2024

PHYSICS — HONOURS

Paper : CC-3

(Electricity and Magnetism)

Full Marks : 50

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Symbols have their usual significance.

Answer *question no.* **1** and *any four* questions from the rest.

1. Answer *any five* questions : 2×5

   (a) Electric field for a point charge q at a distance $\vec{r}$ is given by $\vec{E} = \dfrac{1}{4\pi\epsilon_0} \dfrac{q}{r^3} \vec{r}$. Verify that the field is electrostatic in nature.

   (b) 'The electric field lines never intersect.' — Justify.

   (c) State and explain Gauss' law in dielectric medium.

   (d) A circular coil of wire has 100 turns of radius 12 cm, and carries a current of 1 A in a clockwise direction when viewed from the right side. Find the magnitude of the magnetic field.

   (e) What do you mean by retentivity and coercivity of a magnetic material?

   (f) Write down the Maxwell's electromagnetic field equations in free space explaining the symbols.

   (g) Explain the term quality factor and bandwidth for series LCR circuit.

2. (a) Show that the electric field is always perpendicular to a equipotential surface.

   (b) 12 equal charges q, are situated on each numeral of a clock face. What is the net field at the centre? Now if one charge is removed, what will be the value of field at the centre?

   (c) Suppose a charge Q is distributed within a sphere of radius R in such a way that the charge density $\rho(r)$ at a distance r from the centre of the sphere is

   $$\rho(r) = K(R-r), \text{ for } 0 < r < R,$$
   $$= 0, \qquad \text{for } r \geq R$$

   (i) Determine constant K in terms of Q and R.

   (ii) Calculate the electric field at any point inside the sphere.

   (iii) Find the value of r for which the field is maximum.

   (iv) What is the value of this maximum field? 2+(2+1)+(1+2+1+1)

Please Turn Over

3. (a) A 'pure' dipole 'p' is situated at the origin, pointing in the z-direction.

   (i) What is the force on a point charge q at $(a, 0, 0)$?

   (ii) How much work does it take to move q from $(a, 0, 0)$ to $(0, 0, a)$?

   (b) Define polarization vector $\vec{P}$ for a dielectric substance. What are electric susceptibility and dielectric constant of a medium and how are they related?

   (c) Write down and explain the electrostatic boundary conditions for $\vec{E}$ and $\vec{D}$.   3+3+4

4. (a) A dielectric sphere of radius a carries a (frozen-in) polarization $\vec{P} = k\vec{r}$, where k is a constant and r is the distance from the centre. Use Gauss theorem in dielectrics to find the electric field inside $(r < a)$ and outside $(r > a)$ the sphere.

   (b) A point charge q is placed at a distance r_0, from the centre of a grounded spherical conductor of radius a $(a > r_0)$. Find the electric field at an external point and total charge induced on the sphere by method of electrical image.   4+(4+2)

5. (a) What is Lorentz force? A long straight conductor carries a current I. Determine the force per unit length of the conductor when it is placed in a uniform magnetic field.

   (b) What is the physical meaning of $\vec{\nabla} \cdot \vec{B} = 0$?

   (c) State Ampere's circuital law and using this law derive the magnetic field near a straight infinite current carrying wire.   (2+2)+2+(2+2)

6. (a) Find the self-inductance per unit length of a long solenoid of radius r, carrying n turns per unit length.

   (b) Two coils have self-inductances L_1 and L_2 and mutual inductance M. Show that $M^2 \leq L_1 L_2$.

   (c) A 230 V, 50 Hz ac voltage is applied to a coil $L = 5H$ and $R = 2\Omega$ in series with a capacitance C. What value must C have in order that the voltage across the coil be 400 V?   3+3+4

7. (a) What do you mean by displacement current? Show that Maxwell's equations are consistent with the equation of continuity.

   (b) State Faraday's Law of electromagnetic induction and then show that it can be expressed as $\vec{\nabla} \times \vec{E} = -\dfrac{\partial \vec{B}}{\partial t}$.

   (c) Consider a parallel $L - C$ combination in series with a resistance R. Calculate the output voltage across $L - C$ combination for sinusoidal input.   (1+2)+(2+2)+3

———————————