Chapter – 9
XII Physics

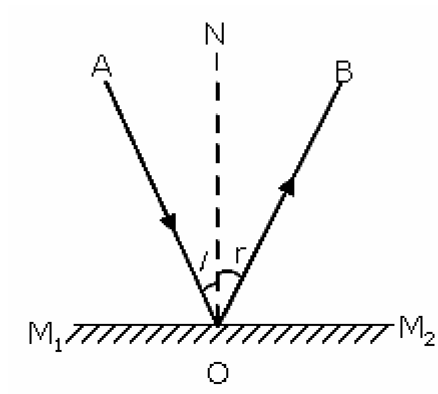
Ray optics and Optical Instruments
Chapter Notes

Key Concepts

1. Laws of Reflection. The reflection at a plane surface always takes place in accordance with the following two laws:

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

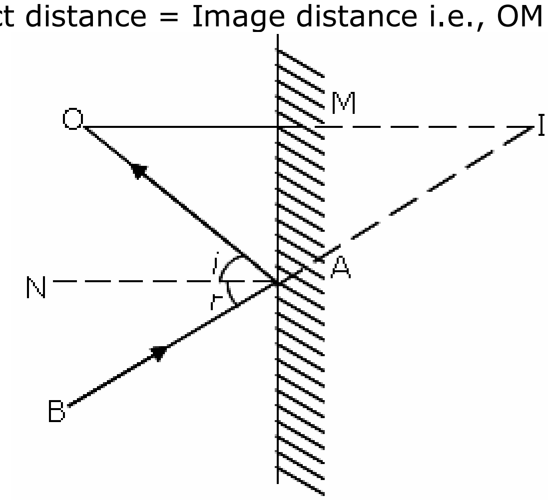
(ii) The angle of incidence, i is equal to the angle of reflection r, i. e., $\angle i = \angle r$.



2. **Formation of Image by the Plane Mirror.** The formation of image of a point object O by a plane mirror is represented in figure. The image formed *I* has the following characteristics:

(i) The size of image is equal to the size of object.

(ii) The object distance = Image distance i.e., OM = MI.



(iii) The image is virtual and erect.
(iv) When a mirror is rotated through a certain angle, the reflected ray is rotated through twice this angle.

3. Reflection of Light from Spherical Mirror.
A spherical mirror is a part cut from a hollow sphere. They are generally constructed from glass.
The reflection at spherical mirror also takes place in accordance with the laws of reflection.

4. Sign Convention. Following sign conventions are the new cartesian sign convention:

(i) All distances are measured from the pole of the mirror & direction of the incident light is taken as positive.
In other words, the distances measured toward the right of the origin are positive.

(ii) The distance measured against the direction of the incident light are taken as negative. In other words, the distances measured towards the left of origin are taken as negative.

(iv) The distance measured in the upward direction, perpendicular to the principal axis of the mirror, are taken as positive & the distances measured in the downward direction are taken as negative.

Note. The focal length of a concave mirror is positive and that of a convex mirror is positive and that of a convex mirror is negative.

5. Focal Length of a Spherical Mirror.
The distance between the focus and the pole of the mirror is called focal length of the mirror and is represented by *f.*
The focal length of a mirror (concave or convex) is equal to half of the radius of curvature of the mirror, i.e., $f = R / 2$.
The straight line joining the pole and the centre of curvature of spherical mirror extended on both sides is called principal axis of the mirror.

6. Mirror Formula is

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

Where u= distance of the object from the pole of mirror

V= distance of the image from the pole of mirror

f= focal length of the mirror

$f = \frac{r}{2}$, where *r* is the radius of curvature of the mirror.

7. Magnification. It is defined as the ratio of the size of the image to that of the object

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

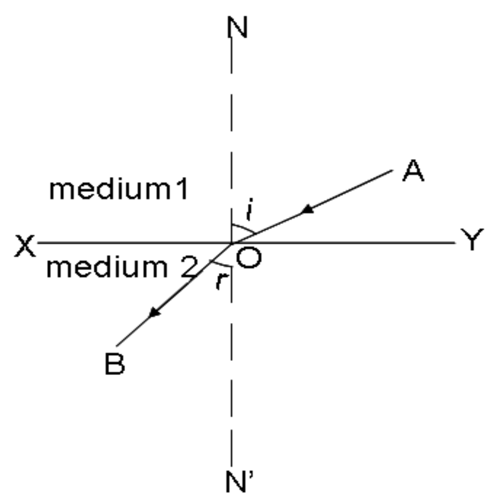
Where *I* size of image and *O*= size of object.

Magnification, m is positive, implies that the image is real and inverted
Magnification, m is negative, implies that the image is virtual and erect.

8. Refraction. When a ray of light falls on the boundary separating the two media, there is a change in direction of ray. This phenomenon is called refraction.

9. Laws of Refraction. (i) The incident ray normal at the point of incidence and refracted ray all lie in one plane.

(ii) For the same pair of media and the same colur of light, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant i.e., $\frac{\sin i}{\sin r} = {}_a\mu_b$



Where ${}_a\mu_b$ is a constant known as **Refractive Index** of the medium b with respect to the medium a ;
i is the angle incidence in medium a and
r is the angle of refraction in medium b.

10. Principle of Reversibility of Light. As light follows a reversible path, we have $\frac{\sin r}{\sin i} = {}_b\mu_a$

Multiplying (i) and (ii), we get

$${}_a\mu_b \times {}_b\mu_a = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin i} = 1$$

$${}_a\mu_b = \frac{1}{{}_b\mu_a}$$

Refractive index of a medium can also be determined from the following:

(i) $$\mu = \frac{\text{Velocity of light in air}}{\text{Velocity of light in the medium}}$$

(ii) $$\mu = \frac{1}{\sin c}$$

Where *c* is the critical angle.

The Critical angle is the angle of incidence in a denser medium corresponding to which the refracted ray just grazes the surface of separation.

11 Apparent Depth of a Liquid. If the object be placed at the bottom of a transparent medium, say water, and viewed from above, it will appear higher than it actually is.
The refractive index μ in this case is given by the relation :
Refractive index of the medium, μ = Real depth /Apparent depth

12 Refraction through a Single Surface. If μ_1, μ_2 are refractive indices of first and second media, R the radius of curvature of spherical surface, formula is

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

where u and v are the distances of the object and the image from the centre of the refracting surface of radius of curvature R respectively.

13. Refraction through a Thin Lens. It R_1 and R_2 are radii of curvature of first and second refracting surfaces of a thin lens of focal length f, then lens-makers formula is

$$\frac{1}{f}=\left(\frac{\mu_2-\mu_1}{\mu_1}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

If the lens is surrounded by air, $\mu_1 = 1$ and $\mu_2 = \mu$ then

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

Thin lens formula is

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

14. Magnification Produced by a Lens

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

Where I is size of image and O is size of object.

15. Power of a Lens. The power of a lens P is its ability to deviate the ray towards axis and is given by

$$P=\frac{1}{f(\text{in metres})}\text{Diopters}$$
$$=\frac{100}{f\,(\text{in cm})}\text{Diopters}$$

The focal length (f) of thin lenses of focal lengths f_1, f_2, f_3………. placed in contact of each other is given by

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}+\ldots\ldots$$

16. Refraction Through Prism. When a ray of monochromatic light is refracted by a prism, the deviation δ produced by the prism is given by

$\delta = i + e - A$

Where i = angle of incidence
e = angle of emergence
A = angle of the prism

The angle of deviation δ_m is minimum, when ray passes symmetrically through the prism. The refractive index μ of the prism is

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

17. Dispersion. The splitting of white light into constituent colours is called the dispersion.

A prism causes deviation as well as dispersion.

18 Optical Instruments, Optical instruments are the devices which help human eye in observing highly magnified images of tiny objects, for detailed examination and in observing very far objects whether terrestrial or astronomical.

19. Human Eye, It is the most familiar and complicated optical instrument provided by nature to living beings. In this device, light enters through a curved front surface, called cornea, passes through the pupil – central hole in the iris. The light is focused by the eye lens on the retina. The retina senses light intensity and colour and transmits the electrical signals via optical nerves to the brain. Brain finally processes the information.

20. Microscope, A simple microscope is a short focal length convex lens. The magnifying power of a simple microscope is

$$M = 1 + \frac{D}{f}$$

The magnifying power, M of a compound microscope is

$$M = M_o \times M_e = \frac{v}{u}\left(1 + \frac{D}{f_e}\right)$$

Where, M_o and M_e denote the linear magnifying of the objective and eye lens.

21. Telescope, (a) The magnifying power, M of refracting telescope is

$$M = \frac{f_o}{f_e}$$

and $L = (f_o - f_e)$; L = length of the telescope.

(b) For the final image is formed at the least distance of distant vision, the magnifying power is given as

$$M = \frac{f_o}{f_e}\left(1 + \frac{F_e}{D}\right)$$

(c) The resolving power of a telescope

$$\theta = \frac{1.22\lambda}{d}$$

where, λ = wavelength of light

d = diameter of the objective of the telescope

θ = angle subtended by the point object a the objective

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