# U.G. 6th Semester Examination - 2023

## PHYSICS

### [HONOURS]

**Course Code : PHY-H-CC-T-13**

**(Electro-magnetic Theory)**

Time : $2\frac{1}{2}$ Hours

Full Marks : 40

*The figures in the right-hand margin indicate marks.*
*Candidates are required to give their answers in their own words as far as practicable.*

1. Answer any five questions: $2\times5=10$

a) The electromagnetic wave travelling in a medium has relative permeability 2.5 and relative permittivity 1.6. Show that the speed of EM wave in that medium will be half of the speed of EM wave in vacuum.

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

c) Calculate the thickness of a half-wave plate for a light of wavelength 650 nm.

[Given index of refraction for the *ordinary axis* = 1.5442; index of refraction for the *extraordinary axis* = 1.5533]

d) What is Skin Depth? Find the phase velocity and the magnitude of attenuation constant of plane wave at a frequency of 10 GHz in polyethelene.

(Given : $\mu = \mu_0$; $\varepsilon_r = 2.3$; $\sigma = 2.56 \times 10^{-4}\ S/m$)

e) 'The terms poor and good conductor depend on frequency'– Explain.

f) State and explain Malus Law.

g) Explain with diagram the difference between single and multimode fibre.

h) What is Planar waveguides?

2. Answer any two questions: 5×2=10

a) What do you mean by numerical aperture? Obtain an expression for numerical aperture and acceptance angle of an optical fibre in terms of the refractive indices. Show that in a conductor the electric and magnetic fields are not in phase. 1+2+2



b) i) An incident wave along $\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}$ falls on a refractive surface at $z = 0$. If the refractive index is $\mu = \sqrt{3}$. Find the propagation vectors for the reflected and the refracted rays.

ii) A light beam has intensity 1.5 $kWm^{-2}$. Calculate the radiation pressure. 3+2

c) i) Show that the Poynting vector is the electromagnetic energy density multiplied by the phase velocity.

ii) How is plane polarized light obtained using double refraction in a crystal? Explain with suitable diagram. 2+3

d) Show that under suitable conditions $\vec{A}$ and $\varphi$ satisfy the inhomogeneous equations

$$\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{A} = -\mu_0 \vec{J}; \left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\varphi = -\frac{\rho}{\varepsilon_0}$$

5

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

a) i) Given the total electromagnetic energy

$$W = \frac{1}{2}\int \left(\vec{E}.\vec{D} + \vec{H}.\vec{B}\right) dv,$$

show from Maxwell's equation that

$$\frac{\partial W}{\partial t} = \oint \left(\vec{E} \times \vec{H}\right).\vec{ds} - \int \left(\vec{E}.\vec{J}\right) dv.$$

ii) Assuming a source-free region, derive the following wave equation from Maxwell's Equations

$$\nabla^2 \vec{E} = \mu\sigma \frac{\partial \vec{E}}{\partial t}.$$

iii) Show that under a gauge transformation of the vector potential $\vec{A}$ and the scalar potential $\phi$, the electromagnetic field vectors are invariant.

b) i) A plane electromagnetic wave falls obliquely on the interface between two simple dielectric media. Assuming the electric vector to be perpendicular to the plane of incidence obtain the expression for the reflection coefficient.



ii) Explain Fresnel's theory of rotation of plane of polarization by an optically active substance.

iii) A plane polarized light is found to rotate 12° due to propagation through 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+2+4

c) i) Electromagnetic wave can easily penetrate in a dielectric medium but can not do so in a conducting medium.– Explain.

ii) Show that the frequency of the wave remains unchanged upon refraction, when an electromagnetic wave is incident on the plane interface between two different media.

iii) The electric field of an electromagnetic wave in vacuum is given by

$$E_x = 0,\ E_y = 30\cos\left(2\pi \times 10^8 t - \frac{2\pi}{3}x\right),\ E_z = 0.$$

Where $E$ is in volts/meter, $t$ in seconds, and $x$ in meters.

Determine:

A) the frequency f,

B) the wavelength $\lambda$,

C) the direction of propagation of th wave,

D) the direction of the magnetic field

4+2+

d) i) Vector potential **A** and scalar potential ( is given by

$$A(x,t) = A_0 e^{i(K.x-\omega t)},\ \varphi(x,t) = 0$$

where $A_0$, **K**, $\omega$ are constant in space an time. Calculate electric field **E**.

ii) Write Maxwells equation in a source fre homogeneous non-conducting mediu and explain its physical significance.

iii) Show that electric field **E** and magnet field **B** obeys wave equation. 3+3+