# RAMAKRISHNA MISSION VIDYAMANDIRA

**(Residential Autonomous College affiliated to University of Calcutta)**

**B.A./B.Sc. FOURTH SEMESTER EXAMINATION, MAY 2025**

**SECOND YEAR [BATCH 2023-27]**

Date : 06/05/2025 **PHYSICS**

Time : 11 am – 1 pm **Paper : 4PHYMJC2** Full Marks : 50

Answer **any five** questions from the following: [5×10]

1. a) Write down the Ampere's circuital law for steady current. Mention a circuit where this law is failed to be satisfied. Give the general form of this law to handle the circuit you have mentioned.
   b) A conservative field is denoted by null value of curl of the corresponding field vector. Thus when magnetic energy is converted to electric field then what would be curve of $\vec{E}$? Convert it to integral form.
   c) State the Poynting's theorem. Write down its mathematical expression mentioning each tern with their significances. [(1+1+2)+(1+2)+(1+2)]

2. a) What are retarded time and retarded potentials.
   b) Derive Sellmeier's equation for the refractive index of a dielectric medium.
   c) Obtain the boundary condition satisfied by the electromagnetic field vector $\vec{H}$ . [(1+1)+5+3]

3. a) The electric field $\vec{E}$ of electromagnetic wave is parallel to the plane of incidence, falls obliquely on the interface between two simple dielectric, non-magnetic media. Using the boundary conditions derive the Frensel formulae. Find the Brewster angle using this formula.
   b) The electric field $\vec{E}$ in a dielectric medium of $\mu_r = 1, \in_r = 4$ is given by
   $\vec{E} = 15 sin\left(10^8 t - \beta z\right) \hat{x} \, V/m$ Calculate $\beta$ and magnetic field $\vec{H}$ . [(5+1)+4)]

4. a) What is differential scattering cross-section. Assuming the time average radiated power per unit area by an oscillating dipole, obtain the expression for the total scattering cross-section.
   b) What do you mean by uniaxial and biaxial crystal? If a point source is illuminating inside one uniaxial crystal comment on its wavefront.
   c) An optical rotation of $15^o$ occurs when light is sent through a certain length of 9% solution of a substance. If light is sent through 15% solution of the same substance, what length of the solution will be required to produce an optical rotation of $25^o$. [(1+4)+(2+1)+2]

5. a) The electric field vectors of two electromagnetic waves propagating in the z-direction in free space are
   $\vec{E}_1 = \hat{x} E_0 \, cos\left(\omega t - kz\right) - \hat{y} E_0 \, sin\left(\omega t - kz\right)$
   and $\vec{E}_2 = -\hat{x} E_0 \, sin\left(\omega t - kz\right) + \hat{y} E_0 \, cos\left(\omega t - kz\right)$
   i) Find the state of polarization of each wave.
   ii) Also, determine the state of polarization of the wave resulting from the superposition of these two waves.
   b) Derive the wave equation from Maxwell's equations for homogeneous isotropic non conducting medium. Show that it has solution in the form of transverse plane waves with wave number *k* and angular frequency $\omega$.
   c) Show that in a conductor the magnetic field $\vec{H}$ leads the electric field $\vec{E}$ in space. [(2+2)+(2+2)+2]

6. a) Find the expression of propagating vector of electromagnetic waves in dilute plasma. Show that the critical frequency ($f_c$) for propagating vector of electromagnetic waves in plasma is given by $f_c = 9\sqrt{n}$ , where $n$ is the electron density.

   b) What is the principle on which Fresnel's explanation of optical rotation is based. Write down the expression for the optical rotation obtained from the theorey. [(3+3)+(1+3)]

7. a) The magnetic intensity of free space is given by $\vec{H} = \hat{y}H_0 \cos\omega\left(t - \frac{z}{c}\right)$ , where $c$ is the speed of light.
   (i) What is the displacement current density if there is no free charges?
   (ii) Verify that the differential form of Faraday's law of electromagnetic induction is satisfied by $\vec{E}$ and $\vec{H}$ .

   b) A sinusoidal conduction current of amplitude $5.5\mu A$ and angular frequency $4\times10^{10} rad/s$ flows through a medium of circular cross-section of diameter 3mm. If the conductivity of the medium is $3.5\times10^{7} mho/m$ and its dielectric constant is unity. Calculate the amplitude of the displacement current density.

   c) Find the unit, dimension and magnitude of the quantity $\sqrt{\mu_0/\in_0}$ .

   d) What is evanescent wave? [(1+2)+2+3+2]

8. a) What is 'skin depth'? Show that for a good conductor the skin depth is $\frac{\lambda}{2\pi}$ , where $\lambda$ is the wavelength in the medium.

   b) In the propagation of electromagnetic wave in vacuum show that $\vec{E},\vec{H}$ and $\vec{k}$ are perpendicular to each other using Maxwell's equation. Here $\vec{E},\vec{H}$ and $\vec{k}$ electric field, magnetism field and propagation vector.

   c) Show that free charges can not be in a stable condition in conducting media. [(1+3)+4+2]

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