UNIT – VI—OPTICS

ALL THE POSSIBLE FORMULAE

- Relation between focal length and radius of curvature of a mirror/lens, f = R/2
- Mirror formula: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$
- Magnification produced by a mirror: $m = -\frac{v}{u} = -\frac{f}{u-f}$
- Snell's law: $\frac{\sin i}{\sin r} = {}^1n_2 = \frac{n_2}{n_1}$
- ${}^2n_1 = \frac{1}{{}^1n_2}$
- $n = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{\lambda_{air}}{\lambda_{medium}}$
- If object is in medium of refractive index n, then $n = \frac{\text{real depth}}{\text{apparent depth}} = \frac{t}{t_{app}}$
- Apparent shift, $x = t - \frac{t}{n} = t\left(1 - \frac{1}{n}\right)$
- Critical angle for total internal reflection: $\sin C = \frac{1}{{}^r n_d} = \frac{1}{n}$
- Refraction at spherical (convex) surface: For object in rarer medium and real image in denser medium, the formula is $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ where n_2 & n_1 are the refractive indices of denser and rarer media.
- Lens formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
- Linear magnification produced by a lens: $m = \frac{I}{O} = \frac{v}{u}$
- Lens maker's formula : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = ({}^a n_g - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$
- Power of a lens: $P = \frac{1}{f}$ diopter (f is in metre)
- Lenses in contact: $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ or $P = P_1 + P_2$
- Focal length of lens in liquid: $f_l = \frac{n_g - 1}{\frac{n_g}{n_l} - 1} \times f_a$
- Refraction through a prism: $r_1 + r_2 = A$ and $i + e = A + \delta$ where A is angle of prism and δ is angle of deviation.
- For minimum deviation, $i = e = i$ and $r_1 + r_2 = r$. Therefore, $\delta_m = 2i - A$
- Refractive Index of the material of prism: $n = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$
- For a thin prism: $\delta = (n-1)A$
- Angular dispersion = $\delta_V - \delta_R$
- Dispersive power, $\omega = \frac{\delta_V - \delta_R}{\delta_Y} = \frac{n_V - n_R}{n_Y - 1}$
- Simple microscope: Magnifying power $M = 1 + \frac{D}{f}$ (if final image is at D)

  $= \frac{D}{f}$ (if final image is at infinity)

- Compound microscope:
  i) Magnification M = $m_o m_e$
  ii) Magnification M = $-\frac{v_o}{u_o}\left\{1+\frac{D}{f_e}\right\} \approx -\frac{L}{f_o}\left\{1+\frac{D}{f_e}\right\}$ (for final image at D)
  ii) Magnification M = $-\frac{v_o}{u_o}\left\{\frac{D}{f_e}\right\} \approx -\frac{L}{f_o}\left\{\frac{D}{f_e}\right\}$ (for final image at infinity)
- Astronomical Telescope:
  i) M = $-\frac{f_o}{f_e}$ and L= $f_o + f_e$ (for final image at infinity)
  ii) M = $-\frac{f_o}{f_e}\left\{1+\frac{f_e}{D}\right\}$ and L= $f_o + u_e$ (for final image at D)

- Resolving power:
  i) **For microscope**: - The resolving power is the reciprocal of limit of resolution or separation between two points such that they are distinct. So, the resolving power is given by R.P.= $\frac{1}{d} = \frac{2\,n\,sin\theta}{\lambda}$
  Here, d = $\frac{\lambda}{2\,n\,sin\theta}$ is limit of resolution, $n\,sin\theta$ is numerical aperture and θ is the well resolved semi-angle of cone of light rays of wavelength λ entering the microscope.
  ii) **For telescope**: - The resolving power is the reciprocal of angular limit of resolution or angle subtended between two points such that they are distinct. So, the resolving power is given by R.P.= $\frac{1}{d\theta} = \frac{a}{1.22\,\lambda}$
  Here, dθ = $\frac{1.22\,\lambda}{a}$ is the angular limit of resolution, 'a' is the aperture or diameter of objective lens.
  - The distance for which ray optics is good approximation for an aperture D and wavelength λ is called Fresnel distance, given by $Z_F = \frac{D^2}{\lambda}$.

- Interference of light:-
  i) If two waves of same intensity I_o interfere, then the resultant intensity will be $I = 4\,I_o \cos^2\frac{\phi}{2}$ where ϕ is the initial phase difference between the waves.
  ii) Resultant intensity at a point in the region of superposition is
  $I = a_1^2 + a_2^2 + 2a_1a_2\cos\phi = I_1 + I_2 + 2\sqrt{I_1\,I_2}\,\cos\phi$ where
  $I_1 =$
  a_1^2 is the intensity of one wave & $I_2 =$
  a22 is the intensity of other wave.
  iii) Condition for maxima: - Phase difference ϕ = 2nπ & path difference Δ= n λ where n = 0,1,2,3,…..

iv) Condition for minima: - Phase difference $\phi = (2n-1)\pi$ &
Path difference $\Delta = (2n-1)\frac{\lambda}{2}$ where n = 0,1,2,3,…..

v) Fringe width $\beta = \frac{D\lambda}{d}$ where D = distance between the slits & the screen,
d= separation between the slits and λ is the wavelength of light used.

vi) Angular fringe width , $\beta_\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

vii) Minimum amplitude, $A_{min} = (a_1 - a_2)$

viii) Minimum intensity, $I_{min} = (a_1 - a_2)^2 = I_1 + I_2 - 2\sqrt{I_1 I_2}$

ix) Position of n^{th} maxima, $y_n = \frac{nD\lambda}{d}$

x) Position of n^{th} minima, $y_n = (n - ½)\frac{D\lambda}{d}$

- Diffraction of light: -
  i) The condition for the position of n^{th} minima : $d \sin\theta = n\lambda$ where d is the width of slit, θ is angle of diffraction and λ is the wavelength of light used.

  ii) Linear half-width of central maximum : $y = \frac{D\lambda}{d}$

  iii) Total linear width of central maximum : β_o or $2y = \frac{2D\lambda}{d}$

- Polarisation of light:-
  i) Brewster's law:- $n = \tan i_p$

  ii) Malus law : $I = I_o \cos^2\theta$

LEVEL – I

1. An object is placed at the principal focus of a concave lens of focal length f. Where will its image be formed? (1

2. A prism of angle 60° gives a minimum deviation of 30°. What is the refractive index of the material of the prism? (1

3. An equi-convex lens has refractive index 1.5. Write its focal length in terms of radius of curvature R. (1

4. Estimate the distance for which ray optics is good approximation for an aperture of 4mm and wavelength 400nm. (1

5. What is Brewster's angle for air to glass transition? Refractive index of glass = 1.5. (1

6. In Young's double slit experiment the slits are separated by 0.28mm and the screen is placed 1.4m away. The distance of 4^{th} bright fringe is measured to be 1.2cm. Determine the wavelength of light used in this experiment. (2

7. An astronomical telescope uses two lenses of powers 10D and 1D. What is its magnifying power in normal adjustment? (2

8. Light of wavelength 500nm falls, from a distant source, on a slit 0.5mm wide. Find the distance between the two dark bands, on either side of the central bright band of the diffraction pattern observed, on a screen placed 2m from the slits. (2

9. An illuminated object and a screen are placed 90cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object. (2

10. The near vision of an average person is 25cm. To view an object with an angular magnification of 10, what should be the power of the microscope? (2

LEVEL – II

1. A mirror is turned through 15°. Through what angle will the reflected ray turn? (1

2. Velocity of light in a liquid is 1.5×10^{8} m/s and in air, it is 3×10^{8} m/s. If a ray of light passes from liquid into the air, calculate the value of critical angle. (1

3. Why does a convex lens of glass of refractive index 1.5 behave as a diverging lens when immersed in carbon disulphide of refractive index 1.65? (1

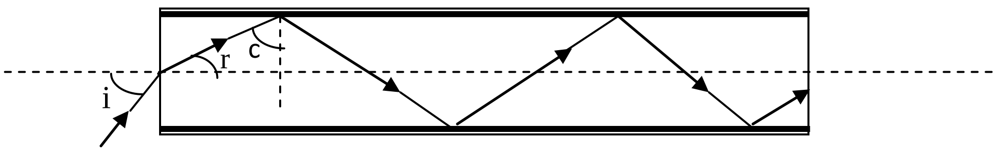
4. Find the angular dispersion produced by a thin prism of 5° having refractive index for red light 1.5 and for violet light 1.6. (1

5. If a person uses spectacles of power +1.0D, what is the nearest distance of distinct vision for him? Given that near point of the person is 75cm from the eye. (2

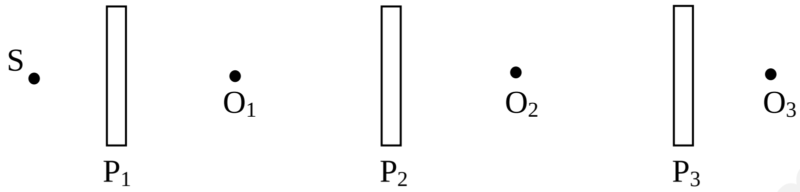
6. In Young's double slit experiment, light waves of wavelength 5.4×10^{-7} m and 6.85×10^{-8} m are used in turn keeping the same geometry. Compare the fringe width in the two cases. (2

7. If the two slits in Young's experiment have width ratio 1:4, deduce the ratio of intensity at maxima and minima in the interference pattern. (2

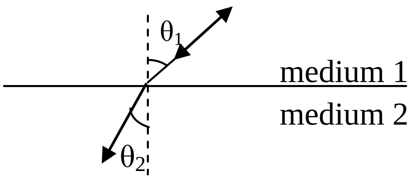
8. Figure shows a cross-section of a 'light pipe' made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made of a material of refractive index 1.44. What is the range of the angles of incident rays with the axis of the pipe for which total reflections inside the pipe take place as shown. (3



9. Three identical Polaroid sheets P_1, P_2 and P_3 are oriented so that the (pass) axis of P_2 and P_3 are at angles of 60° and 90° respectively, with respect to the pass axis of P_1. A monochromatic source, S, of intensity I_o, is kept in front of the Polaroid sheet P_1. Find the intensity of this light, as observed by observers O_1, O_2 and O_3, positioned as shown below. (3



10. Light of wavelength λ_1 propagates from medium 1 incident at angle θ_1. The angle inside medium 2 is θ_2. What is its wavelength in medium 2? (3



LEVEL – III

1. A ray if light is incident on a concave mirror after passing through its center of curvature. What is the value of angle of reflection? (1

2. What is the ratio of fringe width for dark and bright fringes in Young's double slit experiment? (1

3. A dentist uses a small concave mirror of focal length 16mm to view a cavity in the tooth of a patient by holding the mirror at a distance of 8mm from the cavity. Calculate the magnification. (2

4. Show that for a concave mirror, a virtual object forms a real image which is always diminished. (2

5. A point source of light is placed at the bottom of a lake with refractive index 4/3. Show that only 17% light can emerge out of the water surface. (2

6. Why does violet colour deviate more than red in prism? (2

7. A ray of light is incident at an angle of incidence 'i' on one surface of a prism of small angle 'A' and it is found to emerge normally from the opposite surface. If the refractive index of the material of the prism is 'n' , calculate the angle of incidence. (3

8. Calculate the number of fringes displaced when a thin sheet of refractive index 'n' and thickness 't' is introduced in the path of one of the interfering rays. (3

9. A few coloured fringes, around a central white region, are observed on the screen when the source of monochromatic light is replaced by white light in Young's double slit experiment. Give reason. (3

10. Light from two sources has intensity ratio 1:9 and is monochromatic. The light is made to superpose. What will be the resultant intensity obtained if the sources are (i) incoherent & (ii) coherent? (3