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,* $\varepsilon_0 = 8.854 \times 10^{-12} F/M$
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7} H/M$
Sped of light, $C = 3 X 10^8 m/s$

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.

© 2018 The Kenya National Examinations Council

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 $Jc = 0.02 \sin 10^9 t \; A/m^2$. The conductivity of the dielectric $\sigma = 1 \; K \; mho/m$ and the relative permittivity, $\varepsilon_r = 6.5$. Determine the displacement current density, Jd. (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:

$R = 84\Omega/km, G = 10^{-6} mho/km, L = 0.01\ H/km;$
$C = 0.061\ \mu F/km$ *and frequency* $f = 1{,}000\ Hz.$

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 it's 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, $E_0 = 120\,N/C$ and a frequency of f = 50 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 $1.0 \times 10^{-2}\,T$ and electric field of $2.0 \times 10^{6}\,V/m$. Determine the:

(i) electric field energy density;
(ii) magnetic field energy density;
(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 A. Determine the distance from the wire at which the magnetic field intensity H = 1 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:

$$\oint_s P.ds = -\int \sigma E^2.dv - \frac{\partial}{\partial t}\int \frac{1}{2}\varepsilon E^2.dv - \frac{\partial}{\partial t}\int \frac{1}{2}\mu H^2.dv\,. \quad \text{(8 marks)}$$

(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)

THIS IS THE LAST PRINTED PAGE.