12^{th} Standard Physics

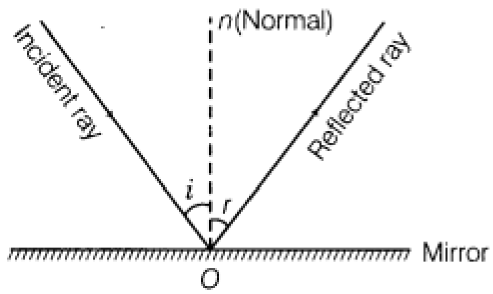
Ray Optics and Optical Instruments

1. Ray Optics or Geometrical Optics In this optics, the light is considered as a ray which travels in a straight line. It states that for each and every object, there is an image.

2. Reflection Reflection is the phenomenon of changing the path of light without any change in the medium.

3. Reflection of Light The returning back of light in the same medium from which it has come after striking a surface is called reflection of light.

4. Laws of Reflection
Two laws of reflection are given as below:
(i) The angle of incidence i is equal to the angle of reflection r.
i.e. $\angle i = \angle r$.
(ii) The incident ray, reflected ray and normal to the reflecting surface at the point of incidence all lie in the same plane.

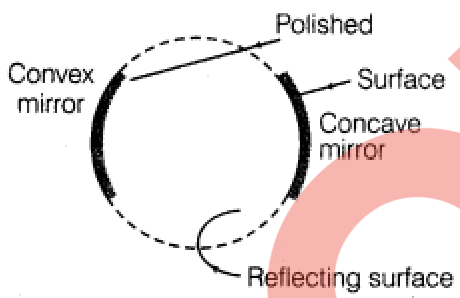


5. Total number of images formed by two plane mirrors inclined at an angle θ with each other is given by

$$n = \frac{360^\circ}{\theta} - 1, \text{ if } \frac{360^\circ}{\theta} \text{ is even integer}$$

$$n = \frac{360^\circ}{\theta}, \text{ if } \frac{360^\circ}{\theta} \text{ is odd integer, where } \theta \text{ is in degree.}$$

6. Reflecting surface of a spherical mirror is a part of a hollow sphere. Spherical mirrors are of two types, (i) Concave spherical mirror (ii) Convex spherical mirror.



7. Sign Convention All measurements should be taken from pole of mirror. All measurements along the direction of incident ray will be positive and opposite to incident ray are negative. All the measurements for the distances above the principal axis are taken as positive and below the principal axis are taken as negative.

8. For a real object, u is negative whereas v is negative for real image and positive for virtual image.

9. Mirror Formula Mirror formula is a relation between focal length of the mirror and distances of objects and image from the mirror.

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

where, $f=$ focal length, $u=$ distance of the object from mirror, $v=$ distance of the image from mirror.

10. Focal length of mirror $(f)=\frac{\text{Radius of curvature}(R)}{2}$

$$f=\frac{R}{2}$$

11. Linear Magnification The ratio of the size of the image formed by a spherical mirror I to the size of the object O is called the linear magnification produced by the spherical mirror.

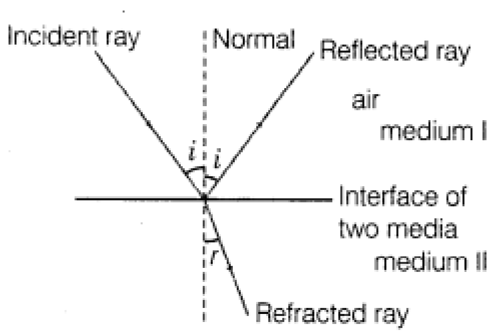
$$m=\frac{I}{O}=-\frac{v}{u}=\frac{f}{f-u}=\frac{f-v}{f}$$

where, $I=$ height of image and $O=$ height of object

12. Magnification (m) It is negative corresponding to real image and positive for virtual image.

13. Refraction The phenomenon of changing in the path of light as it goes from one medium to another is called refraction.

14. Laws of Refraction



Two laws of refraction are given as below:

(i) The incident ray, refracted ray and the normal to the refracting surface at the point of incidence lie in the same plane.

(ii) The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for the two given media. This constant is denoted by n and is called the **relative refractive index.**

n = sin i/sin r (Snell's law)

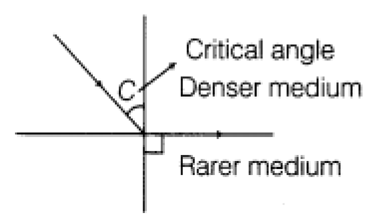
where, n is refractive index of the second medium when first medium is air.

15. **Refractive index** of medium 2 w.r.t. medium 1 is denoted as ${}_1n_2$ and defined as

$$ {}_1\mu_2 = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} $$

where, v_1, λ_1 are speed and wavelength in the first medium, similarly v_2 and λ_2 for second medium.

16. **Critical Angle** (i_c) It is the angle of incidence in denser medium for which angle of refraction in rarer medium is 90°.

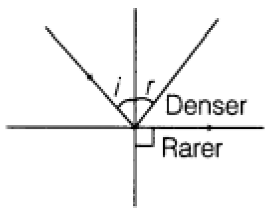


i.e.

$$ \mu = \frac{1}{\sin i_C} $$

where, μ = refractive index of denser medium w.r.t. rarer medium.

17. Total Internal Reflection (TIR) When a ray of light travelling from denser medium to rarer medium is incident at the interface of two medium at an angle greater than the critical angle for the two media, the ray is totally reflected back to denser medium. This phenomenon is called Total Internal Reflection. It occurs only when angle of incidence in denser medium is greater (not equal) than critical angle, i.e. $i > i_c$.



18. Principle of reversibility of light states that when final path of a ray of light after any number of reflections and refractions is reversed, the ray retraces its entire path.

$${}_1\mu_2 \times {}_2\mu_1 = 1 \Rightarrow {}_2\mu_1 = \frac{1}{{}_1\mu_2}$$

19. Refractive index, $\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$

$$\Rightarrow \quad \text{Apparent depth} = \frac{\text{Real depth } (t)}{\mu}$$

$$\text{Apparent shift} = t - \frac{t}{\mu} = t\left(1 - \frac{1}{\mu}\right)$$

20. Mathematically, refractive index is given by the relation

$$\mu = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the material}} = \frac{c}{v}$$

It is also referred to as **absolute refractive index** of the substance.

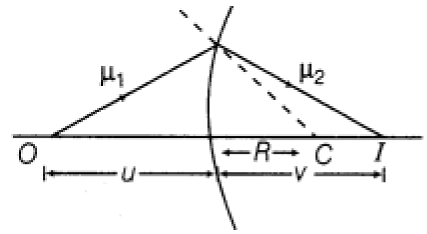
21. For pile up of two or more refracting surfaces of thickness $t_1, t_2, \ldots, t_n$ and corresponding refractive indices $\mu_1, \mu_2, \ldots, \mu_n$, then

$$\text{Apparent depth} = \frac{t_1}{\mu_1} + \frac{t_2}{\mu_2} + \ldots + \frac{t_n}{\mu_n}$$

$$\text{Apparent shift} = t_1\left(1 - \frac{1}{\mu_1}\right) + t_2\left(1 - \frac{1}{\mu_2}\right) + \ldots + t_n\left(1 - \frac{1}{\mu_n}\right)$$

22. Optical fibre, mirage, sparkling of diamond, totally reflecting prism, etc. work on the principle of total internal reflection.

23. (*i*) **Refraction formula** for refraction by convex or concave spherical refracting surface is given by



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

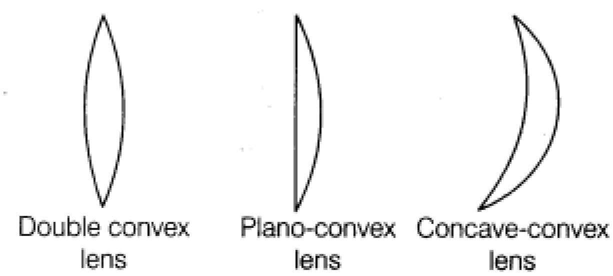
where μ_1, μ_2 are refractive index of rarer and denser media and u, v and R are to be taken with their proper signs.

(*ii*) When refraction takes place from denser to rarer medium, then

$$\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_1 - \mu_2}{R}.$$

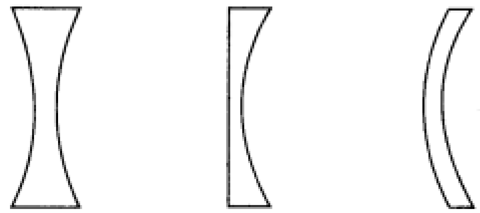
24. Lens is a transparent medium bounded by two surfaces of which one or both surfaces are spherical.

(i) Convex or Converging Lens A lens which is thicker at the centre and thinner at its end is called convex lens.
Convex lenses are of three types which are given as below:



(ii) Concave or Diverging Lens A lens which is thinner at the centre and thicker at its ends is called a concave lens.

Concave lenses are of three types which are given as below:



25. Lens maker's formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

μ = refractive index of material of lens w.r.t. surrounding media and R_1, R_2 = radii of curvatures of two surfaces.

26. When lens of refractive index μ is immersed in a medium of refractive index μ, then

(i) When lens is taken in another medium, then focal length changes to f_m which is given by

$$\frac{1}{f_m} = \left(\frac{\mu}{\mu'} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(i)}$$

(ii) If $\mu' = 1$, i.e. medium is air, the focal length of lens (i.e. f_a) is given by

$$\frac{1}{f_a} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(ii)}$$

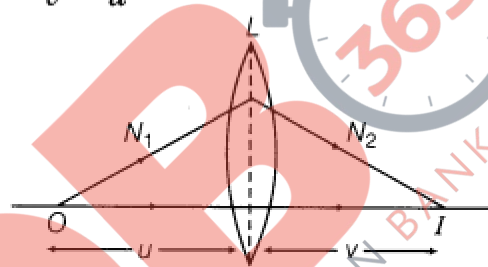
(iii) $\dfrac{f_m}{f_a} = \dfrac{(\mu - 1)}{\left(\dfrac{\mu}{\mu'} - 1\right)}$ [Dividing Eq. (ii) by Eq. (i)].

(iv) If $\mu = \mu' \Rightarrow f_m = \infty \Rightarrow$ lens behaves like a glass slab.

(v) If $\mu < \mu' \Rightarrow f_m > f_a$ and nature reversed.

(vi) If $\mu > \mu' \Rightarrow f_m > f_a$ and nature remains same.

27. (i) **Lens formula** $\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$



(ii) Lateral or transverse magnification, $m = \dfrac{I}{O} = \dfrac{v}{u} = \dfrac{f}{f+u} = \dfrac{f-v}{f}$, where angular magnification $= \dfrac{\theta_0}{\theta}$

where, θ_0 = angle made by image and θ = angle made by object.

(iii) $|m| > 1 \Rightarrow$ image is magnified.

(iv) $|m| < 1 \Rightarrow$ image is diminished.

28. Power of Lens The ability of a lens to converge or diverge the rays of light incident on it is called the power of the lens.

$$P = \frac{1}{f\,(\text{in m})}$$

SI unit of power of lens = dioptre (D) = m^{-1}

29. Power of combination lenses in contact is given by

$$P = P_1 + P_2 + \ldots + P_n$$

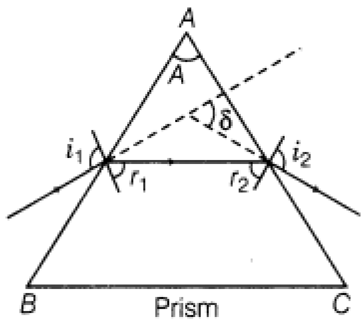
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \ldots + \frac{1}{f_n}$$

30. Magnification by combination of lenses

$m = m_1 \times m_2 \times m_3$ ....

31. (i) Prism have got the property of bending the incident light towards its base.

A prism is a portion of a transparent medium bounded by two plane faces inclined to each other at a suitable angle.



(ii) When the prism is adjusted at angle of minimum deviation, then

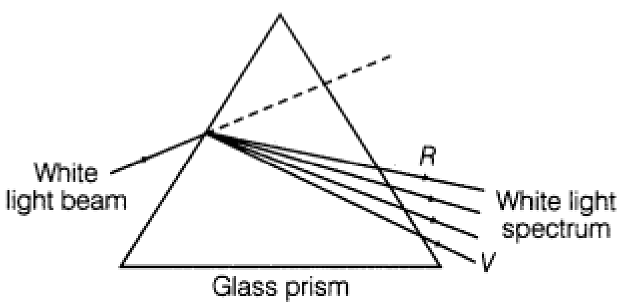
(a) angle of incidence is equal to the angle of emergence

(b) $i_1 = i_2, r_1 = r_2, \delta = \delta_m, A + \delta_m = 2i$ and $2r = A$.

(c) $\mu = \sin\left(\frac{A+\delta_m}{2}\right) / \sin\frac{A}{2} \Rightarrow \delta_m \approx (\mu - 1)A$ (for small angle of prism)

31. Dispersion by a Prism The phenomenon of splitting of light into its component colours is known as dispersion.

Angular Dispersion Angular dispersion produced by a prism for white light is the difference in the angles of deviation for two extreme colours i.e. violet and red.



Angular deviations for violet

$$\delta_V = (\mu_V - 1)A$$

For red, $\delta_R = (\mu_R - 1)A$ and $\delta_Y = (\mu_Y - 1)A$

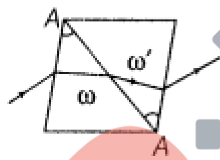
Dispersive Power Dispersive power of a prism is defined as the ratio of angular dispersion to the mean deviation produced by the prism.

Dispersive power, $\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1} = \frac{\delta_V - \delta_R}{\delta} = \frac{\text{Angular dispersion}}{\text{Mean deviation}}$

where, δ = minimum deviation.

Angular dispersion $= \delta_V - \delta_R = (\mu_V - \mu_R)A$

33. Combining two thin prisms we can study two conditions



(i) Dispersion without average deviation $\delta_V - \delta_R = (\mu_Y - 1)\, A(\omega - \omega')$

(ii) Average deviation without dispersion $\delta = (\mu_Y - 1)A\left[1 - \frac{\omega}{\omega'}\right]$

34. **Rayleigh Law of Scattering** It states that scattering $\propto \frac{1}{\lambda^4}$, where wavelength of light is λ and size of particles is very small in comparison to λ.

The bluishness of sky and reddishness of sunrise and sunset could be explained by this law.