JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

UNIVERSITY EXAMINATION FOR THE DEGREE OF MASTERS OF SCIENCE IN PHYSICS

MAIN

REGULAR

COURSE CODE: SPB 9433

COURSE TITLE: ELECTRODYNAMICS

EXAM VENUE: **STREAM: EDUCATION SCIENCE**

DATE: **EXAM SESSION:**

TIME: 3:00HRS

Instructions:

1. **Answer question one (1) (Compulsory) in Section A and ANY other two (2) questions in Section B.**
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.**

Take

- $m_p = 1.673 \times 10^{-27}$ kg
- $m_n = 1.675 \times 10^{-27}$ kg
- $m_e = 9.11 \times 10^{-31}$ kg
- charge on a proton: $q_p = +e = 1.602 \times 10^{-19}$ C
- charge on an electron: $q_e = -e = -1.602 \times 10^{-19}$ C
- charge is quantized: $q = \pm ne \quad n = 0, 1, 2, \ldots$
- Permittivity of free space, ε_0=8.85 x10 $^{-12}$ Fm^{-1}

QUESTION 1 (30 MARKS)

a. Define the term Electric Dipole [2mks]

b. Show that the divergence theorem converts the surface integral in to volume integral [4mks]

b. The average intensity of direct The average intensity of direct sunlight is around 1600 W/m sunlight is around 2400 W/m^2. What is the . What is the average force on a fully absorbing surface of average force on a fully absorbing surface of area 2.00 m area 2.00 m^2? [4mks]

c. State and prove the **First Uniqueness Theorem** [4mks]

d.
  i. Define Lorentz force [2mks]

  ii. Show that Lorentz force is given by $\underline{F} = \underline{F}_e + \underline{F}_m = q\left(\underline{E} + \underline{v} \times \underline{B}\right)$ [6mks]

e. Use the Ampere-Maxwell law to find the magnetic field between the circular plates of a parallel plate capacitor of radius R. Ignore the fringing field) [4mks]

f. State and prove the boundary conditions of electrostatics at the interface of dielectric [4mks]

QUESTION 2 (20 MARKS)

a. In an electromagnetic wave, the electric field of amplitude 1.6 V/m oscillates with a frequency of 2.5 X 10^{10} Hz . Calculate the energy density of the wave [4mks]

b. Define the intensity of an EM wave and by defining all the terms, show that it is given as $I = C\varepsilon_o E_m{}^2$ [6mks]

c. How do the total intensity of an EM wave in a) above differ from the average intensity? Give its expression [6mks]

d. A signal received from a radio station has station has E_m= 0.0240 V/m. What is the average intensity at that point? [4mks]

QUESTION 3 (20 MARKS)

a. Derive the Maxwell's equations for electromagnetic waves travelling in a medium [4mks]

b. Derive the expression between the permittivity of free space, the permeability of free space and the velocity of an electromagnetic wave [4mks]

c. The electric field of an electromagnetic wave in a vacuum is given by;

$$\begin{cases} E_x = 0 \\ E_y = 0 \\ E_z = 24\sin\left(5\pi X 10^8 t + \frac{4\pi}{5}\right) \end{cases}$$

Where E is in V/m, t is in seconds and x in meters

Determine

i. The frequency [4mks]

ii. The wavelength [4mks]

iii. The direction of the propagation of the wave [2mks]

iv. The direction of the magnetic field [2mks]

QUESTION 4 (20 MARKS)

a. For the Stoke's Theorem, show that $\oint_s \vec{A}.d\vec{l} = \oint_s curl\vec{A}.d\vec{s}$ [5mks]

b. Derive an expression for electric field due to a dipole [5mks]

c. Two concentric metal spherical shells, of radius a and b, respectively, are separated by weakly conducting material of conductivity σ

i. If they are maintained at a potential difference V, what current flows from one to the other? [5mks]

ii. What is the resistance between the shells? [5mks]

QUESTION 5 (15 MARKS)

a. Define displacement current and give its expression [4mks]

b. State and derive the four fundamental equations of electromagnetism in intergral form [10mks]

c. The electrostatics and magnetostatics are described by the below Maxwell's equations in differential form

$$\vec{\nabla}.\vec{E} = \frac{1}{\varepsilon_o}\rho - Gauss' sLaw$$

$$\vec{\nabla}.\vec{B} = 0 - Gauss' sLaw$$

$$\vec{\nabla}X\vec{E} = -\frac{\partial\vec{B}}{\partial T} - Faraday' sLaw$$

$$\vec{\nabla}X\vec{B} = \mu_o\vec{J} - Ampere' s.Law$$

By defining all the terms, show how Maxwell modified Ampere's law to $\vec{\nabla}X\vec{B} = \mu_o(\vec{J}_f + \vec{J}_b + \vec{J}_P) + \mu_o\varepsilon_o\frac{\partial\vec{E}}{\partial t} = \mu_o\left(\vec{J}_f + \vec{\nabla}.X\vec{M} + \frac{\partial\vec{P}}{\partial t}\right) + \mu_o\varepsilon_o\frac{\partial\vec{E}}{\partial t}$ for charges in matter

[6mks]