

2507/305

ELECTROMAGNETIC FIELD THEORY

June/July 2018

Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL
DIPLOMA IN AERONAUTICAL ENGINEERING
(AVIONICS OPTION)

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, $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/M}$

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H/M}$

Sped of light, $C = 3 \times 10^8 \text{ m/s}$

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 Coulombs Law.
- (ii) Two charges $q_1 = 5 \times 10^{-8} C$ and $q_2 = -3 \times 10^{-8} C$ are located 16 cm apart in free space. Determine the point between the two charges where the electric potential is zero. (4 marks)
- (b) (i) Define the following with respect to electrostatics:
- I. electric field;
 II. electric field intensity.
- (ii) A point charge $Q = 10^{-9} C$ is placed at a point in free space. Determine the:
- I. electric field intensity at a point 5 cm away from the charge;
 II. difference in potential between two points 20 cm and 10 cm away from the charge. (8 marks)
- (c) Write down Maxwell's equations in both word statement and integral form that describe the space and time dependence of the electric and magnetic fields in a medium. (8 marks)
2. (a) Distinguish between 'lossy' and 'lossless' media citing **one** example of each. (4 marks)
- (b) (i) Describe displacement current as used in electromagnetics.
- (ii) The conduction current density in a lossy dielectric is given by $J_c = 0.02 \sin 10^9 t A/m^2$. The conductivity of the dielectric $\sigma = 1 K mho/m$ and the relative permittivity, $\epsilon_r = 6.5$. Determine the displacement current density, J_d . (9 marks)
- (c) (i) Define skin depth with respect to electromagnetic waves.
- (ii) An electromagnetic wave travels through a conducting medium. Plot the variation of amplitude versus distance. (3 marks)
- (d) (i) Define intrinsic impedance.
- (ii) Determine the intrinsic impedance of free space. (4 marks)
3. (a) State Gaus law of electrostatics. (1 mark)

- (b) A long straight circular conductor of diameter 2 mm carrying a current of 250 A is placed in air.
- (i) Draw a curve showing the variation of the magnetic flux density, β from the conductor surface outwards.
 - (ii) Determine the magnetic flux density at a perpendicular distance of 5 cm from the conductor. (7 marks)

- (c) A transmission line has the following parameters:

$$R = 84 \Omega/km, G = 10^{-6} \text{ mho}/km, L = 0.01 \text{ H}/km;$$

$$C = 0.061 \mu\text{F}/km \text{ and frequency } f = 1,000 \text{ Hz.}$$

Determine the:

- (i) characteristic impedance;
- (ii) propagation constant;
- (iii) velocity of propagation. (12 marks)

4. (a) List **three** properties of electromagnetic waves. (3 marks)

- (b) (i) Draw a waveform of an electromagnetic wave indicating the following:

- I. wavelength;
- II. amplitude.

- (ii) Describe 'uniform plane wave'. (8 marks)

- (c) An electromagnetic wave propagates through aluminium, at a frequency of 1.6 MHz. The conductivity of aluminium is 38.2 MS/m and its electron mobility is $\mu = 1$.

Determine the:

- (i) skin depth;
- (ii) propagation constant;
- (iii) wave velocity. (9 marks)

5. (a) State the following with respect to electromagnetic fields:

- (i) Biot -savart law; ✓
- (ii) Ampere's law. ✓ (2 marks)

- (b) The electric field of an electromagnetic wave has an amplitude of, $E_0 = 120 \text{ N/C}$ and a frequency of $f = 50 \text{ MHz}$.

Determine the:

- (i) magnetic field strength;
 (ii) angular frequency of the electric field;
 (iii) wavelength of the electromagnetic wave. (6 marks)

- (c) Describe the following:

- (i) poynting theorem;
 (ii) electromagnetic shielding. (6 marks)

- (d) A region in space has magnetic field of $1.0 \times 10^{-2} \text{ T}$ and electric field of $2.0 \times 10^6 \text{ V/m}$. Determine the:

- (i) electric field energy density; E
 (ii) magnetic field energy density; B
 (iii) total energy density. (6 marks)

6. (a) Define each of the following, stating their units:

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

- (b) Explain the following terms with respect to electromagnetic waves:

- (i) phase velocity;
 (ii) propagation constant. (4 marks)

- (c) With the aid of a B - H curve, describe the hysteresis loop of magnetization. (10 marks)

- (d) State **two** applications of electromagnetic waves. (2 marks)

7. (a) State **three** factors that affect the magnitude of the electrostatic force between two point charges. (3 marks)

- (b) An infinity long straight wire carries a current $I = 20 \text{ A}$. Determine the distance from the wire at which the magnetic field intensity $H = 1 \text{ A/M}$. (3 marks)

- (c) Using Maxwell's curl equation, show that the poynting theorem for power flowing out of a closed surface, S, is given by:

$$\oint_S P \cdot ds = - \int_V \sigma E^2 \cdot dv - \frac{\partial}{\partial t} \int_V \frac{1}{2} \epsilon E^2 \cdot dv - \frac{\partial}{\partial t} \int_V \frac{1}{2} \mu H^2 \cdot dv. \quad (8 \text{ marks})$$

- (d) Draw the radiation patterns of the following antennae:
- (i) half-wave dipole;
 - (ii) Yagi-uda.
- (6 marks)
8. (a) Define the following with respect to antennae:
- (i) Hertzian dipole;
 - (ii) directivity. ✓
- (2 marks)
- (b) A magnetic field strength of $5\mu A/M$ is detected at a point $\theta = \frac{\pi}{2}$, 2 km from an antenna in air. Neglecting the ohmic losses, determine the power transmitted by the antenna if it is a:
- (i) Hertzian dipole of length $\frac{\lambda}{25}$;
 - (ii) half wave dipole.
- (9 marks)
- (c) Two charges, $Q_1 = 5\mu C$ and $Q_2 = 6\mu C$ are located at (0,4,0) and (3,0,0) respectively. Determine the electric field intensity at (0, 0, 5) metres due to the two charges.
- (9 marks)

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