit of learning code CON/CU/PL/CR/06/5/A

Related Unit of Competency in Occupational Standard Install Fire Control Systems

6.1. Introduction to the unit of learning

This unit specifies the competencies required to install fire control systems. It involves preparing working drawings, selecting tools and equipment for installation, quantifying and costing fire control materials and supplies, installation of fire control systems and maintenance and servicing of fire suppression systems applied in the construction industry.

6.2. Summary of Learning Outcomes

1. Prepare working drawing
2. Select tools and equipment
3. Quantify materials and supplies
4. Install sprinkler systems
5. Install hose reel systems
6. Install wet and dry risers
7. Maintain and service fire suppression systems

6.2.1 Learning Outcome 1: Prepare Working drawings

6.2.1.1 Introduction to the learning outcome

The objective of this learning outcome is to assist you develop competency in fire control drawings and symbols, fire control appliances and specifications

6.2.1.2 Performance Standard

1. Drawings are identified and selected based on the job.
2. Scale of the drawing is determined based on the specifications.
3. Measurements are converted based on scale.

4. Symbols are identified based on best practices.
5. Fire control piping appliances are identified based on the drawings
6. Manufacturers drawing and specifications are interpreted.
7. Working drawings are prepared based on specifications
8. Isometric working drawings are drawn based on best practices.

6.2.1.3 Information Sheet

Working drawings in fire control systems refers to the drawings that are designed to show the layout of the fire control system and appliances.

These fire detail drawings will give a clear idea of the fire evacuation plan for that premises and serve as a great tool when carrying out fire awareness drills & training for the occupants. Fire Plan drawings are also a requirement when submitting drawings for proposed building projects. .

The following additional information should also accompany the drawings:

1. Passive and active fire protection measures
2. Emergency and escape lighting
3. Fire alarm and detection systems
4. Engineered fire solutions used within the building
5. The dimensions of fire exit routes
6. Access and facilities for the fire service

Types of fire control drawings

1. Fire Safety provision drawings - These drawings show the protection features. That is including the extinguishing and smoke control requirements.
2. Fire alarm control panel - A *fire alarm control panel* (FACP), *fire alarm control unit* (FACU), or simply *fire alarm panel* is the controlling component of a *fire alarm* system. ... The *panel* may also supply electrical energy to operate any associated initiating device, notification appliance, *control*, transmitter, or relay.

3. Fire alarm wiring diagrams – This category of drawings clearly shows the connection and wiring of the alarm system.

4. Fire system drawings – This type of drawing clearly shows how fire control system is laid out and incorporated in the structural drawings of a building project.

Fire safety provision drawings.

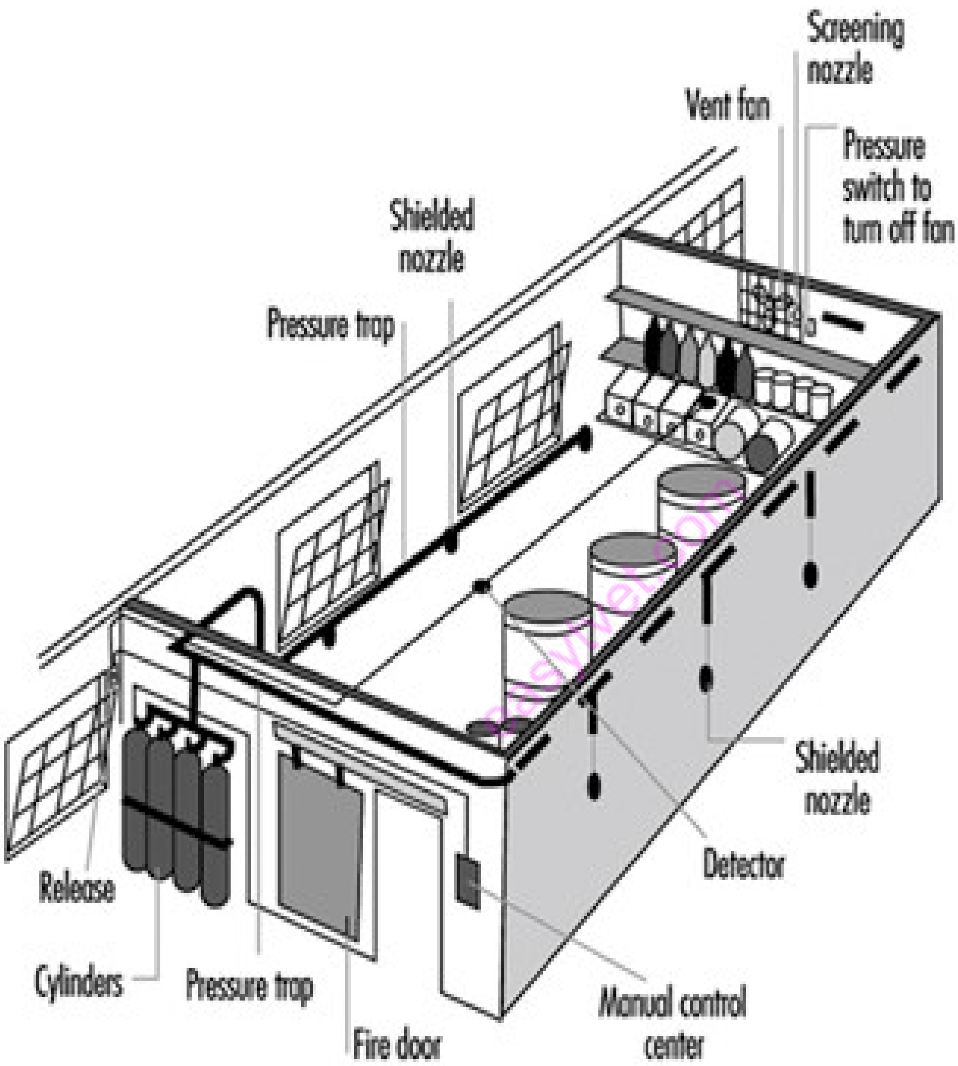


Figure 182- **Fire Safety Provision Drawing**

Fire alarm control panel

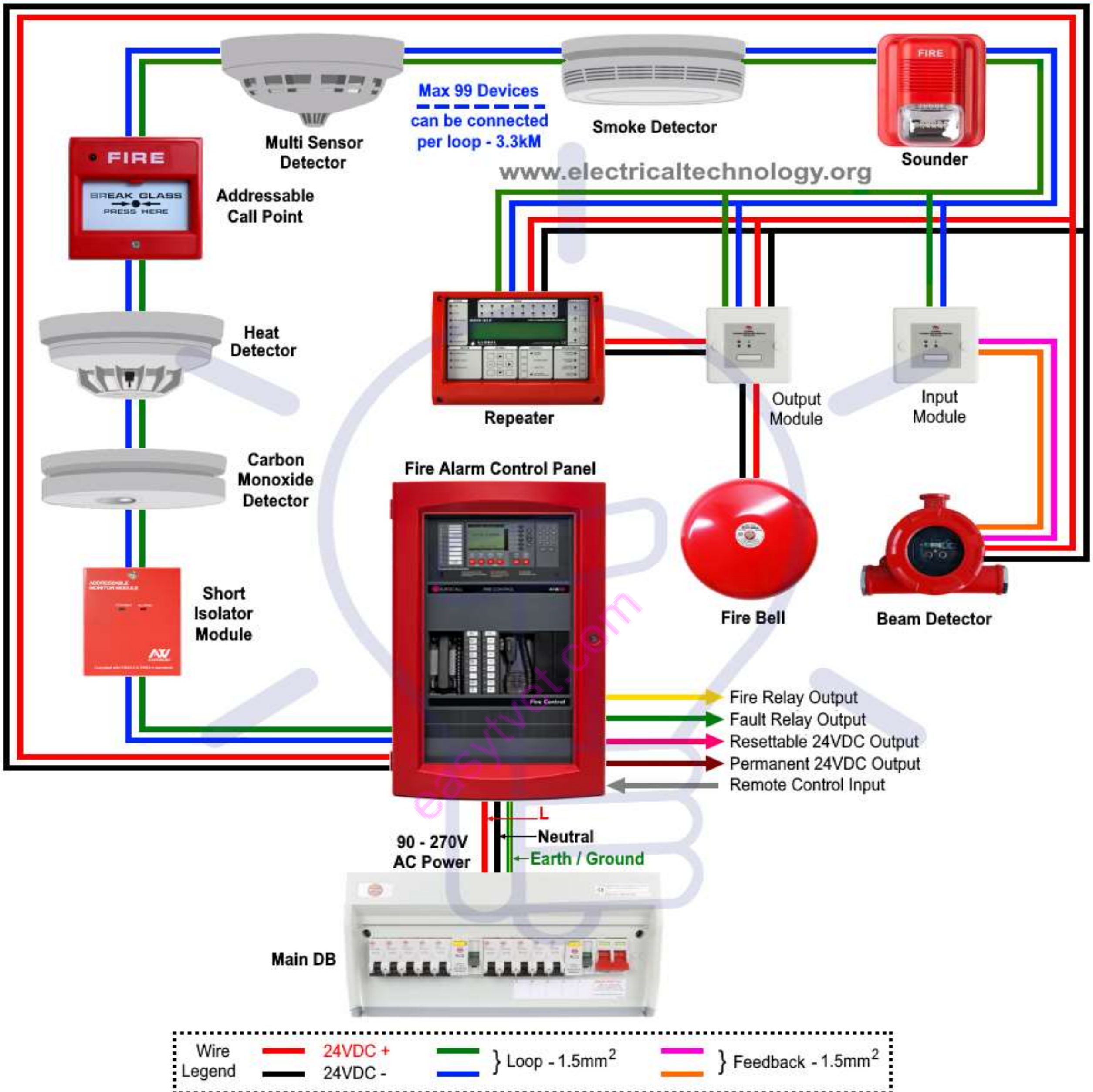


Figure 183 - Fire Alarm Control Panel

Fire alarm wiring diagram

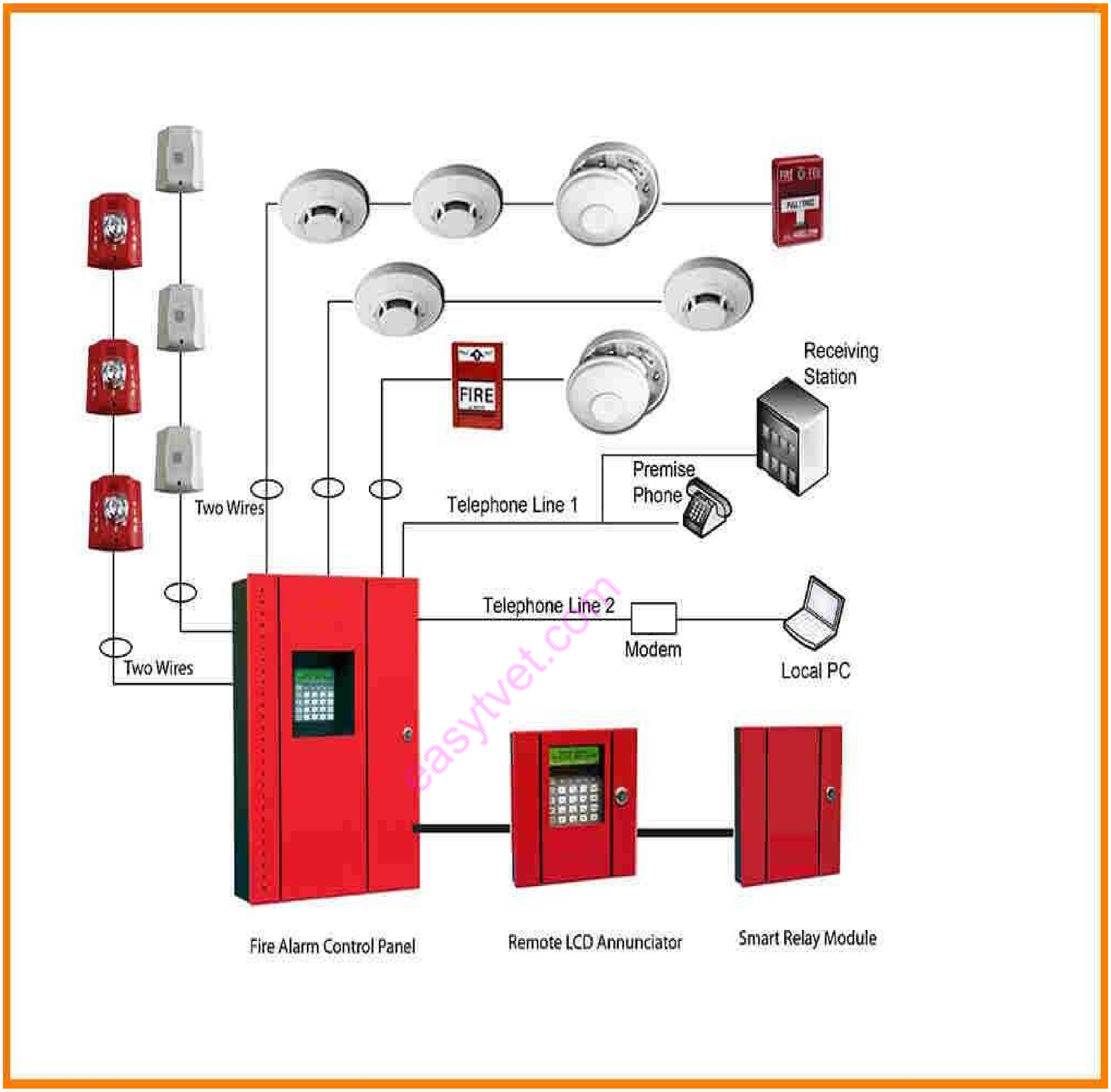


Figure 184 - Fire Alarm Wiring Diagram

FIRE ALARM SYSTEMS

These are the circuits which connect initiating devices such as smoke detectors, heat detectors, manual pull stations, and water flow alarms. Additionally, many system monitor devices important to the overall fire safety of the building also tie in to initiating circuits.

Purpose of Fire Alarm Systems

A properly designed, installed, operated, and maintained fire alarm system can reduce the losses associated with an unwanted fire in any building. These losses include property and, more importantly, human life.

The primary motivation for fire alarm system requirements in building and fire codes is to provide early notification to building occupants so they can exit the building, and to notify the fire service so it can respond to the fire. In settings such as hospitals the fire alarm system provides notification to staff so they can respond to the fire emergency (as opposed to evacuating the building).

Basic Components of a Fire Alarm System Fire alarm systems generally have the following components. Alarm Initiating Device Circuits These are the circuits which connect initiating devices such as smoke detectors, heat detectors, manual pull stations, and water flow alarms. Additionally, many system monitor devices important to the overall fire safety of the building also tie in to initiating circuits. These devices indicate an "abnormal" condition, not a fire or "alarm" condition. They are referred to as "supervisory devices." One example would be the valve supervisory switch or tamper switch of a valve controlling the automatic sprinkler system. These types of devices also may be connected to supervisory type circuits.

Supervisory Devices

1. Alarm Indicating Appliance Circuits

Audible and visible alarm indicating appliances tie in to these circuits to provide warning to the building occupants. Devices which send a signal off premises also can be connected to these circuits.

2. Fire Alarm Control Panel

The fire alarm control panel contains the electronics that supervise and monitor the fire alarm system. The initiating and indicating circuits are connected directly into this panel.

3. Primary Power Supply

The primary electrical supply powers the entire fire alarm system. Primary power for fire alarm systems typically is provided by connecting into the local commercial power service.

4. Secondary Power Supply

A separate power supply that will operate automatically when the primary power fails and is capable of operating the entire system is considered a secondary power supply.

Initiating Devices

Initiating devices fall into one of two main categories: either those that indicate an alarm condition, or those that indicate an abnormal condition of a monitored device.

Fire detection can occur by using any device that responds to conditions caused by fire. The most common byproducts of fire are heat, smoke, flames, and fire gases. In addition, people can detect a fire and initiate an alarm by activating a manual pull station. Also, when a sprinkler system activates and causes an alarm, it is a result of the sprinkler system detecting heat produced by the fire (if the sprinklers have fusible links).

1. Heat Detectors

Heat detectors commonly are used to detect fires. They are not as prone to false alarms and are less expensive than smoke detectors. However, the response of heat detectors may not be adequate in many instances, which limits their usefulness. Heat detectors are slower to respond to fires than are smoke detectors because heat detectors cannot respond to smoke. Heat detectors typically are best suited for detecting fast-growing fires in small spaces

FIRE CONTROL SYMBOLS

Symbols are used in *fire control* to provide a brief, accurate means of representing quantities which would otherwise require extended definition. The symbols should be well understood by the occupants or users of the building. This makes it easier to evacuate people in the case of a fire risk.


Direction arrow
Stairs
Double stairs
Elevator
Emergency exit
Handicapped emergency exit
Use stairs in fire
Fire escape / fire exit
Assembly point
Emergency phone 1
Emergency phone 2
Emergency contact information
Fire blanket
Fire alarm, black
Fire alarm, red
Fire extinguisher 1
Fire extinguisher 2
Fire hose
Fire hose with black text
Fire hose with red text
First aid
Direction
Left arrow
Right arrow
You are here
Entrance
Fire barrier
Underfloor hydrant
Transformer
Fire alarm systems
Fire alarm control panel
Fire department key depot
Biohazard
Radiation hazard
Obstructions
Fire escape
Hazardous materials storage
Danger compressed gas
Flammable material
Oxidant material
Harmful chemicals
Non ionising radiation
Corrosive material
High voltage
Dangerous chemical
Danger of death
Sprinkler connections
Private fire detection system
Exits and entrances
Water supplies
Elevator shaft
Nearest fire hydrant
Electric shut off
Knox box location
Water shut off
Other vertical openings
Roof access
Gas shut off

Figure 185 - Fire Control Symbols

FIRE CONTROL PIPING APPLIANCES

The piping appliance for fire control is set-out in a riser room. The piping appliance system is comprised of :

Fire Alarms

Pipework & Fittings (Tees, 45^0 elbows, 90^0 elbows, Wye-Tees)

Pressure Gauges

Valves

Mortar for pumping the water in the case of a fire risk

The main method of connection commonly used for fire protection pipework is by the use of flanges. The system will be connected to the alarm system that will be used to notify the occupants of a building of the risk of fire.

Figure 186 - Fire Control Piping Appliances

Plan of a Fire Control System

Figure 187 - Fire Control System

Isometric drawing for a fire control system

The isometric drawing will clearly show the orientation of the pipework and the method of connection. Type of fitting and method of fixing is also easily identified from the isometric drawings.

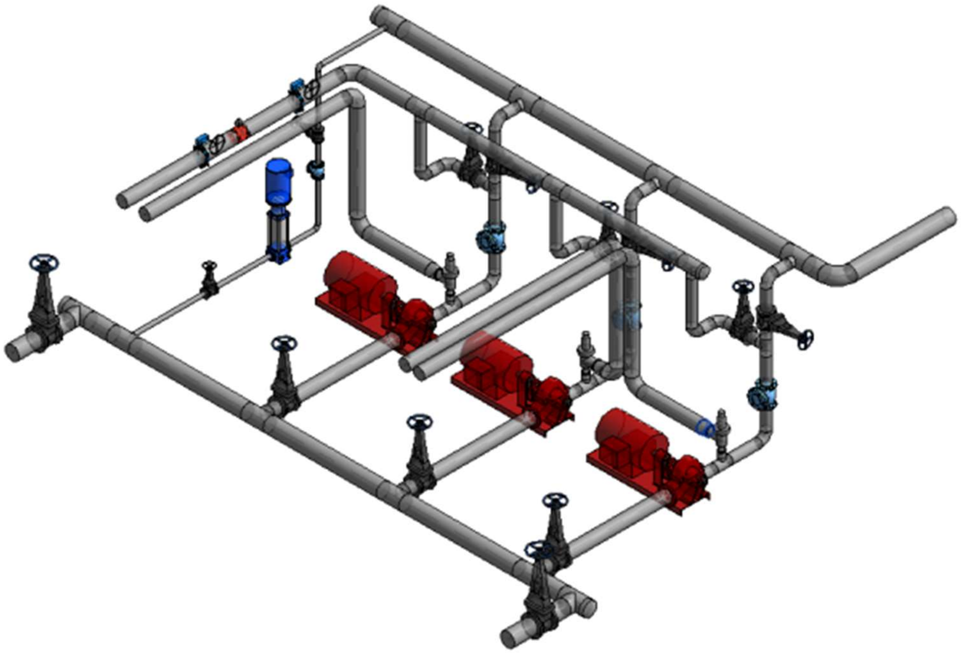


Figure 188 - Isometric diagram for a fire control system

6.2.1.4 Learning Activities

Practical Activities

You are required to visit a residential and a commercial building and identify the fire control piping appliances put in place to mitigate against the risk of fire.

6.2.1.5 Self-Assessment

1. Describe FIVE types of supervisory devices used for a fire alarm system
2. State FOUR types of fire control system drawings
3. State FIVE main components of a fire control piping appliance system
4. What is the use of heat detectors?
5. What is the purpose of fire alarm system?

6.2.1.6 Tools, Equipment, Supplies and Materials

Assorted Pipework

Assorted Fittings

Sample Drawings

May include but not limited to:

Materials.

- Screws
- Adhesives
- Cement
- Sand
- Pipes
- Traps
- Electric cables
- Caulking material
- Fittings
- Valves

Tools and equipment

- Mallet
- PPR machine
- Ball pein hammer
- Mason chisel
- PPR machine / Heat Fusion equipment
- Pipe bender

6.2.1.7 References

Curry, B , Smith C.J, 2015. The Motivate Series: Plumbing Principles and Practices (3rd Edition). Macmillan

6.2.1.8 Model Answers

1. **Describe FOUR types of supervisory devices used for a fire alarm** system

a) Alarm Indicating Appliance Circuits

Audible and visible alarm indicating appliances tie in to these circuits to provide warning to the building occupants. Devices which send a signal off premises also can be connected to these circuits.

b) Fire Alarm Control Panel

The fire alarm control panel contains the electronics that supervise and monitor the fire alarm system. The initiating and indicating circuits are connected directly into this panel.

c) Primary Power Supply

The primary electrical supply powers the entire fire alarm system. Primary power for fire alarm systems typically is provided by connecting into the local commercial power service.

d) Secondary Power Supply

A separate power supply that will operate automatically when the primary power fails and is capable of operating the entire system is considered a secondary power supply.

2. **State FOUR types of fire control system drawings**

a) Fire Safety provision drawings

b) Fire alarm control panel

c) Fire alarm wiring diagrams.

d) Fire system drawings

3. State FIVE main components of a fire control piping appliance system

Valves, Pressure Gauge, Mortar, Assorted fittings, Pipework

4. What is the use of heat detectors

Detecting fires

5. What is the purpose of fire alarm system?

To reduce the losses associated with an unwanted fire in any building

6.2.2 Learning Outcome 2: Select tools and equipment

6.2.2.1 Introduction to the learning outcome

The objective of this learning outcome is to assist you develop competency in fire control drawings and symbols, fire control appliances and specifications

6.2.2.2 Performance Standard

1. ***Personal Protective Equipment*** is used in line with occupational safety and health requirements
2. ***Fire control tools and equipment*** are identified based on the requirements of the job.
3. Fire control tools and equipment are used based on manufacturer's manuals.
4. Fire control tools and equipment are cared for and maintained based on manufacturer's manual and workplace place policy.
5. Fire control tools and equipment are stored based on work place policies

6.2.2.3 Information Sheet

PPE is equipment that will protect the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. It also includes respiratory protective equipment (RPE).

P.P.E is important to make the workplace safe and to also ensure that people are working safely and responsibly to reduce cases of injury and accidents.

a) The lungs, eg from breathing in contaminated air
b) The head and feet, eg from falling materials
c) The eyes, eg from flying particles or splashes of corrosive liquids
d) The skin, eg from contact with corrosive materials
e) The body, eg from extremes of heat or cold

PPE must be properly looked after and stored when not in use, eg in a dry, clean cupboard. If it is reusable it must be cleaned and kept in good condition.

Types of PPE you can use

Eyes

Hazards

Chemical or metal splash, dust, projectiles, gas and vapour, radiation

Make sure the eye protection chosen has the right combination of impact/dust/splash/molten metal eye protection for the task and fits the user properly

Head and neck

Hazards

Impact from falling or flying objects, risk of head bumping, hair getting tangled in machinery, chemical drips or splash, climate or temperature

Some safety helmets incorporate or can be fitted with specially-designed eye or hearing protection

Don't forget neck protection, eg scarves for use during welding of joints

Replace head protection if it is damaged

Ears

Hazards

Noise – a combination of sound level and duration of exposure, very high-level sounds are a hazard even with short duration

Provide the right hearing protectors for the type of work, and make sure workers know how to fit them

Choose protectors that reduce noise to an acceptable level, while allowing for safety and communication

Hands and arms

Hazards

Abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, radiation, biological agents and prolonged immersion in water

Avoid gloves when operating machines such as bench drills where the gloves might get caught

Some materials are quickly penetrated by chemicals – take care during selection.

Wearing gloves for long periods can make the skin hot and sweaty, leading to skin problems.

Using separate cotton inner gloves can help prevent this

Feet and legs

Hazards

Wet, hot and cold conditions, electrostatic build-up, slipping, cuts and punctures, falling objects, heavy loads, metal and chemical splash, vehicles

Footwear can have a variety of sole patterns and materials to help prevent slips in different conditions, including oil - or chemical-resistant soles. It can also be anti-static, electrically conductive or thermally insulating

Appropriate footwear should be selected for the risks identified

FIRE CONTROL TOOLS & EQUIPMENT

These are tools used to fight a fire outbreak and prevent the spread to adjacent property. Common firefighting tools are

Halligans / Pry Tools- also known as a ***Halligan*** tool and is used as a forcible entry tool used by firefighters

 **Fire Department Hooks –** This is a stout pole having a hooked metal head and used especially in firefighting for tearing down walls or ceilings.

 **Fire Department Axes –** This is a special type of **axe** used by firefighters, typically featuring a pick-shaped pointed poll (area of the head opposite the cutting edge) and in a vivid color to make it easily visible during an emergency.

 **Shovels/Brooms/Rakes »**

Rescue Tools – These are are used by firefighters and emergency response crews to rescue trapped victims from collapsed buildings or road traffic incidents. Rescue Tools can be battery operated or powered by hydraulics. These specialist **tools** are very powerful and can lift, move or cut with massive force.

Forcible Entry Tools – These tools are used by firefighters to force entry incase of a fire risk when normal means of entry are locked or blocked

Wildland Tools – This is a common multi-functional tool that has a wide range of use from breaking into a building to tearing down walls in case of a fire.

Spanner and Hydrant Wrenches – These are tools used for tightening lug and pin lug hose connections. They are used in lawn care, in-plant maintenance, and fire fighting operations

Door Chocks & Wedges- These are used by firefighters to control doors and prevent them from closing over. Gives great assistance especially during evacuations in the case of a fire outbreak.

Firefighter Hand Tools -

Seatbelt Cutters – Allows one to cut a jammed seatbelt

Edged Tools


Multi Tools


Window Punches is an instrument needed for evacuation from vehicles after accidents or other auto emergencies e.g fire risk. It is used by applying pressure with the tool on the safety glass of a car window, which will cause the window to shatter and allow for safe evacuation from the vehicle.

.

Before selection of the tools it is important to understand the type of fire so that one is able to identify and pick the correct tool that is needed. There are FIVE main classes of fire

Type of Fire	Class

Fires that involve flammable solids such as wood, cloth, rubber, paper, and some types of plastics.	Class A
Fires that involve flammable liquids or liquefiable solids such as petrol/gasoline, oil, paint, some waxes & plastics, but **not** cooking fats or oils	Class B
Fires that involve flammable gases, such as natural gas, hydrogen, propane, butane	Class C
Fires that involve combustible metals, such as sodium, magnesium, and potassium	Class D
Fires that involve any of the materials found in Class A and B fires, but with the introduction of an electrical appliances, wiring, or other electrically energized objects in the vicinity of the fire, with a resultant electrical shock risk if a conductive agent is used to control the fire.	Class E

After controlling the fire, the tools should be cleaned and returned back in position. This is to ensure that the life of the tool is prolonged.

Care & Maintenance of Tools

This refers to processes and conditions taken to keep tools and equipment working correctly 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 unwanted material before you put them into their proper places. This is also an opportunity to look for any damage or defects and perform the maintenance required.

Hand tool Safety

Some care and maintenance precautions to be observed on tools are:

- Lay tools to be used in a neat arrangement with the cutting edges pointing away
- Do not carry sharp edged tools in the pocket

- When passing sharp tools, first pass the handle to your colleague
- Do not test the sharpness of the edges with your fingers
- Use tools for their intended purpose
- Do not use axes with loose heads
- Cutting Tools should be sharpened to avoid injury

There are different methods of storage of tools

1. STORE

This is a room where firefighting equipment are kept until needed for a firefighting task.

2. TOOL RACK

These wall-mounted or free-standing units may be designed for specific tool types, or suitable for general use. Tool racks are used to store and organize tools in an exposed manner so that tools are easy to identify, retrieve, and return.

3. TOOL BOX/ TOOL KIT

This is a box or container in which one keeps or carries tools especially those used for a particular task.

6.2.2.4 Learning Activities

Practical Activities

You are required to visit a nearby factory and learn how fire control tools and equipment's are stored based on the factories work policies.

6.2.2.5 Self-Assessment

1. State FIVE classes of fire
2. What are the different methods of storage available for firefighting tools and equipment

3. Describe the different methods of care and maintenance of firefighting tools

4. State the use of the following firefighting tools
    a) **Door Chocks & Wedges-**

b) **Fire Department Hooks –**

5. State the types of fires involved in the following classes.
    a) Class A
    b) Class B

6.2.2.6 Tools, Equipment, Supplies and Materials

Assorted firefighting tools

6.2.2.7 References

Curry, B , Smith C.J, 2015. The Motivate Series: Plumbing Principles and Practices (3rd Edition). Macmillan

6.2.2.8 Model Answers

1. **State FIVE classes of fire**

   Class A – Combustible Materials

   Class B – Flammable liquids

   Class C – Flammable Gases

   Class D – Flammable metals

   Class E – Electrical Fires

2. What are the different methods of storage available for firefighting tools and equipment

   Tool box, tool rack, tool store

a) Describe the different methods of care and maintenance of tools
b) When passing sharp tools, first pass the handle to your colleague
c) Do not test the sharpness of the edges with your fingers
d) Use tools for their intended purpose
e) Do not use hammers with loose heads

f) Cutting Tools should be sharpened to avoid injury

3. State the use of the following firefighting tools

a) **Door Chocks & Wedges-** These are used by firefighters to control doors and prevent them from closing over

b) **Fire Department Hooks –** This is a stout pole having a hooked metal head and used especially in firefighting for tearing down walls or ceilings

4. State the types of fires involved in the following classes.

   a) Class A-solid fires e.g wood

   b) Class B-flammable liquids

6.2.3 Learning Outcome 3: Quantify materials and supplies

6.2.3.1 Introduction to the learning outcome

The main focus of this specific learning outcome is to develop knowledge on the estimation of fire control appliances and systems materials and supplies

6.2.3.2 Performance Standard

1. Materials and supplies for fire control systems are identified based on the drawings and specifications.
2. Fittings for fire control systems are identified based on the standards.
3. Fire control materials are quantified and costed based on best practice
4. A schedule of fire control materials is developed based on the drawing and specifications.

6.2.3.3 Information Sheet

Estimation refers to the calculation of a rough estimate or the value of something. After working drawings have been interpreted, the required materials are identified and quantified. The components of a fire system will be different depending on the type of the system.

The main components of a fire control system are:

a) Pipework

b) Assorted Fittings (900 elbows, 450 elbows, straight tees, sockets)

c) Control Valves

d) Pressure gauges

e) Meters

f) Mortar

The main type of materials used for fire system is Steel & Plastic.

TYPES OF FIREFIGHTING FITTINGS

Figure 189 - Fire control fittings

Procedure for estimation

An analysis of the drawing is carefully done to ascertain the type of system and appliances incorporated in the drawing

Similar fittings are counted and grouped together

Spooling is then done to calculate the length of pipework required for the task.

SPOOLING

This is the calculation of the length of pipework that is required for the pipework.

Spooling = Travel – Take-out

Travel refers to the length of the pipe including the fittings whereas take-out refers to the part of the fitting not occupied by the pipe but included in the calculation.

Takeout is equal to the diameter of the pipe.

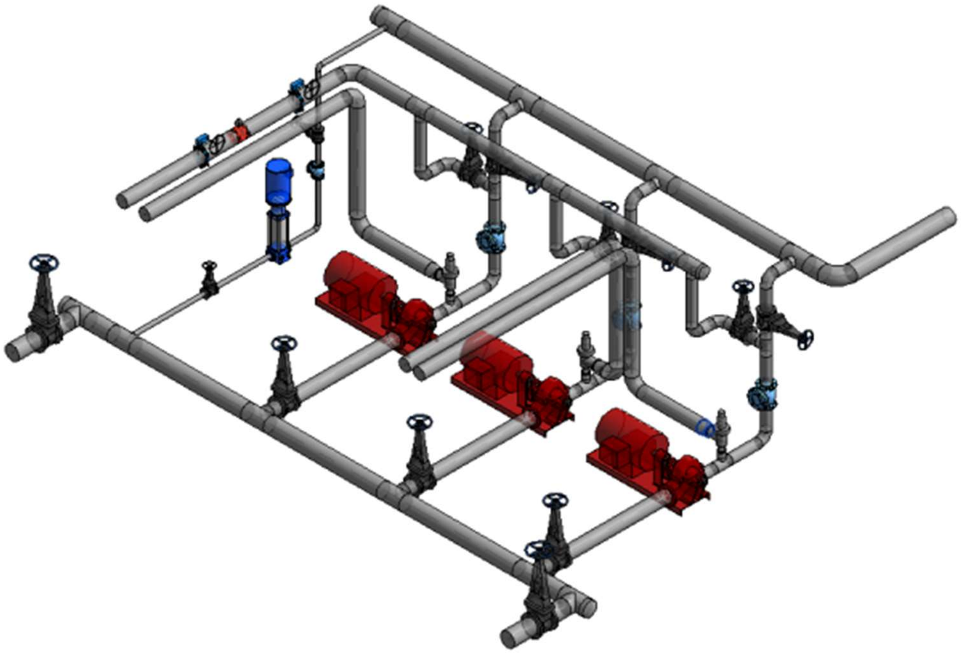
Measurements in a drawing may be given in three forms:

1. Centre to Centre (Includes takeout's at both ends)
2. Centre to end (Has only one fitting at the edge of the pipework.
3. End to End

This information is then compiled and represented in the form of a materials requirement schedule

MATERIALS REQUIREMENT SCHEDULE

Prepare a materials requirement schedule for the fire control system shown



Sample of a Materials requirement schedule

NO	TASK	Materials Required	Quantity	REMARKS
1	PIPEWORK	P.V.C 2" PIPE	10	
	FITTINGS	Straight Tees	14	
		90^0 elbows	13	
		45^0 elbows	6	
		Control Valves	9	
	MORTARS		3	
	METER		1	

The materials requirement schedule will be used to place an order for the delivery of the materials in advance

6.2.3.4 Learning Activities

Practical Activities

You are required to prepare a materials requirement schedule for the drawing given drawing.

6.2.3.5 Self-Assessment

1. Define spooling and state Three types of measurements
2. Sketch 8 types of fire control pipework fittings
3. Describe the procedure for estimation

6.2.3.6 Tools, Equipment, Supplies and Materials

Sprinkler System Test kit

Assorted tools

6.2.3.7 References

Curry, B , Smith C.J, 2015. The Motivate Series: Plumbing Principles and Practices (3rd Edition). Macmillan

6.2.4 Learning Outcome 4: Install sprinkler systems

6.2.4.1 Introduction to the learning outcome

The main focus of this specific learning outcome is to develop knowledge on the installation of the sprinkler system for firefighting.

6.2.4.2 Performance Standard

1. Positions of fire control pipes are set out and marked based on working drawings.
2. Pipes are ***jointed*** in accordance with specifications.
3. Pipes are cut based on type of pipe, drawing specifications and job requirements
4. Pipes are fitted based on drawing specifications and requirements of the job.
5. Spools are calculated based on standards and job requirements
6. Sprinkler heads are fitted according to specifications
7. Sprinkler system is connected to water storage tank
8. Housekeeping is conducted as per workplace procedures.
9. Safety and health practices are observed based on OSHA.
10. ***Tests*** are conducted based on specifications.
11. Faults are corrected based on best practice.

6.2.4.3 Information Sheet

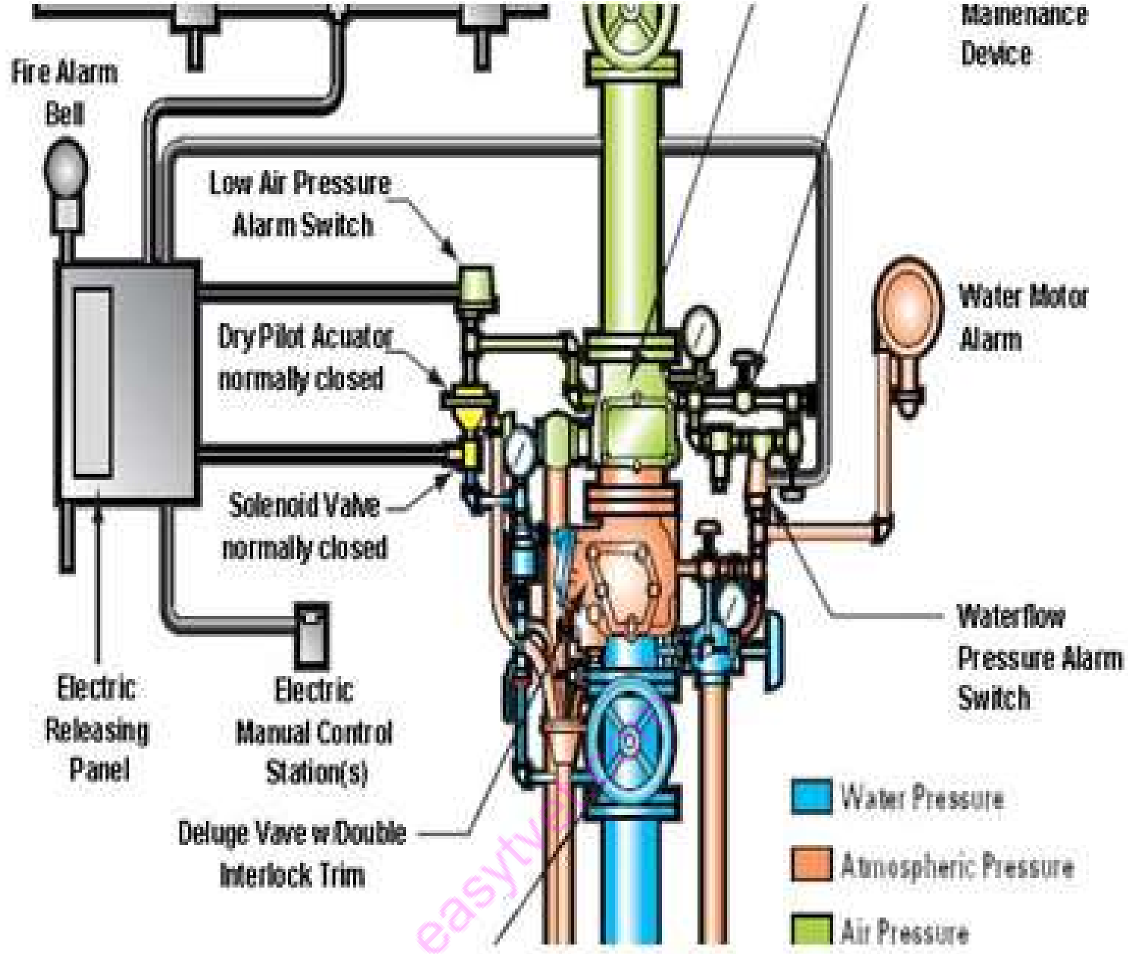
A fire sprinkler system is an active fire protection method, consisting of a water supply system, providing adequate pressure and flowrate to a water distribution piping system, onto which fire sprinklers are connected. Although historically only used in factories and large commercial buildings, systems for homes and small buildings are now available at a cost-effective price Each closed-head sprinkler is held closed by either a heat-sensitive glass bulb or a two-part metal link held together with fusible alloy. The glass bulb or link applies pressure to a pipe cap which acts as a plug which prevents water from flowing until the ambient temperature around the sprinkler reaches the design activation temperature of the individual sprinkler head. In a standard wet-pipe sprinkler system, each sprinkler activates independently when the predetermined heat level is reached. Thus, only sprinklers near the fire will operate, normally just one or two. This maximizes water pressure over the point of fire origin, and minimizes water damage to the building.

Types of Sprinkler systems

Pre-Action Fire Sprinkler Systems:

Like dry pipe systems, pre-action pipes do not hold water within the sprinkler piping and are instead filled with compressed air or nitrogen. Unlike a dry pipe system, the pre-action valve governs the flow of water. There are two types of pre-action systems:

- **Single Interlock:** This system requires a single, preceding fire detection event to occur. This event is almost always through the activation of a heat or smoke detector. Once this happens, the pre-action valve allows water to enter the piping system. If a sprinkler head activates before this, it will sound a trouble alarm, but no water will discharge.
- **Double Interlock:** Some businesses prefer the added layer of protection that a double interlock pre-action system provides. Double Interlock systems require that a preceding fire detection occurs in conjunction with an automatic sprinkler activation before water releases into the pipes. The activation of one alarm alone will not be enough.



Pre-action fire control system

Wet pipe systems

By a wide margin, wet pipe sprinkler systems are installed more often than all other types of fire sprinkler systems. They also are the most reliable, because they are simple, with the only operating components being the automatic sprinklers and (commonly, but not always) the automatic alarm check valve. An automatic water supply provides water under pressure to the system piping.

Dry pipe systems

Dry pipe systems are the second most common sprinkler system type. Dry pipe systems are installed in spaces in which the ambient temperature may be cold enough to freeze the water in a wet pipe system, rendering the system inoperable. Dry pipe systems are most often used in unheated buildings & in parking garages.

Water is not present in the piping until the system operates; instead, the piping is filled with air at a pressure below the water supply pressure. To prevent the larger water supply pressure from prematurely forcing water into the piping, the design of the dry pipe valve (a specialized type of check valve) results in a greater force on top of the check valve clapper by the use of a larger valve clapper area exposed to the piping air pressure, as compared to the higher water pressure but smaller clapper surface area.

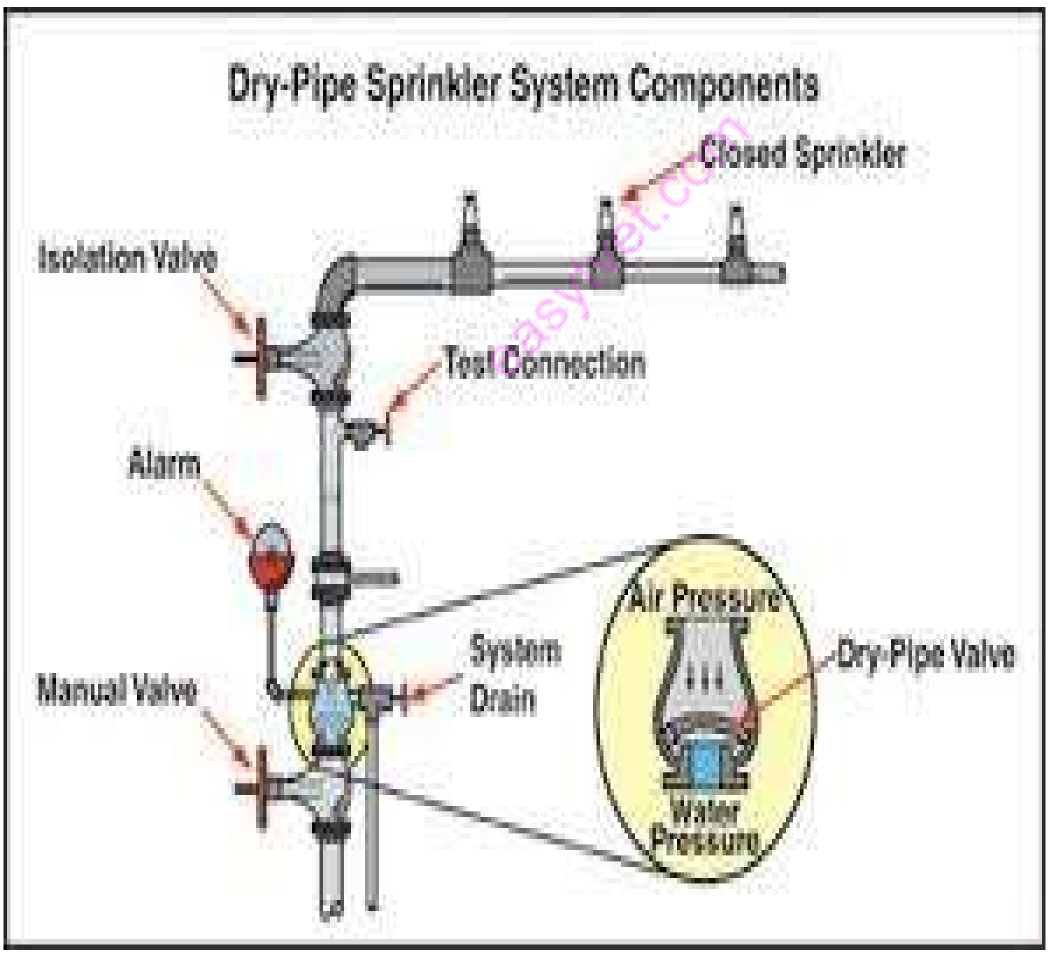


Figure 190- Dry sprinklers

Disadvantages of using dry pipe fire sprinkler systems include:

- If the sprinklers share the same standpipe system as the standpipe system which supplies fire hoses, then the water supply to the fire hoses would be severely reduced or even curtailed altogether.
- Increased complexity: Dry pipe systems require additional control equipment and air pressure supply components which increases system complexity. This puts a premium on proper maintenance, as this increase in system complexity results in an inherently less reliable overall system (i.e. more single failure points) as compared to a wet pipe system.
- Higher installation and maintenance costs: The added complexity impacts the overall dry-pipe installation cost, and increases maintenance expenditure primarily due to added service labor costs.
- Lower design flexibility: Regulatory requirements limit the maximum permitted size (i.e. 750 gallons) of individual dry-pipe systems, unless additional components and design efforts are provided to limit the time from sprinkler activation to water discharge to under one minute. These limitations may increase the number of individual sprinkler zones (i.e. served from a single riser) that must be provided in the building, and impact the ability of an owner to make system additions.
- Increased fire response time: Because the piping is empty at the time the sprinkler operates, there is an inherent time delay in delivering water to the sprinklers which have operated while the water travels from the riser to the sprinkler, partially filling the piping in the process. A maximum of 60 seconds is normally allowed by regulatory requirements from the time a single sprinkler opens until water is discharged onto the fire. This delay in fire suppression results in a larger fire prior to control, increasing property damage.
- Increased corrosion potential: Following operation or testing, dry-pipe sprinkler system piping is drained, but residual water collects in piping low spots, and moisture is also retained in the atmosphere within the piping. This moisture, coupled with the oxygen available in the compressed air in the piping, increases internal pipe corrosion, eventually leading to pin-hole leaks or other piping failures. The internal corrosion rate in

wet pipe systems (in which the piping is constantly full of water) is much lower, as the amount of oxygen available for the corrosion process is lower

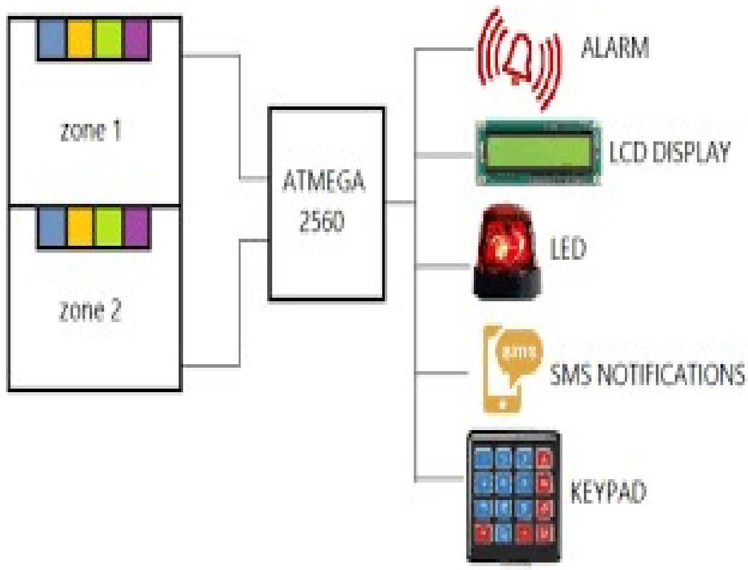
Automatic Fire Alarm Systems

Automatic fire alarm systems often play a major role in loss prevention during a fire emergency. The basic purpose of an automatic fire alarm system is to detect a fire in its early stages, notify the building occupants that there is a fire emergency and report the emergency to first responders. Below is a high-level overview of the components of an automatic fire alarm system.

Fire Alarm Control Panel (FACP); this is the center of the fire alarm system. The fire alarm control panel monitors initiating devices and then activates notification devices when an alarm signal is received. These panels range in scale from a single zone to multiple buildings.

Initiating Devices; Initiating devices detect a fire emergency and communicate it to the fire alarm control panel. These can be triggered both manually (pull stations), as well as automatically in a response to heat, smoke or flame. When one of these initiating devices is triggered, the control panel will go into an alarm state.

Notification Devices; after the control panel receives a signal for an initiating device and goes into an alarm state, the panel initiates output devices that signal to building occupants that there is an emergency situation. These include bells, horns, speakers, chimes, strobes and flashing lights that signal either audibly or visually that there is a fire emergency.



Automatic fire alarm system

Fire sprinkler heads

A fire sprinkler head is the component of a sprinkler system that discharges water when the fire has been detected. It comes in assorted designs.

Figure 191 - sprinkler head

Each sprinkler head contains a trigger mechanism, which opens to release water onto the fire. With conventional heads, suitable for most residential fire sprinkler systems, some water is discharged onto the ceiling.

Upright or pendant spray sprinklers aim all the water straight down and are suited to rooms with high ceilings.

Heads need not be obtrusive and may be recessed in the ceiling or covered with resin caps to make them more aesthetically pleasing.

Side wall sprinklers attach to a high point on the wall. They usually give wider water coverage than conventional sprinkler heads.

The plug inside the head that holds back the water may be made of Wood's metal, a mixture of bismuth, lead, tin, and cadmium that melts at a relatively low temperature, or a small glass bulb containing a glycerin-based liquid that expands and shatters when it gets hot, releasing the water.

Each sprinkler head activates independently. Only sprinklers above the fire will operate, maximizing water pressure over the fire and reducing fire and water damage to the building. Sprinklers use far less water than fire hoses.

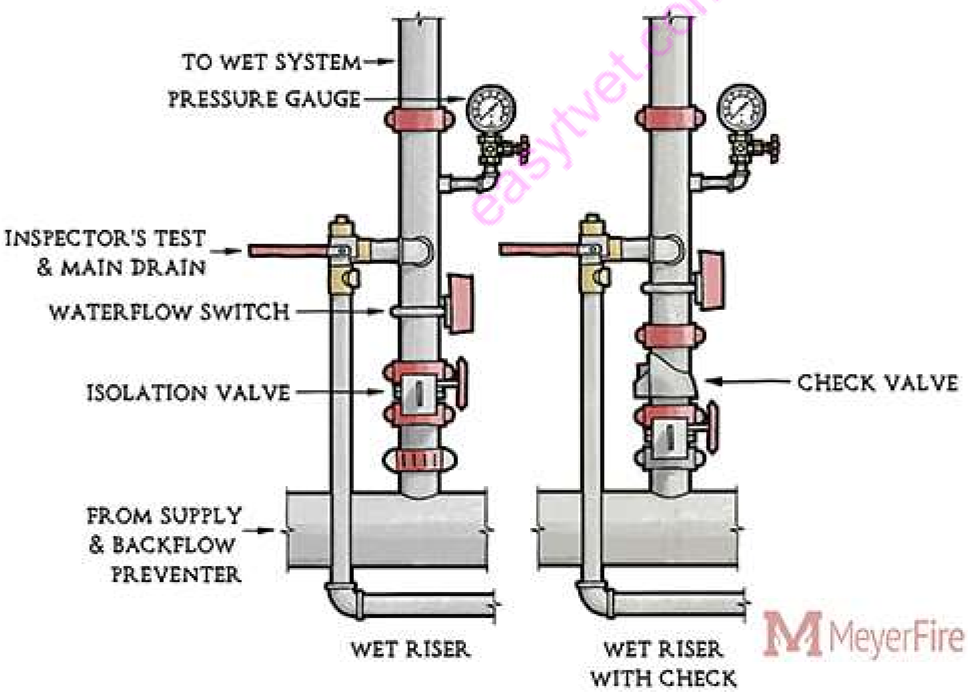


Figure 192- Wet pipe sprinkler system

Types of pipes

G.I (Galvanized Iron) pipes

Description: Galvanized iron pipe was once a popular method of plumbing water supply lines in the home, but it gradually fails due to corrosion and rust. For this reason, it is no longer commonly used and has been largely replaced with copper pipe or PEX plastic pipe. Galvanized iron pipe is difficult to cut and join and not easily fabricated on site by the homeowner. Repairs are usually done by replacing the pipes with copper or PEX.

Prevalent Use: Water supply lines and drain lines in older homes.

PPR pipes

PPR pipe is a straight and rigid cylindrical pipe, made from Polypropylene Random Copolymer plastic, produced through a continuous extrusion process. They are commonly offered in green or white color, and in outer diameter sizes ranging from 20mm to 110mm making the pipe walls far thicker than PVC. PPR pipe is accompanied by a series of connection fittings, parts, and accessories available for every pipe diameter.

Application of PPR Pipe

- **PP-R pipes** are used to build hot and cold water systems, including central heating systems.
- **PP-R pipes** are a part of building heating system, including floor, wall and radiant heating systems.

- **PP-R pipes** can be directly purified water drinking water supply systems.

- **CPVC**

Appearance: Dull white or cream-colored plastic.

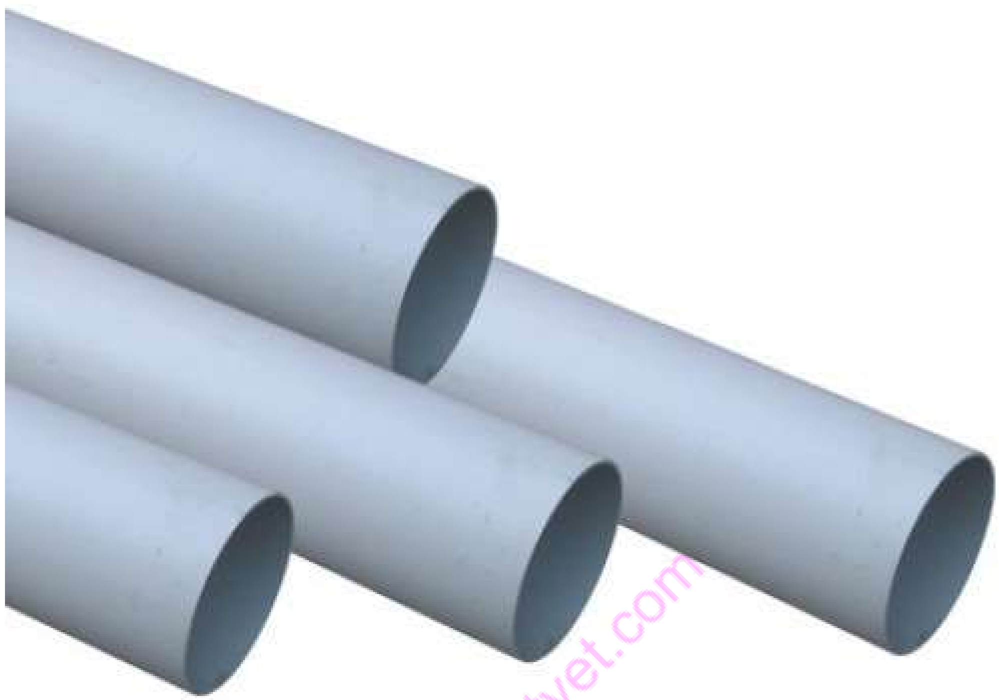
Description: CPVC is an inexpensive rigid plastic that is designed to withstand high pressure and temperature.

Prevalent Use: CPVC is used for hot and cold water supply piping.

Cutting and Fitting: The pipe is easily cut with a tubing cutter or hacksaw. CPVC is joined permanently together using plastic fittings and solvent glue, or with grip fittings where the pipes may need to be disassembled in the future.

PVC pipes (Polyvinyl Chloride)

PVC pipes are used in a wide variety of piping applications, from transportation of drinking water over drainage solutions to advanced fire-sprinkler systems. This popularity owes to a unique combination of properties: safety, durability/cost-efficiency, environmental performance and recyclability.



Joint Methods Used for Pipe and Tube

- Copper pipes are typically joined by soldering, brazing, compression fittings, flaring, or crimping.
- Plastic pipes may be joined by solvent welding, heat fusion, or elastomeric sealing.

Other methods of jointing includes;

- Soldering
- Bronze Welding
- Compression joints
- Flange joints

Fittings.

Pipe fittings are connected to piping using various end connections. Pipe fittings play an important role in the proper functioning of pipes and tubes in various applications.

- **Elbows**: Used to change the angle or direction of the pipe run. Most commonly in 90 degrees and 45 degree turns. The sweep of the fitting describes how fast a transition or change in direction is made.
- **Street Elbows:** One end of the pipe fitting has male threads and the other end has female threads. These are common in galvanized steel and copper pipe. They are convenient because they do away with the need for a nipple and work well in tight quarters.
- **Tee Fittings:** Shaped like the letter T. Allows for branch lines.
- **Couplings:** Used to join two straight pieces of pipe of the same diameter.
- **Reducers:** Used to join pipes of different diameters. Makes a gradual change in diameter.
- **Bushings:** Used to make the diameter of a pipe fitting smaller. They are different from reducers because they make an abrupt change in diameter and take little space.
- **Unions:** Used to join pieces of pipe where pipes cannot be turned or when a piece of equipment may have to be removed for maintenance or replacement.
- **Adaptor Fittings:** Used to change the end of a non-threaded pipe to male or female threads as needed. Most commonly used in copper and plastic plumbing jobs.
- **Caps:** Used to close the end of a dead-end pipe.
- **Plugs:** Used to close an ending on a pipe fitting normally used for inspection or cleanout.
- **Nipples:** Short lengths of pipe threaded at both ends.
- **Wyes:** Used primarily to gain inside access to DWV (drain-waste-vent) systems.
- **Valves:** Devices that control the flow of liquid or gas through or from a pipe. (Compression valves, ball valves, sleeve-cartridge valves, ceramic disc valves, etc)
- **PVC Fittings:** Come in a wide variety of configurations and may be glued (S) or threaded (T)

- **Copper Tubing Fittings:** Use compression fittings. Common fittings are couplings, ells, and tees.

Valves

A valve is a device that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways

There are several valves available for use by plumber. They include.

1. Globe valves
2. Gate valves
3. Plug valve/ plug cork
4. Ball cork
5. Float valve/ ball valve

Common faults in fire sprinkler systems

1. Human Error – One of the top fire sprinkler system problems is human error. Many people believe that these pipes are indestructible, and use them to hang things like ropes and chains or to even help lift heavy objects. This could detrimentally damage the pipes and compromise the fire protection system.
2. Overheating and Freezing – As fire sprinkler systems are activated by heat, it is important to consider where they will be placed and if overheating could occur. This very common malfunction typically occurs when celling temperatures rise over 150-degrees Fahrenheit. Should this be a concern for your building, especially in the high Florida heat, consider different sprinkler heads that are designed to go off at different temperatures and have a sprinkler system installed that is equipped to handle these conditions. Alternatively, and not as common in Florida, the water in the pipes of a fire

sprinkler system has been known to freeze should the necessary precautions not be put in place. Frozen pipes can be prevented with insulation or antifreeze.

3. Mechanical Damage – Just like everything else in life, fire sprinkler systems require maintenance in order to work properly. Neglecting the system could result in mechanical damage.
4. Corrosion – Fire sprinkler systems are based on water, which makes corrosion a common problem. It can impact the functionality of the system and lead to leaks, which could cause water damage to your property. Fire inspections should be done to check for any potential leaks and to replace any pipes that are beginning to corrode.

TESTING OF THE SYSTEM

During a complete fire sprinkler system test, the technician should perform physical checks on all parts of your fire sprinkler system.

- **Smoke test**; forces smoke-filled air through pipe line. The smoke under pressure will fill the main line plus any connections and then follow the path of any leak to the ground surface, quickly revealing the source of the problem.
- **Air test**; it is done by isolating the section of pipe that needs to be tested using plugs, and setting two different pressures for five minutes each. Any change in pressure over those five-minute time periods is measured and recorded.
- **Pressure test**; it is performed to ensure the safety, reliability, and leak tightness of pressure systems. A pressure test is required for a new pressure system before use or an existing pressure system after repair or alteration. There are two methods for pressure tests: hydrostatic and pneumatic.

6.2.4.4 Learning Activities

Practical Activities

You are required to visit a site laying out the sprinkler system learn how the Positions of fire control pipes are set out and marked based on working drawings.

6.2.4.5 Self-Assessment

1. State the two methods of jointing plastic pipes.
2. Explain the following components of fire alarm control.

i. **Fire Alarm Control Panel (FACP**

ii. **Initiating Devices;**

iii. **Notification Devices**

3. State where the following fittings are used in pipe work.

i. Couplings:

ii. Reducers

4. State the two types of pre-action systems:
5. Disadvantages of using dry pipe fire sprinkler systems

6.2.4.6 Tools, Equipment, Supplies and Materials

Sprinkler System Test kit

Assorted tools

6.2.4.7 References

Curry, B , Smith C.J, 2015. The Motivate Series: Plumbing Principles and Practices (3rd Edition). Macmillan

6.2.4.8 Model Answers.

1. State the two methods of jointing plastic pipes.

   i. Solvent welding

   ii. Heat fusion or elastomeric sealing.

2. Explain the following components of fire alarm control.

i. **Fire Alarm Control Panel (FACP)**; this is the center of the fire alarm system. The fire alarm control panel monitors initiating devices and then activates notification devices when an alarm signal is received. These panels range in scale from a single zone to multiple buildings.

ii. **Initiating Devices;** Initiating devices detect a fire emergency and communicate it to the fire alarm control panel. These can be triggered both manually (pull stations), as well as automatically in a response to heat, smoke or flame. When one of these initiating devices is triggered, the control panel will go into an alarm state.

iii. **Notification Devices;** after the control panel receives a signal for an initiating device and goes into an alarm state, the panel initiates output devices that signal to building occupants that there is an emergency situation. These include bells, horns, speakers, chimes, strobes and flashing lights that signal either audibly or visually that there is a fire emergency.

3. State where the following fittings are used in pipe work.

i. **Couplings:** Used to join two straight pieces of pipe of the same diameter.

ii. **Reducers:** Used to join pipes of different diameters. Makes a gradual change in diameter.

4. State the two types of pre-action systems

i. **Fire Alarm Control Panel (FACP)**; this is the center of the fire alarm system. The fire alarm control panel monitors initiating devices and then activates notification devices when an alarm signal is received. These panels range in scale from a single zone to multiple buildings.

ii. **Initiating Devices;** Initiating devices detect a fire emergency and communicate it to the fire alarm control panel. These can be triggered both manually (pull stations), as well as automatically in a response to heat, smoke or flame. When one of these initiating devices is triggered, the control panel will go into an alarm state.

5. Disadvantages of using dry pipe fire sprinkler systems

- Increased complexity
- Increased corrosion potential:
- Increased fire response time:

- Lower design flexibility
- Higher installation and maintenance costs:

6.2.5 Learning Outcome 5: Install hose reel systems

6.2.5.1. Introduction to the learning outcome

The main focus of this specific learning outcome is to develop knowledge on the installation of the hose reel system for firefighting.

6.2.5.2. Performance Standard

1. Positions of fire control pipes are set out and marked based on working drawings.
2. Pipes are ***jointed*** in accordance with specifications.
3. Pipes are cut based on type of pipe, drawing specifications and job requirements
4. Pipes are fitted based on drawing specifications and requirements of the job.
5. Spools are calculated based on standards and job requirements
6. Hose reels are fitted according to specifications
7. Hose reel system is connected to water storage tank
8. Housekeeping is conducted as per workplace procedures.
9. Safety and health practices are observed based on OSHA.
10. ***Tests*** are conducted based on specifications.
11. Faults are corrected based on best practice.

6.2.5.3. Information Sheet

Hose reel system

A fire hose reel is a first attack piece of fire-fighting equipment. This method of firefighting will be used for fire caused by combustible materials. The control nozzle attached to the end of the hose enables the operator to control the direction and flow of water to the fire. Hose reels provided for firefighting purposes must not be used for cleaning purposes

A Hose Reel is a cylindrical spindle made of either metal, fiberglass, or plastic and is used for storing a hose. The most common styles of hose reels are spring driven (which is self retracting), hand crank, or motor driven.

The hose reel system is generally started by opening a valve that is adjusted to the hose reel and control the flow of water. Then we move the hose reel in our desired place then pull
the hose and fight the fire.

Fire hose reels are located to provide a reasonably accessible and controlled supply of water to combat a potential fire risk. The length of a fully extended fire hose is 36 meters with a diameter of 19mm (outside diameter).

These appliances are designed to deliver, as a minimum, 0.33L of water per second. A control nozzle attached to the end of the hose enables the operator to control the direction and flow of water to the fire. All fire hose reels come with a unique ball valve shut-off device, a plastic or solid brass hose reel nozzle and mounting bracket

Figure 193- Hose reel

Hose reels should only be connected to a dedicated ***fire*** line, not the water mains. Should be a minimum of 100mm clearance around all points of ***hose*** drum. Valve height should be between 900mm & 1100mm from floor level. Valve must incorporate an interlock for nozzle.

Basic features of the Fire Hose reel System

- Hose reel set consisting of the drum, hose, nozzle, nozzle clip, and mounting bracket
- Hose reel cabinet, where provided
- Operating signages, labels and instructions

- Pipes and fittings from the water source (either from the Fire Hose reel Water Tank, or direct PUB supply). Where a Fire Hose reel Water Tank is provided, the Fire Hose reel controller panel and pump sets are being inspected as well.

Procedure for installation

Attach the ***hose*** guide to a suitable location about 330 to 350 mm in the side and 330 to 350 mm down the center of the mounting plate. Lift the ***reel*** to the wall mounting plate.

Insert ***hose*** through the ***hose*** guide and place the nozzle into the bracket. Connect the water supply to the shut-off valve

The following tools shall be required for the installation of the hose reel system.

1. Portable hand tools
2. Portable drill machines
3. Grinder
4. Welding Machine
5. Pipe threading machine

Method of Connection to the storage tank

Spooling

This is the calculation of the length of pipework that is required for the pipework.

Spooling = Travel – Take-out

Travel refers to the length of the pipe including the fittings whereas take-out refers to the part of the fitting not occupied by the pipe but included in the calculation.

Takeout is equal to the diameter of the pipe.

Measurements in a drawing may be given in three forms:

1. Centre to Centre (Includes takeout's at both ends)
2. Centre to end (Has only one fitting at the edge of the pipework.
3. End to End

Testing Of the System

In addition to the annual inspection, the fire hose needs to be tested every three years, with the first time being 5 years after the manufacturing date. This test is referred to as the Hose Pressure Service Test. A fire safety professional can take care of this for you along with annual inspections.

As a general guide hose reel testing includes the following:

- Full inspection of hose, valves, re-wind, nozzles – The integrity of the drum gland nuts and internal operating valve is checked.
- Hose checks – hose reels are fully unwound and the condition of the hose and valves/nozzles checked.
- Pressure test – The equipment is filled with water presurised and inspected for any leaks to test the integrity of the reel and hose. Maximum working pressure usually 12 bar so test pressure is typically 18 bar.
- Flow test – The flow rate of the water delivered by the hose is tested with a flow meter to ensure that it delivers water at the required rate.
- Maintenance – Client is advised if any repairs or maintenance is required. Experienced engineers carry an extensive range of spare parts so wherever possible we can carry this work out immediately at a very competitive rate.
- Service labels – Details of these tests are recorded on service labels and attached to the equipment as required.

- Certificate of inspection – If required a certificate of inspection is completed and supplied to prove the fire hose reel has been tested by a competent person in line with BS-EN-671/3.
- Tidy & clean – At the end of the service, the hose reel is cleaned and rewound. Part of our service is to aim to leave the site cleaner and tidier than when we arrived!

6.2.5.4. Learning Activities

Practical Activities

You are required to visit a site laying out the hosereel system and get understanding of all concepts applied during installation and testing.

6.2.5.5. Self-Assessment

1. State five tools used in installation of the hosereel system

2. Describe the procedure for installation of the hosereel system
3. State three forms of measurements in drawing

6.2.5.6. Tools, Equipment, Supplies and Materials

Hose reel testkit

Assorted Plumbing Tools

6.2.5.7. References

Curry, B , Smith C.J, 2015. The Motivate Series: Plumbing Principles and Practices (3rd Edition). Macmillan

6.2.5.8. Model Answers

1. State five tools used in installation of the hosereel system
    - Portable hand tools
    - Portable drill machines
    - Grinder
    - Welding Machine
    - Pipe threading machine

2. **Describe the procedure for installation of the hosereel system**

   Attach the ***hose*** guide to a suitable location about 330 to 350 mm in the side and 330 to 350 mm down the center of the mounting plate. Lift the ***reel*** to the wall mounting plate. Insert ***hose*** through the ***hose*** guide and place the nozzle into the bracket. Connect the water supply to the shut-off valve

3. **State three forms of measurements in drawing**
    - Centre to Centre
    - Centre to end
    - End to End

6.2.6 Learning Outcome 6: Install wet and dry risers

6.2.6.1. Introduction to the learning outcome

The main focus of this specific learning outcome is to develop knowledge on the installation of wet and dry risers for firefighting.

6.2.6.2. Performance Standard

1. Positions of fire control pipes are set out and marked based on working drawings.
2. Pipes are ***jointed*** in accordance with specifications.
3. Pipes are cut based on type of pipe, drawing specifications and job requirements
4. Pipes are fitted based on drawing specifications and requirements of the job.
5. Spools are calculated based on standards and job requirements
6. Fire Hydrants are fitted as per specifications
7. Housekeeping is conducted as per workplace procedures.
8. Safety and health practices are observed based on OSHA.
9. ***Tests*** are conducted based on specifications.
10. Faults are corrected based on best practice.

6.2.6.3. Information Sheet

Dry riser: a system of valves and pipe work which enables the fire service to pump water onto upper floors of a building.

Wet riser: a system of valves and pipe work which is kept permanently charged with water, generally utilising pumps and tanks.

WET RISERS

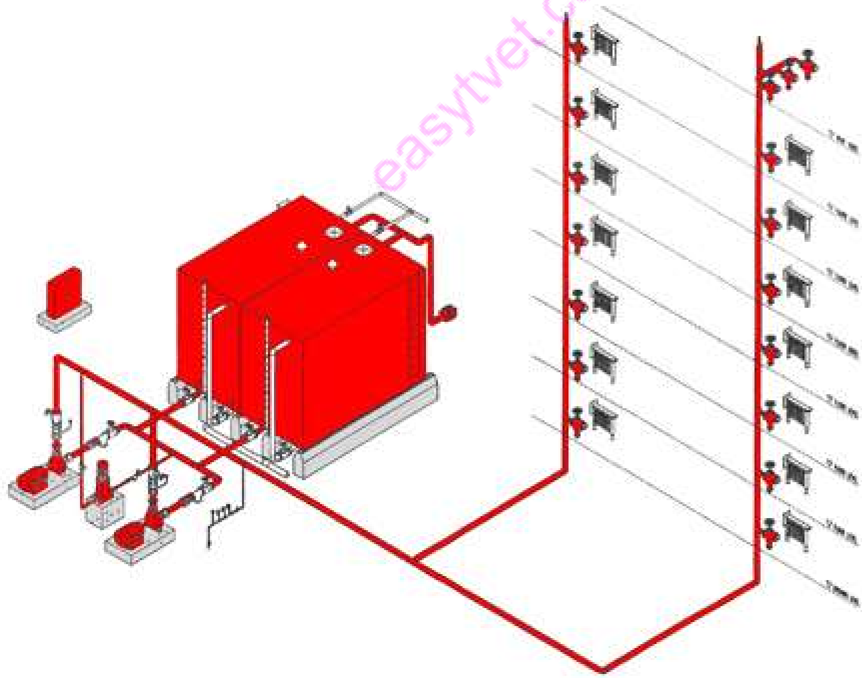
Wet rising mains are fitted in tall buildings due to the excessive pressures required to pump water to high levels. A **Wet riser** is a supply system intended to distribute water to multiple levels or compartments of a building, as a component of its firefighting systems.

They are advantageous to the fire service in two respects. Firstly they provide a fixed distribution

Wet Riser Installation

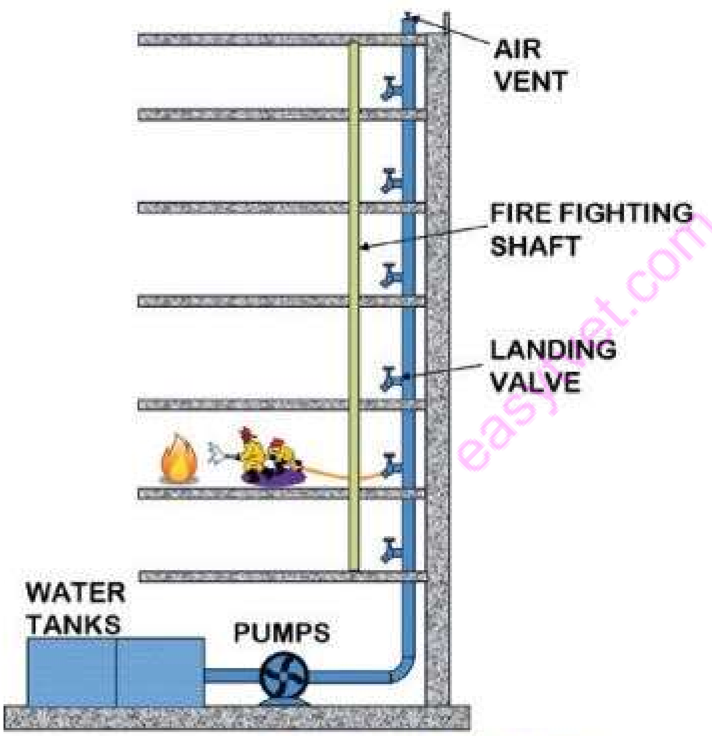
- A Wet Riser System is installed with a Landing Valve at pre-specified locations on each floor
- Typically, a Wet Riser is installed up to and over 50m. The system will be designed to provide high pressure flow at the upper floors.
- A test riser is installed in parallel to the wet riser to allow the evacuation of water from the Wet Riser for flow test purposes.
- PRVs are installed at every floor to ensure the required optimum pressure is delivered in the event of an emergency

Dry Risers Direct will work with you to supply and install the pipework, PRVs and test drain and connecting to the pump ready for commissioning.



The tanks are fitted with an automatic warning system to indicate a low water level.

At protracted incidents the wet rising main tank may need to be augmented and this can be acheived using conventional Fire appliances and additional water supplies (Hydrant, Open water etc)
Wet rising mains are designed to supply 1500 litres per minute for 45 minutes as a minimum. Due to the height of the building and the pressures used, water pressure reduction valves are fitted to the outlets at each floor. Buildings constructed prior to 2006 will have outlet pressures of 4 to 5 Bars. Changes to BS 9990 in 2006 now recommend an outlet pressure of 8 Bars, this recommendation does not affect installations installed before this date.



WET RISING MAIN

Maintenance and Testing

Fire crews should be familiar with the layout and function of any dry riser in their risk area. If any buildinga are fitted with a Wet riser. then it is a special risk (PRM/SSRI). Specific and detailed information on the riser's size, location and performance limits should be included within the risk data.

Wet raiser testing

The annual testing and maintenance of both Dry and Wet Risers is the responsibility of the property owners or managing agents.

• Static pressure shall not exceed 7 bars

• Running pressure 3.5 to 5.5 bars

• Flow rate: – 27 l/s (residential) – 38 l/s (non-residential)Possible failures and corrective measures for wet pipe sprinkler systems and fire detection systems

Riser failure

A defective or otherwise inoperative dry riser will seriously effect fire service operations. Riser failure can be brought about through many factors. An open outlet, restrictive blockage, mechanical failure of the pipework, vandalism and more recently theft of the inlet/outlet fittings.

For all problems, consult equipment and component manuals for troubleshooting directions. Check fuses/lights/breakers/etc., for continuity, check equipment calibration and settings, check for clogged strainers, check for closed manual shutoff valves, check for improperly adjusted valves and equipment and look for faulty equipment and connections.

a. ***Repair of wet pipe sprinkler system and fire detection system*.** It is recommended that adjustments and corrections to wet pipe sprinkler and fire detection systems be done by licensed and bonded fire sprinkler companies and fire detection companies.

b. ***Fire code compliance*.** It is imperative that the NFPA Fire Code standards and manufacturer's recommendations relative to each suppression, detection and alarm system be consulted before any operation is performed on any of these systems.

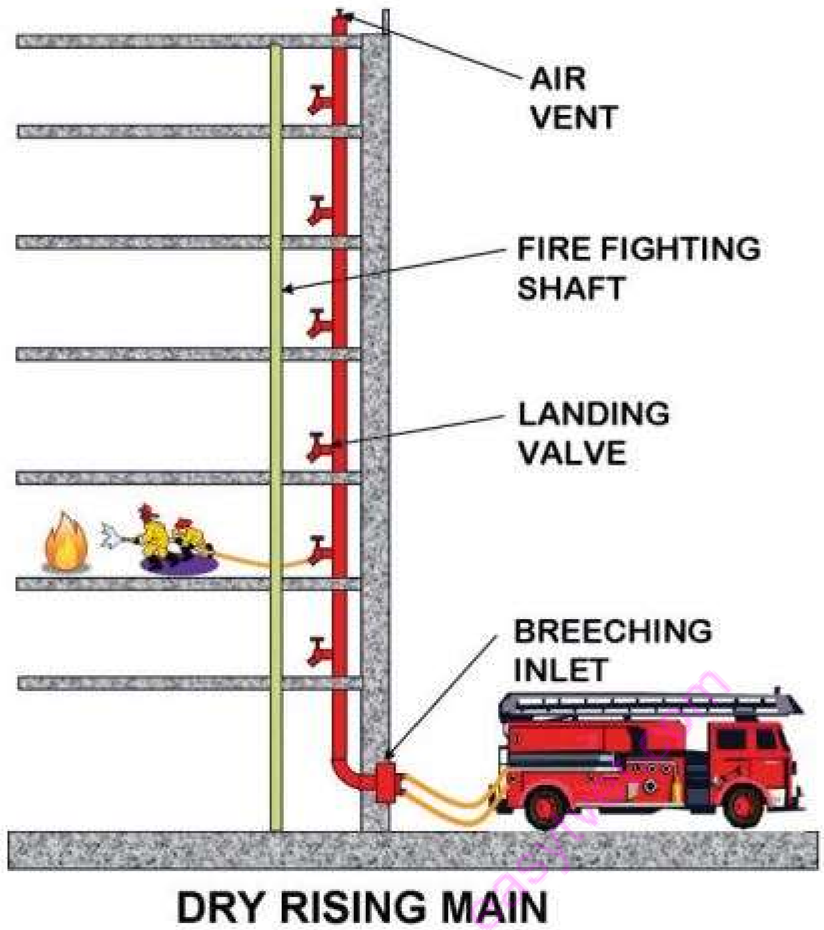
	Areas to Check
Fire detection system	
Devices will not close/trip	Check mechanical alignment of tamper switches Check flow switches Check interlocks and safeties Check for mis-wired circuits Check control panel program Check power supply Check battery back-up power supply Check grounds
Devices trip inadvertently	Check protective device settings and operation Check for mis-wired circuits Check control panel program Check for system overload or short Check grounds Check local environmental conditions

Wet pipe sprinkler system	
Does not flow, flows at a reduced rate	Check shut off valves Check strainers and check valves Check city water supply Check pressures Check safeties and interlocks to fire protection systems Check for open drain valves
Water motor driven alarm does not sound	Check retard chamber Check for closed shut off valves Check strainers and drain Check for clogged water motor

Possible Failures and Corrective Actions for a Wet Pipe Sprinkler and Fire Protection System

Dry risers

A dry riser is a system of pipe work and valves that runs up through a building. The system allows fire fighters to easily access water from each individual floor of the building. It consists of a vertical pipe with a water inlet on ground level located on an external wall and outlets known as landing valves, which are usually located in a dry riser cabinet on each floor. The dry risers are usually located in the fire fighting shaft.



Dry raising main operations

Fire Service Inlets

The dry riser inlet is installed at the fire brigade access level. This breeching connection is usually housed in a red glass fronted box with the wording 'Dry Riser Inlet'. This inlet should be positioned as close as possible to the rising main in order to reduce pressure losses. The inlet box and breeching inlet should be installed with the lower edge of the box between 400mm and 600mm above the ground.

Landing Valves

The landing valves are fitted with a wheeled valve connected directly to a 65mm instantaneous female coupling with a removable blank cap and retaining strap. They are installed at each floor level except the ground floor and should preferably be housed in a red lockable box marked 'Dry Riser'

Dry Riser Maintenance & Servicing

The pipes in wet risers are full of water at all times and have pumps that deliver the water to the outlets, these pumps draw water from storage tanks. The pumps operate when the pressure in the mains drops when a landing valve is opened.

All riser systems installed by our experts are put through extensive visual inspection and pressure testing.

Annual Wet Test

Dry risers are checked and pressurized to a test pressure of 12 bar for a minimum of 15 minutes. All inlets and outlets are checked for leaks and any missing or faulty items replaced. Flow testing is also carried out. If any valves need to be replaced, a further pressure test will be carried out before certification is issued.

Six Monthly Visual Test

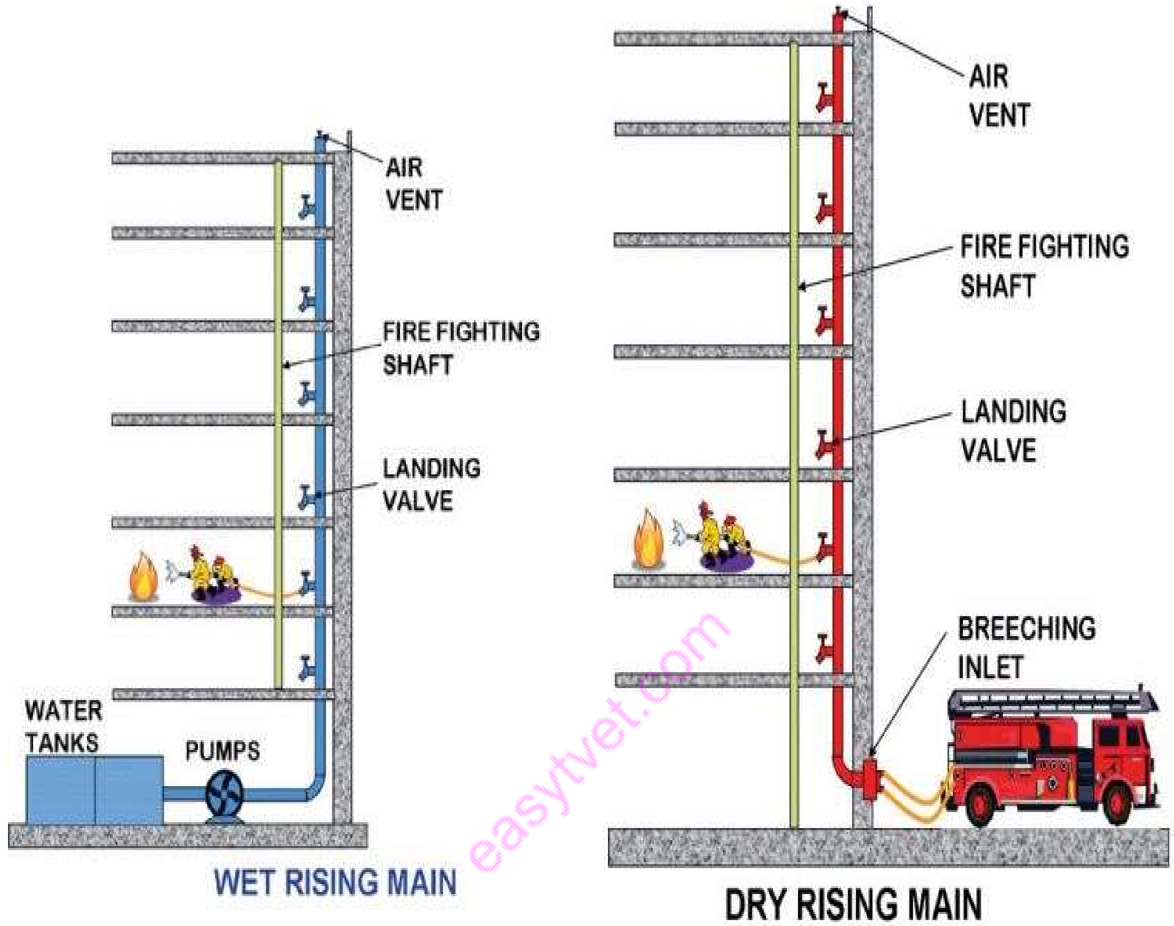
This test involves a visual inspection only as required by British Standards. Any missing or damaged items are replaced during the inspection.

Difference between a **dry** and **wet riser**

A **dry riser system** is designed to be charged with water by the fire brigade. A **wet riser system** is kept full of water via water tanks and pumps.

Advantage of a wet riser over a dry riser for firefighting operations?

The **wet riser** system is similar in design to **dry risers** and can usually be found in buildings **over** 50m tall. Unlike the **dry riser** system, it is kept constantly charged with water, in order that it can provide the same level of protection against a fire in the upper reaches of taller properties as on the lower floors.



Spooling

This is the calculation of the length of pipework that is required for the pipework.

Spooling = Travel – Take-out

Travel refers to the length of the pipe including the fittings whereas take-out refers to the part of the fitting not occupied by the pipe but included in the calculation.

Takeout is equal to the diameter of the pipe.

Measurements in a drawing may be given in three forms:

1. Centre to Centre (Includes takeout's at both ends)
2. Centre to end (Has only one fitting at the edge of the pipework.
3. End to End

TESTING OF THE SYSTEM

Dry Riser - Annual *Wet Test Dry Risers* are checked and pressure tested to 150 PSL or 10 bar for a minimum duration of 15 minutes. All inlets and outlets are then checked for leaks. If any valves or components have to be replaced a further pressure *test* will be carried out before certification is issued.

Wet Riser - The Annual Static Pressure ***Test*** The is very similar to the ***Dry Riser*** static pressure ***test***, however the system is already charged full of water. A pressure reading is taken at each landing valve and additional actions are completed as follows: Check internal cleanliness of storage tanks.

6.2.6.4. Learning Activities

Practical Activities

You are required to visit a site laying out the riser system and get understanding of all regarding Positions of fire control pipes are set out and marked based on working drawings.

6.2.6.5. Self-Assessment

1. Differentiate wet system from dry system
2. Describe the procedure for installation of the wet riser system
3. Describe annual wet test for dry risers.
4. Sketch a wet rising main.

6.2.6.6. Tools, Equipment, Supplies and Materials

Riser testkit

Assorted Plumbing Tools

Overall

6.2.6.7. References

Curry, B , Smith C.J, 2015. The Motivate Series: Plumbing Principles and Practices (3rd Edition). Macmillan

6.2.6.8. Model Answers.

1. **Differentiate wet system from dry system**

   A **dry riser system** is designed to be charged with water by the fire brigade. A **wet riser system** is kept full of water via water tanks and pumps.

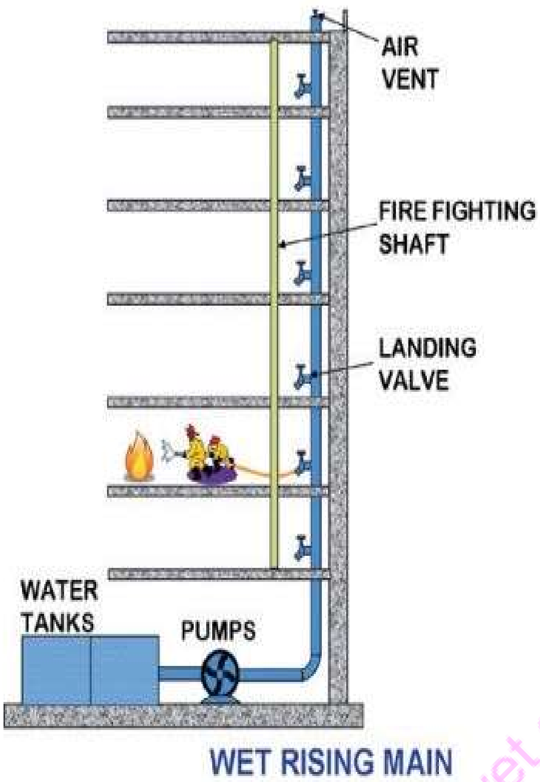
2. **Describe the procedure for installation of the wet riser system**

- A Wet Riser System is installed with a Landing Valve at pre-specified locations on each floor
- Typically, a Wet Riser is installed up to and over 50m. The system will be designed to provide high pressure flow at the upper floors.
- A test riser is installed in parallel to the wet riser to allow the evacuation of water from the Wet Riser for flow test purposes.
- PRVs are installed at every floor to ensure the required optimum pressure is delivered in the event of an emergency

3. **Describe annual wet test for dry risers**

   .Dry risers are checked and pressurized to a test pressure of 12 bar for a minimum of 15 minutes. All inlets and outlets are checked for leaks and any missing or faulty items replaced. Flow testing is also carried out. If any valves need to be replaced, a further pressure test will be carried out before certification is issued

4. **Sketch a wet rising main.**



6.2.7 Learning Outcome 7: Maintain and service fire suppression systems

6.2.7.1. Introduction to the learning outcome

The main focus of this specific learning outcome is to develop knowledge on the maintenance of fire suppression systems

6.2.7.2. Performance Standard

1. Types of maintenance are classified based on standards
2. Regular checks are conducted based on best practice
3. Regular servicing and cleaning are conducted in based on standards
4. Faults are rectified based on best practice

6.2.7.3. Information Sheet

Maintenance

Maintenance is the work necessary to keep the fire system operating properly. One form of maintenance is simply a **response to a failure** identified by a visual inspection or a test of the equipment. Service personnel should notify the system owner immediately whenever deficiencies are found during routine inspection and testing procedures. Considering the fact that life safety and/or mission continuity may be at risk, **repairs should be made as soon as feasibly possible** by qualified personnel. Whenever repairs are not made immediately, a temporary alternative means of protection should be put in place until the fire system is returned to an acceptable level of readiness. Another important form of maintenance is of a preventative nature. Many components in a fire protection system will require **preventative maintenance at a prescribed frequency**. These maintenance activities address components that degrade over time, have a finite lifespan or require periodic resetting or calibration. For example, most fire alarm systems utilize lead-acid type batteries as a secondary (backup) power supply

Maintenance refers to the process of preserving a condition. It is carried out:

- to prevent problems arising,
- to put faults right
- to ensure equipment is working effectively.

Maintenance may be part of a planned program or may have to be carried out at short notice after a breakdown.

Maintenance may be classified into following categories:

(a) Corrective or breakdown maintenance,

(b) Scheduled maintenance,

(c) Preventive maintenance,

Corrective or Breakdown Maintenance:

Corrective or breakdown maintenance implies that repairs are made after the equipment is out of order and it cannot perform its normal function any longer.

Disadvantages of Breakdown Maintenance:

(i) Breakdowns generally occur at unforseen times. This leads to poor, hurried maintenance and excessive delays in performing repairs.

(ii) Reduction of output.

(iii) Faster equipment deterioration.

(iv) Increased chances of accidents and less safety to both workers and the fire suppression system.

(v) More spoilt material.

(vi) Might result to losses especially if the lack of periodic maintenance has a negative effect.

Scheduled Maintenance:

Scheduled maintenance is any repair and upkeep work performed within a set timeframe. It details when given maintenance tasks are performed and by whom. Scheduled maintenance may occur at repeating intervals or in response to a work request.

Scheduled maintenance is a stich-in-time procedure aimed at avoiding breakdowns.

Breakdowns can be dangerous to life and as far as possible should be minimized. Scheduled maintenance practice incorporates (in it), inspection, lubrication, repair and overhaul of certain equipment which if neglected can result in breakdown.

Inspection, lubrication, servicing, etc., of these equipment are included in the predetermined schedule.

Preventive Maintenance:

Preventive maintenance (PM) is **the regular and routine maintenance of equipment and assets in** order to keep them running and prevent any costly unplanned downtime from unexpected equipment failure. A successful maintenance strategy requires planning and scheduling maintenance of equipment before a problem occurs.

6.2.7.4. Learning Activities

Practical Activities

You are required to take a visit to a facility managers office and gather information of the different methods of maintenance performed on their fire suppression systems

6.2.7.5. Self-Assessment

1. State four disadvantages of breakdown maintenance.
2. Describe the corrective maintenance method

3. Differentiate preventive from schedule maintenance
4. State three classification of maintenance.
5. State the purpose of maintenance

6.2.7.6. Tools, Equipment, Supplies and Materials

Notebook & Pens

6.2.7.7. References

Curry, B , Smith C.J, 2015. The Motivate Series: Plumbing Principles and Practices (3rd Edition). Macmillan

6.2.7.8. Model Answers

1. State four disadvantages of breakdown maintenance

- Reduction of output.
- Faster equipment deterioration.
- Increased chances of accidents and less safety to both workers and the system.
- Might result to losses especially if the lack of periodic maintenance has a negative effect.
- More spoilt material.
- This leads to poor, hurried maintenance and excessive delays in performing repairs

2. **Describe the corrective maintenance method**

   Corrective or breakdown maintenance implies that repairs are made after the equipment is out of order and it cannot perform its normal function any longer.

3. **Differentiate preventive from schedule maintenance**

   Preventive maintenance is the regular and routine maintenance of equipment and **assets in** order to keep them running and prevent any costly unplanned downtime from unexpected equipment failure while **Scheduled** maintenance is any repair and upkeep work performed within a set timeframe.

4. **State three classification of maintenance**.

a. Corrective or breakdown maintenance,

b. Scheduled maintenance,

c. Preventive maintenance

5. State the purpose of maintenance

- To prevent problems arising,
- To put faults right
- To ensure equipment is working effectively.

CHAPTER 7: MAINTANANCE OF PLUMBING SYSTEMS

Unit of learning code: **CON/CU/PL/CR/07/5/A**

Related unit of competency in occupational standard: Maintain plumbing systems

7.1 Introduction to the unit of learning

This unit specifies the competencies required to maintain plumbing systems. It involves detecting faults in plumbing systems, quantifying requirements for repair, fixing plumbing system faults and testing plumbing system.

7.2 Summary of Learning Outcomes

1. Detect plumbing systems faults
2. Quantify requirements for repair
3. Fixing plumbing system faults
4. Test plumbing system

7.2.1 Learning outcome 1: Detect plumbing systems faults

7.2.1.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to detect plumbing systems faults. It includes definition of terms and concepts, common faults in plumbing works, causes of faults in plumbing works and ways of rectifying faults in plumbing works

7.2.1.2 Performance Standard

1. Faults in plumbing systems are detected based on functionality
2. Possible causes of the plumbing faults are classified based on routine maintenance reports, design purpose, manufacturer's manual and best practice.
3. Solution for the fault is identified based on best practice.

7.2.1.3 Information Sheet

A plumbing system refers to a system of pipework and fittings so connected for the purpose of supplying cold water, hot water, gas and discharge of waste or used water. In some instances the system may develop faults that will need to be rectified. It will be necessary for one to understand and troubleshoot the fault and fix the fault

TERMS AND CONCEPTS

- O-ring: This is a small rubber ring that goes on the stem screw. It helps to hold the handle in place.
- Aerator: This is the mesh filter at the end of the spigot.
- Refill tube: is the component that replenishes the water within the tank.
- Flapper: a round rubber seal that stops water from draining from the tank and into the toilet bowl.
- Flapper chains: This chain is the component that pulls open the flush valve and allows fresh water into the tank as used water is flushed out.
- Float valve: This is a small ball that sinks down when the tank empties with a flush, opening up the inlet valve on the fill tube
- Heating Mechanism: Device used to heat the water within the storage tank. Electric tanks use two electrically powered internal heating elements. Gas heaters use a burner beneath the tank and have a flue system that allows exhaust to travel through the center of the tank (heating the water as it passes) before being vented outside.
- Thermostat: Measures and maintains the water temperature by calling for heat, when necessary. Using the thermostat, the temperature can be adjusted by the user.

COMMON FAULTS IN PLUMBING WORKS

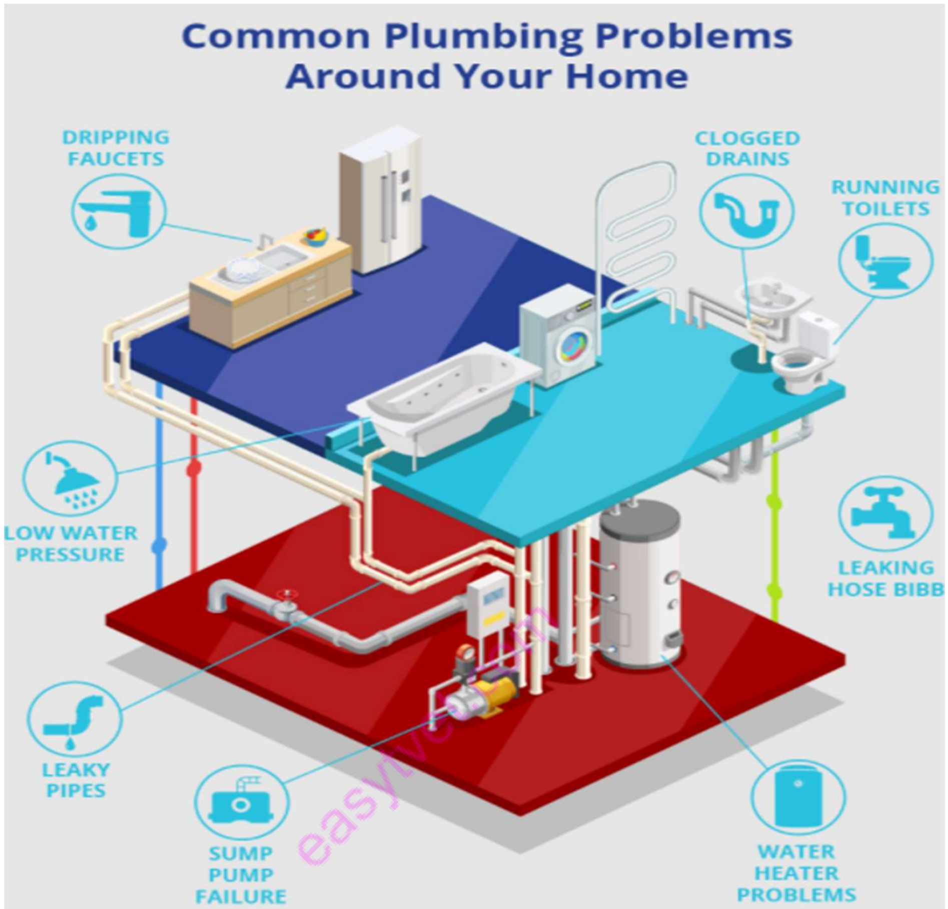


Figure 194 ***common faults in plumbing***

1. Dripping faucets

Some issues that might affect the performance of faucet include: leaks, squeaks and other problems.

2. Leaky pipes

Leaky pipes can be more than just a nuisance, they can cause damage to floors, walls, and furniture, and the dampness can encourage mold to grow as well as attracts bugs. Leaks almost always happen at the pipe joints.

3. Running toilet

A constantly running toilet is generally an indication that one or more internal components of the toilet tank has malfunctioned.

It includes problems like a slow-filling toilet, a toilet that leaks or is noisy or won't flush.

4. Low water pressure

A low water pressure indicates an issue in distribution. If it’s only occurring at one location, it’s usually an issue in the faucet aerator which is usually an easy fix. But if the water pressure is low in several spots around a home, that’s a sign of a bigger problem

5. Slow or clogged drains

Clogged drains are identified when water backs up when emptying a sink or taking a shower.

The kitchen sink drain may contain things like congealed fat and food remnants which may cause a foul smell as well.

In a bathroom sink, bath or shower, the blockage is more likely to be caused by knotted hair and soap scum. Instead of flushing normally, the water backs up in the toilet bowl and may even overflow.

6. Sump pump failure

Installed inside a covered basin in the basement floor, sump pumps tend not to get much attention until they fail. When the basin overflows with infiltrating groundwater that didn’t get properly pumped out, or a water pipe ruptures.

7. Water heater problems

Water heater failure can cause significant damage to the home.

8. Leaking hose bib

9. Sewer system backup

Sewer system backups are smelly, nasty, inconvenient, and can be expensive to fix. If multiple drains and toilets not working and presence of a bad odor of human waste, this is likely the problem.

CAUSES OF FAULTS IN PLUMBING WORKS

1. Dripping faucets

Dripping faucets are annoying, wasteful, and costly. Sometimes, these drips can be caused by:

- A worn-out washer or O-ring: Over time, an O-ring gets worn out as the handle gets pushed and pulled and at some point, a leak starts at the base of the handle.

- Improper faucet installation: If a washer was installed and wasn't the correct size, without a perfect seat, friction loosens the washer and lets water through.

- Old Cartridge: Mineral deposits also clog up the aerator with time and as it clogs, stress is placed on the seals and gaskets.

2. Leaky pipes

They can be caused by all sorts of problems, including:

- Stubborn clogs: When a clog goes untreated, pressure can build up behind it. This pressure can be too much for a pipe, causing it to crack or break.

- Incorrect pipe laying: When it comes to laying pipes, the job should be done by a licensed professional. Pipes and connectors have to be laid correctly. Backflow devices should be used as necessary. If not, leaks may develop.

- Pipe corrosion: When corrosion occurs, the pipe weakens and begins to break down. This can eventually result in a leak.

- Pipe joint damage: The joints are typically the weakest areas of pipes. They are the curved parts of the pipes that cause the water to change direction. In some cases, the joints can weaken over time, which can then allow a leak to form.

- Cracked seals or cracked pipes: Anywhere pipes connect to faucets or other fixtures, rubber seals should have been placed around them. Over time rubber seals wear out, get damaged and break. When the seals are damaged or broken, this breaks the watertight seal and as a result, water can get out.

- Excessive water pressure: Water going through pipes at high speeds increases the risk of pipes bursting. The sudden changes to the direction of water flow can be too much for pipes to bear, eventually resulting in leaks.

- Temperature changes: Temperature fluctuations can cause your pipes to expand or contract. When these fluctuations occur rapidly, expansion and contraction can damage the pipes. If the damage leads to the formation of a crack, then a leak can develop.

3. Running toilet

The issues that cause running toilets include:

- Refill tube problems: The refill tube of the toilet is the component that replenishes the water within the tank. The top of this tube should always remain above water level. However, if it doesn't, intermittent running may occur.

- Worn out flapper seals or flush valves: This component can age to the point of malfunction, or it can develop mineral deposits and/or wear down. All of these can prevent it from properly sealing.

- Improperly sized flapper chains: If the chain is either too long or too short, then it may interfere with the ability of the flush valve to properly close.
- Problems with the float valve: When the tank is filling, the float ball rises, which closes the valve and stops the filling process. If the float ball is misaligned or

malfunctioning in any way, it might not allow the valve to close completely and the water will continue to run.

4. Low water pressure

Low water pressure is a symptom plumbing problems like:

- Too much demand on water: In some homes, having multiple plumbing fixtures on at once can place too high of a demand on the water supply for proper water pressure to be maintained in every fixture.

- Pipe corrosion: When corrosion ultimately occurs, it leads to a buildup of rust. Eventually, this will cause a deterioration of water pressure, until they become blocked entirely.

- Hidden water leaks in your home: A slow leak can lead to a slow water pressure.

- Clogged pipes: If pipes become clogged, these blockages can disrupt water flow through your pipes. With the flow disrupted, water pressure will also go down.

- Cracked or blocked sewer lines

5. Slow or clogged drains

The most common causes of blocked drains are:

- **Unknown objects**: The problem of blocked drains occurs when foreign materials such as soap, hair, food, and fats build up between the drain-pipe and other pipes that flow at the bottom.

- **Heavy storms and rain**: After heavy rain or storms, drains present outdoors are blocked by the leaves, and dirt, etc. that cause the drains to block.

- **Damaged Pipes**: Another major cause of blocked drains is a broken pipe. For water to flow freely, it needs a perfect pipe, or else it may collapse. The main reasons for this are the poor installation of pipes, and tree roots. Tree roots cause high damage underground and might be difficult to investigate where the blockage is.

- **Water flow problems**: It is obvious that drainage is all about gravity. Inadequate falls will develop a regular build-up of dirt and debris leading to obstruction in your pipes.

6. Sump pump failure

Sump pump failures can be related to a problem with the unit or an external issue. Usually, the causes of sump pump failures include:

- Stuck switches: Sump pumps rely on the switch and the float arm in order to operate effectively, and when one of these fails it compromises the entire system.

- An overwhelming amount of water, like after heavy rain: With an excessive influx of water, flooding or heavy rains, the sump pump might not be able to deal with the high amount of water, especially if it's not powerful enough.

- Clogged discharge pipes: If the discharge line is clogged, water will flow back down the pipe.

- Improper sump pump installation: If the manufacturer's instructions are not followed carefully, water damage could result in the future. Improper installation could include anything from installing your pump on the wrong surface, to failing to install a check valve, to not drilling an air relief hole.

- Power failure: The most common cause for sump pump failure is an electrical power outage.

- Aging, with sump pumps around 10 years old being prone to failure

7. Water heater problems

Usually, water heater problems are caused by issues like:

- Heating element failures
    - Water is cold: Cold water is usually caused by either a lack of power, a faulty thermostat or a faulty heating element.

- Water is warm, but not hot enough: If water isn't getting hot enough, the cause could be an undersized water heater, crossed hot and cold connections, or a faulty heating element or thermostat.
- Water is too hot: When water is running too hot, it usually means the thermostat is set too high.

- Corrosion or sediment buildup in systems: Scale and sediment result from repeatedly heating "hard water." If allowed to accumulate without routine cleaning, it can lead to the destruction of one or both of the heating elements.

- Loose or broken electrical connections
- Improper water heater installation
- The wrong size or type of system to support a home's needs

8. Leaking hose bib

It is mostly caused by change in temperature.

9. Sewer system backup

There are three common causes for a sewer system backup:

- Root intrusion: Trees can grow really long roots that intertwine with sewer lines. Roots can grow into a pipe and cause holes or crush the sewer line by growing around it.

- Clogs: Sewage can back up into your home when either your home's drain pipes or main sewer line becomes clogged. Clogs can consist of hair, grease, or other solid materials that end up in the drains.

- Flooding: Flood waters overwhelming the local sanitary sewage system, if the system merges with stormwater drainage, can reduce the flow rate. Slower drainage can make wastewater back up into your home.
- Pipe misalignment.

RECTIFYING FAULTS IN PLUMBING WORKS

Dripping faucets

There are four kinds of faucets: cartridge, compression, ceramic disk, and ball type. A compression faucet relies on rubber washers to seal the valve seat, which can wear out and need to be replaced.

If your faucet is dripping:

- Replace washer or O ring
- Replace old cartridge

Faucet and cartridge

How to fix a leaky cartridge faucet

Figure 195 ***Leaky faucet***

i. Pry off the decorative cap on the handle, remove the handle screw, tilt the handle back, and pull it off.
ii. If there's a threaded retaining clip holding the cartridge in place, use needle-nose pliers to remove it, then pull the cartridge straight up.
iii. Remove the spout and cut off the old O-rings using a utility knife. Coat the new O-rings with nontoxic, heat-proof plumber's grease.
iv. To replace the entire cartridge, match the length of the old cartridge with the length of the replacement. Also match the stem end where the handle attaches.

Compression Faucet

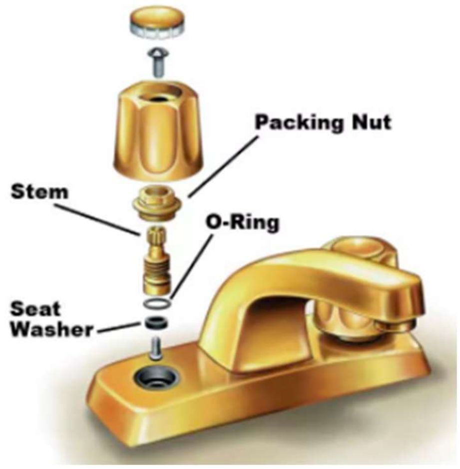


Figure 196 ***Compression faucet***

How to fix a leaky compression faucet

i. Most leaky compression faucets need new seat washers. Use a small slotted screwdriver or utility knife to pry off the decorative cap on the handle, exposing the attachment screws.
ii. Use a screwdriver to remove the handle screw, then pull off the handle.
iii. Use a crescent wrench to unscrew the packing nut and an adjustable wrench to loosen the stem from the faucet body.
iv. Unscrew the rubber washer from the bottom end of the stem to remove and replace the seat washer.
v. Coat the washers with nontoxic, heat-proof plumber's grease.
vi. Pop the stem out of the packing nut and replace the O-ring, the culprit for leaky handles. O-rings range in size from 3/8 to 5/8 inch, so it's crucial to match the exact size of your faucet. Coat the new O-ring with plumber's grease.
vii. The washer sits in a round, recessed disk called a retainer. If the original retainer is damaged, grind it flush and install a replacement retainer ring. If your faucet continues to leak, the seat may be pitted.
viii. Remove the stem and sand the top end of the seat with emery cloth to smooth it out.
ix. If you can't repair the original seat, replace it with a new one

Ceramic-disk Faucet

How to fix a leaky ceramic disk faucet

Leaky ceramic faucet

i. Push the handle back to access the set screw. Remove the screw and lift off the handle.
ii. Remove the escutcheon cap, unscrew the disk cylinder mounting screws, and lift out the cylinder.
iii. With a blunt screwdriver, lift out the neoprene seals from the cylinder. If the seals are damaged, replace them.
iv. Use distilled white vinegar and a soft scouring pad to clean the cylinder openings, then rinse them thoroughly.
v. Replace the seals and reassemble the faucet.
vi. Move the handle to the “on” position and turn the water back on slowly—the force of the returning water can fracture the ceramic disk.
vii. If you’re replacing the entire cylinder (usually not necessary), set it in place and secure it with the new mounting screws.

Ball-type faucet

How to fix a leaky faucet ball-type

This type of faucet contains a lot of parts, which often makes it difficult to find the cause of the leak.

Ball-type faucet

i. Use a pocketknife to pry off the small index cover from the side of the faucet and reveal the hex-head screw.
ii. Loosen the screw with a hex-key wrench and pull off the faucet handle.
iii. Use adjustable pliers to remove the cap and collar.
iv. Using the special tool included in the faucet-repair kit, loosen the faucet cam and lift it out, along with the cam washer and the rotating ball.
v. Reach into the faucet body with needle-nose pliers and remove the rubber seats and springs.
vi. Slip a new spring and rubber seat onto the tip of a pencil and lower it down into the faucet.
vii. Repeat to install the second seat and spring.
viii. Reinstall the stainless-steel ball, making sure to align its keyway with the corresponding tab inside the faucet body.
ix. On top of the stainless-steel ball, install a new rubber gasket and cam cap.
x. Align the keyway on the cap with the corresponding slot.
xi. Hand-tighten the top cap assembly back onto the faucet.
xii. Use a spanner wrench to tighten the nut to provide the proper tension against the stainless-steel ball.

Leaky pipes

How to seal a leaky pipe

- Tape - If a quick fix is needed, waterproof duct tape will be used. Make sure the pipe is bone-dry and apply the tape. Keep wrapping it tightly around the pipe until it is completely sealed.
- Epoxy paste - Cover the crack with epoxy paste and rubber. Wait for it to set and it should temporarily stop the leak.
- Self-tapping plugs - These are plugs that can be inserted into the hole of a pipe and they will expand to fit them.

Whichever temporary fix used, leave it for at least an hour or two to give the repair time to set.

How to fix a copper pipe leak at the joint

Threaded pipes and copper fittings are prone to leaks. To prevent future problems or repair a current leak, seal them with either Teflon tape i. e. plumber's tape or a spray sealant for water leaks.

It needs to be wrapped around the pipe in the opposite direction of how the pipe turns into the fitting. The steps below should be followed on how to use plumber's tape correctly:

i. Clean the pipe with a clean rag
ii. Place the end of the pipe leak tape on the second thread from the end of the pipe and hold it in place
iii. Wrap the tape around the pipe in the opposite direction to the way the pipe turns into the fitting
iv. Make sure the pipe leak tape is wrapped tightly and overlap it as you go
v. Wrap it around 4-6 times
vi. Break the tape off and smooth down over your pipe
vii. Leave for an hour or two before turning the water back on

Replacement

Sometimes, a PVC pipe is too damaged for a simple repair. If this is the case, the damaged section will need to be replaced with a new PVC pipe. To replace the pipe, first, water to the pipe should be turned off.

i. Cut the pipe about one inch to the left and to the right of the damaged area using a ratchet cutter or hacksaw.
ii. Allow any excess water to come out of the pipe and dry with a clean cloth.
iii. Once the damaged pipe is cut away, dry-fit the replacement pipe in the hole, ensuring the pipe's fitting is properly secured around the existing PVC.
iv. Apply PVC primer solvent to the inside of the replacement pipe's fittings and to the outside of the existing pipe.
v. Then, apply glue to the existing, exposed PVC pipe and around the inside of the replacement fitting.
vi. Insert the existing pipe into the replacement fittings, using a twisting motion to secure the pipe with glue.
vii. Hold the pipe firmly for 10 seconds to ensure a strong bond.

Running toilet

A constantly running toilet, or a toilet that tops up its tank by itself, can stem from a variety of issues, including a faulty flapper, a high-water level, or a water-logged float. If none of these seem to be the problem, it probably has a broken valve.

How to fix a running toilet:

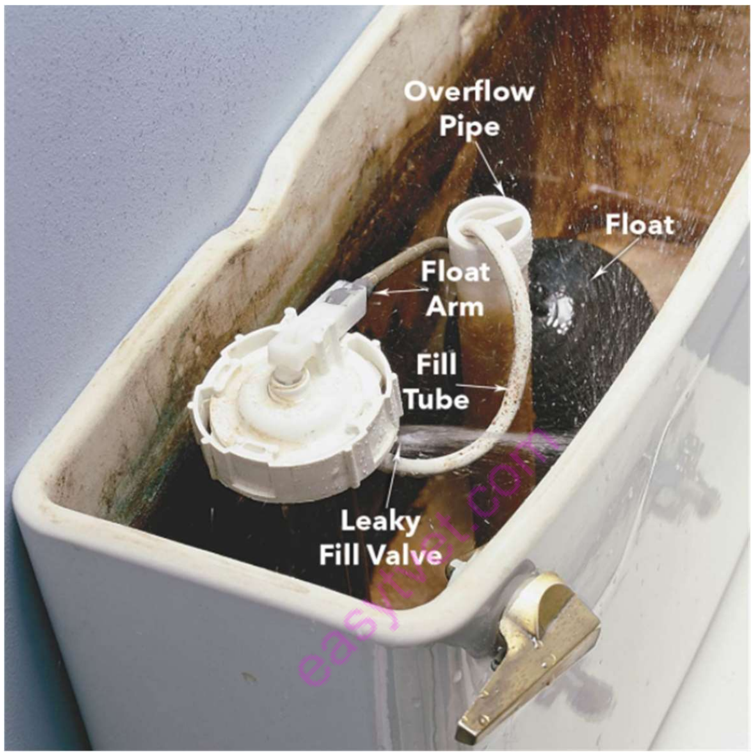
Test the flapper:
A toilet's flapper is a plastic or rubber cap that keeps water in your tank. Over time, your flapper can become brittle and create a faulty seal.

- Push down on the flapper with a stick when you hear the water running and listen for it to stop.
- If it stops, you know the flapper isn't sealing properly. Replace it.
- Check the fill tube length and cut it back so it's at least 1/2-in. above the water line.
- To replace the flapper, first shut off the water supply valve under the toilet
- Flush the toilet to drain out most of the water, then unhook the old flapper.
- Buy a new flapper of the same type and install it according to the instructions on the package.
- Hook the flapper chain onto the flush lever arm so there's a little slack when the flapper is closed.

Test the flapper

Check the fill valve for a leak

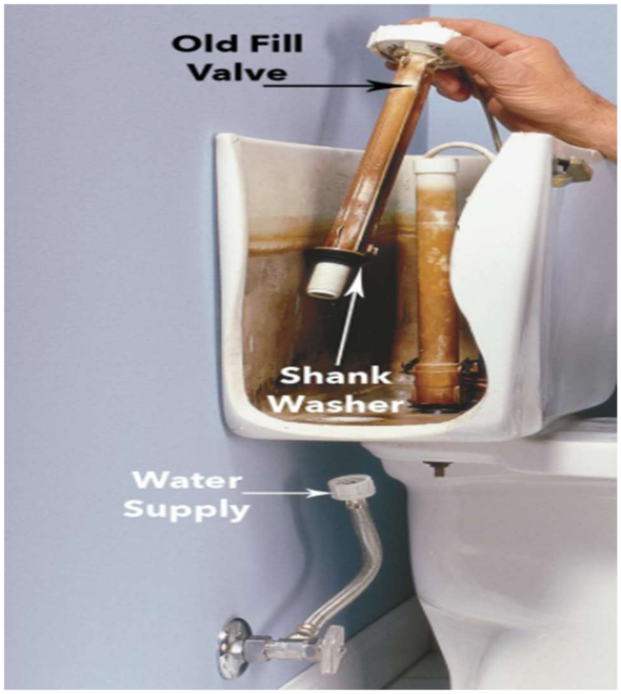
- Flush the toilet and look for a fill valve leak.
- Lift up on the toilet float arm when the tank is filling to see if the water stops.
- Bend or adjust the toilet float arm so the tank stops filling when the water level is 1/2- to one-inch below the top of the overflow pipe.
- If the fill valve still leaks, replace it.



Check the fill valve

Remove and replace old toilet fill valve

- Turn off the water supply, flush the toilet and sponge the remaining water from the tank.
- Disconnect the water supply line, unscrew the fill valve locknut and lift out the old fill valve.

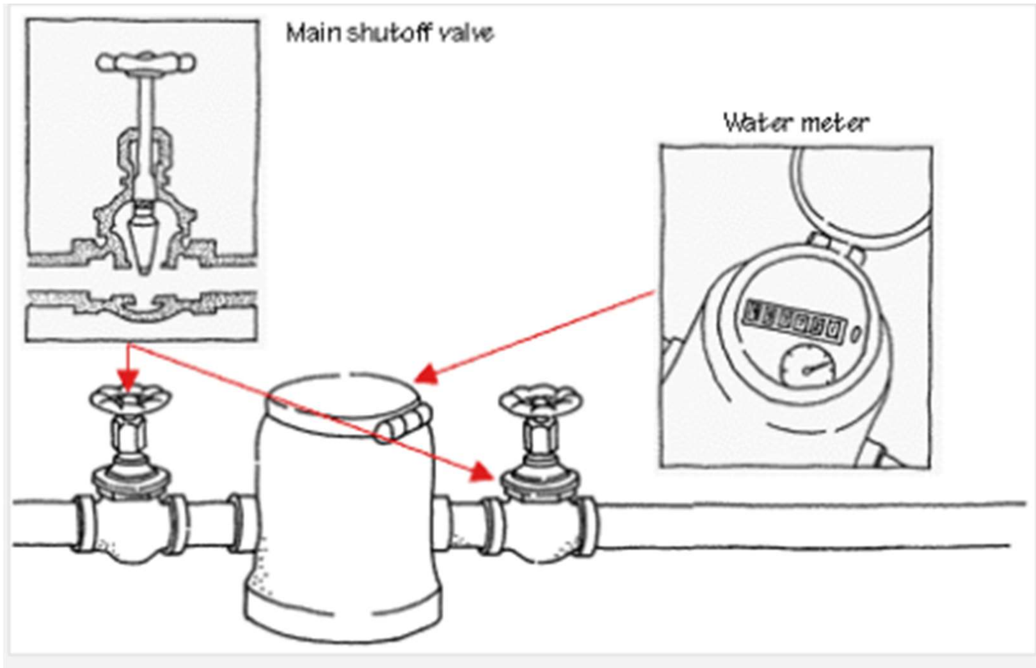


replacing old toilet fill valve

- Insert the new fill valve into the tank according to the instruction sheet and tighten the locknut a half turn past hand tight.

Low water pressure

- There should be a water shutoff valve next to the meter, in fact, there may be one on each side of the meter as shown below.



meter

Be sure the valves are entirely open turned counter clockwise as far as they will go. If you discover that a supply valve is partially closed, opening it should solve the problem.

- If low pressure is still being experienced, pipes need to be cleaned out or replaced to address the issue.

Slow or clogged drains

i. Most bathroom drain clogs result when dirt, skin flakes, and especially hair binds to soap scum on the walls of drain pipes. Over time, this gunk accumulates and reduces water flow.
Troubleshooting: Remove and clean the drain stopper. Use the humble drain plunger, keeping in mind to block the over-flow drain in the tub or sink. If that doesn't work, remove the drain elbow joint and clean it out. Clean drain stoppers routinely to prevent clogs and use a hair strainer drain-cover to trap hair before it goes down the drain.

ii. Clogged toilets mainly happen when people try flushing down items that do not dissolve or break apart in water.
Troubleshooting: The plunger is the first. The most effective plungers shoot jets of water to clear the drain pipe. Many have anti-microbial coatings. Next, use an inexpensive hand-powered drain auger. While not a pleasant experience, a hand auger can reach between 2 to 5 feet down the toilet's drain pipe to break-up or retrieve things that are blocking the pipe.

iii. Kitchen sink drains clog when cooking grease or oil cake onto drain pipe walls.
Troubleshooting 1: Start by running very hot water down the drain to soften the clog, followed by a dollop of dish detergent and then more hot water. Wait a few minutes, and then use a plunger and repeat the hot water. If you still have no luck, you might want to move onto a chemical drain opener. Again, use caution.

Troubleshoot 2: Take half a cup of baking soda and pour down the drain, and then pour half a cup of vinegar. After 15 minutes, flush out the drain with hot water

Add equal parts of salt, vinegar and baking soda. After one hour pour hot water into it

Add half a cup of salt and equal amount of baking soda, sprinkle it into the drain and then flush it with hot water.

iv. Drain pipe slope determines how well water carries waste to the sewer line. If there's too much slope, water can run too fast and leave waste material behind. Over time, the buildup forms a blockage. If the pipe slope doesn't have enough slope, then the water and waste pool in the pipe. Some waste will settle out and, again, form a blockage.
Troubleshooting: First, check that nothing is blocking the vent pipe opening on your roof. Sometimes birds or other animals build nests on top of un-enclosed vent pipes for warmth. Also check under sinks for gulp valves. Gulp valves are typically mounted at the end of a drain line and look like a plastic cap from a can of spray paint. The valve prevents sewer gas from escaping the drain line but lets air into the vent pipe when there's enough suction. If you fill the sink with water and then drain it out all at once, you should hear air getting sucked into the gulp valve. If not, the valve might need to be

replaced. Also, if there is a constant odour of raw sewage in your home, contact a professional plumbing service immediately.

Sump pump failure

Ensure that: Ooccasional checks are performed on the sump pump.
Proper sump pump installation is done

How to unclog a sump pump

i. Unplug the sump pump.
ii. Pick the sump pump up and turn it over to examine the impeller at the bottom of the pump. If there is nothing visibly lodged in the impeller, try spinning the impeller with a finger. If it moves freely, the impeller is not the problem.
iii. Replace the pump and plug it back in.
iv. Grasp the hose in one hand and activate the pump's switch manually by gently pulling up on the float with the other hand until the pump comes on.
v. Shake the hose vigorously while the pump is running. This should dislodge anything that is clogging the inside of the hose and water should start to run freely again.
vi. If water does not start running, remove the hose and lay it flat on the floor. Shine a flashlight in one end and see if you can see the light coming out the far end of the hose. If not, you can try cleaning the hose out with a broomstick. However, the easiest thing to do is to replace the hose.
vii. If the pump still seems to be clogged, something must be lodged inside the pump's chamber. Seek professional help.

Water heater problems

Condensation

A puddle on the floor may be the result of condensation that formed on the outside of the tank. Condensation occurs when most of the water inside the tank is cold. This can happen during periods when hot water usage in the home is especially high. The cold tank, reacting with the warmer air inside the home, causes condensation. The water then drips off the tank and onto the floor, which gives the appearance of a leaking tank.

Try to even out hot water demands in the household so that less than half the tank contains cold water at any given time.

Pipes

A typical hot water heater connects to two pipes -- a cold water supply line and a hot water line. The pipes often have elbow joints so they can bend toward the water heater. Either of these water lines can leak, particularly at the joints. If water sprays from a fitting or pipe, the problem is clear. A dripping pipe or joint is less noticeable.

Tighten loose fitting joints to stop leaks. If this does not solve the leak, turn off the water supply and power supply, then disconnect the fittings. Allow the temperature on hot water lines to cool down before working on them. Wrap the threaded end of each fitting with plumber's tape, then reconnect the joints.

Gaskets

Electric hot water heaters rely on one or two heating elements to warm the water. Because the elements project into the tank, they are sealed with gaskets to prevent leakage. Water may collect under the tank if the gaskets wear or become damaged to the point of leaking. Each element is behind a cover plate, but you must turn off electrical power to the water heater before examining the elements.

Move the insulation out of your way, and check all around the element gaskets for the presence of water, which indicates a drip. Drain the tank before removing and replacing elements and element gaskets.

Pressure Relief Valve

Should pressure rise too high inside the tank, the relief valve opens. Steam escapes and the pressure returns to normal. Once inside the house, the steam quickly condensates and produces a puddle at the bottom of the tank. Too high an operating temperature is usually to blame for excessive tank pressure. Keep the hot water at about 120 degrees Fahrenheit to keep pressure in check and save on energy costs at the same time.

If pressures build often, especially after turning down the water heater's thermostat, a faulty pressure relief valve is the likely cause. Have a professional plumbing professional replace the valve. A faulty pressure relief valve is a potentially dangerous situation and must be addressed immediately.

Tank

Once the tank itself starts to leak water, and you are certain there is no other cause for the leakage, it's time to replace the water heater. The inside of the tank eventually corrodes from mineral deposits and from the constant strain of heating and cooling. There is no way to repair a leaking tank.

Leaking hose bibb

Fixing a leaky hose bib almost always involves one (or both) of two things:

- Replacing the compression washer at the end of the inner valve stem. This will allow the stem to fully close down against the valve seat, keeping the hose bib from constantly dripping.
- Replacing the packing string that is wrapped around the valve stem under the packing nut. This will prevent water from seeping up around the handle each time you use the faucet.

leaking hose bibb

It's generally easiest to address both possible causes of leaking when servicing a hose bib the stem washer and the handle packing string.

1. Shut Off the Water

Begin by shutting off the water to the hose bib.

2. Remove the Handle

Use a screwdriver to remove the screw that holds the handle of the hose bib to the valve stem, then pull the handle off a bit of wiggling may be required. Carefully set the handle and screw aside.

3. Unscrew the Packing Nut

Next, use a channel-lock pliers or adjustable wrench to unscrew the packing nut (sometimes called a bonnet nut) that secures the valve stem to the faucet body.

4. Remove the Valve Stem

Remove the valve stem from the faucet body. Usually this involves unscrewing the stem from the threaded body of the faucet

Inspect the rubber or neoprene washer at the end of the valve stem. If it is hardened, cracked, or deformed, this is very likely the cause of your leaky faucet. Unscrew the brass screw holding the washer in place on the stem. Brass is a soft metal, so use care when unscrewing it. If the screw gets damaged, you may need to replace it washer kits often come with replacement screws.

Choose an exact replacement for the old washer and attach it to the end of the valve stem with a screw.

5. Replace the Packing String

Unwrap the old graphite or Teflon packing string from around the valve stem beneath the packing nut, then wrap several loops of new strong around the stem in a clockwise direction .

6. Reassemble the Faucet

Thread the valve stem back into the body of the faucet, then thread the packing nut onto the top of the faucet. Tighten the packing nut slightly with a wrench, then put the faucet handle back onto the stem and check the operation of the faucet. Tightening the packing nut too much may make the handle hard to turn. The handle should turn freely, and you should be able to feel the washer compress down against the valve seat inside the faucet.

7. Test the Faucet

Turn the water back on and check the operation of the faucet, inspecting for leaks. If you experience any leaking around the handle, slightly tighten the packing nut a little further.

Sewer system backup

How to rectify a sewage backup

- Install a new plastic pipe or cut tree roots. To prevent tree roots from damaging a sewer line, replace it with a new plastic pipe. If tree roots still grow in the sewer, cut the roots occasionally.
- Install a backwater prevention valve. This fixture allows sewage to leave but prevents it from backing up into your home. Backwater valves are typically installed into a sewer line and sometimes into a drain line in the basement.
- Sewage pump maintenance. Ensure the sump pump is constantly checked.

7.2.1.4 Learning Activities

Activity:

Clogged drain and toilet.

- A toilet suddenly shows immediate signs of a clog. Instead of flushing normally, the water backs up in the toilet bowl and even overflows.
- You are expected to clear the blockage to restore the drains or toilet back to normal.

7.2.1.5 Self-Assessment

1. **What tools are required to unclog a sink?**
2. What is the home remedies to clear clogged drain?
3. Explain what is the common reason for sump pump failure?
4. Explain how you can fix a leaky PVC water pipe?
5. **What is referred as building drain?**
6. What is meant by air lock?
7. How can one avoid low water pressure?
8. A client has an old brass faucet in their bathroom that they want to keep, but it constantly drips hot water from its spout. They have replaced the washer in the hot water faucet, but the spout still drips. How can the faucet be repaired so as it stops wasting the hot water?
9. Why would the water bill of a client be extremely high?

10. Is it safe to use chemical drain cleaners?

7.2.1.6 Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:

Tools and Equipment

- Pipe wrench
- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vices
- Taps
- Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Portable drill
- Mallet
- Ball pein hammer
- Mason chisel
- PPR machine / Heat Fusion equipment
- Pipe bender
- Trowel
- De-clogging wire / de-clogging machine
- Toilet pump

Supplies and Materials

- Screws
- Adhesives
- Cement
- Sand
- Pipes
- Traps
- Electric cables
- Caulking material
- Fitting
-

7.2.1.7 References

C.J. Smith., B. Curry., Practical Plumbing (The Motivate series).,1998

F. Hall., Plumbing Technology

Black & Decker., The Complete Guide to Plumbing.,2008

Model Answers

1. What tools are required to unclog a sink?
    - Cup Plunger
    - Duct tape or wash cloth
    - Sink Auger
    - Channeled type pliers
    - Bucket

2. What is the home remedies to clear clogged drain?

    - Take half a cup of baking soda and pour down the drain, and then pour half a cup of vinegar. After 15 minutes, flush out the drain with hot water
    - Add equal parts of salt, vinegar and baking soda. After one hour pour hot water into it
    - Add half a cup of salt and equal amount of baking soda, sprinkle it into the drain and then flush it with hot water

3. Explain what is the common reason for sump pump failure?
   Sump pump is usually used in the basement area to remove the accumulated water during flood. Moreover, there are few reason it may stop working all of sudden.

   Switching problem
   Accumulation of excess debris, interfering with the switching
   The pump can move inside the basin, and that may interfere with the switching mechanism

4. Explain how you can fix a leaky PVC water pipe?
    i. Drain the water out and make the leakage pipe dry
    ii. Now take a coupling, similar to the size of the pipe that is leaking
    iii. Now cut the coupling into half
    iv. Make sure that the half you going to use should have stop inside, as you have to slide the leakage pipe into it
    v. Slather the inside of the patch with adhesive, make sure that you have enough of the adhesive on your patch, as that is the portion that going to connect with the leaked pipe.

vi. Place the patch onto the pipe and slide it into place and keep it overnight to get dry

5. What is referred as building drain?

The lowest point in a drainage system where the interior drainage pipe meet and are conveyed into the sewer is referred as Building Drain.

6. What is meant by air lock?

The confining of air between two traps. Air lock may occur both on the drainage and on the hot and cold-water supply system.

7. How can one avoid low water pressure?
   - Install a filtration system to keep minerals out of your pipes to avoid future build-up.
   - Check pipes regularly to find and repair leaks early.

8. A client has an old brass faucet in their bathroom that they want to keep, but it constantly drips hot water from its spout. They have replaced the washer in the hot water faucet, but the spout still drips. How can the faucet be repaired so as it stops wasting the hot water?

A spout leak in a compression faucet is caused either by a defective seat washer or a damaged valve seat. They can replace most valve seats with exact duplicates, using a valve seat wrench. If a worn valve seat can't be removed, use a valve seat dresser to grind it until smooth.

9. Why would the water bill of a client be extremely high?

A ridiculously high-water bill can be as a result of any of the following factors:

- Leaky taps or faucets

This is the most common cause of increase rate in water bills - a dripping faucet wastes water and causes an increase in the utility bill.

- Leaking toilets

Toilets account for 24% of the water used daily. It has been estimated that a leaking toilet can waste up to 200 gallons of water daily.

- Inefficient fixtures

Outdated plumbing works are the causes of leaks and other plumbing problems. If you are experiencing a hike in water bills, it may be time to have the outdated plumbing works replaced.

- Leaky Line

An increase in water bills can be caused when the underground water pipes in your home are leaking or loose. These can be caused by tree roots activity, animal activity, or even earthquakes.

- Water Waste

The water bills may be high because water is used recklessly.

10. Is it safe to use chemical drain cleaners?

Drain cleaners are usually very toxic, not a good thing to keep around the home especially if you have children or pets. These toxic chemicals also have a negative effect on your pipes, causing deterioration from the inside out. When this happens, the drains lines will need to be replaced. There are various products on the market that contain "friendly" bacteria and enzymes. These work great for keeping drain sludge and grease from building up on the pipes. For serious clogs contact a professional plumber.

7.2.2 Learning Outcome 2: Quantify requirements for repair.

7.2.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to Quantify requirements for repair. It includes, definition of terms and concepts, materials and supplies for repair, estimation of quantities, appliance and fittings and reference to manufacturer's manual.

7.2.2.2 Performance Standard

1. Appliances and fittings that need replacement are identified based on the requirements of the job.
2. Materials required for plumbing fault repair are identified based on requirements of the job.
3. Supplies required for plumbing fault repair are identified based on requirements of the job.
4. Materials and supplies required are quantified and costed based on specifications

7.2.2.3 Information Sheet

Terms and concepts

Pipe fitting: It is used in the plumbing system to join multiple pipes of same size or different sizes, to regulate the flow or to measure the flow.

Materials and supplies for repair

Adhesives

Keeping seals tight and waterproof is essential, from bathroom and plumbing applications to aquariums. Plumbing sealants prevent water damage and help keep fixtures, sinks, and faucets working for a long time.

What are plumbing silicone sealants?
Silicone sealants are a form of liquid adhesive commonly used in building, bonding, and repairing many materials, including finishing joints and filling seams or other gaps. Since they are waterproof and offer durable elasticity and stability in both high and low temperatures, silicone sealants work particularly well as plumbing sealants.

Plumbing silicone sealants are typically available in tubes and cartridges. Because of their many practical uses and easy, tidy application, silicone sealants can be a good alternative to putty for sealing bonds around plumbing fixtures. Other uses include the undersides of sink strainers or pop-up drain fittings for sinks and tubs.

APPLYING A PLUMBING SILICONE SEALANT
Applying plumbing silicone sealant is an easy process, but doing it properly is critical to ensure a durable, waterproof seal.

i. Clean the surface. Make sure that the surface is completely clean and dry. Any dust, dirt, or particles can potentially cause a weaker seal.
ii. Using the sealant cartridge. Load the cartridge into a sealant gun. Use a hobby knife to cut off the cartridge seal and open the applicator nozzle, just enough to allow a narrow line of sealant. Pull the handle to fill the nozzle with sealant.
iii. Apply the sealant. Hold the gun at a 45-degree angle. Squeeze the trigger carefully to create an even, steady flow of sealant, dragging the tube nozzle slowly along the target seam. For an even seal, wet your finger with soapy water and spread the applied sealant evenly along the seam, clearing away any excess or residue as you go.
iv. Curing. Silicone sealants must cure before achieving full bond strength. Curing silicone doesn’t require any special steps, just a bit of patience. Curing can take from 24 hours to several days (check your product’s instructions).

Pipes

Pipes must not contaminate water, and must be suitable for the pressure, flow and temperature of the water they are carrying.

Factors to consider
Pipe materials and components must not contaminate potable water. They must also be:

- suitable for the expected temperatures and pressures
- compatible with the water supply, to minimize the potential for electrolytic corrosion
- suitable for the ground conditions (if used underground) to minimize the potential for corrosion of the exterior of the pipe
- suitable for the local climate (if used outdoors) such as freezing conditions or atmospheric salt or Sulphur
- able to withstand UV effects (if used outdoors).

1. Copper

Copper has long been used for all types of domestic water services and distribution because it:

- is durable
- has good corrosion resistance
- is malleable and easy to bend
- is self-supporting
- has good flow characteristics
- requires few fittings
- can be recycled.

Copper may be annealed (i.e., heated, then cooled slowly) which improves its properties, for example making it less brittle and stronger.
Although copper in general has good corrosion resistance, this depends on the environment. Acidic conditions, either from the soil (if buried) or from the water, can cause corrosion, so local pH levels should be checked before using copper pipes.

2. Polybutylene (PB)

Polybutylene is a plastic material that was introduced in the late 1970s and used extensively for water supply pipes until the mid-1990s. Unfortunately, one brand of polybutylene gained a reputation for failure, resulting in a significant drop in use.

Polybutylene has excellent properties for use as water supply pipework, including:

- low cost

- flexibility
- ease of installation
- ability to be used for both hot and cold-water services
- frost resistance.

In outdoor situations, it must be protected from UV exposure.

3. Polyethylene

High density polyethylene (often called alkathene or polythene) has been used since the early 1960s. It is suitable for both potable water and wastewater services but it can only be used for cold water supply.

It is the most commonly used plastic pipe for supplying the mains water to a dwelling.

Polyethylene:

- is durable
- is corrosion resistant
- has good flow characteristics
- is lightweight and flexible
- is easy to install
- has a good bending radius
- is inexpensive
- requires few fittings.

4. Polypropylene (PP)

There are three types of polypropylene:

- P-H has good mechanical properties and excellent chemical resistance for use as industrial and sewerage waste pipes systems
- PP-R has good resistance to high internal pressure so it is suitable for domestic pressure water supply systems and both hot and cold-water services
- PP-B is suitable for buried sewerage and wastewater drainage as it has good impact strength, particularly at low temperatures, and excellent chemical resistance.

The use of polypropylene has been increasing since the late 90s as it is:

- chemical and corrosion resistant
- heat resistant
- lightweight

- easy to install
- frost resistant.

In outdoor situations, it must be protected from UV exposure.

5. Cross – linked polyethylene (PEX)

PEX tubing is made from a cross-linked, high density polyethylene polymer, which results in a stronger material that polyethylene. Properties include:

- more durability under extremes of temperature and chemical attack
- greater resistance to cold temperatures, cracking and brittleness on impact
- it can be used for hot water supply and hydronic heating systems, as well as potable water supplies
- flexibility
- ease of installation
- it can be used for indoor and buried outdoor situations.

PEX is not recommended for outdoor above ground use – although it can withstand some UV exposure, this should not exceed the manufacturer's instructions.

6. Unplasticised Polyvinylchloride (Upvc or PVC-U)

Today in domestic construction it is used chiefly for drains, wastes and vents, and is rare for water supply in new individual houses. The primary jointing method for uPVC is solvent welding, where solvents soften the surfaces of the material, which then chemically fuse together. A rubber ring (elastomeric seal) joint system is also available. This piping:

- is inexpensive
- is easy to handle
- has low resistance to flow.

Traps

It is a fitting in a P-, U-, S- or J-shaped type. Traps are fitted near a plumbing fixture. The trap bend is fitted to prevent sewer gases from entering the building. If the gases are inserted back into home, then it could lead to people inhaling foul smell, which could cause illnesses. It could even explode.

Caulking agents

It is a sealant but differs from plumbers' putty. A big difference in both is that a silicone caulk cannot be replaced.

It is a sticky material and is an adhesive one. It is hard enough that you can use it everywhere. It also has a rubbery touch to it that keeps it elastic for quite some time. It can be so tight after applying, you would need a scrapping tool to remove this sealant.

Sealant and glue
Silicone sealants are a form of liquid adhesive commonly used in building, bonding, and repairing many materials, including finishing joints and filling seams or other gaps. Since they are waterproof and offer durable elasticity and stability in both high and low temperatures, silicone sealants work particularly well as plumbing sealants.

Water proofing agents
Concrete is the main building material used in all civil constructions and it is prone to shrinking. Concrete hence requires protection due to porosity, cracks & potential to reaction with atmospheric gases such as CO2. Apart from that, the structures have various joints & connections which need to be considered & given extra protection.

Plumbing fittings
Various types of pipe fitting are available in plumbing systems for different purposes and functions. They are made up of different materials like copper, iron, brass, PVC, etc.
Some of the most common types are as follows.

Collar: While joining two pipes in the same length, collar is used. It is fitted at the end of the pipe.

Gasket: They are mechanical seals, generally ring-shaped and fitted for sealing flange joints. A flange joint is a plate or ring to form a rim at the end of a pipe when fastened to the pipe. Gaskets are made as per by construction, materials and features. Important gaskets used are nonmetallic, spiral-wound and ring-joint type.

Offset: When an assembly of fittings on a pipeline makes one section of pipe out of line and parallel to a second section, then it is known as an offset

Elbows: Such pipe fittings are used to change the direction of the flow. They are majorly available in two standard types - 90- and 45-degree angles owing to their high demand in plumbing. The 90-degree elbow is primarily used to connect hoses to water pumps, valves, and deck drains, while the 45 degree elbow is mostly used in water supply facilities, electronic and chemical industrial pipeline networks, food, air-conditioning pipelines, garden production, agriculture, and solar-energy facility.

Elbow

Couplings: A coupling is a pipe fitting used to stop leakages in broken or damaged pipes. The pipes to be connected should be of the same diameter. The two kinds of couplings used in plumbing are regular coupling and slip coupling. The regular coupling is arranged between the two pipes to prevent further leakages with the help of rubber seals or gaskets on the both sides. The slip coupling itself contains two pipes to repair the damaged lengthy pipes.

Coupling

Union: This type of pipe fitting is almost similar to coupling in terms of functions, but just with a difference, i.e. a union can be removed easily any time while the coupling cannot. A variety of dielectric unions are used to join pipes made of different materials to avoid any kind of galvanic corrosion between them. These pipe fittings comprise of a nut, female and male ended threads.

Union

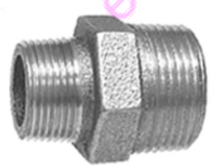
Adapters: Adapters are connected to pipes to either increase their lengths or if pipes do not have appropriate ends. These pipe fittings make the ends of the pipe either male or female threaded as per the need. This permits unlike pipes to be connected without any need of extensive setup. They are mostly used for PVC and copper pipes.

Adapter

Nipple: This is a short butt of a pipe that works as a connection between two other fittings having male threads. A close nipple is a type of pipe fitting having continuous threading on them. They are mostly used in hoses and plumbing.

Nipple

Reducer: This pipe setting is used to reduce the flow size of the pipe from the bigger to smaller one. There are two kinds of reducers- concentric reducer and eccentric reducer. Reducer the former one is in the shape of a cone used for gradual reducing of the size of the pipe. The latter one has its one edge facing the mouth of the connecting pipe reducing the chances of air accumulation.



Reducer

Tee: This T-shaped pipe fitting used in the plumbing system has one inlet and two outlets arranged at an angle of 90 degrees to the main pipe. This kind of fitting is used to connect the two pipes and make their flow direction as one. If all the three sides of this fitting are same in size, it is called equal tee, otherwise unequal tee.

Tee

Cross: This type of pipe fitting contains four openings in all the four major directions. This fitting is adjoined to four pipes meeting at common point. There is either one inlet and three outlets or vice-versa to flow water or any other liquid in four different directions. These kinds of pipe fittings are commonly used in fire sprinkler systems.

cross

Flanges: A flange is another pipe fitting used to connect pipes, pumps, valves, and other components to form a full-fledged piping system. They come with a flexibility of easily cleaning or inspecting the whole system from within. They are fixed to the pipes using welding, threading or screwing techniques and then finally sealed with the help of bolts. They are used in residential pump systems and majorly for industrial purposes.

Flanges

Caps & Plugs: Both these pipe fittings are used to close the ends of the pipe either temporarily or permanently. The plugs are fitted inside the pipe and threaded to keep the pipe for future use. There are a good number of ways a cap can be applied to the pipe like soldering, glue, or threading depending on the material of the pipe.

Caps and plugs

Bushings: These pipe fittings are used to combine pipes of different sizes together by decreasing the size of the larger fitting to the size of the smaller pipe. Bushings are not always threaded inside out and occupy very little space in comparison to a union or coupling used for the same purpose.

bushings

Wyes: Such type of pipe fittings are used in drainage systems and have a branch line at 45 degrees to keep the flow of water smooth. When the sanitary tees fail to work in a horizontal connection, such cases needs a wye.

Wyes

Valves: Valves are used in the plumbing system to stop the flow of gases or liquids. There are of three types:

- Throttling
- Isolation
- non-return.

The isolation valves are used to disconnect a part of the piping system temporarily for maintenance or repair.

The throttling valves are used to regulate the amount of pressure of a liquid in a pipe; they can also withstand the stress caused by this process.

Valves

Barb: A barb is another useful pipe fitting used in the plumbing system that connects flexible tubing to pipes. It has a male-threaded end on one side that connects with the female threads, and the other end has a single or a multi-barbed tube that is inserted in the flexible tubing.

Barb

Diverter tee: This kind of a tee-shaped pipe fitting is commonly used in the pressurized hydronic heating systems to redirect a part of the flow from the main line to the side branch connected to a heat exchanger.

Diverter Tee

Gaskets and O-rings

Gaskets: A gasket is a flat piece of material that sits between to flat surfaces. The gasket's material whether neoprene, rubber, silicone or another flexible substance prevents liquid or air (or sometimes both) from leaking in or out of an area.

O-Rings: They are circular, ring-shaped pieces that sit in a groove between two (usually cylindrical) parts. The compression of the two parts creates the airtight and liquid-tight seal.

O-rings can be made from many flexible materials, like rubber, neoprene, or polyurethane. While the ring-shape is a staple characteristic of o-rings, the height and thickness of the ring can vary based on your design.

Difference between a Gasket and O-Ring

Both perform the same basic function of stopping liquids or gasses from ingressing or egressing.

2. The shape of the seal is one key criteria where the difference between an O ring and a gasket becomes very clear. In some applications, only a gasket will work because the shape of the joint makes it difficult or impossible to design a good seal using an O ring, which requires a groove to sit in.

2. The other key factors are temperature and pressure. The material used to make the seal is a critical factor with regards to operating temperature. While both O rings and gaskets can perform well in a wide temperature range, gaskets have the edge in extreme temperatures. O rings, however, are the superior choice in applications with extreme pressure. Under pressure, an O ring's performance will improve while a gasket's effectiveness will decrease

Estimation of quantities

Illustration of a composite rate build-up for Sanitary Fittings

Composite Rate Build up - Wash Hand Basin

Step 1
Determine the group unit of measurement. When you are measuring e.g., a wash hand basin in elemental or approximate quantities estimating, the group unit of measurement is the number (No)

Step 2
The second step is listing all associated bill items that can be mapped to wash hand basins by number. These are:

- 520x440mm Vitreous china vanity basin and accessories: (No.) Rate – Ksh.6,000.00
- 15mm basin mixer and accessories – (No.) Rate – Ksh.3, 000.00
- 40mm Brass sink P trap – (No.) Rate – Ksh.600.00
- 15mm Star chrome plated bibtap and accessories – (No.) Rate – Ksh.4, 000.00
- 15mm Copper service pipe 350mm girth – (No.) Rate – Ksh.300.00

- 15mm Chromium plated full way ballcock shut-off control valve with screw type control – (No.) Rate – Ksh.500.00

Step 3

Rate build up for items which are linked to the wash basin by number. Since the group unit is the number (No.), you should convert the bill item rates to cost per wash hand basin.

Rate build up

Sanitary fitting	**Quantity (No.)**	**Rate cost per wash hand basin Ksh.**
Vitreous China Vanity basin	1No.	6, 000. 00
Basin mixer	1No.	3, 000. 00
Sink P trap	1No.	600. 00
Bibtap	1No.	4,000. 00
Copper service pipe	1No.	300.00
Shut-off control valve	1No.	500.00
Composite Rate – Sanitary fittings		14, 400. 00

The composite rate for items which can be mapped to the Wash Basin by number is Ksh.14,400.00 per wash basin.

Elemental Layout and Grouping

Items which go into the element INTERNAL PLUMBING and component Sanitary Fittings are stated in the description below:

	Unit	**Quantity**	**Unit rate**	**Cost/ m^2**	**Subtotal**	**Cost**
Internal plumbing						
520x440mm Vitreous china drop-in vanity basin including 15mm basin mixer, 40mm Brass sink P trap,	No		14,400.00			

15mm Star chrome plated bibtap, 15mm Copper service pipe 350mm girth, 15mm Chromium plated full way ballcock shut-off control valve and all accessories – chains, waste union, plug, brackets etc.						

7.2.2.4 Learning Activities

Activity

A client has an issue with a water closet that is consistently having an issue with blockage. Identify, quantify and cost the materials and supplies required for while preparing to remove the old water closet, the precautions to observe while removing the water closet and the preparation in installing a new water closet.

7.2.2.5 Self-Assessment

1. What factors will you consider in choosing the right sealant/adhesive?
2. Which of the following is not a factor to consider when choosing water pipes?
   a. suitable for the expected temperatures and pressures
   b. compatible with the water supply
   c. suitable for the local climate
   d. not able to withstand UV effects

3. What are the three types of valves?

4. Which device is fitted to prevent wastage of water from automatic flushing cisterns at times when the cistern is not in use?

5. Of the following which is not true about copper pipes?

a. They are durable
b. They have a poor corrosion resistance
c. Are malleable and easy to bend
d. Has good flow characteristics

6. Why are silicone sealants preferred for plumbing works?

7.2.2.6 Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:
Tools and Equipment

- Pipe wrench
- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vices
- Taps
- Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Portable drill
- Mallet
- Ball pein0 hammer
- Mason chisel
- PPR machine / Heat Fusion equipment
- Pipe bender
- Trowel
- De-clogging wire / de-clogging machine
- Toilet pump

Supplies and Materials

- Screws
- Adhesives
- Cement
- Sand
- Pipes

- Traps
- Electric cables
- Caulking material
- Fitting

7.2.2.7 References

Joseph J. Galeno and Sheldon T. Greene., RSMeans Plumbing Estimating Methods, 3rd Edition

F. Hall., Plumbing Technology

Black & Decker., The Complete Guide to Plumbing.,2008

7.2.2.8 Model Answers

1. What factors will you consider in choosing the right sealant/adhesive?

There are various types of silicone sealants available, and while all offer the same general adhesive properties, some sealants are formulated for specific applications.

- The composition of the sealant determines how elastic it is, what materials it works best with, and how quickly it hardens.
- For use in the bathroom or other wet areas, the best choice is a mold-resistant sealant. This will prevent deterioration and blackening of the joint as it is exposed to moisture over time.
- Acidic components in some adhesives may lead to oxidation on some target surfaces, such as mirrors, stone, and marble tiles, aluminum or copper. If this is a concern, choose an acid-free sealant. Again, check your product information to confirm.
- For most general purposes, look for a universal sealant. It's a powerful waterproof plumbing silicone sealant, perfect for use with metal, glass, rubber, tile, and porcelain. Useful both indoors and outdoors, its flexible and impact- and temperature-resistant formula make it ideal for almost all plumbing applications.

2. Which of the following is not a factor to consider when choosing water pipes?
   a. suitable for the expected temperatures and pressures

b. compatible with the water supply
c. suitable for the local climate
d. not able to withstand UV effects

3. What are the three types of valves?
    - Throttling
    - Isolation
    - non-return.

4. Which device is fitted to prevent wastage of water from automatic flushing cisterns at times when the cistern is not in use?
    An Automatic Flow Cut Off Device

5. Of the following which is not true about copper pipes?
    a. They are durable
    b. They have a poor corrosion resistance
    c. Are malleable and easy to bend
    d. Has good flow characteristics

6. Why are silicone sealants preferred for plumbing works?
    They are waterproof and offer durable elasticity and stability in both high and low temperatures,

7.2.3 Learning Outcome 3: Fix plumbing system faults

7.2.3.1. Introduction to the learning outcome

This learning outcome specifies the content of competencies required to Fix plumbing system faults. It includes, terms and concepts, types of maintenance, maintenance reports & schedules, PPEs and their use, plumbing tools and equipment, rectification procedures, safety, care and maintenance of plumbing tools and equipment, plumbing parts repair/replacement, housekeeping and storage of plumbing tools and equipment

7.2.3.2. Performance Standard

1. Notice for maintenance operation are issued as per standard operating procedure.
2. Affected areas are closed/isolated based on best practice
3. Tools and equipment are identified and used based on job requirements.
4. Fault is repaired based on standard operating procedures
5. Housekeeping is observed as per best practice
6. Safety and health practices are observed based on OSHA.

7.2.3.3. Information Sheet

TYPES OF MAINTENANCE

Preventive Maintenance

Preventive maintenance is aimed at catching and fixing problems before they happen. It is most commonly carried out in the form of regular inspections, usually occurring multiple times per year.

When you inspect a system or a piece of technology, carefully check for all signs of wear, tear or imminent breakdown. Replace damaged parts immediately. This will prevent having to go into "crisis mode" if something breaks unexpectedly.

The primary benefit of preventive maintenance is that it can eliminate unplanned shutdown time as you will ideally catch problems before they occur.

Condition-Based Maintenance

Condition-based maintenance is sometimes considered to be a more advanced alternative to preventive maintenance. Rather than being inspected according to a schedule, machines and systems are carefully observed for changes that could indicate upcoming failure.

With condition-based maintenance, technicians observe the system running and identify variables that could affect functioning, like temperature, vibration speed, power, the presence or absence of moisture, and more.

Another strategy within condition-based maintenance is predictive maintenance.

Predictive Maintenance

Predictive maintenance refers to a specific type of condition-based maintenance in which systems are constantly observed via sensor devices. These devices are attached to components of the system and feed constant, real-time data to software. The software then interprets this data and warns maintenance technicians of approaching danger.

Predictive maintenance is generally considered to be the most advanced and intensive type of maintenance. This is because there is a lot of data to interpret – and the sensor devices themselves need to be regularly maintained and checked.

Corrective Maintenance

Corrective maintenance is initiated when a problem is discovered while working on another work order. With corrective maintenance issues are caught 'just in time'.

For example, during a scheduled maintenance check or while fixing another issue, a maintenance technician notices that a pipe in a HVAC system is not working as it should. Corrective maintenance is then scheduled for a future date where the problem is repaired or replaced.

Because corrective maintenance issues are found 'just in time', it reduces emergency repairs and increases employee safety.

Predetermined Maintenance

Unlike other styles, predetermined maintenance is carried out using rules and suggestions created by the original manufacturer, rather than the maintenance team. These suggestions are based on experiments and gathered data.

The manufacturer provides statistics and guidelines, usually when the equipment is first purchased and will include data providing the average lifespan of both the entire system and its various parts. The manufacturer will suggest how often parts should be inspected, serviced and replaced.

Relying solely on a predetermined schedule may risk system failures as technicians may not be able to anticipate problems. It can also cause multi-family maintenance teams to replace parts too early, resulting in additional costs. Additionally, predetermined maintenance doesn't guarantee that a system won't break down since the program is based on statistics and not the actual state of the equipment.

Maintenance reports & schedules

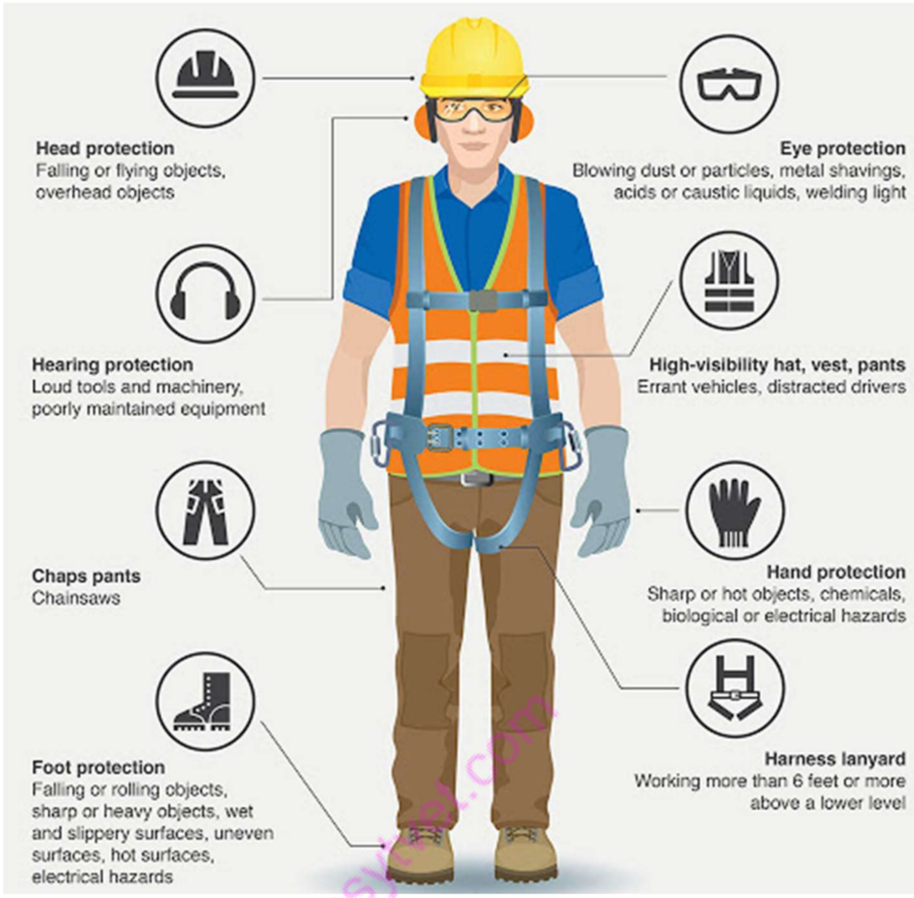
Some benefits of a maintenance report include:

- **It helps maintain reliability**
  This ensures that operating equipment is always made available as needed and in working condition.
- **It helps ensure safety**
  Regular checkups can prevent unexpected risks to the individuals involved in doing repairs.
- **It improves efficiency**
  The early identification of defects and their immediate repairs can save the company both money and time in the long run.
- **It promotes good recordkeeping**
  The regular documentation of equipment repairs and diagnostics helps you identify broader trends while supporting investigations in the future.

P.P.E.s

Plumbing Safety Tools

PPE can be defined as safety gear that protects plumbers against safety or health risks when handling the job. The main objective of a protective gear for a plumber is to reduce plumber exposure to hazards related to plumbing.
Below are essential PPE for plumbers commonly used on plumbing and their benefits.



PPE's

Helmets

Protective helmets are important in a plumbing site because they prevent injuries from flying or falling objects. Recently, due to advanced technology, some hard hats are equipped with accessories, such as earmuffs and shields. A plumber should consider buying a well-fitted protective helmet to prevent inconveniences. Too small or too large hard hats are inappropriate to use. Falling or flying objects might lead to severe head injuries.

Masks

Production of toxic substances is common in plumbing sites. Respiratory protection gears, such as respirators, are designed to protect a plumber from fumes, dust, and other dangerous substances that could lead to respiratory problems. Respiratory protection gears are important in areas where there's air contamination.

1. Safety shoes

Some safety shoes are designed to limit damage to your toes from falling objects. A steel plate is placed in the toe area of such shoes so that your toes are not crushed if an object impacts there. Other safety shoes are designed for use where danger from sparking could cause an explosion. Such danger is minimized by elimination of all metallic nails and eyelets and by the use of soles that do not cause static electricity.

2. Goggles

Proper eye protection is of the utmost importance for all personnel. Eye protection is necessary because of hazards posed by infrared and ultraviolet radiation, or by flying objects such as sparks, globules of molten metal, or chipped concrete and wood. These hazards are ever-present during welding, cutting, soldering, chipping, grinding, and a variety of other operations. It is imperative for you to use eye protection devices, such as helmets, face shields, and goggles, during eye-hazard operations.
Appropriate use of goggles will limit eye hazards. Some goggles have plastic lenses that resist shattering upon impact. Others are designed to limit harmful infrared and ultraviolet radiation from arcs or flames by use of appropriate filter lenses. Remember, eye damage can be excruciatingly painful.

3. Gloves

Use gloves whenever you are required to handle rough, scaly, or splintery objects. Special flameproof gloves are designed for gas and electric-arc welding to limit danger and damage from sparks and other hot flying objects. Personnel in the electrical fields are usually required to wear insulating rubber gloves. Be sure to follow all regulations prescribed for the use of gloves. Gloves must not be worn around rotating machinery unless sharp or rough material is being handled. If such is the case, Extreme Care Should Be Exercised to prevent the gloves from being caught in the machinery.

4. Safety belts and straps

The safety strap and body belt shown are what might be called your extra hands when you work aloft. The body belt, strapped around your waist, contains various pockets for small tools. The safety strap is a leather or neoprene-impregnated nylon belt with a tongue-type buckle at each end. While you are climbing you will have the safety strap hanging by both ends from the left ring.

PLUMBING REPAIR TOOLS AND EQUIPMENT

Sink Auger

A sink auger (also called a drum auger or canister auger) is the ultimate weapon for breaking up and clearing clogs in sink and tub drains.

A sink auger consists of a flexible stainless steel cable with a corkscrew tip at the end. The cable is coiled within a drum canister and is extended into a drain to reach a clog and clear it. The drum has a handle, and there's a thumbscrew that locks the cable to the canister, and when you insert the cable into the drain and turn the handle, the rotating drum snakes the cable through bends in the drain pipe, allowing the cable tip to penetrate clogs and pull them out.

sink auger

Toilet or Closet Auger

The toilet auger (also called a closet auger or water closet auger) is used to clear clogs in toilets.

A toilet auger has a long metal rod with a bend for reaching into the hole at the bottom of the toilet bowl. A rubber sleeve covers the bend to protect the porcelain in the toilet from being scratched. Once the tool is in place, you push and rotate the auger cable to snake it into or through the clog.

Flange Plunger (Toilet Plunger)

The flange plunger, or ball or toilet plunger, is a specially shaped plunger used to clear clogs in toilets. It works like a regular plunger but has a flange—an extended rubber flap below the dome of the plunger head—that helps seal around the hole at the bottom of the toilet bowl. With the bottom opening sealed, the plunger can effectively create the hydraulic pressure necessary to dislodge most clogs from a toilet.

flange plunger

Cup Plunger (Sink and Tub Plunger)

The cup plunger may be the most common plumbing tool in the home. It has a rubber cup-like shape and a wooden handle and is used to clear clogs in sinks, tubs, and showers. Do not use this plunger for clearing toilet clogs; that requires a specially shaped plunger called a flange plunger (previous slide). Some flange plungers, though, can be used as standard cup plungers when the flange is tucked up inside.

cup plunger

Plumber's Tape

Plumber's tape is an essential material for preventing leaks at threaded plumbing connections. Often called Teflon tape (although it's not made with Teflon-brand material), plumber's tape is a thin white tape that you wrap around threads on pipes and fittings before twisting the parts together. It adds a bit of lubricant to aid threading and also helps to seal the joint to prevent leaks. Made with PTFE (PolyTetraFluoroEthylene), it is silky in texture and is sold in small rolls.

plumber's tape

Channel-Type Pliers

Channel-type pliers are commonly known by the brand name Channel-Locks, and are also known as slip-joint pliers.They're similar to regular adjustable pliers but have extended adjustment sections as well as angled jaws, allowing you to grip pipes or other plumbing parts of almost any size. The long handles provide tremendous leverage for squeezing and twisting. You can use them to grip heavy steel pipe or to gently tighten large plastic nuts on sink drains. If you own only one specialty plumbing tool, this should be the one.

channel-type pliers

Adjustable Pipe Wrench

An adjustable pipe wrench is the quintessential metal plumbing tool. It provides tremendous leverage and grip. It is designed to grip round objects (such as pipes) securely by digging its sharp serrated teeth into the pipe with increasing pressure as the wrench is turned.

A pipe wrench leaves teeth marks behind and is not recommended for removal of shiny fixtures or for small or fragile pipes, like copper water pipes. Pipe wrenches are primarily used on galvanized steel and iron pipe and on heavy-duty fixtures with rough finishes, such as outdoor spigots or hydrants.

Pipe wrench

Faucet Valve-Seat Wrench

A faucet valve-seat wrench is a simple tool used to remove the valve seats on a compression faucet. Compression faucets, the oldest style of faucet, work by compressing a rubber washer against a valve seat in the faucet body.

When the washer wears out, the valve seat can become damaged and rough, preventing a complete seal. When that happens, you can remove the valve seat and replace it, using a valve seat wrench. If the seat is not removable, you must regrind it to a smooth surface using a reseating tool.

faucet valve-seat wrench

Faucet Packing, Washers and O-rings

Faucet packing and rubber washers and O-rings are lifesavers for fixing leaky valves on sinks, radiators, and other old or traditional equipment. Packing is a graphite- or wax-coated string that you wrap around valve stems and pack under packing nuts to create a watertight seal. Rubber washers and O-rings are sold in variety packs containing several different shapes and sizes. If you're fixing an old faucet and can't find an official replacement part at the store, a variety pack well have the part you need. It's handy to have one around because it might save you a trip to the store.

Tubing Cutter

The tubing cutter is an essential plumbing tool if you're working with copper pipe. Copper requires clean, square cuts, and tubing cutters do just that—with much less effort than a hacksaw. It has a thin cutting wheel that cuts the metal and a flat pressure wheel that applies pressure when you turn the tool's knob. Clamp the tool onto a pipe and rotate it around the pipe, tightening the knob after every two or three rotations. The cutting wheels gradually cut through the material.

After making the cut, remove the burr on the inside of the pipe, using the de-burring tool (a triangular metal piece) that is fitted to the body of the tubing cutter.

tubing cutter

Washers

These are simple round, flat, disks with a hole at the center that sits inside the faucets and showerheads.

washers

Uses of washers:

- The rubber, plastic, or metallic washers are used to control the intense flow of water through the faucets and showerheads.
- Washers are lifesavers for fixing leaky valves on sinks, radiators, and other old or traditional equipment.

- Pipe wrench

Pipe wrench size should be selected such that its opening exactly pits the pipe and should not be used for bending, raising or lifting pipe.

It is used for:

- screwing and unscrewing small pipes.
- tightening of nut and bolts, fixing of small taps, valves etc in pipelines.

pipe wrench

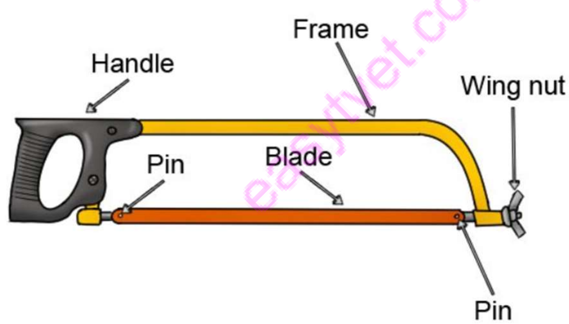
- Pipe cutter

It is used for cutting of pipes. It is placed around pipes and tightens so that it holds the pipe tight. However, over tightening may damage pipe. The cutter is rotated around the pipe one to two times and then the pipe is tightened again. The process is repeated unless the pipe is cut. Pipe cutters are available for cutting of pipes from 25-150 mm.

pipe cutter

- Hacksaw

It is used for cutting pipes of smaller diameters (15-25 mm). It consists of frame, handle, prongs, tightening screw and nut. The frame may be fixed type or adjustable type. Blade is fixed in position by means of tightening screw. The direction of the cutting teeth of the blade is to be in the forward direction.



pipe hacksaw

- Pipe Threading Equipment

It is used for threading external taper threads of pipe. Pipe is fixed in the pipe vice and threading is done with help of the die set as per pipe size requirement.

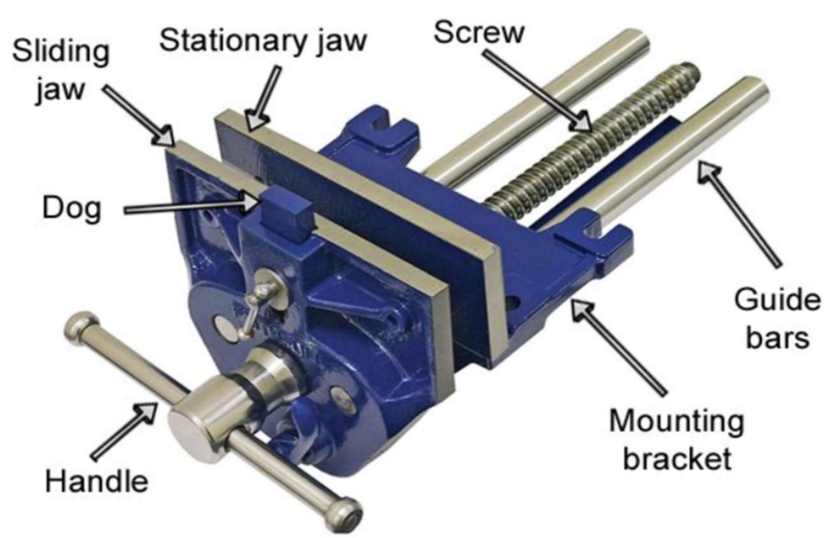
: pipe threading equipment

Using instructions:

g. Take required size of pipe threading die.
h. Fix the pipe in the pipe vice tightly.
a. Cut the pipe to required size at right angle.
b. Hold the die in right angle of the pipe and put some oil on pie.
c. Cut the thread on the pie with die rotating in clockwise direction. Rotate the die in anti clockwise direction so that the cut material will come out.
d. Clean the chips or burr.

- Bench vice

It is used for holding pipes in position rigidly for cutting and threading. Pipe vices are available in market in various sizes for holding pipes starting from 37 mm diameter.



bench vice

1. The Base
The base of the vise is the part that holds everything together. It is truly the life of the party. The base of the vise is fastened to the bench and it comes in different designs. Some can be clamped in place; the others can be bolted. There are also swivel and vacuum bases available for different purposes.

2. The Jaw
This is where everything stays. The jaw is jaw-like and clamps everything in place. It comes in two different parts. Considering the nature of the job, the jaws can take the form of wood, plastic, or metal.
The sliding jaw: this part of the jaw moves when the handle is turned. It also applies pressure on the object being clamped. If you are new to clamping, it's pretty easy to spot out which part of the clamp is the sliding jaw, since it's the part that allows motions and has a handle sticking through.
The static jaw: this part is fixed. This is the vise that enforces solidity. The sliding jaw backdrops in this component applying pressure for its immovability. You can identify the static jaw by its size.

3. The Slide
This part moves when the handle is turned, applying pressure to the object. It is attached to the sliding jaw.

4. Main Screw
The force applied to the handle is transformed into the movement of the sliding jaw, which moves towards the static jaw. This jaw is conspicuously attached to the handle and extends through the vise.
The main screw is an essential part. It is so vital that if the main screw is not manufactured based on the type or comes with flaws creating weaknesses, the vise will not hold well at all.

5. Handle
The handle has a lever attached to it.
Applying too much force on the handle can be tempting. But if done out of proportion, it can lead to explosive results. The power applied to move the handle multiplies and gets accompanied by the actions of the main screw. While clamping, if any material observes a bend, it's best to stop and reverse the handle to release the pressure level.

6. The Anvil
This can come in handy form when light-shaping of materials.

7. Serrated Jaws
This is the actual point where the vise meets with whatever it is you are fastening. Take precautions with anything other than metal. The jaws can do a 'damage job' when too much pressure is applied.

8. Pipe Jaws
These pipe jaws can be found inside the sliding and static jaw. They allow you to hold pipes and other oddly shaped objects in place, and present you with the prerogative to cut them easily.

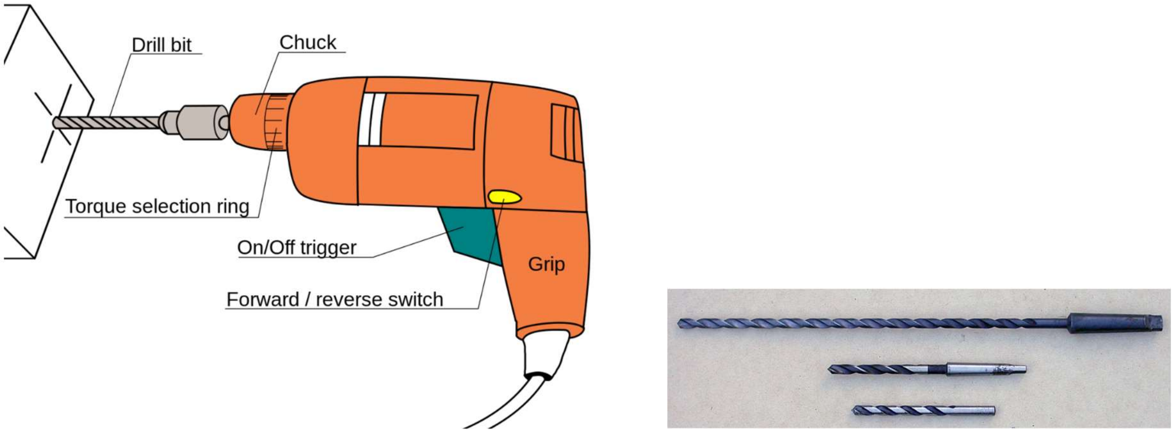
- Spanner

Spanner is used for fixing and opening nuts and bolts. Different types of spanners and size are available as per requirement of pipe size.

spanner

- Drill with various sizes of bits

It is a tool primarily used for making round holes or driving fasteners. It is fitted with a bit, either a drill or driver, depending on application, secured by a chuck. Some powered drills also include a hammer function.



drill and bits

- PPR machine / Heat Fusion equipment

It is a pipe welding machine set used for welding plastic pipes.

PPR

- Pliers

These are used everyday by plumbers. Easily tighten or loosen nuts and bolts that wrenches can’t grab onto.

Pliers

- Pipe bender

It is used for bending pipes. Fix wooden stopper to one end of the pipe. Fill the pipe with sand completely. Fix wooden stopper from other side of pipe. Fix the pipe in the machine. Location of the bend should be in center of pulley. Tight the screw. Bend the pipe with help of lever till required bend. Remove stopper and sand from pipe.

Pipe bender

SAFETY, CARE AND MAINTENANCE OF PLUMBING TOOLS AND EQUIPMENT

The following rules will make maintenance easier and safer.

i. Keep each tool in its proper storage place.
ii. Keep your tools in good condition. Protect them from rust, nicks, burrs, and breakage.

iii. Use each tool only for the job it was designed to do. Each particular type of tool has a specific purpose. If the wrong tool is used when performing maintenance or repairs, it may cause damage to the equipment being worked on or damage the tool itself. Improper use of tools results in improper maintenance. Improper maintenance results in damage to equipment and possible injury or death.
iv. Safe maintenance practices. Always avoid placing tools on or above machinery or an electrical apparatus. Never leave tools unattended where machinery are running.
v. Never use damaged tools. A battered screwdriver may slip and spoil the screw slot, damage other parts, or cause painful injury. A gauge strained out of shape will result in inaccurate measurements.

The following precautions for the care of tools should be observed:
i. Clean tools after each use. Oily, dirty, and greasy tools are slippery and dangerous to use. Never hammer with a wrench.
ii. Never leave tools scattered about. When they are not in use, stow them neatly on racks or in toolboxes.
iii. Apply a light film of oil after cleaning to prevent rust on tools.
iv. Inventory tools after use to prevent loss.

SAFETY PRECAUTIONS FOR USE WITH PORTABLE ELECTRICAL TOOLS
When portable electric tools are used, you should use the following procedures:
- Before portable electrical tools are used, they must be inspected and approved.
- Prior to the use of any portable electric tools, you should make sure the tools have a current ship's inspection mark. Additionally, visually examine the attached cable with the plug and any extension cords for cracks, breaks, or exposed conductors and damaged plugs. When any defects are noted, the tools should be turned in to the ship's electrical shop for repair before use. Before plugging in any tool, be sure the tool is turned off.
- Personnel using portable electric tools are required to wear safety glasses/goggles.
- Portable electric tools producing hazardous noise levels in excess of the limits set are required to be conspicuously labeled. Personnel using tools designated as producing hazardous noise levels are required to wear proper ear protection, as issued by the medical department.
- Only explosion-proof portable electric tools should be used where flammable vapors, gases, liquids, or exposed explosives are present.

- Hand-held portable electric tools authorized for use on board ship shall be equipped with ON/OFF switches, which must be manually held in the closed ON position to maintain operation.
- Rubber gloves must be worn when you are using portable electric tools under hazardous conditions; for example, wet decks, bilge areas, working over the side, in boats, and so forth.
- Leather glove shells should be worn over rubber gloves when the work being done, such as sheet metal work, could damage the rubber gloves.

HOUSEKEEPING

Why should we pay attention to housekeeping at work?

Effective housekeeping can help control or eliminate workplace hazards. Poor housekeeping practices frequently contribute to incidents. If the sight of paper, debris, clutter and spills is accepted as normal, then other more serious hazards may be taken for granted.

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. It also requires paying attention to important details such as the layout of the whole workplace, the adequacy of storage facilities, and maintenance. Good housekeeping is also a basic part of incident and fire prevention.

Effective housekeeping is an ongoing operation: it is not a one-time or hit-and-miss cleanup done occasionally. Periodic "panic" cleanups are costly and ineffective in reducing incidents.

What is the purpose of workplace housekeeping?

Poor housekeeping can be a cause of incidents, such as:

- tripping over loose objects on floors, stairs and platforms
- being hit by falling objects
- slipping on greasy, wet or dirty surfaces
- striking against projecting, poorly stacked items or misplaced material
- cutting, puncturing, or tearing the skin of hands or other parts of the body on projecting nails, wire or steel strapping

To avoid these hazards, a workplace must "maintain" order throughout a workday.

What are some benefits of good housekeeping practices?

Effective housekeeping results in:

- 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)

How do I plan a good housekeeping program?

A good housekeeping program plans and manages the orderly storage and movement of materials from point of entry to exit. It includes a material flow plan to ensure minimal handling. The plan also makes sure that work areas are not used as storage areas by having workers move materials to and from work areas as needed. Part of the plan could include investing in extra bins and more frequent disposal.

Worker training is an essential part of any good housekeeping program. Workers need to know how to work safely with the products they use. They also need to know how to protect other workers such as by posting signs (e.g., "Wet - Slippery Floor") and reporting any unusual conditions.

Housekeeping order is "maintained" not "achieved." Cleaning and organization must be done regularly, not just at the end of the shift. Integrating housekeeping into jobs can help ensure this is done.

A good housekeeping program identifies and assigns responsibilities for the following:

- clean up during the shift
- day-to-day clean up
- waste disposal
- removal of unused materials
- inspection to ensure clean up is complete

Do not forget out-of-the-way places such as shelves, basements, sheds, and boiler rooms that would otherwise be overlooked.

Storage of plumbing tools and equipment

Step 1

Figure out how much space is needed for the number of tools available. Get a shelving unit to store smaller tools and equipment.

Step 2

Organize the tools and equipment. Allocate shelves and drawers to store smaller plumbing tools. For larger tools and equipment, organize by type for easy location. Keep the parts for each specific tool close by.

Step 3

Clean out dirt and debris from tools. Oil power tools to lubricate moving parts. Repair loose handles and clean out oil or other fluids used to power the tool. Sharpen blades and replace worn out parts.

Step 4

Set up racks. Mount racks along the wall of the storage area to hang, cords and other equipment. Wind long cords in a loop and hang from rack. Place tools on racks by the handle. Draw the outline of the tool with a permanent marker to identify its place, or use labels to mark the location.

Step 5

Create a library. For tools and equipment that have various functions, designate a library area within the storage space for user manuals and warranty sheets. Store the booklets alphabetically and in a dry area. Type up a sheet listing all of the books to create simple table of contents.

7.2.3.4.Learning Activities

Activity:

A client has an issue with a water closet that is consistently having an issue with blockage. Describe the procedure to follow while preparing to remove the old water closet, the precautions to observe whle removing the water closet and the preparation in installing a new watercloset.

7.2.3.5.Self-Assessment

1. What pre-cautions should a plumber take for health and safety purposes?
2. Mention some health and safety issues that plumbers face?
3. What is the main use of the tool below?

4. What is the importance of good housekeeping?

5. A bench vice is used for holding pipes in position rigidly for cutting and threading. Which three parts can be identified from a bench vice?

6. What is your understanding of the following types of maintenance?
   i. Preventive maintenance
   ii. Predictive maintenance

7. What are the various types of protective equipment used by plumbers?

8. Why are plumbing maintenance reports & schedules important?

7.2.3.6.Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:

Tools and Equipment

- Pipe wrench
- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vices
- Taps
- Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Portable drill
- Mallet
- Ball pein0 hammer
- Mason chisel
- PPR machine / Heat Fusion equipment
- Pipe bender
- Trowel
- De-clogging wire / de-clogging machine
- Toilet pump

Supplies and Materials

- Screws
- Adhesives
- Cement
- Sand
- Pipes
- Traps
- Electric cables
- Caulking material
- Fitting

7.2.3.7.References

I.C.S. Lewis., Samuel R. & Staff., Plumbing tools and Materials., 1991

C.J. Smith., B. Curry., Practical Plumbing (The Motivate series).,1998

F. Hall., Plumbing Technology

7.2.3.8.Model Answers

1. What pre-cautions should a plumber take for health and safety purposes?
   - Avoid awkward body positions, and take break every 30 minutes.
   - Learn safe lifting techniques
   - Wear appropriate footwear and gloves while handling sewage plant or metal pipes
   - Keep tools and equipment's in working condition, to avoid any unexpected accident due to inoperative tools
   - To avoid electric shock use only power tools that can be used in a wet environment and have GFCI (Ground fault circuit interrupter).
   - Keep work area clear

2. What is some of the importance of proper storage of tools and equipment?

   - it is an important factor for safety and health as well as good business
   - Improves appearance of general-shop and construction areas
   - Reduces overall too cost through maintenance.
   - This also ensures that tools are in good repair at hand
   - Teaches workers principles of (too) account ability

3. What are some pointers to follow in storing tools and equipment?
   - Have a designated place or 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 rot in use with sharp edge down
   - Put frequently used item in conveniently accessible location
   - Gather and secure electrical cords to prevent entanglement or snagging.
   - Cutting boards should be stored vertically to avoid moisture collection.
   - Metal equipment can be stacked on one another after drying such as storage dishes and bowls.
   - Make sure the areas where you are stoning the equipment are clean, dry and not overcrowded

4. Mention some health and safety issues that plumbers face?

- Exposure to a hazardous substance like lead, sulfur dioxide, mould, carcinogenic substances
- Exposure to flammable and combustible materials
- Working in awkward positions may lead to musculoskeletal injuries
- Lifting heavy or awkward objects
- Risk of eye injury from flying particles
- Burns from hot equipment's like steam lines, hot water heater, etc.
- Cut and bruises due to a sharp end of pipes
- Risk of electric shock while digging under-ground water pipes

5. What is the main use of the tool below?

To tighten mildly tight against the non-threaded portion of a pipe that has a threaded end.

6. What is the importance of good housekeeping?
   - 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, vapors)
   - 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

7. A bench vice is used for holding pipes in position rigidly for cutting and threading. Which three parts can be identified from a bench vice?
   - Sliding jaw
   - Screw
   - Stationary jaw
   - Dog

- Guide bars
- Handle
- Mounting bracket

8. What is your understanding of the following types of maintenance?

i. Preventive Maintenance

Preventive maintenance is aimed at catching and fixing problems before they happen. It is most commonly carried out in the form of regular inspections, usually occurring multiple times per year.

When you inspect a system or a piece of technology, carefully check for all signs of wear, tear or imminent breakdown. Replace damaged parts immediately. This will prevent having to go into "crisis mode" if something breaks unexpectedly.

The primary benefit of preventive maintenance is that it can eliminate unplanned shutdown time as you will ideally catch problems before they occur.

ii. Predictive Maintenance

Predictive maintenance refers to a specific type of condition-based maintenance in which systems are constantly observed via sensor devices. These devices are attached to components of the system and feed constant, real-time data to software. The software then interprets this data and warns maintenance technicians of approaching danger.

Predictive maintenance is generally considered to be the most advanced and intensive type of maintenance. This is because there is a lot of data to interpret – and the sensor devices themselves need to be regularly maintained and checked.

9. What are the various types of protective equipment used by plumbers?
   - Helmets
   - Masks
   - Googles
   - Safety shoes
   - Gloves
   - Safety belts and straps

10. Why plumbing maintenance are reports & schedules important?
    - It helps maintain reliability
    - It helps ensure safety
    - It improves efficiency
    - It promotes good recordkeeping

7.2.4 Learning Outcome 4: Test plumbing system

7.2.4.1.Introduction to the learning outcome

This learning outcome specifies the content of competencies required to Test plumbing system. It includes, testing plumbing systems, types of tests and reinstating plumbing systems.

7.2.4.2.Performance Standard

1. Plumbing system is tested based on specifications
2. Make good repaired work area based on best practices
3. Normal supply is reinstated where necessary as per the design

7.2.4.3.Information Sheet

Objectives of the Testing plumbing Works

The objectives of the testing plumbing works are:

a. To verify proper functioning of the equipment/system after installation
b. To verify that the performance of the installed equipment/systems meet with the specified design intent through a series of tests and adjustments
c. To capture and record performance data of the whole installation as the baseline for future operation and maintenance.

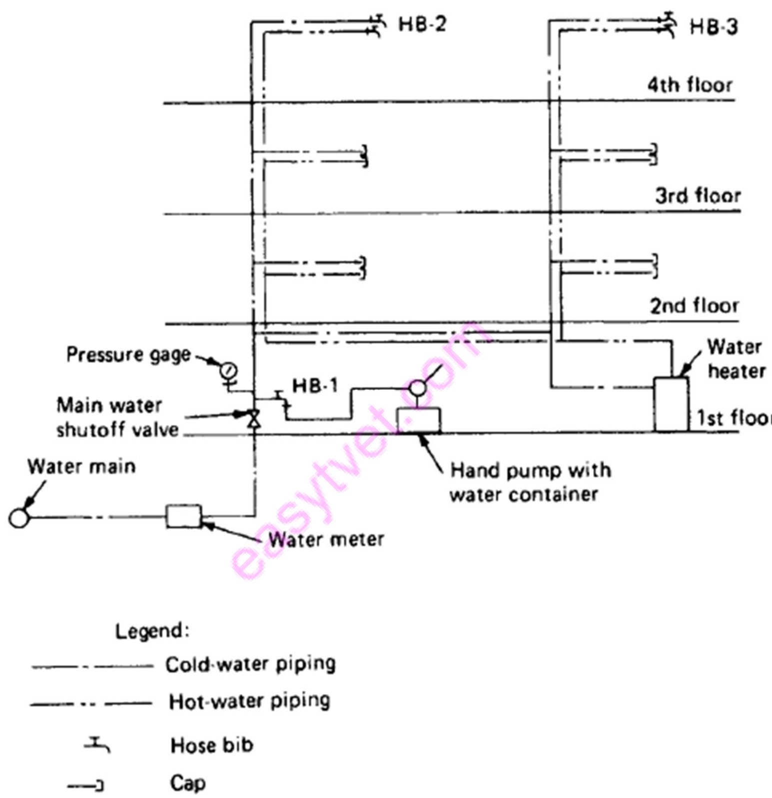
Testing the Rough Piping Installation

The following steps should be taken in testing the piping system before the fixtures, faucets, trim, and final connections are made to the equipment:

1. Install hose bibs for filling the piping system with water and to permit the evacuation of air from (i.e., venting) the system.

There should be a hose bib (or similar device) at the bottom of the piping system for filling the system with water and at least one more at the highest point of the system for venting.
Depending on the size and piping layout, several other hose bibs may be required for venting the system.

2. Cap all openings.
All connections to future fixtures must be capped so they are watertight. Temporary caps will be removed after the pressure test, described below, is completed.



piping layout

3. Fill the system with potable water.
With the bib at the top of the piping system in the open position, fill the system with water through the hose bib located at the bottom position. Air will then be forced out of the piping through the top bibs.
During the time the piping system is being filled, all hose bibs for venting must be open. When water emerges from all the open hose bibs, all air in the system has been displaced by water. Then all hose bibs must be tightly closed.

4. Attach a pump and a pressure gauge to the piping system.

Depending on the size of the piping system, the pump (used to create pressure in the system) may be a manual pump or a centrifugal pump activated by an electric motor. In general, a manually operated pump is satisfactory for most applications. Water should then be pumped into the system until the pressure gage indicates the pressure desired for the test.

5. Subject the piping system to a hydrostatic test. The magnitude of the test pressure that is required by various codes or jurisdictions is different, but it is usually recommended that test pressure be equal to or higher than the following:
    a. % times the pressure at which the piping system will operate. Water pressure of existing water supplies can be obtained from the local water department.
    b. 125 psi (862 kPa).

6. Sustain the maximum pressure for a period of at least 3 h.
After the test pressure is attained, close hose bib HB-1. Maximum pressure should be sustained for this period of time without any loss of pressure, as determined from readings of the pressure gage. If pressure is maintained, the system is watertight. If the pressure decreases, there is a leak in the system. The pipes should then be inspected to determine the location of the leaks. The leaks should be repaired and a new pressure test performed. This process must be repeated until it is shown that the maximum pressure is maintained without pressure loss for at least 3 h.

7. If during the testing procedure, the water supply system may be subject to freezing, an air test may be substituted for the hydrostatic test of Step 6.
The air test is carried out as follows. First replace the water pump with an air compressor.
Then raise the air pressure to 40 psi (276 kPa). At this pressure, check for leaks by applying liquid soap to the joints and connections. When all leaks appear to have been corrected, raise the air pressure to a value equal to 1% times the water pressure to which the system will be subjected. With the air compressor turned off and the hose bib HB-1 shut off, the pressure must be maintained within the system for a period of at least 2 h. If this is not the case, then previously undetected leaks must be found and repaired and the entire system retested.

Testing the Complete Plumbing System

After the rough piping installation has been shown to be watertight and has been accepted, then the following steps should be taken:

1. Install and connect all faucets, fixtures, hose connections, trim, and valves.
2. Connect the water piping system to the water supply.

3. Subject the entire system to the hydrostatic test of Step 5, above. Check for leaks. When all leaks have been detected and repaired, proceed with the operation test of the next step.
4. All bibs, fixtures, flush valves, pumps, tanks, and other appurtenances should be activated to show that the water quantities required for proper operation are adequate and that their operation is satisfactory.

DISINFECTING THE WATER SUPPLY SYSTEMS IN BUILDINGS

After the above testing has been completed, all aerators, filters, and strainers should be cleaned (after disinfection, they must be replaced), and the entire system should be flushed with portable water to rid it of impurities and debris.

Water should be run through the piping by opening the various faucets and valves until, by visual inspection, the water appears to be running clean, and no impurities such as sand, rust, and similar small particles are observed in the bowls of the plumbing fixtures.

The following procedure, performed by approved applicators or qualified personnel, is recommended:

1. One of the following chemicals, all of which add chlorine to the water, may be used to disinfect water:
   - chlorine gas
   - chlorine liquid
   - sodium
   - hypochlorite
   - calcium hypochlorite
2. Inject a disinfecting agent through the hose bib located at the water service entrance. The injection should take place at a slow and even rate. The flow of this disinfection agent into the main connected to the public water supply is prohibited. Therefore, during disinfection, either the water supply connection should be disconnected or the main water valve should be effectively shut off to prevent any contamination from entering the main water supply.

3. Allow the disinfecting agent to flow into the system by opening hose bibs or faucets in each branch until the chlorine residual concentration is not less than 50 ppm of available chlorine. Then close all valves and accessories. Allow the chlorinated water to stand in the system for a period of not less than 24 hr.

4. After the 24-hr period of retention, the residual chlorine should not be less than 5 ppm. If it is less, the above process must be repeated.

5. If the concentration of residual chlorine is 5 ppm or greater, flush the system thoroughly with portable water before it is put in service.

6. The flushing should continue until;

    iii. the residual chlorine in the system, as measured by orthotolidin tests, is not greater than that in the main water supply
    iv. biological tests show that there is absence of coliform organisms. Such water samples should be taken from faucets located at the highest floor and farthest from the main water supply.

7. If it is impractical to disinfect the water storage tank by the above means, then the entire interior of the tank should be swabbed with a solution containing 200 ppm of available chlorine and allowed to stand for at least 3 hrs before flushing.

8. After final flushing of the system has been completed, at least one water sample should be obtained from the cold-water line and the hot-water line. Water samples must be submitted to a state laboratory which should certify that the water does not contain organisms in excess of standards for potable water.

TYPES OF TESTS

Plumbing system inspection and tests

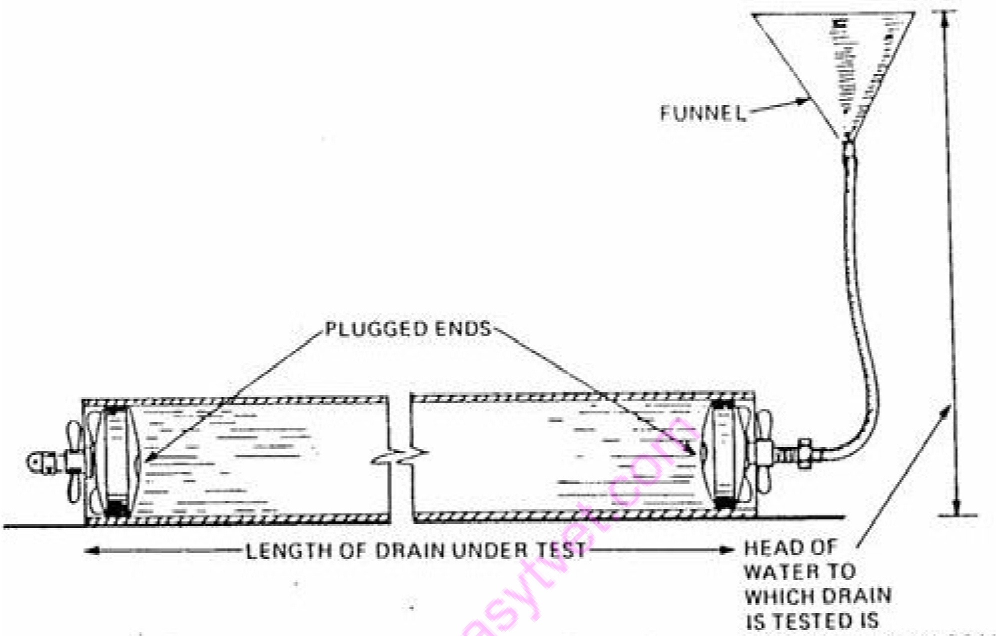
These tests are for the purpose of ensuring correct work, free from defects arising in construction and manufacture. There are three different methods of testing the plumbing system - the water test, air test and peppermint test or smoke test. Of these, the water, peppermint, and smoke tests are most commonly used.

The water and air tests are chiefly used as the first test on new work. When it comes to the final test, either the peppermint or smoke test may be applied.

On old work in residences and other finished and occupied buildings, the water test cannot be applied, owing to the damage that might result. Under these conditions, either the peppermint or smoke test should be used.

- Water test

Most plumbing codes allow air or water to be used for preliminary testing of drainage, vent, and plumbing pipes. After the fixtures are in place, their traps should be filled with water and a final test made of the complete drainage system.



Water testing of drains.

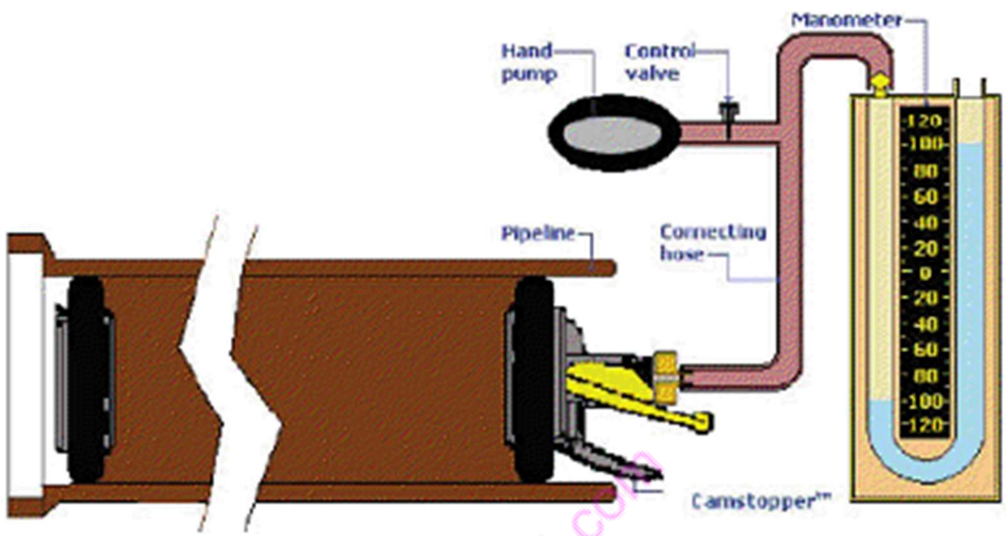
Procedure:
The water test shall be applied to the drainage and vent systems either in its entirety or in sections. If applied to the entire system, all openings in the piping shall be tightly closed, except the highest opening, and the system filled with water to a point of overflow.

If the system is tested in sections, each opening shall be tightly plugged except the highest opening of the section under test, and each section shall be filled with water, but no section shall be tested with less than a ten (10) foot (3m) head of water.

In testing successive sections, at least the upper ten (10) feet (3m) of the next proceeding section shall be tested, so that no joint or pipe in the building (except the uppermost ten (10) foot (3m) of the system) shall have been submitted to a test of less then a ten.(10) foot (3m) head of water. The water shall be kept in the system, or the portion under test, for at least fifteen (15) minutes.

- Air test

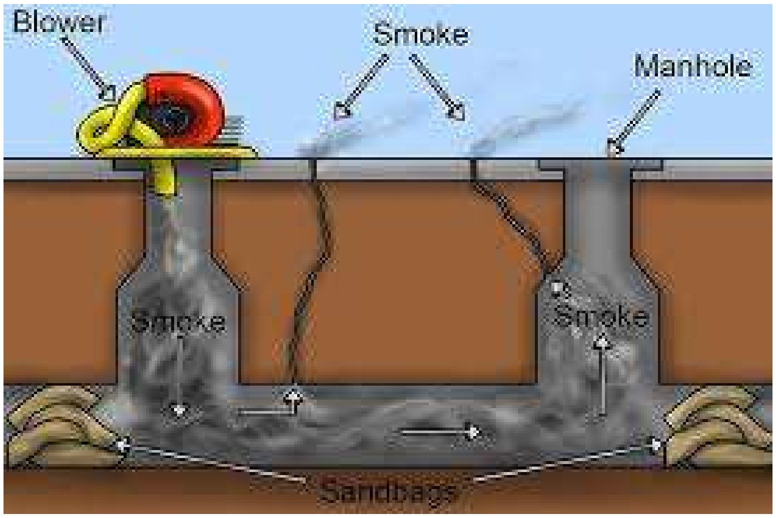
An air test is made by sealing all pipe outlets and subjecting the piping to an air pressure throughout the system. The system should be tight enough to permit maintaining this pressure for at least 15 min without the addition of any air.



- Smoke test

The smoke test is another test that can be applied to roughed-in new work. It is used most frequently, however, in testing old work, or in testing new work after the fixtures have been set. The manner of applying a smoke test is to close all openings, the same as for the water test, and also the openings at the roof. The testing machine, which is made especially for this purpose, is then connected to the piping system, and the smoke turned into the pipes.

Oily waste or rags are placed in the machine and lighted, thus generating a heavy smoke which will entirely fill the pipes, and escape through any leaks that may exist—which are thereby easily detected. The smoke test is preferred by many, as it is cleaner than the water test, should any leaks develop, and there is no wetting down of the building.



- Peppermint test

The peppermint test is applied by putting about two ounces of oil of peppermint into the system at the roof, after all openings have been closed as with the other tests, and pouring about a gallon of hot water into the piping, immediately closing the opening with a plug kept at hand for the purpose. The fumes of the peppermint are supposed to travel throughout the system of piping, and to penetrate any existing leaks, the presence of which can then be detected from the characteristic smell. There being no pressure applied in this test, there is a possibility of the odour not escaping through very small leaks; and this test, therefore, is not so reliable as the water or smoke tests.

The person who puts the peppermint in the piping should not try to look for leaks, as he will carry the odour around with him through the building, and is apt to imagine that he smells leaks where in reality they do not exist.

- Building sewer test
  Building sewers shall be tested by plugging the end of the building sewer at its point of connection with the public sewer or private sewer disposal system and completely filling the building sewer with water from the lowest to the highest point thereof, or by approved equivalent low pressure air test, or by another test as may be prescribed by the Administration Authority. The building sewer shall be watertight at all points.

- Water piping

Upon completion of a section or of the entire hot and cold water supply system, it shall be tested and proved tight under a water pressure not less than the working pressure in which it is to be used.

The water used for tests shall be obtained from a potable source of supply. A fifty (50) pound per square inch (344.5 kPa) air pressure may be substituted for the water test. In either method of test, the piping shall withstand the test without leaking for a period of not less than fifteen (15) minutes.

7.2.4.4.Learning Activities

Activity

You have purchased a used rubber hose at a market and are considering using the hose pipe as temporary channel for the waste water from you washing machine to the washbasin, but you are concerned about leaks.

Before installing the pipe test the hose for leaks.

7.2.4.5.Self-Assessment

1. Testing plumbing systems is the responsibility of the building owner
    a. False
    b. True

2. For some installations, several plumbing systems can be tested and inspected simultaneously, such as the building sewer and water service when they are installed in the same trench
    a. False
    b. True

3. An air test is a plumbing system test in which inlets and outlets to the system are sealed and air is forced into the system until a uniform air pressure of 5 psi is reached and maintained for 15 min without additional air being added to the system
    a. False
    b. True

4. A hand pump or portable air compressor is used to force air into the plumbing system, and is typically used when testing smaller installations, such as a one-family dwelling
    a. False
    b. True

5. Always wear a protective helmet (hard hat) and eye protection when performing air and water tests using test plugs and do not stand directly in front of an outlet where a test plug is installed
    a. False
    b. True

6. Malleable iron plugs and caps have male and female threads, and are removed from a pipe end using a pipe wrench
    a. False
    b. True

7. Water tests are typically performed on PEX systems since it is less time-consuming to perform a water test than an air test
    a. False
    b. True

8. A final air test is a test of the plumbing fixtures and their connections to the sanitary drainage system
    a. False
    b. True

9. Underground sanitary drainage and vent piping is tested and inspected after it is covered with earth and backfilled
    a. False
    b. True

10. Odor and final air test are performed on sanitary drainage and vent piping
    a. False
    b. True

7.2.4.6. Tools, Equipment, Supplies and Materials

Functional Plumbing Workshop with the following:

Tools and Equipment

- Pipe wrench
- Pipe cutter
- Hacksaw
- Pipe Threading Equipment
- Vices
- Taps
- Punch
- Files
- Screwdrivers
- Drill with various sizes of bits
- Portable drill
- Mallet
- Ball pein0 hammer
- Mason chisel
- PPR machine / Heat Fusion equipment
- Pipe bender
- Trowel
- De-clogging wire / de-clogging machine
- Toilet pump

Supplies and Materials

- Screws
- Adhesives
- Cement
- Sand

- Pipes
- Traps
- Electric cables
- Caulking material
- Fitting

7.2.4.7.References

Fred Hall & Roger Greeno., 2009., Building services handbook incorporating current building & Construction regulations., 5th Edidition

David V. Chadderton., 2007., Building Services Engineering., 5th Edition

7.2.4.8.Model Answers

1. Testing plumbing systems is the responsibility of the building owner
   a. False
   b. True

2. For some installations, several plumbing systems can be tested and inspected simultaneously, such as the building sewer and water service when they are installed in the same trench
   e. False
   f. True

3. An air test is a plumbing system test in which inlets and outlets to the system are sealed and air is forced into the system until a uniform air pressure of 5 psi is reached and maintained for 15 min without additional air being added to the system
   e. False
   f. True

4. A hand pump or portable air compressor is used to force air into the plumbing system, and is typically used when testing smaller installations, such as a one-family dwelling
   a. False
   b. True

5. Always wear a protective helmet (hard hat) and eye protection when performing air and water tests using test plugs and do not stand directly in front of an outlet where a test plug is installed
    a. False
    b. True

6. Malleable iron plugs and caps have male and female threads, and are removed from a pipe end using a pipe wrench
    a. False
    b. True

7. Water tests are typically performed on PEX systems since it is less time-consuming to perform a water test than an air test
    a. False
    b. True

8. A final air test is a test of the plumbing fixtures and their connections to the sanitary drainage system
    e. False
    f. True

9. Underground sanitary drainage and vent piping is tested and inspected after it is covered with earth and backfilled
    a. False
    b. True

10. Odor and final air test are performed on sanitary drainage and vent piping
    a. False
    b. True