2507/305
ELECTROMAGNETIC FIELD THEORY
Oct./Nov. 2019
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;
Mathematical tables/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, $\mu_0 = 4\pi \times 10^{-7} H/M$
Sped of light, $C = 3\,X\,10^8 m/s$
Plank's constant, $h = 6.626 \times 10^{-34}$

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.

Turn over

1. (a) (i) Outline **two** sources of electromagnetic radiations.

(ii) Table 1 shows types of electromagnetic waves. Complete the table. (8 marks)

Table 1

SNo.	Wave	Example of Detectors	Typical Application
1	Radio wave	Aerial	___
2	Micro-wave	___	Heating
3	Infra-red	___	Remote controls
4	Visible light	LED	___
5	Ultraviolet	Film	___
6	X-rays	Very fast electrons	___

(b) (i) Define electric field intensity.

(ii) Determine the electric field intensity at point (0,0,4) due to charge of 2 nC distributed uniformly on a line. (8 marks)

(c) Explain Faraday's Law for time varying fields. (4 marks)

2. (a) (i) Define magnetic flux density and state it's units.

(ii) State Ampere's circuit law and write it's mathematical representation. (4 marks)

(b) Figure 1 shows a square coil of side 'a' carrying a current I. Show that the flux density B at point P, distance Z from the centre 'O' of the coil is given by:

$$B_z = \frac{2\sqrt{2\mu.I}}{\Pi}\left(\frac{a^2}{(a^2+4z^2)\sqrt{a^2+2z^2}}\right)$$

(7 marks)

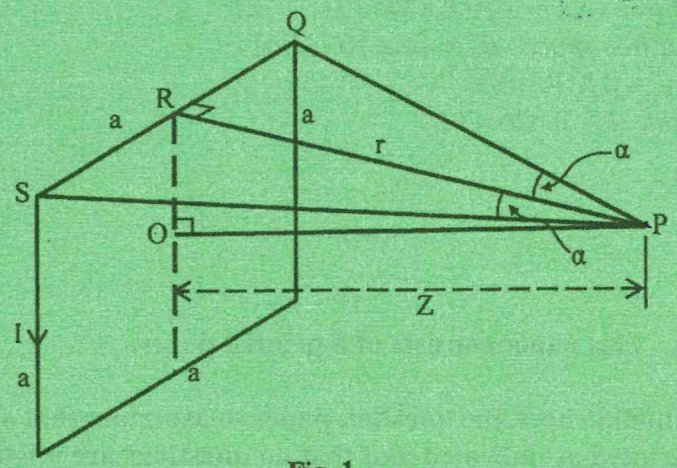

Fig. 1

(c) With the aid of a labelled diagram, describe the step-by-step method of determining the B-H curve. (9 marks)

3. (a) (i) State **two** applications of Gauss's law.

(ii) A sphere of radius R = 8 m has a charge Q = 30 μ C uniformly distributed throughout the surface. Determine the electric field at a distance r = 4 m from the sphere. (7 marks)

(b) State Maxwell's equations in words and write their mathematical expressions in differential form. (8 marks)

(c) Two straight wires are placed parallel to each other in $x-y$ plane, 10 mm apart. The current flowing through one wire is 1 A in the x-direction. If a current of 1 A is passed through the second wire in the same direction, determine the force exerted per unit length on each wire. $Q = CV$ $d = 10mm$ (5 marks)

4. (a) Explain displacement current density with respect to parallel plate capacitor and state it's units. (4 marks)

(b) The conduction current density in a lossy dielectric medium is given by $Jc = 0.002 \sin 10^9 t$ A/m^2. The conductivity $\delta = 10^3$ mho/m and $\varepsilon_r = 6.5$. Determine the displacement current density. (6 marks)

(c) (i) State 'Poynting theorem'.

(ii) Derive the Poynting theorem equation using Maxwells Curls equations. (10 marks)

5. (a) (i) State **two** properties of uniform plane waves,

(ii) Explain the skin effect with respect to electromagnetic waves. (5 marks)

(b) A lossy dielectric medium has an intrinsic impedance of $200\angle 30^\circ\ \Omega$ at a particular frequency. The plane wave propagating through the dielectric has the magnetic field component given by the expression

$$\vec{\mathbf{H}} = 10e^{-\alpha x}\cos(\omega t - \tfrac{1}{2}x)\hat{a}y \text{ A/m.}$$

Determine the:
(i) electric field component, $\vec{\mathbf{E}}$;
(ii) propagation constant;
(iii) skin depth. (10 marks)

(c) (i) Sketch an electromagnetic wave propagating in the Z-direction.

(ii) Explain why attenuation of an electromagnetic wave does not occur in a lossless medium.

(5 marks)

6. (a) State Biot Savart law and write it's mathematical expression. (2 marks)

(b) Define each of the following with respect to electromagnetic waves:

(i) wavelength;
(ii) intrinsic impedance.

(2 marks)

(c) A transmission line has the following parameters.

Resistance R = 84 Ω/km, conductance G = 10^{-6} mho/km
Inductance L = 0.01 H/km, capacitance C = 0.061 μF/km
and frequency, f = 1,000 Hz.

Determine the:

(i) characteristics impendance;
(ii) propagation constant;
(iii) velocity of propagation.

(10 marks)

(d) Differentiate between the following magnetic materials:

(i) soft magnetic materials;
(ii) hard magnetic materials.

(6 marks)

7. (a) Write Maxwell's equations in vector form. (4 marks)

(b) Using the vector identify $\vec{\nabla} \times \vec{\nabla} \times \vec{\mathbf{E}} = \vec{\nabla}(\vec{\nabla}.\vec{\mathbf{E}}) - \vec{\nabla}^2 \vec{\mathbf{E}}$

Show that the wave equation for electric field intensity is given by the expression:

$$\vec{\nabla}^2 \vec{\mathbf{E}} = j\omega\mu(\sigma + j\omega\varepsilon)\vec{\mathbf{E}}$$

(6 marks)

(c) (i) State Faraday's law in differential form.

(ii) An electric field is given by the expression:

$$\vec{\mathbf{E}} = 20\sin(10^8 t - \beta x)\widehat{a_z}$$

Using the law in c(i), determine the expression for the magnetic field $\vec{\mathbf{H}}$.

(8 marks)

(d) Outline **two** types of wave polarization. (2 marks)

8. (a) State Poynting energy conservation theorem and write it's mathematical expression in differential form. (3 marks)

(b) An electromagnetic wave has a wavelength of 625 nm. Determine the:

(i) frequency of the wave;
(ii) energy of the wave.

(4 marks)

(c) (i) Outline **two** properties of magnetic shield materials.

(ii) With the aid of a diagram, describe how a magnetic shield works.

(7 marks)

(d) A ferrite material has a magnetic flux density of 0.05T and a relative permeability of $\mu_r = 50$. Determine the:

(i) susceptibility, χ_m;
(ii) magnetic field strength, H;
(iii) magnetization, M.

(6 marks)

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