JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES
UNIVERSITY EXAMINATION FOR DEGREE OF BACHELOR OF EDUCATION (SCIENCE)
4TH YEAR 2ND SEMESTER 2021/2022 ACADEMIC YEAR
MAIN
RESITS/SPECIAL

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.**

Question One (30 Marks)

(a) Given that $\vec{A} = x^2\hat{x} + 3xz^2\hat{y} - 2xz\hat{z}, calculate$

(i) Curl A. (4 marks)

(ii) Grad (div A). (3 marks)

(b) A positive point charge Q is placed at the center of a surface.

(i) Derive Gauss' law in integral form for this case

(ii) Explain why the law is still expected to hold even if the surface is not spherical (4 marks)

(c) An infinite straight wire of radius R carries a current I. Find the magnetic field at a distance r from the center of the wire where $r > R$. Explain any physical conditions that guide your calculations (5 marks)

(d) Write down the Maxwell's equations in differential form for electromagnetic waves in a vacuum (4 marks)

(e) Show that the velocity of electromagnetic waves in a vacuum is given by $v = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$ (10 marks)

Question Two (20 Marks)

(a) Unlike electric field, magnetic field lines always form closed loops. Explain this (2 marks)

(b) Explain the physical significance of each of the Maxwell's equations (4 marks)

(c) Consider an electromagnetic wave with its E-field in the y-direction. Apply the relation $\frac{\partial E_y}{\partial x} = -\frac{\partial B_z}{\partial x}$ to the harmonic wave $\vec{E} = \vec{E}_0\cos(kx - wt)$, to show that $E_0 = cB_0$ (6 marks)

(d) A current I is uniformly distributed over a wire of square cross-section with side a. Find the volume current density $\vec{j}$ (2 marks)

(e) Find the rate of change with time of the magnetic field at a location in which the induced electric field is given by

$$\vec{E}(x,y,z) = \vec{E}_0\left(\left(\frac{z}{z_0}\right)^2\hat{i} + \left(\frac{x}{x_0}\right)^2\hat{j} + \left(\frac{y}{y_0}\right)^2\hat{k}\right)$$ (6 marks)

Question Three (20 Marks)

(a) Using Faraday's law of electromagnetic induction and definition of e.m.f in a current, derive Maxwell's third equation in differential form (7 marks)

(b) Explain the significance of Poynting vector (3 mark)

(c) A radio station transmits a 10 Kw signal at a frequency of 100 MHz. At a distance of 1 Km from the antenna, find

(i) The amplitude of the electric and magnetic strengths. (5 marks)

(ii) The energy incident on a square of side 10 cm in 5 minutes (Assume that it radiates as a point source) (5 marks)

Question Four (20 Marks)

(a) Determine the real electric field for a monochromatic plane wave of amplitude E_0, frequency ω, that is travelling in the negative-direction and polarized in the z-direction (8 marks)

(b) State any two assumptions made in deriving the magnetic vector potential $\vec{A}(\vec{r}) = \frac{\mu_0}{4\pi}\int \frac{\vec{J}(\vec{r}')}{(\vec{r}-\vec{r}')}$ (4 Marks)

(c) Find the vector potential of an infinite solenoid with n turns per unit length, radius R and current I (8 marks)

Question Five (20 Marks)

(a) An infinite straight wire carries the current $I(t) = \begin{cases} 0, & t \leq 0 \\ I_0, & t > 0 \end{cases}$. Find the resulting electric and magnetic fields (12 marks)

(b) A primitive model for an atom consists of a point nucleus $(+q)$ surrounded by a uniformly charged spherical cloud $(-q)$ of radius a as shown in Figure 1, below.

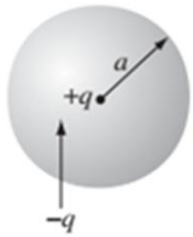

Figure 1

Calculate the atomic polarizability of such an atom. (8 marks)