LAIKIPIA UNIVERSITY

UNIVERSITY EXAMINATIONS

1ST SEMESTER 2022/2023 ACADEMIC YEAR

THIRD YEAR EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE)

PHYS 313: ELECTRICITY AND MAGNETISM II

STREAM: R ***TIME: 2 HRS***

DAY: FRIDAY [8.30AM – 10.30AM] ***DATE: 09/12/2022***

THIS QUESTION PAPER CONSISTS OF FOUR (4) PAGES

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Where necessary use the constants $\mu_0 = 4\pi \times 10^{-7}$Tm/A, e = 1.602 x 10^{-19}C, ε_0 = 8.854 x10^{-12} F/m,

SECTION A: (Compulsory) TOTAL MARKS FOR THIS SECTION IS 30.

QUESTION ONE [30 marks]

a) State Gauss's law. (1 mark)

b) Give two statements of Gauss's law. (2 marks)

c) If charge q_0 = 1.6 x 10^{-19}C is moving in an electric field with a force of 3.2 x 10^{-12}N; Calculate;

i. Potential difference between the starting point and ending point of this charge. (4 marks)

ii. Work done on the charge if it moved 2 cm. (4 marks)

d) Give **TWO** properties of an electric field. (2 marks)

e) Find the field outside a uniformly charged cube of length *r* and surface change density σ. (7 marks)

f) A metal sphere of radius r_a is supported on an insulating stand at the center of a hollow metal sphere of inner radius r_b. There is a charge $+q$ on the inner sphere and a charge $-q$ on the outer part. Show that the potential difference between the plates is

$$V_{ab} = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_a} - \frac{1}{r_b}\right)$$

(6 marks)

g) Show that for a circular loop carrying current the magnetic flux at some position P is given by the expression;

$$\vec{B} = \frac{\mu_0 NI}{2r}$$

(4 marks)

h) The potential near a point charge *q* in free space is given as

$$\psi(r) = \frac{q}{4\pi\varepsilon_0 r^3}$$

Given that $r = (x^2 + y^2 + z^2)^{1/2}$, find the electric acting on the charge. (4 marks)

i) Calculate the flux through an area of 18.0 mm^2 inclined at 10^0 when an electric field of 20 Vm^{-1}. (2 marks)

j) A conductor cable contains 1.0 x 10^{28} m^{-3} of free electrons and has a thickness of diameter 1.128 mm. If the drift velocity of the electrons is 2.0 x 10^{-5} ms^{-1}, determine the current necessary to create this velocity. (4 marks)

QUESTION TWO [15 MARKS]

a) Give the integral form of Ampere's law (2 mark)

b) Prove that electric field $\vec{E}$ is the gradient of the potential, that is,

$$\vec{E} = -grad\,\phi$$

(5 marks)

c) Given FOUR applications of electromagnetism. (4 marks)

d) The electric field $\vec{E}$ in a certain region of a sphere of 2 cm from the charge is 100 Vm^{-1}. Find the charge Q at this point. Explain also if the field is radially inward or outward. (4 marks)

QUESTION THREE [15 MARKS]

a.) A scalar function $V = x^2y^2 + z^2$. The rate of change of this function with position is a vector given by;

$$-\vec{E} = \frac{\partial V}{\partial x}\mathbf{i} + \frac{\partial V}{\partial y}\mathbf{j} + \frac{\partial V}{\partial z}\mathbf{k}$$

At point (4, 1, 2), find the magnitude of $\vec{E}$. (5 marks)

b.) Calculate the displacement current density if it is assumed that there are no contributions to the macroscopic field from the atoms of the metal and the relative permittivity is unity. (4 marks)

c.) State Biot-Savart law. (1 mark)

d.) Potential at some point S is given as

$$\phi\,(x, y, z) = 2xy^2\mathbf{i} - xyz\mathbf{j} + 3x^2y\mathbf{k}$$

Determine *div* ϕ at (0, -1, -2). (5 marks)

QUESTION FOUR [15 MARKS]

a) A 7-pC positive charge is situated 60 cm from a 3-pC negative charge. Find the field **E** half-way between the charges. (5 marks)

b) Explain **three** classifications of transmission lines. (5 marks)

c) The current in a wire varies with time according to the equation

$i = 3t^3 - 2t^2$

where i is in amperes and t is in seconds.

(i) How many coulomb's pass across section of the wire in the time interval between $t = 1$ s and $t = 4$ s? (3 marks)

(ii) What constant current would transport the same charge in the same time interval? (2 marks)

QUESTION FOUR [15 MARKS]

a) A conductor cable has a thickness of 3.5mm. If the conductor is connected across 24V power supply and current of 2A, determine the conductivity of this material if the conductor is 12 m long. (5 marks)

b) An electric dipole, consisting of charges of magnitude 1.48 nC separated by 6.23 μm, is in an electric field of strength 1100 N/C. What is the magnitude of the electric dipole moment? (5 marks)

c) A circuit with capacitor as a load has emf given by $V_o\sin(\omega t)$ with $V_0 = 9.0$ v, and a capacitance of 25 μF

i) Calculate the peak currents at 60 Hz. (3 marks)

ii) Find the current and voltage at 2.0 ms for the 60 Hz frequency. (2 marks)

QUESTION FIVE [15 MARKS]

a) A point charge is at a distance of 0.15 mm from some location k. Find the electric field at this location. **(3 marks)**

b) Calculate charge density λ in the case above given that electric field is 202 V/m. (3 marks)

c) A spherical shell of outer radius 1.5 cm and inner radius 0.5 cm has a charge density ρ = 5 nC/m^3. Using Gauss's law, find the charge in the shell. (3 marks)

d) Given that an electric potential is;

$$\phi(x, y, z) = -3x^2y\mathbf{i} - y^2z\mathbf{j} - 2xz\mathbf{k}$$

Find

i) grad ϕ (3 marks)

ii) curl ϕ (3 marks)