1 (Sem–3/FYUGP) PHY42MJ

2025

PHYSICS

(Major)

Paper : PHY4300204 MJ

(Electromagnetic Theory)

Full Marks : 45

Time : 2 hours

The figures in the margin indicate full marks for the questions.

1. *(i)* Write the expression for electric field vector, where the magnetic field is polarized along y-direction. 1

   (ii) Express the Poynting's theorem in differential form. 1

   (iii) Define the term birefringence. 1

   (iv) What is the function of the Fresnel rhomb ? 1

(v) Write Maxwell's equations for harmonically varying fields. 1

2. Answer ***any five*** questions :

(i) Derive the expression for electric field in terms of the electromagnetic potentials. 2

(ii) At what frequencies may sea water be considered as a good conductor ? Given $\sigma = 4\Omega^{-1}m^{-1}$ and $\sigma \geq 0.01\ \omega\varepsilon$. 2

(iii) Under what situation do the o-ray and e-ray move with the same velocity ? 2

(iv) Why is calcite said to be a negative crystal ? 2

(v) For an electric field expressed as $E(z,t) = E_{\circ}\ sin(kz - \omega t)\hat{x}$, draw the plane of polarization of E-field. 2

(vi) Explain the physical basis of optical rotation. 2

(vii) Does an unpolarized light be polarized by reflection? Justify your answer. 2

(viii) Calculate the minimum thickness of a $\frac{\lambda}{4}$ plate made of calcite for Na-yellow light $\lambda = 589nm$. 2

(ix) Write two significance of Displacement current. 2

(x) Define specific rotation for an optically active solution. What happens if a plane-polarized white light is allowed to pass through an optically active substance? 1+1=2

3. Answer ***any four*** questions

(i) Show that in free space, the electric and magnetic fields vectors are perpendicular to the propagation vector. 5

(ii) Draw a neat diagram of a section of Nicol prism parallel to the principal section. What should be the length-to-breadth ratio of a Nicol prism ?

4+1=5

(iii) Write the characteristics of a lossless dielectric medium. For an *em* wave propagating in such a medium, find

(i) the phase constant,

(ii) velocity of the *em* wave, and

(iii) the Phase difference.

2+3=5

(iv) Consider a plane *em* wave where the amplitudes of the electric field components are E_{ox} and E_{oy}. Explain the formation of linear and circularly polarized light in relation to the orientation of E_{ox} and E_{oy}.

2½+2½=5

(v) List one difference between transmission lines and waveguides. Define the terms TE, TM and TEM associated with the propagation of *em* waves through a waveguide. Why is the TEM mode of vibration not allowed in a rectangular waveguide ? 5

(vi) A parallel beam of plan polarized light of wavelength 5896 Å in air is incident on a quartz crystal. Find the wavelength of *o*-ray and *e*-ray in the crystal, given that $\mu_o = 1.5418$, $\mu_e = 1.5508$ 5

(vii) For sea water, calculate skin depth if conductivity $\sigma = 4.3\ \Omega^{-1}m^{-1}$ and frequency is 100 *Hz*. Hence, show that radio communication becomes difficult with submarines at large depths. Show that metals are opaque to visible light. 2½+2½=5

(viii) The electric field component of a plane monochromatic *em* wave propagating through free space along the z-direction is given by $E = E_\circ \sin(kz - \omega t)\hat{x}$. Calculate the corresponding H field. 1+3+1=5

4. Answer ***any one*** question :

(i) Show that for an *em* wave propagating in a conducting medium the propagation vector is a complex parameter. Show how this leads to the attenuation of the *em* wave. Define skin depth.

6+3+1=10

(ii) Describe, with proper diagram, the construction and working of Laurent's half-shade polarimeter. 6+4=10

(iii) If the electric field vector is perpendicular to the plane of incidence of an *em* wave propagating from one medium to another medium then show with a diagram the incident, reflected and transmitted waves with properly denoting the direction of the electric field, magnetic field and the propagation vector. Derive the expression for amplitude reflection coefficient.

3+7=10

(iv) For a uniaxial crystal, derive the expression for the refractive index of *e*-rays in any direction in terms of the refractive index of *o*-ray and principal refractive index of *e*-ray. Describe with diagram the polarization by double refraction. 6+4=10
