2507/305
ELECTROMAGNETIC FIELD THEORY
March/ April 2024
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN AERONAUTICAL ENGINEERING (AVIONICS OPTION)

MODULE III

ELECTROMAGNETIC FIELD THEORY

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
answer booklet;
non-programmable scientific calculator.
*This paper consists of **EIGHT** questions.*
*Answer any **FIVE** questions in the answer booklet provided.*
All questions carry equal marks.
Maximum marks for each part of a question are as shown.
Candidates should answer the questions in English.

Take: Permittivity of free space, $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ H/M$;

This paper consists of 5 printed pages.

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

1. (a) (i) State **two** sources of electromagnetic waves.

(ii) Draw the electromagnetic wave spectrum in the direction of increasing wavelength. (6 marks)

(b) State **two:**

(i) properties of electromagnetic radiation.

(ii) applications of electromagnetic radiation. (4 marks)

(c) (i) Describe cross product of two vectors

(ii) Given the vector $\bar{A} = \rho \cos\phi \bar{a}\rho + Z \sin\phi \bar{a}\phi$, evaluate $\oint \bar{A}.d\bar{l}$ around the edge l of the wedge defined by $0 \leq \rho \leq 2, 0 \leq \phi \leq 60^{o}$, Z=0 shown in figure1. (10 marks)

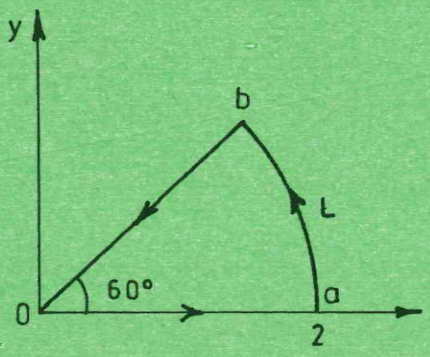

Fig. 1

2. (a) (i) State Gauss' law of electrostatics.

(ii) Figure 2 shows an infinite line charge density ρ_L C/m lying a long the Z-axis. Using Guss' law, derive the expression for electric field intensity.

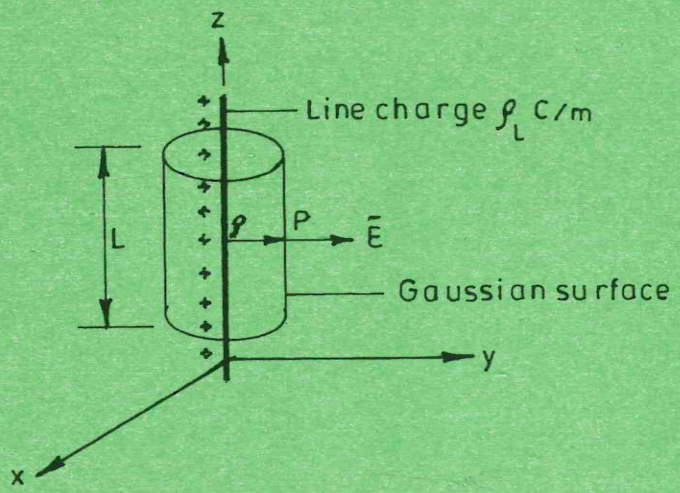

Fig. 2

(iii) A uniform charge of line distribution density $\rho_L = 25\, nC/m$ is located at x = 3 m and y = –5 m. Determine the electric field at $(-3, -1, 5)m$.

(12 marks)

(b) For the vector field $\bar{A} = x^2yz\,\bar{a}\,x + xz\,\bar{a}z$, determine its:

(i) Diverge, $\nabla . \bar{A}$
(ii) curl, $\nabla \times \bar{A}$ (8 marks)

3. (a) State;

(i) **four** properties of electric field lines.
(ii) superposition principle of electrostatic forces. (5 marks)

(b) Using superposition principle, derive the expression for resultant force experienced by a test charge Q due to point charges Q_1, Q_2, Q_3 ..... Q_n located at distance R_1, R_2, R_3 ..... R_n respectively. (3 marks)

(c) (i) Define electric field intensity.
(ii) Derive the expression for force, F on a point charge q located (0,0, h) m due to charge of surface charge density ρ_s C/m^2 uniformly distributed over the circular surface r = a, z = 0 m. (12 marks)

4. (a) State the **four** fundamental vector field quantities. (4 marks)

(b) (i) Distinguish between convection and conduction currents in electromagnetic field.

(ii) A 9.6×10^9 Hz uniform plane wave is propagating in space where $\mu_r = 2$ and $\varepsilon_r = 3$. Determine the:

(I) Velocity of propagation;
(II) Phase constant,
(III) Intrinsic impedance. (8 marks)

(c) Table 1 shows electromagnetic field quantities, symbols and units. Copy and fill the table.

Table 1

Field Quantity	Symbol	Unit
-	F	-
Conductivity	-	-
-	$\bar{J}$	-
-	-	C

(8 marks)

5. (a) From the equation $\nabla \times \bar{H} = \bar{J}$, derive the equation of continuity for magnetostatic fields. (4 marks)

(b) (i) Distinguish between Lossy and Lossless dielectrics.

(ii) An electric field in free space is given by $\bar{E} = 50\cos(10^8 t + \beta x)\bar{a}y\, V/m$. Determine the

(I) Direction of propagation;

(II) Constant β

(III) time it takes to travel a distance of $\frac{\lambda}{2}$. (10 marks)

(c) (i) State poynting's theorem.

(ii) Ina non-magnetic medium, the electric field intensity is: $\bar{E} = 4\sin(2\Pi \times 10^7 t - 0.08x)\bar{a}x\, V/m$. Determine the time-average power carried by the wave, given the intrinsic impedance. (6 marks)

6. (a) (i) List **three** electrical devices whose operation is based on magnetic field effect;

(ii) Distinguish between magnetic scalar potential and magnetic vector giving an expression for each quantity. (7 marks)

(b) Figure 3 shows a cylindrical Gaussian surface for magnetostatic field at the interface between two different dielectrics of permeabilities μ_1 and μ_2 respectively. Using Gauss's law, show that the normal component of the magnetic flux density (β) is continuous across the boundary. (5 marks)

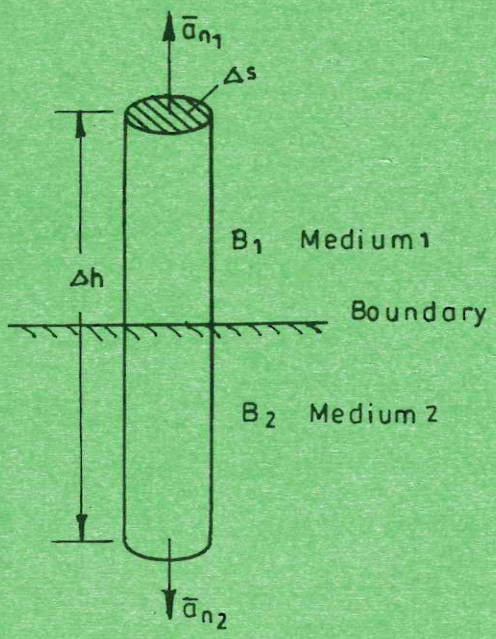

Fig. 3

(c) With the aid of a labelled diagram, describe the operation of Faraday's disc generator. (8 marks)

7. (a) (i) Define uniform plane wave as used in electro magnetic fields.

(ii) The equation of a wave in a lossless medium is described by:

$$\bar{E}y(x,t) = C_1 \cos(wt - \beta x) + C_2 \cos(wt + \beta x)$$

(I) Obtain the expression for the wave in positive direction.

(II) Determine the wave velocity;

(III) Describe the wave at the instant when $C_1 = C_2$.

(7 marks)

(b) (i) Define electrostatic potential

(ii) Three point charges –1nC, 4nC and 3nC are located at (0,0,0), (0,0,1) and (1,0,0) respectively. Determine the energy in the system. (8 marks)

(c) An A.C voltage source $V = V_o$ Sin wt is connected across a parallel plate capacitor C. Show that the displacement current in the capacitor is the same as the conduction current in the wires. (5 marks)

8. (a) (i) State Gauss' law in eletrostatics.

(ii) Applying the law in a(i), show that $\nabla . \bar{D} = \rho_v$

where $\bar{D}$ - electric flux density.

ρ_v - volume charge density. (7 marks)

(b) Given $\bar{D} = y^2 z^3 \bar{a}x + 2xyz^3 \bar{a}y + 3xy^2 z^2 \bar{a}z \; pc/m^2$ in free space, determine the

(I) Total flux passing through the surface x =3, $0 \leq y \leq 2$, $0 \leq z \leq 1$ in metres in the direction away from the origin.

(II) Magnitude of electric field intensity at P(3,2,1). (9 marks)

(c) State frequency range for each of the following telecommunication bands:

(i) VHF;

(ii) MF. (4 marks)

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