



MACHAKOS UNIVERSITY

University Examinations 2021/2022

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FOURTH YEAR SUPPLEMENTARY/SPECIAL EXAMINATION FOR

BACHELOR OF EDUCATION (SCIENCE) AND BACHELOR OF EDUCATION
(SPECIAL NEEDS)

SPH 401: ELECTRODYNAMICS

DATE: 18/03/2022

TIME: 2:00-4:00 PM

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, $\epsilon_0=8.85 \times 10^{-12}$ F/m
- ❖ $K = 8.99 \times 10^9$ Nm²C⁻²
- ❖ Electronic charge, $e = 1.6 \times 10^{-19}$ C
- ❖ Permeability of free space, $\mu_0=4\pi \times 10^{-7}$ Tm/A

QUESTION ONE (30 MARKS)

- a) State Gauss's law (2 marks)
- b) Define electric displacement of charges (2 marks)
- c) 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) What will be the capacitance if a material with dielectric constant of 3.7 is placed between the plates (1 mark)
 - iii) Determine the electric field within the plates and the energy stored. (4 marks)
- d) Find the vector potential when the field intensity $20x^3$ varies from (0,0,0) to (0,3,0). (3 marks)
- e) Calculate the speed of a beam of light moving in space. (3 marks)
- f) While writing its mathematical expression, state Faraday's law (4 marks)
- g) State and write the equation of Stoke's law (3 marks)
- h) Determine the magnitude and direction of the force experienced by an electron charge in an electric field of 5 N/C and magnetic field of $2.5 \hat{i}$ T and traveling with a velocity of $1.5 \hat{k}$ m/s. (5 mks)

QUESTION TWO

- a) An isolated positive point charge, Q, is approached by a positive test charge Q_0 , moving from infinity to a distance r from Q. Show that the electric potential V is given by, (6 marks)

$$V = KQ/r$$

- b) 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? And based on this curve, provide the two SI units representing this relationship. (6 marks)
- c) Using Gauss' law, find the electric field due to a uniformly charged sphere of radius r with a surface charge density of ρ at a point P, distance R;
- i) $r \gg R$ (3 marks)
 - ii) $r = R$ (2 marks)
 - iii) $r \ll R$ (3 marks)

QUESTION THREE

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

$$U_E = \frac{1}{2} D \cdot E \quad (4 \text{ marks})$$

- 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;

$$u_T = \epsilon_0 E^2$$

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

QUESTION FOUR

- a) Show that the electric displacement, D , is given by $D = \epsilon_0(1 + \chi)E$ where χ is the material susceptibility. (4 marks)

- b) Write Maxwell's equations in both differential and integral forms. (8 marks)

- c) Discuss the physical meaning of the four Maxwell's equations. (8 marks)

QUESTION FIVE

- a) An electric dipole consisting of two charges of $0.2 \mu\text{C}$ separated by a distance of 2.0 cm is placed in an external field of 10^5 N/C . What maximum moment is exerted by the dipole? (4 marks)

- b) Using Gauss' law, show that for a parallel-plate capacitor with a vacuum dielectric, its capacitance is given by. (8 marks)

$$C = \frac{\epsilon_0 A}{d}$$

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