2602/304
ELECTROMAGNETIC FIELDS THEORY
AND COMMUNICATION SYSTEMS
June / July 2023
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING (TELECOMMUNICATION OPTION)

MODULE III

ELECTROMAGNETIC FIELDS THEORY AND COMMUNICATION SYSTEMS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Mathematical tables;
Non-programmable scientific calculator;
Drawing instruments.

*This paper consists of **EIGHT** questions in **TWO** sections; **A** and **B**.*
*Answer any **TWO** questions from section **A** and any **THREE** questions from section **B** in the answer booklet provided.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.

Take: *Free space wave velocity,* $c = 3 \times 10^8\ m/s$
Free space wave impedance $Zo = 120\pi\ \Omega$
Electronic charge, $e = 1.602 \times 10^{-19} C$.
Permittivity of free space, $\varepsilon_0 = 8.854 \times 10^{-12}\ F/M$
Permeability of free space, $\mu_o = 4\pi \times 10^{-7}\ H/M$

This paper consists of 9 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

SECTION A: ELECTROMAGNETIC FIELDS THEORY

*Answer any **TWO** questions from this section.*

1. (a) State Maxwell's equations for time varying fields in point form and explain the physical significance of each. (8 marks)

(b) The electric field intensity, $\vec{E}$, in free space is given by $\vec{E} = 5\sin(10^6\pi t - 4z)\vec{a}_y$. Determine the expressions for:

(i) magnetic flux density, $\vec{B}$.
(ii) magnetic field intensity, $\vec{H}$;
(iii) electric flux density, $\vec{D}$.

(8 marks)

(c) A cuboid defined by $0 < x < 2, 0 < y < 2, 0 < z < 2$ metres contains a volume charge of density, $\rho_v = 15xyz\ \mu C/m^3$. Determine the total outward electric flux from the cube. (4 marks)

2. (a) Distinguish between magnetic flux and magnetic field strength with respect to electrodynamics. (2 marks)

(b) With aid of a sketch, describe the Biot-Savart law of magnetism. (4 marks)

(c) Figure 1 shows a diagram of a rectangular coil, $0.5\,m \times 0.8\,m$. The coil rotates at $\omega = 25\pi$ radians/S in a magnetic field $\vec{B} = 0.7\,\vec{a}_z$ Teslas. Determine the expression for the:

(i) magnetic flux;
(ii) induced voltage.

(5 marks)

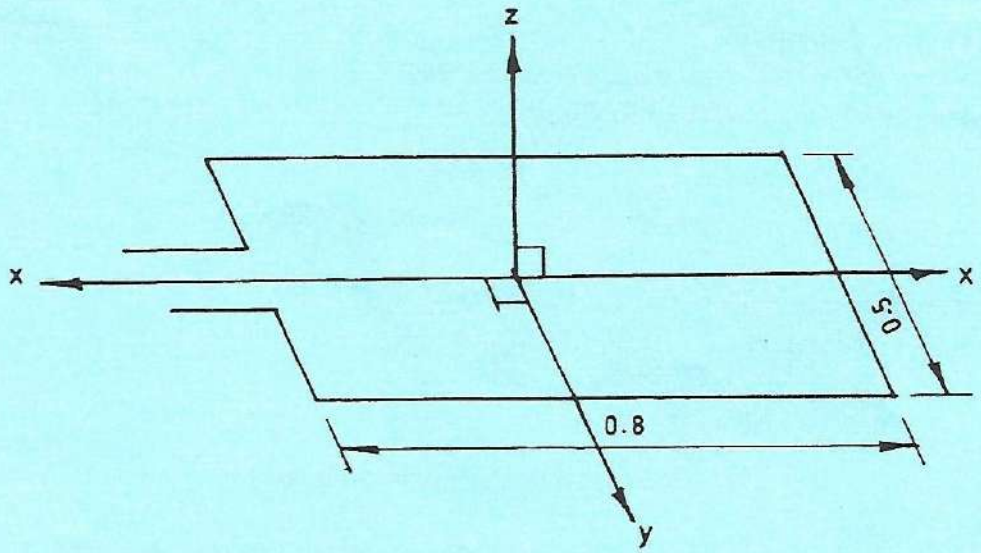

Fig. 1

(d) Table 1 shows bands of electromagnetic waves, frequency ranges, and areas of application. Complete the table.

Table 1

Electromagnetic wave	Frequency range	Area of application
X-rays	-	-
Ultra-violet	-	-
Infra-Red	-	-

(9 marks)

3. (a) Figure 2 shows an Hystresis coop of a magnetic material.

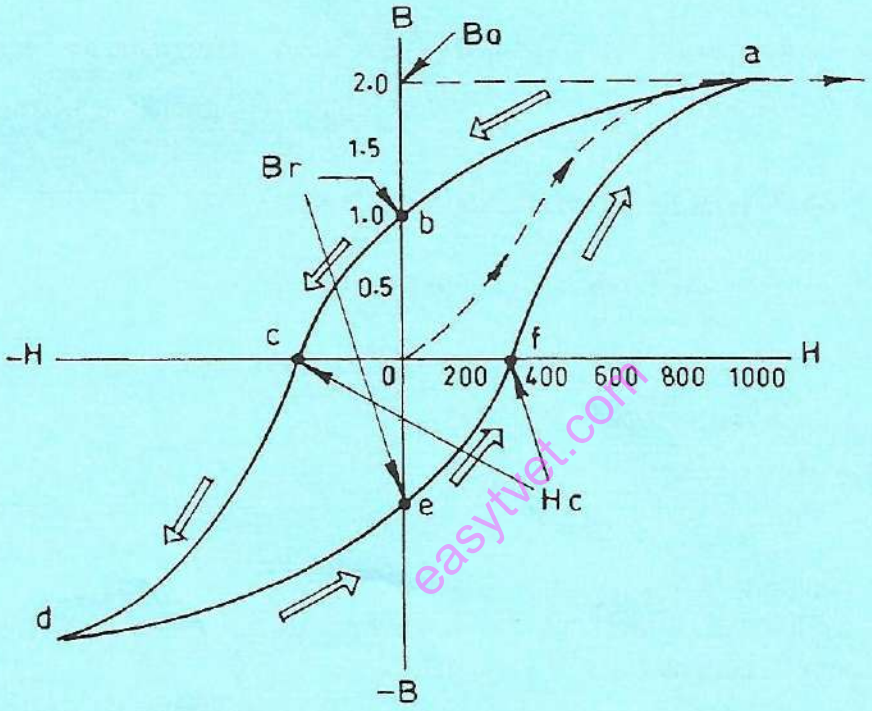

Fig. 2

(i) Identify the quantities labelled Hc, Br and Bo.

(ii) Define each quantity in a(i).

(6 marks)

E = A cos ωt +

(b) The electric field of a plane wave in a dielectric is given by

$$E = 3.77 \times 10^{-2} \cos\left(2\pi \times 10^{8} t - \frac{4\pi}{3} z\right).$$

The relative permeability of the dielectric $\mu r = 1$. Determine the:

(i) relative permittivity of the dielectric;
(ii) dielectric impedance;
(iii) wavelength of the wave in the dielectric;
(iv) expression for the magnetic field, H.

(10 marks)

(c) A vector potential, $\vec{A}$, is given by $\vec{A} = 6(x^2 + y^2 + z^2)\vec{a}_x$.

The magnetic flux density, $\vec{B}$, is defined by $\vec{B} = \nabla \times \vec{A}$. Determine the value of $\vec{B}$.

(4 marks)

SECTION B: COMMUNICATION SYSTEMS

*Answer any **THREE** questions from this section.*

4. (a) Define each of the following with respect to TV systems:

(i) hue;
(ii) flyback

(2 marks)

(b) State any **two** of the following:

(i) types of analogue colour TV systems;

(ii) colour difference signals.

(4 marks)

(c) Figure 3 shows a block diagram of a digital TV transmitter. Explain the functions of each of the following blocks:

(i) quantisation and PCM;
(ii) data encryption;
(iii) data compression;
(iv) multiplexer.

(8 marks)

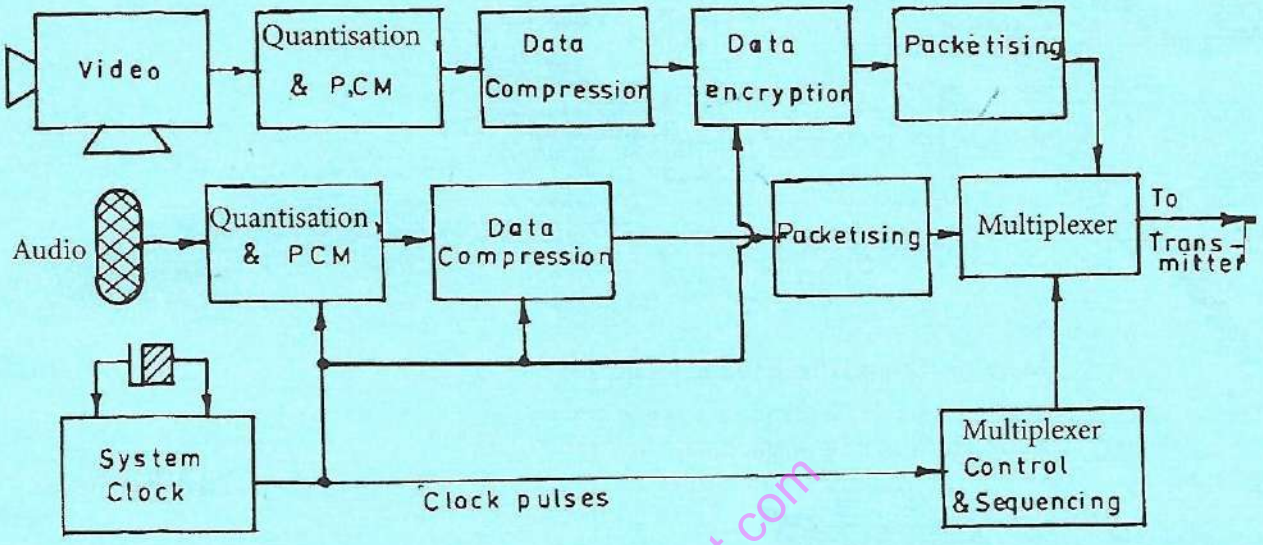

Fig. 3

(d) Explain **three** challenges facing migration from analog to digital TV transmission.

(6 marks)

5. (a) Figure 4 shows a block diagram of a CW Doppler Radar Tx/Rx with a heterodyne receiver.

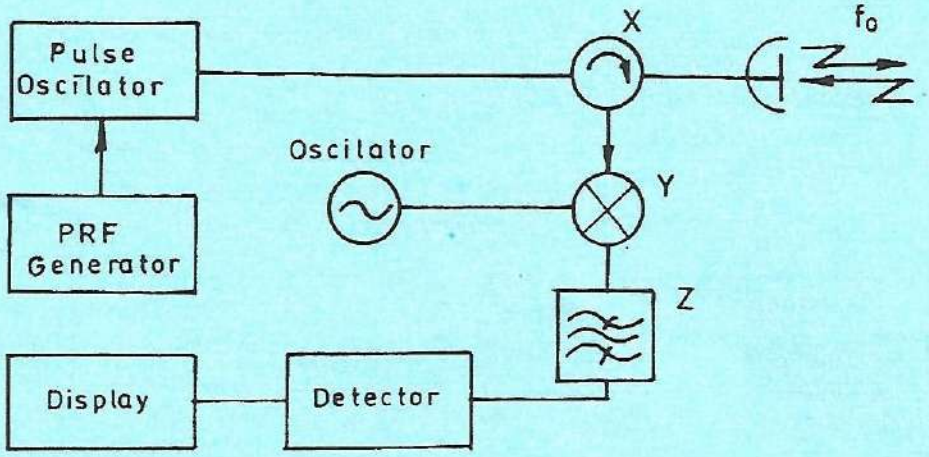

Fig. 4

(i) Identify the parts labelled x, y and z.

(ii) State the function of each part in a(i).

(6 marks)

(b) A radar transmitter has a mean power of 500 kW, a pulse repetition frequency (PRF) of 2500 pps and a pulse width of 0.8 μS. Determine the:

(i) duty cycle;
(ii) transmitted peak power;
(iii) maximum unambiguous range.

(6 marks)

(c) Figure 5 shows a diagram of a Doppler radar illumination for directing a missile to a target.

(i) Describe its operation.

(ii) State **two** limitations of the system.

(8 marks)

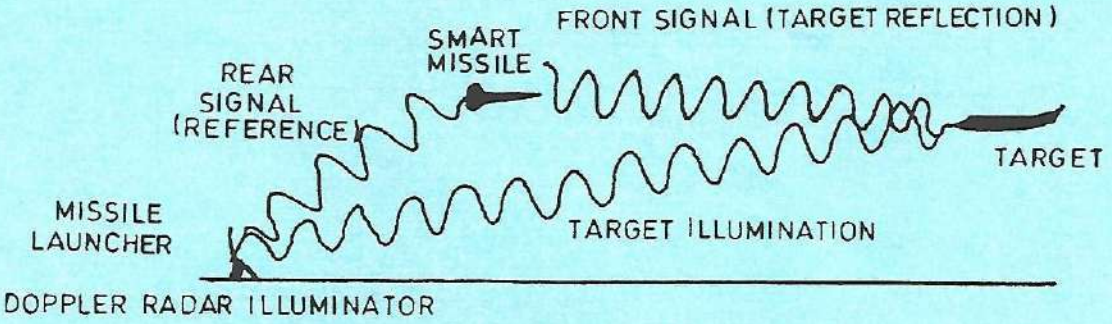

Fig. 5

6. (a) Define each of the following with respect to satellite communication:

(i) stabilization;
(ii) footprint.

(2 marks)

(b) (i) Describe a VSAT.

(ii) State **three** areas of VSAT applications.

(5 marks)

(c) Describe each of the following satellite types:

(i) geosynchronous;
(ii) polar;
(iii) defence.

(6 marks)

(d) Table 2 shows the uplink parameters of a satellite system.

Table 2

	UPLINK PARAMETERS	PARAMETER VALUE
1.	Earth station transmitter output power at saturation, 200 W	33 dBW
2.	Earth station transmit antenna gain	64 dB
3.	Uplink atmospheric losses	0.6 dB
4.	Free space path losses	206.5 dB
5.	Satellite antenna gain	20 dB
6.	Uplink frequency	4 GHz

Determine the:

(i) EIRP for earth station, in dBW;
(ii) carrier power density at the satellite;
(iii) received power at the satellite, in dBW.

(7 marks)

7. (a) Define each of the following with respect to waveguides:

(i) characteristic impedance;
(ii) cut-off frequency.

(2 marks)

(b) Draw a labelled diagram of a travelling wave tube microwave amplifier and describe its operation. (8 marks)

(c) A rectangular waveguide has dimensions W x h, metres, and propagates the $TE_{1,0}$ mode. The electric field across the guide is given by:

$$e = E_o \sin\left(\frac{\pi x}{W}\right).$$

The guide impedance is Z_T.

(i) sketch the electric field across the guide.
(ii) show that the total power flow across the guide is given by the expression, $W_T = \frac{E_o h W}{4 Z_T}$.

(8 marks)

(d) State the functions of each of the following microwave devices:

(i) Hybrid-T;
(ii) isolator.

(2 marks)

8. (a) (i) Draw a labelled block diagram of an independent side-band AM (ISB-AM) transmitter.

(ii) State with reasons **one** merit of ISB-AM.

(iii) State **two** application areas of ISB-AM.

(8 marks)

(b) State **two** merits of frequency modulation (FM) radio transmission. (2 marks)

(c) An FM reactance modulator uses an oscillator whose capacitance and inductance are 25 pF and 0.101 μH respectively. When a modulating signal of 5 kHz is applied the effective capacitative becomes 24.92 pF. Determine the:

(i) carrier frequency;
(ii) frequency deviation of the modulated wave;
(iii) modulation index;
(iv) system bandwidth.

(10 marks)

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