2025

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 :

   (a) A body of mass 15 gm oscillates about a fixed point simple harmonically with amplitude 8 cm. If the body is attracted towards the fixed point when at a distance of 4 cm from it with a force equal to the weight of 10 gm, find the period of oscillation. 3

   (b) What do you mean by sharpness of resonance? Define quality factor and bandwidth with reference to resonance. 1+2

   (c) Derive the one-dimensional differential wave equation that is satisfied by any arbitrary wave function $y = f(ct \pm x)$. 3

   (d) With a suitable diagram, explain why the central spots of Newton's ring interference pattern is different for reflected and transmitted light. 3

   (e) Distinguish between Fresnel and Fraunhoffer diffraction. 3

   (f) What do you mean by coherent light sources? In interference experiments with ordinary light, why are the two beams always derived from the same source of light? 3

   (g) Write down three differences between grating spectra and prism spectra. 3

   (h) A ray of light is incident on the surface of a glass plate of refractive index 1.732 at polarizing angle. Calculate the angle of refraction of the ray. 3

Section - B

Answer ***any five*** questions.

2. (a) A particle of mass m is located in a one-dimensional potential field along the x-axis given as $V(x) = V_0(1 - \cos\beta x)$ [where V_0 and β are constants]. The displacement of the particle caused by the given potential is small.

   (i) Determine the force that acts on the particle and show that it's a linear restoring force.

   (ii) If at $t = 0$, $x = 0$, determine the expression for displacement of the particle.

(iii) Show that the time period of oscillation of the particle, $T = \frac{2\pi m}{\beta^2 V_0}$.

(b) When steady state displacement of a linear harmonic oscillator under the action of an external periodic force $F\,e^{j\omega t}$ is given as,

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

Determine the instantaneous velocity of the particle and prove that the velocity and the displacement differ in phase by $\frac{\pi}{2}$.

(c) From the above, determine the condition for amplitude resonance and velocity resonance. (2+2+2)+2+(2+2)

3. (a) What do you mean by damped vibration?

(b) If the motion of a damped oscillation be along x-axis, write down its differential equation. Solve the equation and show when the motion will be oscillatory.

(c) A mass of 20 gm is acted on by a restoring force of 5 dynes/cm and a resisting force of 2 dynes-sec/cm. Find whether the motion is aperiodic or oscillatory. 2+(1+5+2)+2

4. (a) Define group velocity and phase velocity.

(b) What are beats?

(c) When two S.H.M.s of same frequency but of different amplitude and phases are acting on a particle in two mutually perpendicular directions, show that the resultant motion of the particle is elliptic.

(d) Show that the velocity of transverse waves along a stretched string of mass per unit length m is given by $\sqrt{\frac{T}{m}}$, where T is the tension in the string. 2+2+4+4

5. (a) What do you mean by normal modes of vibration?

(b) For a stretched string of length L fixed rigidly at the two ends, the displacement at a point x at time t is $y(x,t) = \sum_{n=1}^{\infty} \sin\left(\frac{n\pi x}{L}\right)\left[a_n \cos\left(\frac{n\pi ct}{L}\right) + b_n \sin\left(\frac{n\pi ct}{L}\right)\right]$ in usual notation. Obtain the fundamental frequency in terms of tension of the string and mass per unit length. State the initial conditions that one should use in the cases of a plucked string and a struck string.

(c) For the case of plucked string, obtain the expressions for a_n and b_n. 2+(2+1½+1½)+5

6. (a) State Fermat's principle. Applying Fermat's principle and using a suitable diagram, prove the laws of reflection on plane surface.

(b) Explain how the interference pattern obtained from a Young's double slit arrangement satisfy the law of conservation of energy.

(c) Calculate the fractional change in fringe width in a Young's double slit experiment if the wavelength of incident ray is changed from 5000 Å to 6000 Å. (1+4)+4+3

7. A Newton's ring arrangement typically consists of a plano convex lens on a glass plate in air.

(a) What is the shape of the film?— Justify.

(b) Why an extended source is used in a Newton's ring arrangement?

(c) In a Newton's ring experiment, the diameter of the 5th and the 15th dark ring are 3.36 mm and 5.9 mm respectively.

(i) Find the diameter of the 25th dark ring.

(ii) If a liquid of refractive index μ is now introduced at the relevant location of the apparatus so that the diameter of the 25th dark ring now appears to be 6.83 mm. Determine the value of μ.

(d) Show by means of suitable calculation that the widths of the Newton's rings vary with their number. 2+2+(3+2)+3

8. (a) Find an expression of resolving power of grating.

(b) Consider a diffraction grating of width 5 cm with slit width 0.0001 cm and width of the opaque space between the two slits is 0.0002 cm. What is the corresponding grating element? How many orders would be observable, if $\lambda = 5500$ Å?

(c) What are Fresnel's half-period zones? Find the area of the n^{th} half period zone with reference to a plane wavefront. 4+(1+2)+(2+3)

9. (a) Define optic axis and principal section for a double refractory crystal.

(b) What is a quarter wave plate? Discuss how it can be used to produce circularly and elliptically polarized light.

(c) Find the state of polarization when x- and y- components of the electric field are

$$E_x = E_0 \cos(\omega t + kz) \text{ and } E_y = \left(E_0/\sqrt{2}\right)\cos(\omega t + kz + \pi)$$

(d) What do you mean by rotatory polarization? Write down Biot's law for rotatory polarization. Hence, define specific rotation. 3+(2+1+1)+2+(1+1+1)
