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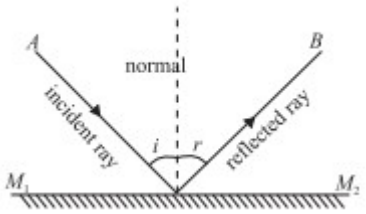
REFLECTION AND REFRACTION OF LIGHT

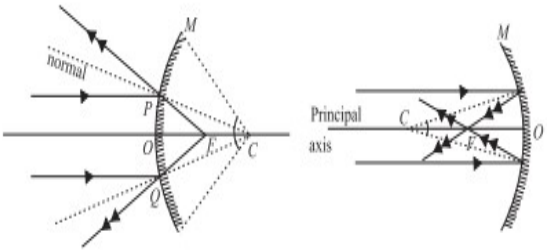
REFLECTION OF LIGHT FROM SPHERICAL SURFACES

Law 1 –The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence always lie in the same plane.

Law 2 –The angle of incidence is equal to the angle of reflection

$\angle i = \angle r$





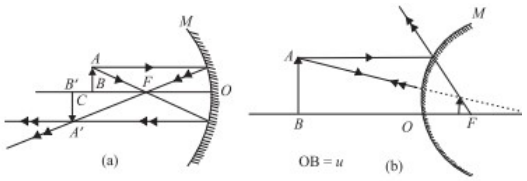
- The centre of the sphere, of which the mirror is a part, is called the centre of curvature of the mirror
- The radius of this sphere defines its radius of curvature.
- The middle point O of the reflecting surface of the mirror is called its pole.
- The straight line passing through C and O is said to be the principal axis of the mirror. The circular outline (or periphery) of the mirror is called its aperture and
- The angle ($\angle MCM'$) which the aperture subtends at C is called the angular aperture of the mirror.
- Aperture is a measure of the size of the mirror.
- A beam of light incident on a spherical mirror parallel to the principal axis converges to or appears to diverge from a common point after reflection. This point is

known as principal focus of the mirror.

- The distance between the pole and the principal focus gives the focal length of the mirror.
- A plane passing through the focus perpendicular to the principal axis is called the focal plane.
- Considering small aperture mirrors and rays close to the principal axis, called paraxial rays.
- The rays away from the principal axis are called marginal or parapheral rays.)

Ray Diagrams for Image Formation

- The ray of light through centre of curvature retraces its path.
- The ray of light parallel to the principal axis, on reflection, passes through the focus; and the ray of light through F is reflected parallel to the principal axis
- Real image of an object is formed when reflected rays actually intersect. These images are **inverted** and can be projected on a screen. They are formed on the same side as the object in front of the mirror
- Virtual image of an object is formed by reflected rays that appear to diverge from the mirror. Such images are always erect and virual; these cannot be projected on a screen. They are formed behind the mirror



MIRROR FORMULA

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

$$m = \frac{\text{size of the image}}{\text{size of the object}} = \frac{h_2}{h_1}$$

$$\frac{A'B'}{AB} = \frac{-v}{-u}$$

$$m = -\frac{h_2}{h_1} = \frac{v}{u}$$

Refraction of Light

- When light passes obliquely from a rarer medium (air) to a denser medium (water,glass), there is a change in its direction of propagation.
- **This bending of light at the boundary of two dissimilar media is called refraction**.

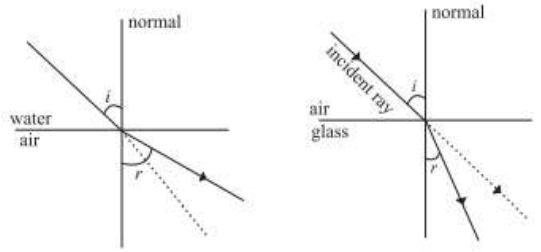
When a ray of light is refracted at an interface, it obeys the following two laws :

Law I : The incident ray, the refracted ray and the normal to the surface at the point of incidence always lie in the same plane.

Law II : The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given pair of media.

It is independent of the angle of incidence when light propagates from a rarer to a denser medium. Moreover, for

a light of given colour, the ratio depends only on the pair of media.

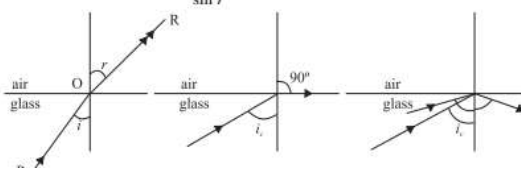


$$\mu_{wg} = \frac{\mu_{ag}}{\mu_{aw}}$$

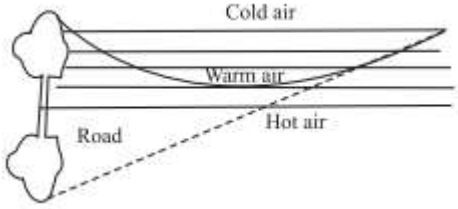
when light travels from water to glass, the refractive index of glass with respect to water can be expressed in terms of the refractive indices of glass and water with respect to air.

TOTAL INTERNAL REFLECTION

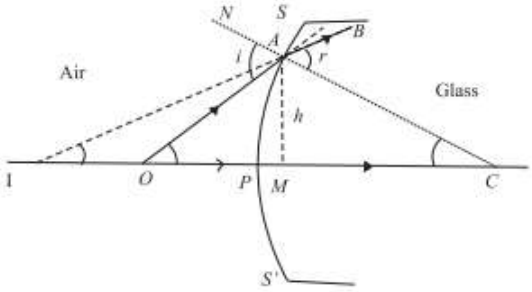
- Light must travel from an optically denser to an optically rarer medium.
- The angle of incidence in the denser medium must be greater than the critical angle for the two media.



Mirage : Mirage is an optical illusion which is observed in deserts or on tarred roads in hot summer days. This, creates an illusion of water, which actually is not there.



REFRACTION AT A SPHERICAL SURFACE



$$\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$$

Thin lens : If the thickness of a lens is negligible in comparison tothe radii of curvature of its curved surfaces, the lens is referred to as a thin lens.

- **Principal axis** is the line joining the centres of curvature of two surfaces of the lens.
- **Optical centre** is the point at the centere of the lens situated on the principal axis. The rays passing through the optical centre do not deviate.
- **Principal focus** is the point at which rays parallel and close to the principal axis converge to or appear to diverge. It is denoted by *F* Rays of light can pass through a lens in either direction. So every lens has two principal focii, one on its either side.
- **Focal length** is the distance between the optical centre and the principal focus. As per the sign convention, *OF* is positive for a convex lens and negative for a concave lens.

- **Focal plane** is the plane passing through the focus of a lens perpendicular to its principal axis.

Newton's Formula

$$x_1x_2 = f_1f_2$$

$$f_1 \equiv f_2 = f \text{ (say), then } x_1x_2 = +f^2$$

$$f = \sqrt{x_1x_2}$$

FORMATION OF IMAGES BY LENSES

The following properties of the rays are used in the formation of images by lenses:

- A ray of light through the optical centre of the lens passes undeviated.
- A parallel ray, after refraction, passes through the principal focus.
- A ray of light through F or F' is rendered parallel to the principal axis after refraction.
- Any two of these rays can be chosen for drawing ray diagram

The lens formula

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

$$\frac{1}{f} = \frac{2}{x+D} + \frac{2}{D-x} = \frac{2}{D+x} + \frac{2}{D-x}$$

$$\frac{1}{f} = \frac{2(D-x+D+x)}{D^2-x^2}$$

$$\frac{1}{f} = \frac{4D}{D^2-x^2}$$

$$f = \frac{D^2-x^2}{4D}$$

The magnification of a lens is defined as the ratio of the height of the image formed by the lens to the height of the object

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

POWER OF A LENS

The power of a lens is defined as the reciprocal of its focal length in metre

$$P = 1/f$$

- The S1 unit of power of a lens is m^{-1}
- The power of a convex lens is positive and that of a concave lens is negative

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

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

Check Yourself

1. Mirage is a phenomenon due to
   (A)refraction of light
   (B) reflection of light
   (C)total internal reflection of light
   (D)diffraction of light.
2. For a total internal reflection, which of the following is correct?
   (A) Light travels from rarer to denser medium.
   (B) Light travels from denser to rarer medium.
   (C) Light travels in air only.
   (D) Light travels in water only.
3. An under-water swimmer cannot see very clearly even in absolutely clear water because of
   (A) absorption of light in water
   (B) scattering of light in water
   (C) reduction of speed of light in water
   (D) change in the focal length of eye lens

4. The image formed by a concave mirror is
   (A) always real
   (B) always virtual
   (C) certainly real if the object is virtual
   (D) certainly virtual if the object is real
5. Which of the following phenomena is used in optical fibers ?
   (A) Total internal reflection
   (B) Scattering
   (C) Diffraction
   (D) Refraction

1 C 2 B 3 D 4 C 5A

Stretch Yourself

1. An object of size 3.0cm is placed 14cm in front of a concave lens of focal length 21 cm. Describe the nature of the image by the lens. What happens if the object is moved farther from the lens?
2. . A small object is placed at a distance of 15cm from two coaxial thin convex lenses in contact. If the focal length of each lens is 20cm. Calculate the focal length and the power of the combination and the distance between the object and its image.
3. What is the nature and position of image formed when the object is at (i) infinity (ii) 2 f (iii) f in case of concave mirror and convex mirror.
4. How is +2.5 dioptre different from –2.5 dioptre? Define dioptre.

Hint to Check Yourself