Five-Year Integrated M. Sc. Examination 2021-2022

Semester: III

Paper: PH-2-3-1

Subject: Physics (Electricity and Magnetism)

Time: Three Hours **Full Marks: 60**

Questions are of value as indicated in the margin

Answer *Question No. 1* and *any three* from the rest

1. Answer any five questions: 5x3 = 15

(a) Obtain Coulomb's law from Gauss's law in electrostatics.

(b) Derive the equation of continuity from Maxwell's equations. Write the significance of the equation of continuity.

(c) Show that the two equations $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ and $\vec{\nabla}.\vec{B} = 0$ are compatible with each other.

(d) The maximum value of electric field in an electromagnetic wave in free space is 1000 V m^{-1}. Find the maximum value of the magnetic field in the wave.

(e) Define plane waves. Write the mathematical expression for a plane electromagnetic wave moving in z-direction.

(f) Compare sound waves with electromagnetic waves.

2. (a) Explain the physical significance of the divergence and curl of an electric field.

(b) State Ampere's circuital law. Discuss why and how it was modified to include the displacement current.

(c) Evaluate $\iint \vec{E}\,.\overrightarrow{ds}$ where $\vec{E} = 4xz\hat{\imath} - y^2\hat{\jmath} + yz\hat{k}$ and S is the surface of the cube bounded by x = 0, x = 1; y = 0, y = 1; z = 0, z = 1.

4+6+5 = 15

3. (a) Starting from Faraday's law, derive maxwell's third equation in differential form.

(b) State and establish Poynting's theorem. Express the theorem in the following differential form

$$\frac{\partial u}{\partial t} + \vec{\nabla}.\vec{s} = 0$$

where $\vec{s}$ is the Poynting's vector and u is the total electromagnetic energy density. Compare it with the equation of continuity and give an interpretation of $\vec{s}$.

5+10 = 15

4. (a) Starting from Maxwell's equations, show that the electric and magnetic fields in vacuum satisfy wave equations.

(b) If the electric field of an electromagnetic wave has an rms (root-mean-square) strength of 3.0×10^{-2} V m^{-1}, how much energy is transported across a 1.00 cm^2 area in one hour?

(c) What do you mean by scalar and vector potentials? Explain.

5+5+5 = 15

5. (a) Electromagnetic waves are emitted from two different sources with

$E_1(x, t) = E_{10}\cos(kx - \omega t)\hat{j}$, $E_2(x, t) = E_{20}\cos(kx - \omega t + \varphi)\hat{j}$.

(i) Find the Poynting vector associated with the resultant electromagnetic wave.

(ii) Find the intensity of the resultant electromagnetic wave.

(iii) Repeat the calculations above, if the direction of propagation of the second electromagnetic wave is reversed so that

$E_1(x, t) = E_{10}\cos(kx - \omega t)\hat{j}$, $E_2(x, t) = E_{20}\cos(kx + \omega t + \varphi)\hat{j}$.

(b) Briefly describe the procedure of generating electromagnetic fields by moving an infinite sheet of charge with a velocity, $\vec{v} = v\,\hat{j}$. Draw appropriate diagrams to explain the procedure.

(c) Explain the working principle of Helmholtz double coil galvanometer.

(2+2+2)+4+5 = 15