2024

PHYSICS — HONOURS

Paper : DSCC-3

(Waves and Optics)

Full Marks : 75

The figures in the margin indicate full marks.

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

Section - A

1. Answer ***any five*** questions : 3×5

   (a) What is meant by interference? Explain the essential condition for sustained interference.

   (b) What is interference by division of amplitude?

   (c) Distinguish between Fresnel and Fraunhofer class of diffraction.

   (d) Explain why an extremely thin film illuminated by white light appears to be perfectly black when viewed by white light.

   (e) For sodium light (5890Å and 5896Å) is incident normally on a grating with 1000 lines/cm with width of ruling 2 cm. Calculate the angle of diffraction for both the wavelengths in first order. Also find the resolving power.

   (f) Distance between two points in a medium is 2 cm. The optical path corresponding to this distance is 3 cm. Find the refractive index of the medium and the speed of light in that medium.

   (g) What is optical activity? Define specific rotation.

   (h) The refractive indices of an anisotropic crystal for ordinary and extraordinary rays are $\mu_0 = 1.54425$ and $\mu_e = 1.55338$. What should be the thickness of the crystal so that it acts as a quarter wave plate for a light of wavelength 5500Å?

Section - B

Answer ***any five*** questions.

2. The steady state displacement of a particle serving as a linear harmonic oscillator under the action of an external periodic force $Fe^{j\omega t}$, is given by

$$x = \frac{\frac{F}{m} e^{j(\omega t - \phi)}}{\left[\left(\omega_0^2 - \omega^2\right)^2 + b^2\omega^2\right]^{\frac{1}{2}}}$$

(a) Find the instantaneous velocity of the particle and determine its phase difference with displacement.

(b) Determine the conditions for amplitude resonance and velocity resonance.

(c) Derive an expression for sharpness of resonance in terms of half-power frequency ω_1 and ω_2.

(d) Show that for such a vibration $\frac{\text{Average potential energy}}{\text{Average kinetic energy}} = \frac{\omega_0^2}{\omega^2}$. (3+1)+(2+2)+2+2

3. (a) Two collinear harmonic oscillations with same amplitude but different frequencies superpose. Find the expression for resultant amplitude.

(b) From the expression obtained in (Q3-a), find the number of beats formed per second.

(c) Two perpendicular simple harmonic motions with same frequency but unequal amplitude superpose. What will be the nature of resultant motion if the phase difference between them is π?

(d) Fifty tuning forks are arranged in order of increasing frequencies and any two successive forks give 5 beats when sounded together. If the frequency of the last fork is double of the first one, find the frequency of the first fork. 4+3+3+2

4. (a) What is meant by a progressive wave?

(b) A plane progressive wave is represented by $y(vt - x)$. Show that the particle velocity $\frac{dy}{dt} = -v\frac{dy}{dx}$, where '$v$' is the wave velocity.

(c) Using the result of (Q4-b), set up the differential equation of a plane progressive wave.

(d) The equation of a plane progressive is $y = 0.01 \sin(4\pi t - 0.02\pi x)$ where 'x' and 'y' are in 'm'. Find the amplitude and wave velocity. Also find the phase difference at any instant of time between two points 50 m apart. 2+3+2+(1+2+2)

5. (a) Find the frequency of the second overtone if the wave velocity is $v = \sqrt{\frac{T}{m}}$, where T is the tension on the string and 'm' is its mass per unit length.

(b) Prove that group velocity $v_g = v_p - \lambda\frac{dv}{d\lambda}$, where the symbols have their usual meanings.

(c) The phase velocity of a wave is given by $v = \frac{a}{\sqrt{\lambda}}$, where λ is the wavelength of the wave. Determine the group velocity.

(d) A 20 cm long string of mass 1 gm is fixed at both ends. The tension of the string is 0.5N. The string is set to vibration by an external vibrator of frequency 100Hz. Find the separation between successive nodes on the string. 3+3+2+4

6. (a) Using Fermats Principle, prove the laws of refraction at the plane surface separating two media.

   (b) Using Fermats principle, prove the laws of reflection for reflection at a concave surface.

   (c) State the nature of wavefronts for following sources :

   (i) A point source

   (ii) A line source

   (iii) Source at infinity. 5+4+3

7. (a) In Youngs double slit experiment the amplitude of interfering waves are in the ratio 2 : 3. Find the ratio between the maximum intensity to minimum intensity formed as a result of superposition of light from the two slits.

   (b) By what process does interference occur in Newtons ring experiment? Draw a neat labelled diagram of the experimental arrangement.

   (c) The diameter of the 4^{th} and 24^{th} Newton's ring are 0.6 mm and 3.6 mm respectively. If the wavelength of the light used is 6000Å, find the radius of curvature of the planoconvex lens.

   (d) Why is an extended source required to see the fringes in a wedge shaped film? Explain with diagram. 3+4+2+3

8. (a) What is a zone plate? Show how a zone plate behaves in a manner similar to a convex lens.

   (b) The intensity expression for double slit Fraunhofer diffraction with slit width 'b' and slit spacing 'a' is

$$I = 4I_0 \cos^2\beta \frac{\sin^2\gamma}{\gamma^2},$$

   where $\beta = \frac{\pi(a+b)\sin\theta}{\lambda}$ and $\gamma = \frac{\pi b \sin\theta}{\lambda}$.

   Find the conditions of maxima and minima. Also find the condition for missing order.

   (c) The number of rulings for a grating is per mm is 50. Find the maximum number of orders visible when illuminated by a light of wavelength 5800Å. (1+3)+(5+1)+2

9. (a) Why only transverse waves can be polarised?

   (b) A left circularly polarized light (λ = 580 nm) is incident normally on a doubly refractory crystal of thickness d = 0.0058 mm with the optic axis cut parallel to the surface. What will be the state of polarization of emergent beam? ($n_0 - n_e$ = 0.15)

   (c) What are meant by positive crystal and negative crystal?

(d) A light is allowed to pass through a rotatable polariser. On rotating the polariser complete extinction occurs at two particular orientations. What is your inference about the incident light? Give reasons.

(e) The amount of rotation of the plane of polarization of a linearly polarised light passing through a tube of length 25 cm containing sugar solution of strength 20% is 18°. Find the specific rotation of the sugar solution. 2+2+3+3+2
