JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF BIOLOGICAL, PHYSICAL, MATHEMATICS AND ACTUARIAL SCIENCES

UNIVERSITY EXAMINATION FOR DEGREE OF BACHELOR OF EDUCATION (SCIENCE)

2023/2024 EXAMINATIONS

MAIN REGULAR

COURSE CODE: SPH 410
COURSE TITLE: ELECTRODYNAMICS
EXAM VENUE: **STREAM: EDUCATION**
DATE: **EXAM SESSION:**
TIME: 2:00 HRS

Instructions:

1. **Answer question 1 (Compulsory) and ANY other 2 questions.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

Useful constants

$$\nabla \times \left(\nabla \times \vec{F}\right) = \nabla\left(\nabla \cdot \vec{F}\right) - \nabla^2 \vec{F}$$

$\varepsilon_0 = 8.85 \times 10^{-12}$F/m
$\mu_0 = 4\pi \times 10^{-7}$H/m

SECTION A (Compulsory)
Question 1 (30 marks)

(a) Distinguish between a vector and a scalar field and give an example of each. (3 marks)
(b) The beam current in a television tube is 1.9 mA, and the beam cross-section is circular with radius 0.5 mm. Find the current density. (3 marks)
(c) Explain what necessitated the alteration of Ampere's law by Maxwell. (2 marks)
(d) An electron, moving at 2.0 x 10^5 m/s, enters a magnetic field of strength 5.2 x 10^{-3} T at an angle of 35°. Find the force experienced by the electron. (2 marks)
(e) A signal is beamed towards the earth with a power of 10 kW from a satellite in stationary orbit. The beam width covers a region roughly circular and 1000 km in diameter. Find the electric field strength at the receiver in mV/m. (4 marks)
(f) An electromagnetic plane wave in vacuum has E-field given by $E_z = 10sin\pi(2 \times 10^6 x - 6 \times 10^{14} t), E_x = E_y = 0$.Find the frequency and intensity of the wave. (4 marks)
(g) Use Stoke's theorem to show that $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$. (4 marks)
(h) Explain the principle of operation of a Hertzian dipole. (2 marks)
(i) Find the vector potential of an infinite solenoid with *n* turns per unit length, radius *R* and current *I*. (4 marks)
(j) At what rate must the potential difference between the plates of a parallel plate capacitor with a 2 μF capacitance be changed to produce a displacement current of 1.5 A? (2 marks)

SECTION B (Answer any TWO questions in this section)

Question 2 (20 marks)

(a) A particular electromagnetic field in free space is defined by: $E_x = 0, E_y = E_0 sin(kx + \omega t), E_z = 0, B_x = 0, B_y = 0, B_z = -\frac{E_0}{c} sin(kx + \omega t)$. Show that this field can satisfy Maxwell's equations, hence state the relationship between ω and k for this to be so. (8 marks)
(b) A radio station transmits a 10 kW signal at a frequency of 100 MHz. Assuming it radiates as a point source, find the amplitudes of the electric and magnetic field strengths at a distance of 2 km from the antenna. (6 marks)
(c) Derive an expression for the displacement current in a parallel plate capacitor. (6 marks)

Question 3 (20 marks)

(a) A thin ring of radius *R* has a uniform positive linear charge density around its circumference. Find the electric field $\vec{E}$ at a point *P* which is a distance *z* from the plane of the ring along its central axis. (9 marks)
(b) Investigate whether Stoke's theorem holds for the function $\vec{A} = (2xz + 3y^2)\hat{\jmath} + (4yz^2)\hat{k}$ and the surface formed by a 2 x 2 square on the y-z plane of Cartesian coordinate system. (11 marks)

Question 4 (20 marks)

(a) Show that at any point in the electromagnetic field the energy density stored in the electric field is equal to that stored in the magnetic field. (4 marks)

(b) List down the Maxwell's equations as in vacuum, in integral, form and explain the significance of each. (5 marks)

(c) Convert each of the equations in (b) above from integral to differential form. (11 marks)

Question 5 (20 marks)

(a) Explain what you understand by retarded potentials. (2 marks)

(b) An infinite straight wire carries the current

$$I(t) = \begin{cases} 0, t \leq 0 \\ x, t > 0 \end{cases}.$$

Find the resulting electric and magnetic fields. (8 marks)

(c) For an electromagnetic wave in vacuum, show that the velocity is given by

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}.$$ (10 marks)