2025

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

(a) What is meant by resonance in a series LCR circuit?

(b) Determine the electrostatic field due to a potential $\phi(r)=\frac{A}{r}e^{-\lambda r}$ where A and λ are constants.

(c) At the upper surface of the earth's atmosphere the time averaged magnitude of Poynting's vector is $<S>=1.35\times10^3$ W/m^2. Calculate the magnitude of the electric field. If sunlight strikes a perfect absorber, what pressure does it exert?

(d) The electric field in the x-y plane is given as $\vec{E}=2axi+byj$ where a and b are constants. What is the charge density responsible for this field?

(e) Starting from Gauss's law, show that the electrostatic potential satisfies Poisson's equation.

(f) A point charge is placed in front of a conducting sphere of radius 'r_0' at a distance 'd' from the centre of the sphere. Find the location and value of the image charge.

(g) Write the Maxwell's equations in free space and obtain the wave equation for electric field.

(h) If $\vec{B}$ is a uniform magnetic field, show that the vector potential $\vec{A}(r)=\frac{1}{2}\left(\vec{B}\times\vec{r}\right)$.

2. (a) State Coulomb's law. Hence obtain $\vec{\nabla}\times\vec{E}=0$ and explain its significance.

(b) The electric field in a region is given as $\vec{E}=kr^3\hat{r}$ where k is a constant. Calculate the charge contained within a spherical surface of radius 'a' centred at the origin.

(c) Find out the electrostatic potential and field at a point lying on the axis of a uniformly charged circular disc. (1+2+1)+4+4

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3. (a) What do you understand by coefficient of coupling? A coil of self-inductance 100 mH is connected in series with another coil of self-inductance 169 mH. The effective inductance of the combination is found to be 70 mH. Determine the coefficient of coupling.

(b) A series LCR circuit is driven by a sinusoidal voltage. Find out the expressions for instantaneous current and the current at resonance. Draw and explain the phasor diagram corresponding to resonance. (1+3)+(2+2+2+2)

4. (a) Show that electric field is always perpendicular to an equipotential surface.

(b) For an arbitrary localized charge distribution, obtain the multipole expansion of the electrostatic potential at a point well outside the charge distribution.

(c) Show that the electric potential at a point $\vec{r}$ due to an electric dipole at $\vec{r}'$ with dipole moment $\vec{p}$ can be written as $\phi(r) = -\vec{p} \cdot \vec{\nabla}\phi_0$, where ϕ_0 is the potential at $\vec{r}$ due to a unit positive point charge placed at $\vec{r}'$. Assume that the length of the dipole is very small compared to $|\vec{r} - \vec{r}'|$. 2+5+5

5. (a) What is electric polarization? Find its SI unit.

(b) Compare two properties of Diamagnetism, Paramagnetism and Ferromagnetism.

(c) What do you mean by free current and bound current? Establish the relation $\vec{J}_b = \vec{\nabla} \times \vec{M}$ where the symbols have their usual meanings. 3+3+(2+4)

6. (a) Obtain Faraday's law of electromagnetic induction in differential form.

(b) What is motional e.m.f.? The self inductance of two coils are L_1 and L_2 and their mutual inductance is M. Show that $M \leq \sqrt{L_1 L_2}$. What is the physical significance of $M = 0$, when L_1 and $L_2 > 0$?

(c) Show that the density of energy stored in a magnetic field strength $\vec{B}$ is

$$u_m = \frac{1}{2\mu_0} \int B^2 dV$$

where the symbols have their usual meanings. 2+(2+3+1)+4

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

(b) Show that the displacement current in a parallel plate capacitor is equal to the conduction current in the current leads.

(c) State the prove Poynting theorem. (2+3)+3+4

8. (a) In a current free region $B_x = ax + bz$ and $B_y = ax + cy$ where 'a', 'b', 'c' are constants. Find a possible form of B_z assuming all currents outside.

(b) A vector potential $\vec{A} = \beta x\hat{i} + 2y\hat{j} - 3z\hat{k}$ satisfies the Coulomb gauge condition. What is the magnitude of β?

(c) Show that in an electromagnetic wave, the electric field $\vec{E}$, the magnetic field $\vec{B}$ and the propagation unit $\hat{n}$ are related as $\hat{n} \times \vec{E} = c\vec{B}$ when c is the speed of light in free space.

(d) What is Brewster's law? Light is incident from air on glass of refractive index 1.5. Calculate the Brewster's angle.

(e) An electromagnetic wave is propagating from one linear dielectric medium to another with no free charges or currents. Write down the boundary conditions at the interface of the media.

2+2+3+(1+2)+2

9. (a) Show that the momentum density of an electromagnetic wave is given as $\vec{S}/c^2$ in vacuum where $\vec{S}$ is the Poynting vector.

(b) Determine the expression for the phase angle by which the magnetic field lags behind the electric field when an electromagnetic wave propagates through a conducting medium. Determine the angle for an ideal conductor.

(c) Starting from the Maxwell's equations, obtain the expression for skin depth of a conductor.

3+(3+2)+4
