[This question paper contains 2 printed pages.]

Sr. No. of Question Paper : 2060 **Your Roll No................**

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Name of Course : B.Sc. (Hons.) Physics-NEP: UGCF

Semester : **II**

Name of the Paper: : Electricity and Magnetism

Unique Paper Code : **2222011202**

Duration: 3 Hours **Maximum Marks: 90**

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. **All** questions carry equal marks.
3. Q. No. **1** is compulsory.
4. Answer **any four** of the remaining five questions.
5. Use of non-programmable scientific calculators are allowed.

1. Attempt **any six** questions from the following: $(6 \times 3 = 18)$

(a) Two negative charges of unit magnitude and a positive charge q are placed along a straight line. At what position and for what value of q will the system be in equilibrium? Discuss if it is stable or unstable equilibrium.

(b) The linear charge density on a rod of length L is given by $\lambda\,(x) = \lambda_0 + \frac{x}{2}$, where λ_0 is a constant and x is the distance from one end of the rod. Find the total charge on the rod.

(c) A charge $-q$ is placed in vacuum at the point $(d, 0{,}0)$, where $d > 0$. The region $x \leq 0$ is filled uniformly with a conductor. Find the electric field at the point $\left(\frac{d}{2}, 0{,}0\right)$.

(d) Given that $\vec{E}_1 = 5\hat{\imath} - 2\,\hat{\jmath} + 3\hat{k}\ \ (V/m)$ at the charge-free dielectric interface between two different dielectric materials with relative permittivity's $\epsilon_1 = 4$ and $\epsilon_2 = 3$ respectively. Find the electric field $\vec{E}_2$ and electric displacement $\vec{D}_2$ in the second dielectric.

(e) A magnetic field is given by the expression $\vec{B} = axz\,\hat{\imath} + byz\,\hat{\jmath} + c\hat{k}$, where *a, b* and c are some constants. Find a relation between a and b.

(f) A vector potential in a region is given by $\vec{A} = az^2\hat{\imath}$. Find the volume current density in the region.

(g) Write down Maxwell's equations for free space in differential form explaining their physical significance.

2.

(a) The electric potential of a charge configuration is expressed as $V(r) = A\frac{e^{-\lambda r}}{r}$, where A and λ are constants. Find the electric field $\vec{E}(r)$, the charge density $\rho(r)$, and total charge Q. (8)

(b) State and prove First uniqueness theorem. (7)

(c) Use Laplace's equation to find the potential for the region between two concentric spheres when $V_1 = 0$ volt at $r = 2\ m$ and $V_2 = 150$ volt at $r = 3\ m$. (3)

3. (a) A conducting sphere of radius R, is placed at the origin. The point charges $\pm q$ are located at distance $\mp d$ from the centre of the sphere (with $d > R$). Using method of images, determine the magnitude and positions of the image charges. Also, find the electric potential at an arbitrary field point P due to the real charges and image charges. (8)

(b) A long, straight wire carries a uniform line charge density λ. The wire is surrounded by a cylindrical layer of rubber insulation extending up to a radius a. Determine the electric displacement field $\vec{D}$ and the electric field $\vec{E}$ both inside and outside the rubber insulation. (7)

(c) Thin dielectric rod of cross-section A extends along z −axis from $z = 0$ to $z = L$. The polarization of the rod is along its length and is given by $\vec{P} = (ax^3 + b)\hat{k}$, where a and b are some constants. Obtain the bound volume and surface charge densities at each end of the rod. (3)

4. (a) Derive an expression for magnetic field along the axis of two identical coaxial coils of radius R and turns N, separated by a distance d and carrying current I in the same direction. Plot a graph showing the variation of the magnetic field along the axis. (8)

(b) Find the magnetic field of an infinite uniform surface current described by surface current density $\vec{K} = K\hat{\imath}$ flowing over $z = 0$ plane. (7)

(c) Explain the significance of continuity equation in electromagnetism. (3)

5. (a) Starting from Biot-Savart's law for a volume current, show that

$$\vec{\nabla} \times \vec{B} = \mu_o \vec{J}$$

and hence show that $\oint \vec{B} . \vec{dl} = \mu_o I$. (8)

(b) Show that the energy density of a magnetic field B, in vacuum is given by $\frac{B^2}{2\mu_0}$, where μ_0 is the permeability of free space. (7)

(c) Distinguish diamagnetic, paramagnetic and ferromagnetic materials. (3)

6. (a) State and prove Gauss's law in electrostatics. Prove that the electrical intensity at a distant r from a charged wire of infinite length is $\vec{E} = \frac{\lambda}{2\pi\varepsilon_o r}\hat{r}$, where λ is the linear charge density and $\hat{r}$ is the unit vector along distance r. (8)

(b) Show that the electric potential due to a polarized object is given by

$$V = \frac{1}{4\pi\varepsilon_o}\left(\oint_S \frac{\sigma_b}{r} dS + \int_V \frac{\rho_b}{r} d\tau\right)$$

where σ_b and ρ_b are bound surface charge density and bound volume charge density respectively. (7)

(c) At a certain point in a region the magnetic field is given by the expression $\vec{B}(t) = B_0 \cos(kz - \omega t)\,\hat{\jmath}$, where, B_0, k and ω are some constants. Find the curl of the induced electric field at that point. If the z −component of the induced electric field is zero, find the x −component of the induced electric field. (3)