

2026

PHYSICS — HONOURS

Paper : DSCC-6

(Electromagnetism)

Full Marks : 75

*The figures in the margin indicate full marks.**Candidates are required to give their answers in their own words as far as practicable.*Answer **question no. 1** and **any five** questions from the rest.1. Answer **any five** questions :

3×5

- State Uniqueness theorem. Explain how this theorem is used to solve electrostatic problems by the method of electrical image.
- Show that the dipole moment of a charge distribution is independent of origin if total charge is zero.
- A series combination of an inductance L and a resistance R is connected in parallel with a capacitor of capacitance C . Find the impedance of the circuit. What will be the resonant frequency?
- A metallic disc of radius a is rotated about its axis with a constant angular velocity in a uniform magnetic field $\vec{B}$ perpendicular to its plane. Calculate the potential difference between the rim and the center of the disc.
- Two coils of self inductance L_1 and L_2 are connected in series. Find the equivalent inductance.
- For a plane electromagnetic wave show that the energy is shared equally by the electric and the magnetic field. What happens inside a conductor?
- How and why did Maxwell introduce the idea of displacement current?
- What sort of a physical situation suggest wave number (k) may be complex?

- A field $\vec{E} = A(x^2\hat{x} + y^2\hat{y} + z^2\hat{z})$ exists in a cube of side L centered at the origin. Using differential form of Gauss' law calculate the total charge inside the cube.
 - If $\phi = \sinh \alpha x \cos \beta y \cos \gamma z$ represents an electrostatic potential in a charge free region then find the relation between α , β and γ .
 - Consider a static charge distribution with charge density $\rho(\vec{r}')$. Find the potential at any point $P(\vec{r})$ due to this charge distribution. Identify the dipole and quadrupole term.
 - Find the dipole moment of a thin rod that lies along the z -axis from $z = -L/2$ to $z = L/2$ with linear charge density $\lambda(z) = \lambda_0(z/L)$.

3+2+(3+1)+3

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3. (a) If there is a dielectric sphere in a uniform electric field obtain the expressions for electric fields inside and outside the sphere.
- (b) An uncharged conducting sphere of radius R is placed in an uniform electric field $\vec{E} = E_0 \hat{z}$. State the boundary conditions. Find the potential at any point outside the sphere. Also find the induced charge density.

[Given : Solution of Laplace's equation with azimuthal symmetry can be written as

$$V(r, \theta) = \sum_{l=0}^{\infty} \left(A_l r^l + \frac{B_l}{r^{l+1}} \right) P_l(\cos \theta). \quad (3+3)+(1+3+2)$$

4. (a) Consider a dielectric medium with polarization $\vec{P}$. Show that it has volume charge distribution $\rho_b = -\vec{\nabla} \cdot \vec{P}$ and surface charge distribution $\sigma_b = \vec{P} \cdot \hat{n}$ due to polarization.
- (b) A dielectric sphere of radius R has a polarization $\vec{P} = k\vec{r}$. Calculate the volume and surface charge density of polarization charge in the sphere. Hence find the total charge in the sphere due to polarization.
- (c) Two similar point charges q are kept separated by a distance $2d$ in air. Now an earthed conducting sphere of radius a is placed midway between them. If $d \gg a$ show that the introduction of the sphere just neutralises the force between the point charges if $a \approx \frac{d}{8}$. 4+4+4
5. (a) Differentiate between current resonance and voltage resonance in ac circuits. What are their analogs in forced vibration?
- (b) Explain the terms (i) phase resonance (ii) dynamic resistance in a parallel resonant circuit.
- (c) A coil of inductance L_1 and resistance R_1 is connected in parallel with another coil of inductance L_2 and resistance R_2 . The combination is fed by an ac source. Prove that the currents in the two coils will be in phase provided the mutual inductance M between the coils is $M = \frac{R_1 L_2 - R_2 L_1}{R_1 - R_2}$. (3+1)+(2+2)+4
6. (a) State the differential form of Ampere's law. Show that the magnetic vector potential $\vec{A}$ satisfies the relation $\nabla^2 \vec{A} = -\mu_0 \vec{J}$ provided Coulomb gauge is satisfied. Write down the expression of the magnetic vector potential for volume currents and line currents.
- (b) Consider a long thin straight wire carrying current I . Find the magnetic vector potential outside the wire.
- (c) An electron circulates round a nucleus in a path of radius 5.1×10^{-11} m at a frequency of 6.8×10^{15} rev/s. Calculate the magnetic dipole moment. (1+3+1)+4+3

7. (a) A current carrying loop placed in a uniform magnetic field feels torque but no net force.— Explain.
 (b) Derive the boundary conditions for $\vec{B}$ and $\vec{H}$ at the interface of two different media having surface current density $\vec{K}$.
 (c) Consider two arbitrary loops C_1 and C_2 carrying currents I_1 and I_2 respectively. Find the mutual inductance between them. Calculate the mutual inductance between two parallel coaxial circular loops C_1 and C_2 (Assume the loop C_2 is much smaller than C_1). 3+3+(3+3)
8. (a) Show that the electromagnetic waves are transverse in nature.
 (b) Show that energy flow of electromagnetic waves is in the direction of wave propagation.
 (c) Write the Maxwell equations in a conducting medium and explain them.
 (d) The intensity of sunlight reaching the earth's surface is about 1300 W.m^{-2} . Calculate the strength of electric and magnetic fields of the incoming light. 3+3+2+4
9. (a) What are Lorentz and Coulomb gauges?
 (b) Show that an excess charge placed at any point in a medium of conductivity σ and permittivity ϵ decays exponentially with relaxation time $\tau = \frac{\epsilon}{\sigma}$. Discuss how τ can measure the quality of a conductor.
 (c) Obtain the differential form of Poynting's theorem. 3+(4+2)+3
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