2507/305
ELECTROMAGNETIC FIELD THEORY
Oct./Nov. 2021
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 **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, $\mu_0 = 4\pi \times 10^{-7}\ H/M$
Speed of light, $C = 3 \times 10^8 m/s$

This paper consists of 6 printed pages.

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

Turn over

1. (a) State:

(i) **Two** sources of electromagnetic radiations.

(ii) **One** application of each of the following electromagnetic waves:

(I) x-rays;
(II) ultra-violet waves;
(III) gamma rays.

(5 marks)

(b) (i) Distinguish between vector and scalar quantities as used in electromagnetic field theory.

(ii) A vector in an electromagnetic field is given as $A = A_x a_x + A_y a_y + A_z a_z$. Derive an expression for a unit vector a_A along vector A.

(5 marks)

(c) (i) Write the ranges of variables used in cylindrical co-ordinate system when analysing electromagnetic field waves.

(ii) A point $P(-2,6,3)$ is located in a cartesian field. Express P in spherical co-ordinate system.

(7 marks)

(d) A vector in an electric field is given as $\vec{V}$. Write an expression for:

(i) divergence of $\vec{V}$;

(ii) curl of $\vec{V}$;

(i) laplacian of $\vec{V}$.

(3 marks)

2. (a) State **four** factors that determine the magnitude of a force between two point charges. (4 marks)

(b) Figure 1 shows two point charges Q_1 and Q_2 located at radii r_1 and r_2 from the origin $(0,0,0)$.

(i) Redraw the diagram and show the direction of the force exerted by charge Q_2 on Q_1.

(ii) Derive an expression for the force in (i).

(5 marks)

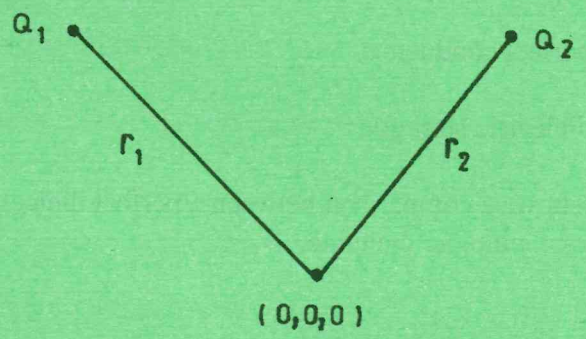

Fig. 1

(c) Two point charges $Q_1 = 2 \times 10^{-5}$ C and $Q_2 = -4 \times 10^{-5}$ C are located in free space at $(1,3,-1)$ and $(-3,1,-2)$ respectively in a cartesian co-ordinate system. Determine the electric field intensity at $(3,1,-2)$ due to the two charges. (6 marks)

(d) Using Gauss' law, derive the Maxwells first law of electrostatics. (5 marks)

3. (a) (i) State Stokes theorem.

(ii) Write the Maxwells second equation of electrostatics.

(4 marks)

(b) (i) Define electric potential of a point charge.

(ii) A point charge Q is moved from a point A to a point B in an electric field of intensity, E. Show that the potential difference between the two points is given by:

$$V_{AB} = -\int_A^B \vec{E}.dl$$

Where dl - differential length.

(iii) Explain the meaning of the negative sign in (ii).

(7 marks)

(c) An electric field is given by $E = \left(\frac{X}{2} + \delta y\right)a_x + \delta x a_y \text{ V/m}$. Determine the work done in moving a point charge $Q = -20\,\mu\text{C}$ from the:

(i) origin to point $(4,0,0)$ m;

(ii) point $(4,0,0)$ to $(4,2,0)$ m.

(9 marks)

4. (a) (i) Define each of the following terms as used in electromagnetic fields theory:

(I) perfect conductor;

(II) dielectric strength.

(ii) **Table 1** shows a comparison between a perfect dielectric and a perfect conductor. Complete the table. (5 marks)

Table 1

Perfect dielectric	**Perfect conductor**
$\sigma = 0$	J =
E =	σ =

(b) (i) Explain 'polarization' with reference to electric fields.

(ii) Explain the importance of boundary conditions in electrostatics.

(iii) List **three** types of boundaries in electromagnetic fields theory.

(7 marks)

(c) The flux lines of an electric field passes from air into glass, making an angle of 25° with the normal at the air side. If the relative permittivity ε_r for glass is 5 and the electric field intensity in air is 250 V/m.

Determine the:

(i) angle that the flux lines make with the normal on the glass side.

(ii) flux density in glass.

(8 marks)

5. (a) (i) Define magnetic flux ϕ with reference to magnetostatics.

(ii) Write the expression for magnetic flux ϕ in (a) (i).

(3 marks)

(b) (i) State Amperes circuital law in magnetostatics.

(ii) With aid of a diagram derive the expression for Amperes circuital law in (b) (i).

(10 marks)

(c) A current carrying loop placed in air has a diameter of 4 cm and loop current of 6 mA. Determine the value of magnetic flux density in the loop. (3 marks)

(d) Determine the polarisation, P in a dielectric material with $\varepsilon_r = 3.0$ and $D = 4.0 \times 10^{-7} ac/m^2$. (4 marks)

6. (a) Define electric field intensity in electrostatics. (2 marks)

(b) With aid of a diagram derive the expression for infinite line charge. (9 marks)

(c) A charge of $2\mu C$ is situated at $(0,2,0)M$. Another charge of $-1\mu C$ is located at $(0,-2,0)M$.

(i) Sketch the arrangement of the charges.

(ii) Determine the value of electric field intensity E at the point $(0,-1,0)M$.

(9 marks)

7. (a) State **four** vector field theorems in magnetic fields. (4 marks)

(b) Table 2 shows attributes of electrostatics and magnetostatic. Complete the table.

Table 2 (8 marks)

Attribute	Electrostatics	Magnetostatics
Sources		Steady current J
Field and fluxes	E and D	
Potential	Scalar V $E = -\nabla V$	
Governing equations in differential form		$\nabla \cdot B = 0$ $\nabla \times H = J$

(c) In an experiment on magnetism in air, the magnetic field density is 1.5×10^{-2} Tesla's and the electric field strength is 1.8×10^{6} volts / metre. Determine the total energy density of the fields. (8 marks)

8. (a) Define the term momentum flux in electromagnetics. (2 marks)

(b) With the aid of a labelled diagram describe the electromagnetic energy flow out of a 12 V d.c battery. (7 marks)

(c) A plane electromagnetic wave of intensity 4 watts/m^2 strikes a mirror of area 25 cm^2 held perpendicular to the approaching wave.

Determine the:

(i) momentum transferred by the wave to the mirror per second;

(ii) value of force exerted on the mirror by the wave.

(11 marks)

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