2507/305
ELECTROMAGNETIC FIELD THEORY
June/July 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, $\mu_0 = 4\pi \times 10^{-7} H/M$

This paper consists 4 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 **four** sources of electromagnetic radiations. (4 marks)

(b) With the aid of a labelled block diagram, describe detection of radiation using the scintillation counter. (9 marks)

(c) List **five** radiations in the electromagnetic spectrum. (5 marks)

(d) Determine the energy associated with a microwave having a frequency of 1.5 GHz. (2 marks)

2. (a) Explain each of the following terms as used in electrostatics and state their SI units:

(i) electric field intensity;
(ii) electric flux. (6 marks)

(b) Draw a labelled diagram showing each of the following as applied in electrostatics:

(i) uniform field;
(ii) superposition of electric fields. (4 marks)

(c) (i) State the Gauss law in electrostatics.
(ii) Using the law in (c)(i) derive the expression for the electric field due to long straight uniformly charged wire at a point lying at a distance 'r' from the wire. (8 marks)

(d) A small charge $Q = 4mC$ is found in a uniform electric field of $E = 3.6N/C$. Determine the force on the charge. (2 marks)

3. (a) Explain the term 'magnetostatics'. (2 marks)

(b) Explain each of the following as used in magnetostatics:

(i) magnetic field strength;
(ii) magnetic flux density. (4 marks)

(c) (i) State **two** Faraday's laws of electromagnetic induction.
(ii) Derive the expression for amperes circuital law due to a current carrying wire in integral form. (9 marks)

(d) A semicircular piece of wire with radius 0.22 m carries a current of 120 A. Using bio-savart law in differential form, determine the magnetic field at the centre. (5 marks)

4. (a) State the **four** Maxwells equations in differential form. (8 marks)

(b) **Figure 1** shows an electric circuit. Using Maxwells equations, derive the expression for the current I_d. (6 marks)

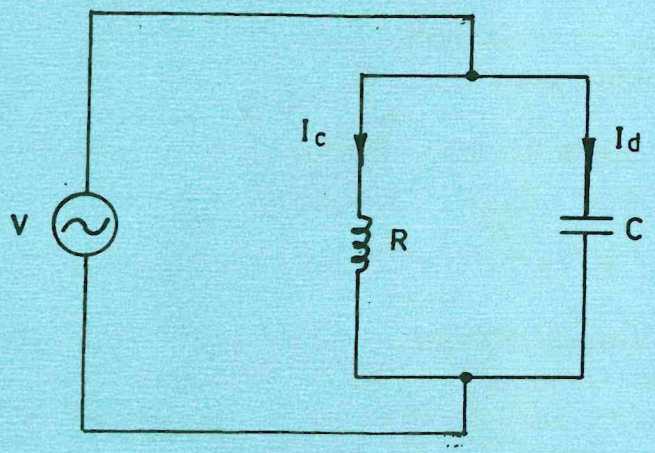

Fig.1

(c) Given $E = 20\sin(wt - \beta y)\,\hat{a}y\,V/m$ in a free space, Use Maxwells equation to determine:

(i) D;
(ii) B. (6 marks)

5. (a) List **five** properties of electromagnetic waves. (5 marks)

(b) (i) Define phase velocity with reference to travelling waves.
(ii) A wave travelling in X-direction and having two frequencies of equal amplitude is given by the expression $\bar{E}_y = \bar{E}_0\cos(wt - \beta x)$. Determine the expression for:

I. phase velocity;
II. group velocity. (8 marks)

(c) Describe 'phase constant' with reference to electromagnetic waves. (2 marks)

(d) A parallel plate capacitor has distance of separation between plates of 2 mm and area 30 cm^2. If a p.d. of 250 V is connected across the capacitor, determine the:

(i) electric field;
(ii) displacement current. (5 marks)

6. (a) State **three** types of plane waves. (3 marks)

(b) A plane electromagnetic wave is given by: $\vec{\mathbf{E}}(z,t) = E_0 \cos(kz - wt)\hat{i}$.

Determine the:

(i) direction of wave propagation;
(ii) corresponding magnetic field $\vec{\mathbf{B}}$. (9 marks)

(c) A loss less transmission line has a capacitance of 40 uF and a velocity of propagation of 2.0×10^8 cm/s.

Determine the:

(i) phase constant at 180 MHz;
(ii) inductance of the line;
(iii) characteristic impedance of the line. (6 marks)

(d) Explain 'intrinsic wave impedance' as used in communication lines. (2 marks)

7. (a) (i) Explain electromagnetic shielding. (6 marks)

(ii) List four types of materials used for electromagnetic shielding. (6 marks)

(b) (i) State 'Poynting's theorem'.
(ii) Write Poynting's theorem in integral form and explain each term of the equation. (7 marks)

(c) List **three** properties of TEM wave. (3 marks)

(d) In an air filled rectangular guide, the cut-off frequency for $TE_{10} = 60 \times 10^8 Hz$ and TE_{01} is 10 GHz. Determine the dimensions of the guide. (4 marks)

8. (a) Explain 'energy density' in electromagnetics. (2 marks)

(b) In a certain region of space, the magnetic field is 2×10^{-2}T and the electric field stress is $10 \times 10^6 v/m$. Determine the combined energy density in both fields. (6 marks)

(c) Explain each of the following with reference to electromagnetic waves:

(i) momentum;
(ii) divergence. (4 marks)

(d) Given $\ell_s = x^2 + xy$, determine $\int_s \ell s ds$ over the region $y \leq x^2$, $0 < x < 1$. (8 marks)

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