2507/305
ELECTROMAGNETIC FIELD THEORY
Oct./Nov. 2023
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** of the **EIGHT** questions 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: *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 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.

Turn over

1. (a) List **three** types of electromagnetic waves and state one area of application of each. (6 marks)

(b) Draw and label a diagram showing electromagnetic wave propagation. (6 marks)

(c) With aid of a diagram describe the radiation detector using the ionization chamber. (6 marks)

(d) Explain 'short wave radiation'. (2 marks)

2. (a) Explain the following terms as used in electrostatics:

(i) Electric field;
(ii) Electric flux density;
(iii) Equipotential surface.

(6 marks)

(b) (i) Draw the electric field of each of the following point charges:

I. positive point charge.
II. negative point charge.

(ii) An electric force of 9N is acting on a charge of $3\,\mu C$.
Determine the electric field due to the charge at any point.

(6 marks)

(c) (i) State 'coulombs law';

(ii) Figure 1 shows three point charges situated in air. Determine $\overline{E}$ at point P. (8 marks)

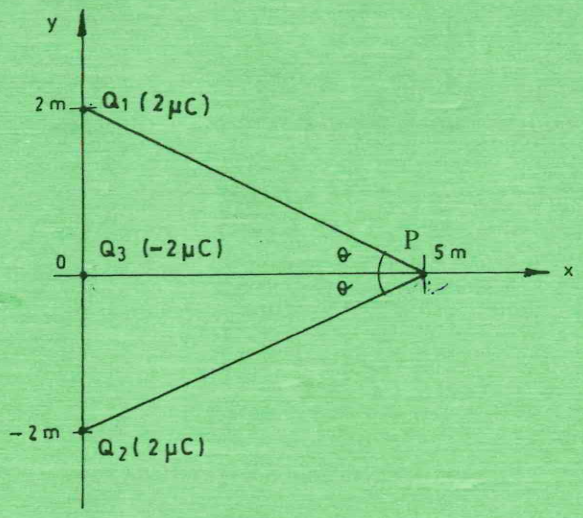

Fig. 1

3. (a) Write the expression and SI unit of each of the following quantities in magnetostatics:

(i) magnetic field density:
(ii) magnetization force. (4 marks)

(b) Describe 'Bio-savart law'. (2 marks)

(c) (i) Two parallel wires each of the length l metres are separated by a distance r metres. Current I_1 and I_2 flows through the wires in the same direction. Determine an expression for the force, F between the conductors.

(i) State the nature of the force in (c)(i). (7 marks)

(d) A solenoid of 1000 turns, has a radius of 12 cm and a length of 20 cm. If a current of 5A flows through the solenoid, determine the:

(i) magnetic flux density;
(ii) magnetic flux. (7 marks)

4. (a) Write the four maxwells equations in integral form and state the law represented by each. (8 marks)

(b) Derive the equation of continuity in time varying form for time varying fields using Maxwells equations. (6 marks)

(c) In a free space, $\overline{E} = 10\,Cos\,(\omega t - 60x)\,\hat{a}y\,V/m$.
Determine the:

(i) Current density, I_d;
(ii) Angular velocity, ω. (6 marks)

5. (a) Explain each of the following with reference to electromagnetic waves:

(i) propagation constant;
(ii) attenuation constant. (4 marks)

(b) Show that the wave equation in free space is given by:

$$\nabla^2 E = \mu\Sigma\frac{\delta^2 E}{\delta t^2}$$

(8 marks)

(c) An electromagnetic wave propagates along the x-direction. The magnetic field oscillates at a frequency of 10^9 Hz and has an amplitude of 10^{-5} Tesla along the Y-direction. Determine the:
(i) wavelength of the wave;
(ii) wave linear velocity;
(iii) angular velocity.

(8 marks)

6. (a) State **two** characteristics of TEM waves. (2 marks)

(b) (i) Define 'characteristics impedance with reference to transmission lines.
(ii) Show that the impedance in (b) (i) for a loss-less line is given by:

$$Z_o = \sqrt{\frac{L}{C}}$$ (7 marks)

(c) A uniform plane wave at 1200 MHz is propagating through a non-magnetic dielectric with $\varepsilon_r = 5$ and the loss angle tan $\sigma = 0.02$ in the Z-direction. Determine the:

(i) velocity;
(ii) wavelength;
(iii) phase constant, β;
(iv) Attenuation constant, α. (8 marks)

(d) Determine the input impedance of a short circuited transmission line of length $\frac{\lambda}{4}$ and characteristics impedance of $480\,\Omega$. (3 marks)

7. (a) State **two** types of materials used in electromagnetics. (2 marks)

(b) (i) Describe 'skin effect' in electric conductors.
(ii) List four methods of reducing skin effect in (b) (i). (6 marks)

(c) A conductor of conductivity $\sigma = 10^5$ mho/m and $\mu r = 5$ operates at a frequency of 12 KHz. Determine the ratio of free space wavelength to wavelength in the conductor. (9 marks)

(d) Table 1 shows the characteristics of loss less and lossy dielectrics when subjected to electromagnetic waves.

Table 1

Characteristics of dielectrics	Loss less dielectric	Lossy dielectric
J	J = 0	
ε	$\varepsilon = \varepsilon_r \varepsilon_o$	
μ		$\mu = \mu_o \mu_r$

Copy and complete the table. (3 marks)

8. (a) Determine the divergence of the vector field:

$$\overline{A} = 2yz\,\hat{a}_x + 5xy\hat{a}y + y\hat{a}_z$$

at the point (1,–2, 3)

(8 marks)

(b) With the aid of a diagram and using Gauss law, show that the expression for electric flux density for infinite sheet of charge is given by:

$$D = \frac{\rho_s \hat{a}z}{2}$$

(6 marks)

(c) Given that $D = 10Xa\hat{x}\ c/m^2$, determine the flux crossing 2 m² area that is normal to the x-axis at x = 4 cm.

(4 marks)

(d) State two reasons for electromagnetic shielding.

(2 marks)

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