PRACTICE QUESTION PAPER — SET 1

PHY-M-T-3: ELECTRICITY AND MAGNETISM

Full Marks: 40 **Time: 2 Hours**

Answer all questions. The figures in the margin indicate full marks. Symbols have their usual meanings.

1. **Answer any four questions:** **[2 × 4 = 8]**

   (a) State Gauss's Law in electrostatics and write its differential form.

   (b) What is the electrostatic potential at a distance r from an electric dipole of dipole moment $\vec{p}$ at an angle θ to the dipole axis?

   (c) Define electrical susceptibility and write its relation with the dielectric constant.

   (d) Write down Biot-Savart's Law in vector form for a current element $I\,d\vec{l}$.

   (e) Define the quality factor (Q-factor) of a series LCR resonance circuit.

2. **Answer any four questions:** **[4 × 4 = 16]**

   (a) Using the method of images, find the potential and electric field due to a point charge q placed in front of an infinite grounded conducting plane.

   (b) Establish the relations between electric field $\vec{E}$, polarization $\vec{P}$, and electric displacement vector $\vec{D}$.

   (c) State Ampere's circuital law and use it to find the magnetic field inside a toroid of N turns carrying current I.

   (d) State and prove the reciprocity theorem for mutually coupled circuits.

   (e) State Thevenin's theorem and explain its application in simplifying linear DC networks.

3. **Answer any two questions:** **[8 × 2 = 16]**

   (a) (i) Derive an expression for the electrostatic energy of a uniformly charged spherical shell of radius R and total charge Q.

   (ii) State and prove the uniqueness theorem for electrostatic boundary value problems.

   (b) (i) Analyze the growth and decay of current in an L-R series circuit connected to a DC source.

   (ii) Define complex impedance and reactance. Find the resonance frequency of a series LCR circuit.

   (c) (i) Explain the working principle of a Ballistic Galvanometer. Derive the formula for charge sensitivity in terms of ballistic deflection and logarithmic damping.

   (ii) Discuss the phenomenon of magnetic hysteresis and explain the significance of the B-H curve.

PRACTICE QUESTION PAPER — SET 2

PHY-M-T-3: ELECTRICITY AND MAGNETISM

Full Marks: 40 **Time: 2 Hours**

Answer all questions. The figures in the margin indicate full marks. Symbols have their usual meanings.

1. **Answer any four questions:** **[2 × 4 = 8]**

   (a) Write down Poisson's and Laplace's equations in electrostatics.

   (b) Define magnetic vector potential $\vec{A}$ and write its relation with magnetic field $\vec{B}$.

   (c) State Faraday's law of electromagnetic induction in differential form.

   (d) What is electromagnetic damping in a ballistic galvanometer? How is it minimized?

   (e) State Norton's theorem for linear DC networks.

2. **Answer any four questions:** **[4 × 4 = 16]**

   (a) Calculate the force and torque acting on an electric dipole placed in a uniform electric field.

   (b) Find the capacitance of a parallel-plate capacitor partially filled with a dielectric slab of thickness t and dielectric constant K.

   (c) Derive the expression for the magnetic field at the center of a circular current-carrying loop using Biot-Savart's law, and establish its magnetic dipole moment.

   (d) Discuss the growth of charge in a C-R charging circuit and define its time constant.

   (e) Write down Maxwell's equations in free space and explain the physical significance of each.

3. **Answer any two questions:** **[8 × 2 = 16]**

   (a) (i) Using the method of images, determine the potential due to a point charge q placed at a distance d from the center of a grounded conducting sphere of radius a ($d > a$).

   (ii) Find the induced surface charge density on the sphere.

   (b) (i) Define self-inductance and mutual inductance. Derive the Neumann formula for mutual inductance between two circuits.

   (ii) Calculate the energy stored in a magnetic field carrying a current I through an inductor of inductance L.

   (c) (i) Analyze a parallel LCR circuit connected to an AC source. Find its resonance frequency, impedance, and bandwidth.

   (ii) Explain the relation between magnetic induction $\vec{B}$, magnetic intensity $\vec{H}$, and magnetization $\vec{M}$ ($\vec{B} = \mu_0(\vec{H} + \vec{M})$).

PRACTICE QUESTION PAPER — SET 3

PHY-M-T-3: ELECTRICITY AND MAGNETISM

Full Marks: 40 **Time: 2 Hours**

Answer all questions. The figures in the margin indicate full marks. Symbols have their usual meanings.

1. **Answer any four questions:** **[2 $\times$ 4 = 8]**

   (a) Prove that the electrostatic field is conservative ($\nabla \times \vec{E} = 0$).

   (b) Define polarization vector $\vec{P}$ and mention its unit and dimensions.

   (c) State Ampere's circuital law and write down its curl form ($\nabla \times \vec{B} = \mu_0 \vec{J}$).

   (d) State Lenz's law of electromagnetic induction and explain how it manifests conservation of energy.

   (e) State the Maximum Power Transfer theorem for DC circuits.

2. **Answer any four questions:** **[4 $\times$ 4 = 16]**

   (a) Calculate the electrostatic energy of a system of discrete point charges q_i located at positions $\vec{r}_i$.

   (b) Derive the boundary conditions for electric field vector $\vec{E}$ and electric displacement vector $\vec{D}$ across an interface between two dielectric media.

   (c) Calculate the magnetic force experienced by a moving point charge q in combined electric and magnetic fields (Lorentz force).

   (d) Discuss the electrical oscillations in an ideal L-C circuit and derive the differential equation for its frequency of oscillation.

   (e) Find the current and charge sensitivities of a Ballistic Galvanometer.

3. **Answer any two questions:** **l[8 $\times$ 2 = 16]**

   (a) (i) Use Gauss's law to find the electric field inside and outside an infinitely long cylinder carrying a uniform volume charge density ρ.

   (ii) Find the capacitance of a cylindrical capacitor of inner radius a and outer radius b.

   (b) (i) State and prove Superposition theorem for electrical network analysis.

   (ii) Explain the working of a series LCR circuit driven by an AC source, and determine expressions for power dissipation and average power factor.

   (c) (i) Discuss magnetic properties of matter: classify dia-, para-, and ferro-magnetic substances based on their magnetic susceptibility χ.

   (ii) Explain the significance of logarithmic damping correction in ballistic galvanometer measurements.

PRACTICE QUESTION PAPER — SET 4

PHY-M-T-3: ELECTRICITY AND MAGNETISM

Full Marks: 40 **Time: 2 Hours**

Answer all questions. The figures in the margin indicate full marks. Symbols have their usual meanings.

1. **Answer any four questions:** **[2 $\times$ 4 = 8]**

   (a) What is electric flux? State its SI unit.

   (b) Define magnetic susceptibility and magnetic permeability of a medium.

   (c) Write down Kirchhoff's laws for AC circuits involving complex impedances.

   (d) Define mutual inductance and write down its reciprocal relation between two coils.

   (e) State the physical significance of displacement current introduced by Maxwell.

2. **Answer any four questions:** **[4 $\times$ 4 = 16]**

   (a) Derive the expression for the electric field of a dipole at any arbitrary point in polar coordinates.

   (b) Explain polarization charges (bound volume and surface charges) and their relations with polarization $\vec{P}$.

   (c) Using Ampere's circuital law, find the magnetic field inside and outside a long straight solenoid carrying current I.

   (d) Discuss transients in a discharging C-R circuit and sketch the decay curve of charge with time.

   (e) Explain the concept of a constant-voltage and constant-current source in network theorems.

3. **Answer any two questions:** **[8 $\times$ 2 = 16]**

   (a) (i) Prove that the divergence of magnetic induction is zero ($\nabla \cdot \vec{B} = 0$), and discuss its physical implication regarding magnetic monopoles.

   (ii) Derive the magnetic vector potential $\vec{A}$ due to a localized steady current distribution.

   (b) (i) Analyze the behavior of a series LCR circuit at resonance. Derive expressions for resonant frequency, quality factor (Q), and band width ($\Delta\omega$).

   (ii) State and verify Thevenin's theorem for a resistive bridge network.

   (c) (i) What is a Ballistic Galvanometer? Derive the equation of motion of its coil during a transient discharge.

   (ii) Discuss how logarithmic damping affects ballistic deflection and how the correction is applied to experimental readings.