M.Sc. (PHYSICS) FIRST YEAR EXAMINATION, 2022

(First Year, Second Semester)

ELECTRODYNAMICS

Time: Two hours **Full Marks: 40**

Use separate answer scripts for each group

Group A

Answer any two questions

1. (a) Write down Lorentz's transformation matrix from a rest frame S to a moving frame S' which is moving with velocity $\vec{v}$ along X-axis. Hence obtain the transformations of the components of 4-velocity η^{μ} and 4-momentum vector p^{μ}. Compare the 4-velocity transformation results with ordinary velocity transformations.

b) Show that the components of ordinary force vectors transform according to the following equations

$$F_y' = \frac{F_y}{\gamma(1-\beta\,\frac{u_x}{c})}\;; \qquad F_z' = \frac{F_z}{\gamma(1-\beta\,\frac{u_x}{c})}\;; \qquad F_x' = \frac{F_x - \beta\,(\boldsymbol{U}.\boldsymbol{F})/c}{(1-\beta\,\frac{u_x}{c})}$$

Where the symbols have their usual meaning.

c) Suppose a field is purely magnetic in S' frame. Obtain the nature of the same field when observed from S frame, where S is the rest frame and S' is the moving frame.

(5 + 3 + 2)

2. (a) Explain the concept of retarded potential?

Write down the inhomogeneous wave equations. Obtain the solutions of the inhomogeneous wave equations for the scalar potential for the non-static case using the concept of retarded potential.

(b) The electric and magnetic fields due to an oscillating electric dipole are given by

$$\vec{E} = -\frac{\mu_0 p_0 \omega^2}{4\pi}\left(\frac{Sin\theta}{r}\right)\cos\omega(t-\frac{r}{c})\,\hat{\theta}$$

$$\vec{B} = -\frac{\mu_0 p_0 \omega^2}{4\pi c}\left(\frac{Sin\theta}{r}\right)\cos\omega(t-\frac{r}{c})\,\hat{\emptyset}$$

[Turn over

Calculate the Poynting vector for the above dipole and also obtain an expression for the total power radiated by the above dipole.

Plot the intensity profile of the dipole graphically.

(5 + 5)

3. (a) How point charge is defined in Maxwell's electrodynamics?

Suppose a point charge q is moving in a specified trajectory and you have to calculate the scalar and vector potential at a point P. Can two points on the trajectory communicate with P at a particular time t? Justify your answer.

(b) Show that the scalar potential $V(\vec{r}, t)$ and vector potential $\vec{A}(\vec{r}, t)$ of a moving point charge are related by the equation

$$\vec{A}(\vec{r}, t) = \frac{\vec{v}}{c^2} V(\vec{r}, t)$$

where the symbols have their usual meanings.

(c) Consider a current carrying straight wire in rest frame S. Show that when observed from a moving frame, S' the wire will appear to have non-zero net charge density.

In this context explain inter dependence of electric and magnetic field.

(2 + 4 + 4)

Group - B

Answer any ONE question

1. (a) A conducting sphere of radius R carries a charge Q on its surface. A point charge q is placed at a distance $d > R$, from its centre.
   i. Calculate the force f the charge q feels.
   ii. Plot $\frac{f}{q^2}$ against $\frac{d}{R}$ to show that even if Q and q are of same sign, they attract each other in a region close to the surface of the sphere.

   (b) A thin circular ring of radius R carries a charge Q uniformly distributed along its circumference. Calculate the electrostatic potential at a point that does *not* lie on the axis that passes through the centre of the ring and perpendicular to its plane.

   Marks: (9 + 3) + 8 = 20

2. A dielectric sphere of radius R and of permittivity ϵ_1 is placed in a medium of permittivity ϵ_2, through which passes an electric field $\vec{E} = E\hat{z}$. The potential along the plane that is perpendicular to this electric field and cuts the sphere in two equal halves is Φ_0.

   (a) Find the potentials inside and outside the sphere.

   (b) Explain with the help of diagrams how the electric field lines intersect the surface of the sphere for the cases when (i) $\epsilon_1 > \epsilon_2$ and (ii) $\epsilon_1 < \epsilon_2$.

   (c) Evaluate the bound charge density along the surface of the sphere.

   Marks: 10 + 6 + 4 = 20