MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FOURTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF EDUCATION (SCIENCE)

BACHELOR OF EDUCATION (SPECIAL NEEDS)

SPH 401: ELECTRODYNAMICS

DATE: **TIME:**

INSTRUCTIONS TO CANDIDATES

Answer **QUESTION ONE** which is *COMPULSORY* and **ANY OTHER TWO** questions.

Question 1 carries **30** marks and the others carry **20** marks each.

YOU MAY USE:

You may need to use the following constants

- Permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ F/m
- $K = 8.99 \times 10^{9}\ Nm^2C^{-2}$
- Electronic charge, $e = 1.6 \times 10^{-19}$ C
- Permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ Tm/A
- Speed of light, $c = 2.998 \times 10^8 m/s$

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Sketch a graph of the magnitude of electric charge on either plate of a capacitor versus the magnitude of the potential difference between the plates. What does its slope indicate? What does the area under this curve represent? (3 marks)

b) State Gauss's law (1 mark)

c) Calculate the vector potential when the field intensity $-23y^2$ varies from (1, -2, 0) to (1, 6, 0). (3 marks)

d) An EM wave travels in a medium at a speed of $2x10^8$ m/s. The relative permittivity of the medium is 1.2. Calculate the relative permeability (4 marks)

e) Calculate the impedance experienced by a particle that is moving in space (2 marks)

f) Define electric displacement of charges (1 mark)

g) A parallel-plate capacitor has plates with dimensions 7cm by 9cm separated by 4mm. The plates are connected across a 48V battery.

i) Determine the capacitance and the charge on each plate. (3 marks)

ii) Determine the electric field within the plates and the energy stored. (4 marks)

h) State and write the equation of Stoke's law (3 marks)

i) A long straight wire has a current in it. At a perpendicular distance of 0.05 m from the wire, the magnetic induction caused by the current is 2×10^{-5} T. Calculate the current in the wire. (3 marks)

j) Calculate the electric field applied on a system with electrons having a velocity 5m/s subjected to a magnetic flux of 3.6 units. (3 marks)

QUESTION TWO (20 MARKS)

a) Show that the work done in moving a positive charge q_o from a distance r to a charge Q is given by

$W = \frac{Qq_o}{4\pi\varepsilon_o r}$ (8 marks)

b) Show that the electric displacement, D, is given by $D = \varepsilon_o(1 + \chi)E$ where χ is the material susceptibility. (4 marks)

c) Show that the capacitance c of a spherical shaped conductor of inner a and outer radii b respectively is given by

$c = 4\pi\varepsilon_0 \frac{ab}{b-a}$ (8 marks)

QUESTION THREE (20 marks)

a) Show that the energy density for a parallel plate capacitor in an electric field is given by;

$U_E = \frac{1}{2} D.E$ (4 marks)

b) Derive the expressions for Poisson's and Laplace's Equations. (8 marks)

c) For a region of empty space with EM waves, show that the total energy density, u_T is given by;

$$U_T = \varepsilon_o E^2$$

where all the constants have their usual meanings (8 marks)

QUESTION FOUR (20 MARKS)

a) Show that the Laplacian function also operates on the vector potential $\vec{A}$ as $\nabla^2\vec{A} = -\mu J$. (8 marks)

b) Define polarization of charges (2 marks)

c) While describing their physical meanings, identify both the differential and integral forms of Maxwell's equations . (10 marks)

QUESTION FIVE (20 MARKS)

a) An electric dipole consisting of two charges of 0.2 μC separated by a distance of 2.0 cm is placed in an external field of 10^5 N/C. Calculate maximum moment is exerted by the dipole? (4 marks)

b) The magnetic field of a plane EM radiation is $\vec{B} = 10^{-9}\, Cos\left((\pi m^{-1})y + (3\pi \times 10^8 s^{-1})t\right)\hat{\boldsymbol{\imath}}\, T$. Calculate.

(i) The wavelength, frequency & speed of the wave (3 marks)

(ii) The complete vector expression for $\vec{E}$ (2 marks)

(iii)The time-average energy flux carried in the wave (3 marks)

c) For a region of empty space with EM waves, show that the non-averaged Poynting vector is given by;

$$\vec{S} = \frac{1}{\mu_o}\vec{E}_o \times \vec{B}_o$$

where all the constants have their usual meanings (8 marks)