Electrodynamics
ISI B.Math
Final Exam : June 04, 2026

Total Marks: 80
Time : 3 hours
Answer all questions

1. (**Marks:** $5+5+5+5$)

(i) Find the potential corresponding to the electric field given below. $\mathbf{E} = k[y^2\hat{\mathbf{x}} + (2xy + z^2)\hat{\mathbf{y}} + 2yz\hat{\mathbf{z}}]$

(ii) A point charge is at a distance d from a grounded infinite conducting plane. How much energy is required to move the charge infinitely far from the plane ?

(iii) Consider two concentric spherical metal shells of radii r_1 and r_2. If the outer shell has a charge q and the inner shell is grounded, what is the charge on the inner shell ?

(iv) A uniform electric field E_0 in the x direction is produced by an appropriate charge configuration. A thin sheet of charge σ per unit area is placed perpendicular to the x- direction at $x = 0$. If the initial charge configuration is assumed to be undisturbed by the presence of the sheet, what is the total electric field on either side of the sheet?

2. (**Marks:** $7+4+9$)

(a) A small loop of wire(radius a) lies a distance z above the centre of a large loop(radius b). The planes of the two loops are parallel and they are perpendicular to the common axis. Suppose current I flows through the big loop. Find the flux through the little loop. Hence find the mutual inductance.

(b) An experimental physicist claims that he has generated the following magnetic field in the laboratory by using an appropriate steady current source. $\mathbf{B} = k(xy\hat{\mathbf{x}} + 2yz\hat{\mathbf{y}} + 3xz\hat{\mathbf{z}})$ where k is a constant with appropriate units. Can his result be correct ? Justify your answer.

(c) A uniform magnetic field $\mathbf{B}$ points in the x direction while a uniform electric field points in the z direction. A particle of charge q at rest is released at the origin. Find its subsequent trajectory.

3. (**Marks:** $4+6+6+4$)

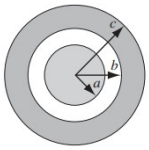
(a) Write down the full set of Maxwell's equations for the electric field $\mathbf{E}$ and the magnetic field $\mathbf{B}$ in the presence of a charge density ρ and current density $\mathbf{J}$ in differential form.

(b) Explain how the "displacement current" term added to Ampere's law by Maxwell removes the inconsistency in Ampere's Law for non-static magnetic fields.

(c) An electric field which is a solution of source free Maxwell's equations is given by a monochromatic plane wave of amplitude E_0, angular frequency ω, wavelength λ and phase angle zero that is travelling in the negative x direction and polarized in the z direction. Write down the expression for the electric field and the corresponding magnetic field which is also a solution of source free Maxwell's equation. Find the energy density of the electromagnetic field corresponding to this solution.

(d) A point charge q is travelling in the along the x axis at constant speed v. Another point charge q is proceeding at the same speed along the y axis. Argue that mechanical linear momentum is not conserved for this system. No explicit calculation is required, qualitative reasoning considering the direction of the forces should suffice. Does this imply that the law of conservation of momentum does not hold for this system ?

Explain.



4 (**Marks:** $8 + 5 + 5 + 2$)

(a) A certain coaxial cable consists of a copper wire, radius a, surrounded by a concentric copper tube of inner radius c. The space between is partially filled (from b out to c) with material of dielectric constant ϵ_r, as shown. Find the capacitance per unit length of this cable.

(b) A steady current I flows down a long cylindrical wire of radius a . Find the magnetic field, both inside and outside the wire, if

(i) The current is uniformly distributed over the outside surface of the wire.

(ii) The current is distributed in such a way that J is proportional to s, the distance from the axis.

(c) It is claimed that the energy "stored in a magnetic field " $\mathbf{B}$ is given by $\int B^2 d\tau$ where the integral represents a volume integral over all space. Explain in what sense a magnetic field can store energy though magnetic forces do no work .