B.Sc. 6th Semester (Honours) Examination, 2023 (CBCS)

Subject : Physics

Course : CC-XIII

(Electromagnetic Theory)

Time: 2 Hours **Full Marks: 40**

The figures in the margin indicate full marks.

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

1. Answer *any five* of the following questions: 2×5=10

(a) Given the scalar and vector potentials as below, find out $\vec{E}$ and $\vec{B}$.

$\phi(\vec{r}, t) = 0$

$\vec{A}(\vec{r}, t) = \hat{j}A_0 \sin(kx - \omega t)$, where A_0, k and ω are constants.

(b) Show that the frequency of the electromagnetic wave does not change upon reflection and refraction at the interface of two dielectric media.

(c) "If an unpolarized beam is allowed to fall on a gas, then the scattered beam perpendicular to the incident beam is linearly polarized."—Why?

(d) For an EM wave travelling in vacuum, the value of the amplitude of $\vec{E}$-field is 30π V/m. Find the value of the amplitude of $\vec{H}$ field.

(e) What do you mean by Evanescent wave?

(f) State Poynting's theorem.

(g) Find the state of polarization of the following light beams:

(i) $\vec{E} = \hat{i}a \sin(\omega t - kz) + \hat{j}a \cos(\omega t - kz)$

(ii) $\vec{E} = \hat{i}a \sin(\omega t - kz) + \hat{j}b \sin(\omega t - kz)$

(h) A plane wave is incident normally on a uniaxial negative crystal. Draw the wavefronts for the refracted rays and the direction of vibrations when the optic axis is

(i) parallel to the direction of the incident wave,

(ii) perpendicular to the direction of the incident wave (considering both cases, i.e., optic axis within the plane of the paper and perpendicular to the plane of the paper).

2. Answer *any two* of the following questions: 5×2=10

(a) What is intermodal dispersion? Derive an expression of intermodal dispersion for a step-index fibre. Find the temporal broadening and the spread in space for a 1km long step-index fibre having core of refractive index 1·500 and a cladding of refractive index 1·489. 1+2+(1+1)=5

(b) Deduce an expression for the refractive index of a dilute ionized gaseous medium. Hence, show that,

(i) the electromagnetic wave of frequency less than plasma frequency can not propagate through the medium,

(ii) the plasma frequency, $f_p = 8{\cdot}98\sqrt{n_0}$ Hz, where n_0 is electron number density in the m^{-3} unit.

[Given electronic charge $e = 1{\cdot}6 \times 10^{-19}$ C, mass of electron $m_e = 9 \times 10^{-31}$ Kg, free space permittivity $\varepsilon_0 = 8{\cdot}85 \times 10^{-12} C^2/N\text{-}m^2$. 3+1+1=5

(c) Explain in brief, Fresnel's theory of rotation of the plane of polarization by an optically active substance. A plane polarized light is found to rotate 12° due to propagation through a 20 cm polarimeter tube. If the specific rotation of the solution is 60° $dm^{-1}g^{-1}cm^3$, find the concentration of the solution. 4+1=5

(d) Given the electric field $\vec{E} = E_0(\hat{\jmath} + a\hat{k})e^{ik_0[-ct+(y+\sqrt{3}z)]}$ where a is a constant. Find out

(i) the value of a,

(ii) velocity of wave,

(iii) refractive index of the medium. 3+1+1=5

3. Answer *any two* of the following questions: 10×2=20

(a) A plane polarized electromagnetic wave with its electric vector parallel to the plane of incidence is incident obliquely on the interface between two simple dielectrics. Obtain the expressions for the amplitude reflection coefficient and amplitude transmission coefficient. Hence prove Brewster's law. 3+3+4=10

(b) Consider the propagation of a plane electromagnetic wave through a linear homogeneous isotropic conducting medium having no accumulated charge or externally induced current. Derive the wave equations for electric and magnetic fields. Show that the field amplitudes are spatially attenuated. Also derive an expression for the relative phase difference between electric and magnetic fields. 4+3+3=10

(c) Derive Malus' law.

If we introduce a polaroid in the path of the following polarized light beams having different states of polarization (mentioned below) and rotate the polaroid about the direction of propagation, then the following three observations are noted (see below):

States of polarization	Observations
i) Linearly polarized. ii) Circularly polarized iii) Elliptically polarized iv) Unpolarized v) Mixture of linearly polarized and unpolarized vi) Mixture of circularly polarized and unpolarized vii) Mixture of elliptically polarized and unpolarized	i) Complete extinction at two positions ii) No variation of intensity iii) Variation of intensity without complete extinction

Mention the possible states of polarization for each observation with proper explanations. Also explain how to distinguish the states of polarizations if there is more than one state present you think, in any of the observations. 3+(3+2+2)=10

(d) What are the planar symmetric and asymmetric dielectric waveguides? Consider a transverse electric wave (TE–wave) propagating through an asymmetric dielectric waveguide. Starting from Fresnel's equations, derive the expressions for phase change due to total internal reflections. Write down the transverse resonance condition and hence deduce the eigenvalue equations for the symmetric waveguide. 1+4+3+2=10
