B.Sc./6th Sem (H)/PHS/23(CBCS)

# 2023

## 6th Semester Examination

## PHYSICS (Honours)

### Paper : C 13-T

### [Electromagnetic Theory]

[CBCS]



Full Marks : 40 Time : Two Hours

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

Answer any ***five*** questions from Q.1-Q.-8. 2×5=10

1. The space-time dependence of the electric field of a linearly polarized light in free space is given by $\vec{E} = E_0 \cos(\omega t - kz)\hat{i}$, where $E_0$, $\omega$ and $k$ are the amplitude, the angular frequency and the wave vector, respectively, Find the time average energy density associated with the electric field.

2. How is the wave vector of an incident electromagnetic wave modified for the propagation of the wave through a conducting medium? What is its consequence?

3. What do you mean by gauge transformation?

P.T.O.

4. What do you mean by Phase Retardation plates?

5. If the vector potential $\vec{A} = ax\hat{i} + 2y\hat{j} - 3z\hat{k}$, satisfies the Coulomb gauge, find the value of the constant $\alpha$.

6. What is birefringence? Give some of its application in display devices.

7. A uniform volume charge density is placed inside a conductor (with resistivity $10^{-2}$ $\Omega$m). Calculate the time when the charge density reduces to $(1/e)$ time of its initial value.

8. Explain why only a thin coating of gold is sufficient to manufacture a highly conducting wire.

Answer any ***four*** questions from Q.9-Q.14. 5×4=20

9. A dilute electron gas with free electron concentration $N$ is subjected to a simple harmonic electric field of angular frequency $\omega$.

   (a) Determine the velocity of an electron.

   (b) Derive the expressions of the conduction current density and displacement current density.

   (c) Show that the effective dielectric constant of the electron gas is $1-\left(Ne^2 / m\varepsilon_0\omega^2\right)$. 1+2+2

   [Symbols have their usual significance]

10. (a) Write the physical significance of the Poynting vector. What is the relation between the Poynting vector, electromagnetic energy density, and phase velocity? 1+1





(b) Show that the time averaged electric and magnetic energy densities in vacuum are equal. 3

11. (a) What do you mean by linearly polarized, circularly polarized, and elliptically polarized waves? Give the expression for the $\vec{E}$ field in each case. 2+2

(b) Show that TEM waves cannot occur in a waveguide. 1

12. (a) Consider a rectangular waveguide with the dimensions $a$ = 3.33 cm and $b$ = 2.50 cm. For the propagation of the $TE_{11}$ mode find the range of frequencies. Which kind of filter does this waveguide behave like in this case? 2+1

(b) A step-index fiber has a core index of refraction of $n_1$ = 1.425. The cut-off angle for light entering the fiber from air is found to be 8.50°. What is the numerical aperture of the fiber? What is the index of refraction of the cladding of this fiber? 1+1

13. (a) Derive, considering TE waves, the expressions of the cut-off wavelength and guide wavelength for propagation of an electromagnetic wave between parallel plates. 3

P.T.O.

(b) Show that $v_p g_g = c^2$ where $v_p$ and $v_g$ are the phase and group velocities, respectively, and $c$ is the velocity of light. 2

14. Show that normal component of electric displacement vector is not continuous at the boundary. How does birefringence explain double refraction? 3+2

Answer any ***one*** question from Q.15-Q.16. 10×1=10

15. (a) What is Babinet's compensator? Explain how it can be used to analyse elliptically polarized light. 1+3

(b) What are Biot's laws for rotatory polarization? Define specific rotation of a solution. 2+1

(c) A TEM wave of frequency 300 GHz propagates in vacuum along the positive $x$-direction. It has an electric field of amplitude 28.28 V/m. The wave is linearly polarized with the plane of vibration of the electric field at an angle of 45° to the $xz$-plane. Give the expressions of the electric and magnetic fields. 3

16. (a) What are the $s$-polarization and $p$-polarization of electromagnetic waves? 1

(b) Deduce the expressions of amplitude coefficients for reflection and transmission for a $p$-polarized electromagnetic wave and discuss their variations. 4



(c) How is the concept of Brewster's angle explained for $p$-polarized wave in specific conditions? Show diagrammatically. 2+1

(d) Find the reflectance and the transmittance of a plane electromagnetic wave incident normally from air on a dielectric surface of refractive index 1.4. 2