2507/305
ELECTROMAGNETIC FIELD THEORY
June/July 2022
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;
Drawing instruments;
Non-programmable scientific calculator.
*This paper consists of **EIGHT** questions.*
*Answer any **FIVE** 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 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 **two** methods of detecting electromagnetic radiations.

(ii) Explain the use of three dimensional co-ordinate system in the analysis of electromagnetic fields. (4 marks)

(b) Figure 1 shows a differential element placed in Cartesian system. Derive **three** expressions for the differential surface area. (6 marks)

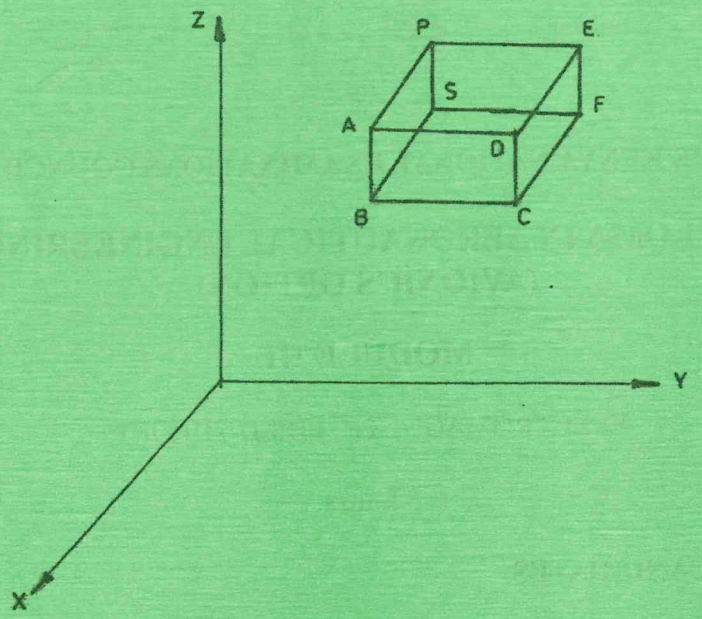

Fig. 1

(c) (i) Distinguish between solenoidal and irrotational vectors.

(ii) A vector field $\vec{P}$ exists round a closed path of length l. Write an expression for the:

(I) circulation of vector P around the path.

(II) electric flux through the surface enclosed by the path.

(4 marks)

(d) (i) State divergence theorem.

(ii) Show that the divergence of a curl of a vector $\vec{A}$ located in a cartesian field is equal to zero.

(6 marks)

2. (a) Derive an expression for the force per unit charge of two identical charges, Q located R meters from each other in an electric field. (3 marks)

(b) Two point charges $Q_1 = 20\ \mu C$ and $Q_2 = 300\ \mu C$ are located at points (0, 1, 2) and (2, 0, 0) respectively in an electric field. Determine the:

(i) distance between the charges;

(ii) force on charge Q_1 due to charge Q_2. (7 marks)

(c) (i) Define each of the following terms:

(I) charge density.
(II) current density.

(ii) Distinguish between convection and conduction currents in electrostatics. (4 marks)

(d) A square plate in the X - Y plane is situated in a space defined by $-3\ m \leq X \leq 3\ m$ and $-3\ m \leq Y \leq 3\ m$. If the surface charge density $e_s = 2y^2\ \mu c/m^2$, determine the total charge on the plate. (6 marks)

3. (a) State Maxwell's equation in time varying fields. (4 marks)

(b) (i) State **three** properties of uniform plane electromagnetic waves.

(ii) Show that the intrinsic impedance of a medium in free space $\eta = 120\pi$. (6 marks)

(c) Derive the expression for wave equation in free space in terms of electric field intensity E, using Maxwell's equations. (10 marks)

4. (a) (i) Define wave propagation.

(ii) A material has a relative permittivity $\varepsilon_r = 1$, relative permeability $\mu_r = 1$, and conductvity $\sigma = 0.25 \times 10^{-12}$ siemens/meter. If the wave frequency is 1.6 MHz, determine the propagation constant. (5 marks)

(b) Table 1 shows the relative quantities for various types of media for electromagnetic waves. Complete the table. (7 marks)

Table 1

Medium	**Conductivity** σ	**Permittivity** ε	**Permeability** μ
Free space	0	——	——
Lossless dielectric	——	$\varepsilon_0 \varepsilon_r$	——
Lossy dielectric	$\sigma \neq 0$	——	——
Good conductor	——	ε_0	$\mu_0 \mu_r$

(c) (i) A travelling wave moving at a speed of u m/s has a wavelength of λ m. The wave takes T seconds to repeat itself. Derive an expression for the phase constant β for the wave.

(ii) The electric field of a 1 MHz plane wave travelling in the Z-direction in air points along the X-direction. If the phase constant β is 1.2 π mV/M, determine the expression for E (Z, t).

(8 marks)

5. (a) Define the following terms as used in magnetostatics:

(i) magnetic flux density, B.

(ii) magnetic field intensity, H.

(4 marks)

(b) (i) State Biot-savrat's law in magnetostatics.

(ii) Write the expression for the law in (b)(i).

(4 marks)

(c) A current of 2A flows through two infinitely long parallel lines. Determine the force exerted between the wires when the distance between them is 0.5 m. Take the total length of the parallel wires to be 5 m. (7 marks)

(d) (i) State Faraday's law in magnetostatics.

(ii) A conducting wire of radius 0.2 cm, conductivity of $\sigma = 1.2 \times 10^7 \, s/m$ and relative permittivity $\varepsilon_r = 1$. If the conduction current is $I_c = 5 \sin \omega t \, (mA)$, determine the value of the eletric field intensity E.

(5 marks)

6. (a) (i) (I) State Coulomb's law of force in electrostatics.

(II) Write the expression for the law in (a)(i)I.

(ii) A rain drop has a charge of 0.45 μC and electric field of 60 V/m. Determine the force on the rain drop.

(6 marks)

(b) Derive the expression for electric lux density for a point charge placed at the origin.

(6 marks)

(c) A negative charge of 2 μC is located at a point (0, –2)m and another charge of 1 μC at a point (0, 2)m. Determine the voltage at point (0, 1)m. (8 marks)

7. (a) State **three** classifications of magnetic materials. (3 marks)

(b) With the aid of a diagram, describe the B–H characteristic curve-of a magnetic material.

(7 marks)

(c) (i) Derive the expression for the energy density contained in a magnetic field.

(ii) A magnetic field density is 0.2×10^{-2} Teslas in a region of free space. Determine the energy of the field.

(10 marks)

8. (a) State **four** instruments used in determining various wavelengths of electromagnetic waves. (4 marks)

(b) (i) Explain the term 'free space' with reference to electromagnetic fields.

(ii) List Maxwell's equations for free space.

(6 marks)

(c) (i) Define 'depth of penetration' with reference to electromagnetic fields.

(ii) Determine the ratio of free space wavelength to the wavelength in an electric cable with $\sigma = 8 \times 10^5\ mho/m$, and relative permeability $\mu_r = 4$ at a frequency of 8 kHz.

(10 marks)

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