B.Sc. 6th Semester (Honours) Examination, 2024 (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) 'Ampere's law is bound to fail for non-steady currents'—justify the statement.

(b) How do polarized sunglasses reduce glare caused by light?

(c) Performance of a waveguide made of pure Ag and Ag-coated brass would appear identical in the microwave region — Justify the statement.

(d) How to distinguish between (i) circularly polarized light and (ii) a mixture of unpolarized and circularly polarized light?

(e) Prove that Maxwell's equations include the equation of continuity.

(f) What are the advantages and disadvantages of a bi-quartz polarimeter?

(g) Using Hagen-Rubens formula, show that radar waves of frequency 1 MHz may get almost totally reflected from the surface of an aeroplane made of metal having conductivity $\sigma = 5.8 \times 10^7$ S/m and permeability μ_0.

(h) The electric field of an EM wave propagating in certain medium is given by $\vec{E} = \hat{k}E_0 \cos(10^7 x + 10^7 y - 10^{15} t)$ V/m. Find the refractive index of the medium.

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

(a) What is skin depth? Calculate the skin depth for silver at a frequency of 10 GHz. Given the conductivity $\sigma = 3 \times 10^7\ (\Omega - m)^{-1}$, and permeability $\mu = \mu_0 = 4\pi \times 10^{-7} Hm^{-1}$.

Show that the skin depth in a poor conductor is independent of the frequency and is given by $\delta = \frac{2}{\sigma}\sqrt{\frac{\epsilon}{\mu}}$. 1+2+2=5

(b) (i) Two Nicols are crossed to each other. One of them is then rotated through 60°. Calculate the percentage of incident polarised light that will pass through the optical system.

(ii) A quarter wave plate is placed in between two crossed Nicols, and then the plate is rotated by 360°. Discuss the probable variation of intensity, if any, in the observation through the analyser? 3+2=5

(c) What is graded-index fibre? Discuss its advantages over step-index one.

Find the numerical aperture of a step-index fibre when the refractive indices of the core and cladding are 1.51 and 1.47 respectively. Calculate the angle of acceptance of the fibre when it is placed in air. 1+1+2+1=5

(d) What are the planar symmetric and asymmetric dielectric waveguides?

A planar dielectric waveguide of 100 μm width, has $n_1 = 1.490$ (core) and $n_2 = 1.470$ (clad) at the free-space source wavelength of $1\mu m$. Estimate the number of supported modes. 2+3=5

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

(a) Show that in a harmonically varying electromagnetic field represented by complex notations, the time average Poynting's vector can be expressed in the form real part of $\frac{1}{2}(\vec{E} \times \vec{H}^*)$, where $\vec{H}^*$ is the complex conjugate of $\vec{H}$.

In a region of space, the Poynting vector is given by $\vec{s} = \hat{k}0.8\cos^2(kz - \omega t)\ \mathrm{W/m^2}$.

Find the time average EM power passing through an area $0.01\ \mathrm{m^2}$ on a plane $3x + 4z = 7$.

Show that the momentum density stored in EM field is given by $\vec{P}_{em} = \vec{s}/c^2$ in vacuum. 5+3+2=10

(b) Consider the propagation of electromagnetic waves through a dilute ionised gas such as the ionosphere. Obtain the expression for the refractive index of such a medium. What is electron plasma frequency? How are the electromagnetic waves reflected from the ionosphere? 6+2+2=10

(c) Explain clearly (i) optically active substance and (ii) specific rotation.

Explain in brief, how Fresnel demonstrated experimentally, his theory of optical rotation.

The rotation in the plane of polarisation $(\lambda = 5893\ \text{Å})$ in a certain substance is 10° per cm. Calculate the difference between the refractive indices for right-handed and left-handed circularly polarised light in the substance. (2+2)+3+3=10

(d) A plane electromagnetic wave polarized perpendicular to the plane of incidence is incident obliquely on the interface of two simple dielectric media. Using boundary conditions, obtain the expressions for amplitude reflection and transmission coefficients. If the angle of incidence for such waves is 30° on air-glass interface, find the values of amplitude of reflection and transmission coefficients.

[Assume non-magnetic dielectric medium with $\mu \approx \mu_0$]

[Given refractive indices of air and glass are 1 and 1.5 respectively] 6+4=10