to a more optically dense medium and obtained the same result.

$$\text{Refractive-index} = \frac{\text{velocity of light in first medium}}{\text{velocity of light in second medium}}$$

3. Diffraction: This is a phenomenon whereby waves bend round obstacles. It is also the spreading of waves after passing through tiny openings, aperture, a hole or a slit. The smaller the width of the aperture, the smaller the wavelength, the greater will be the spreading of the waves. Similarly, the bigger the width of the aperture, the longer the wavelength, the smaller will be the spreading of the waves.

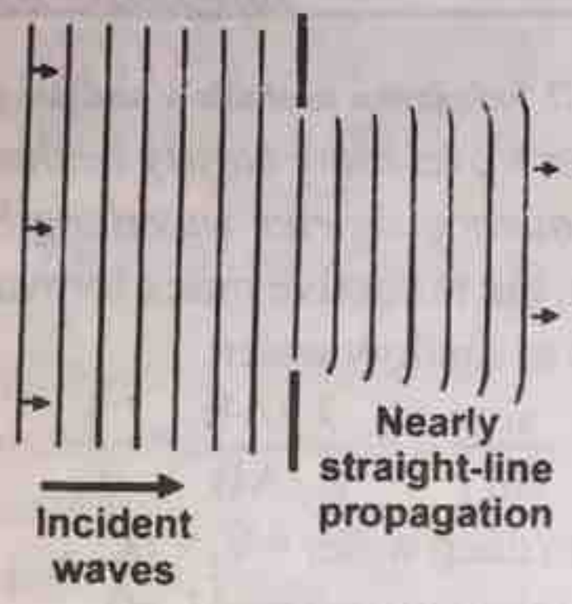


Fig. 27.9(a) Diffraction of waves through wide openings

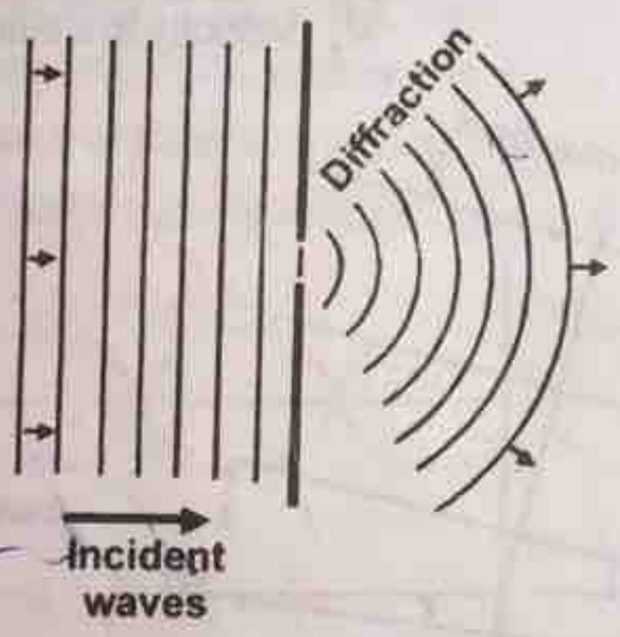


Fig. 27.9(b) Diffraction of waves through narrow openings

4. Interference: This occurs when two waves from a source cross each other's path. i.e the interaction of two (coherent) waves which move simultaneously through the same medium. If the crest of one arrives simultaneously as the troughs of the other, it is referred to as *constructive interference*. But if the crest of one does not arrive simultaneously as the troughs of the other, it is referred to as *destructive interference*

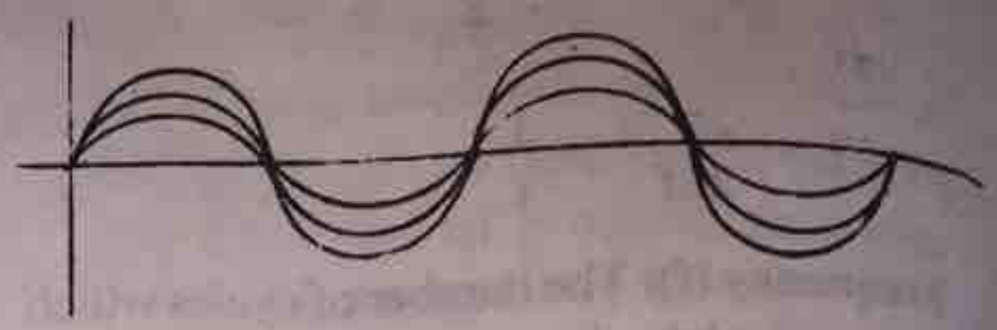


Fig. 27.10(a) Constructive interference

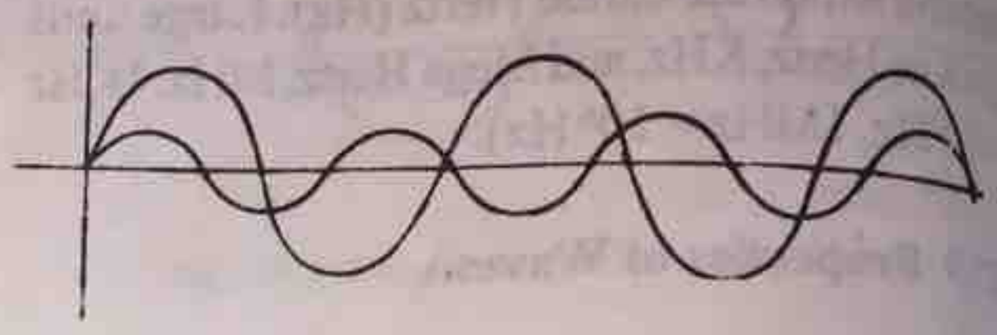


Fig. 27.10(b) Partial constructive interference

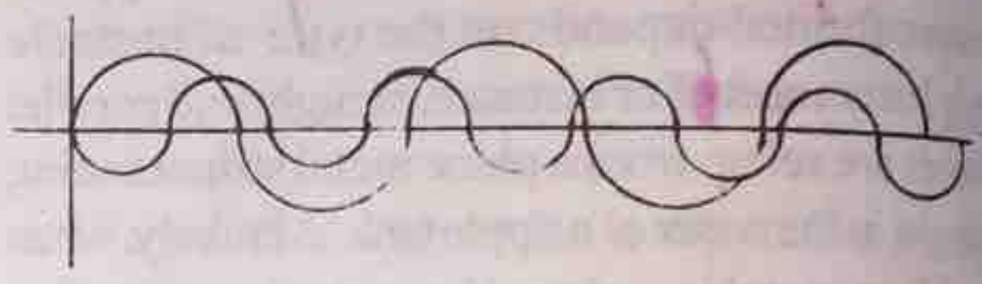


Fig. 27.10(c) Partial destructive interference

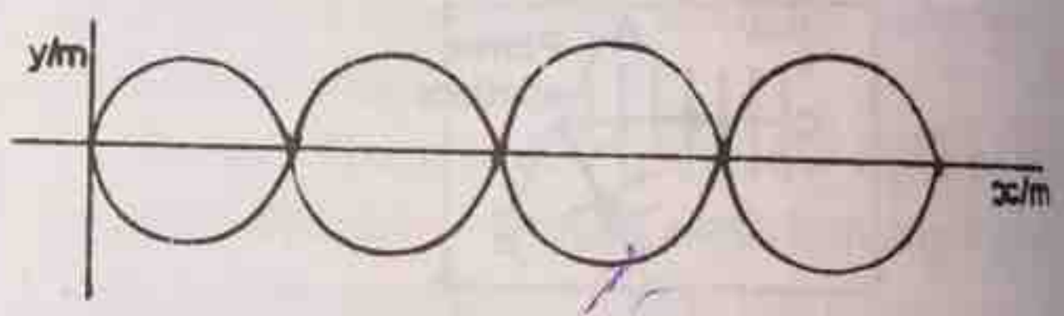


Fig. 27.10(d) Total destructive interference

5. Polarization: It simply means that confinement of waves in one direction occurs only in transverse waves.

Plane polarization of light means the fluctuations or vibrations are constructed to vibrate only in one plane perpendicular to the direction of the light.

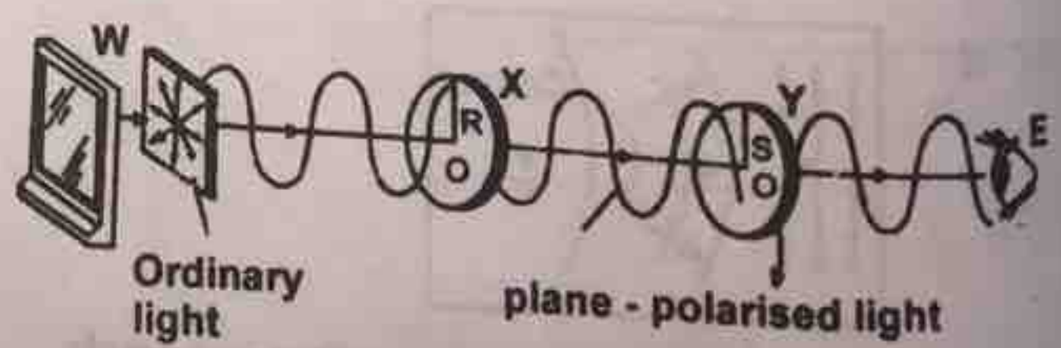


Fig. 27.11 (a) Plane-polarised light

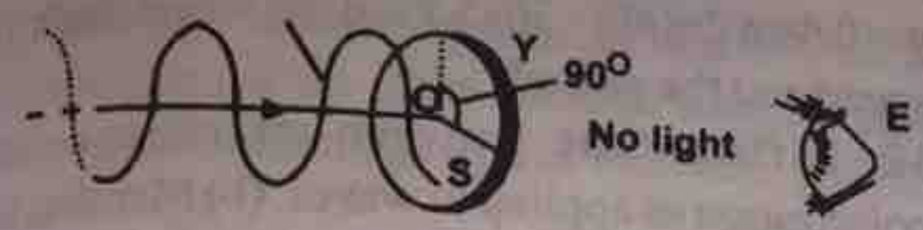


Fig. 27.11 (a) Polarisation of light

Application of plane-polarized light

1. Production of three - dimensional films
2. Determination of concentration of sugar solution.
3. For a study, areas of great stress in glass or celluloid are cut to a special design.
4. Polarized cameras
5. Sun glasses to reduce the intensity of light.

27.10 Representation of Waves

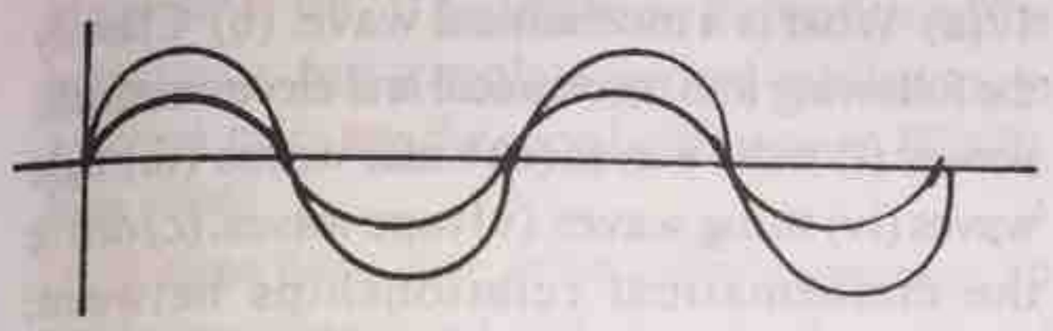


Fig. 27.12 Representation of waves

A progressive wave can be represented by the equation, $y = A \sin(\omega t - \varphi)$

where y = vertical displacement, x = horizontal displacement.

A= Amplitude, ω = angular velocity ($rads^{-1}$)

φ = phase angle, measured in radian (rad)

$$\omega = 2\pi f = \frac{2\pi V}{\lambda} = \frac{2\pi}{T}$$

$$K = \frac{2\pi}{\lambda}, \quad \varphi = kx = \frac{2\pi}{\lambda} x$$

$$y = A \sin(\omega t - kx) \quad \text{.....(i)}$$

$$y = A \sin 2\pi ft - \frac{2\pi x}{\lambda}$$

$$= A \sin 2\pi ft - \frac{x}{\lambda} \quad \text{.....(ii)}$$

$$y = A \sin \frac{2\pi vt}{\lambda} - \frac{2\pi x}{\lambda}$$

$$= A \sin \frac{2\pi}{\lambda}(vt - x) \quad \text{.....(iii)}$$

$$y = A \sin \frac{2\pi t}{T} - \frac{2\pi x}{\lambda}$$

$$= A \sin 2\pi \frac{t}{T} - \frac{x}{\lambda} \quad \text{.....(iv)}$$

Worked example 27.1

The plane progressive wave is represented by the equation

$y = 4 \sin(100\pi t - 50\pi x)$. Find the:

(i) amplitude (ii) frequency (iii) wavelength (iv) velocity.

Solution

$$y = A \sin \left(2\pi ft - \frac{2\pi}{\lambda}\right) x = A \sin 100\pi t - 50\pi x$$

Comparing coefficients, (i) A = 4m

(ii) $2\pi f = 100\pi$

$$f = \frac{100\pi}{2\pi} = 50\text{Hz}$$

(iii) $\frac{2\pi}{\lambda} = 50\pi$

$$\lambda = \frac{2\pi}{50\pi} = \frac{2}{50} = 0.04\text{m} \ (4\text{cm})$$

(iv) $V = f\lambda$

$= 50 \times 0.04 = 2\text{m/s}$

Worked example 27.2

A source of sound produces waves in air of wavelength 3.42m. If the speed of sound in air is 330m/s, what is the period of vibration.

Solution

v = 330m/s, λ = 3.42m

$$V = \frac{\lambda}{T} \Rightarrow T = \frac{\lambda}{V} = \frac{3.42}{330} = 1.036 \times 10^{-3} \text{ sec.}$$

Worked example 27.3

A wave has a frequency of 30Hz and a wavelength of 40cm. What is the velocity of the wave?

Solution F = 30Hz, λ = 40cm = 0.4m

$V = f\lambda$

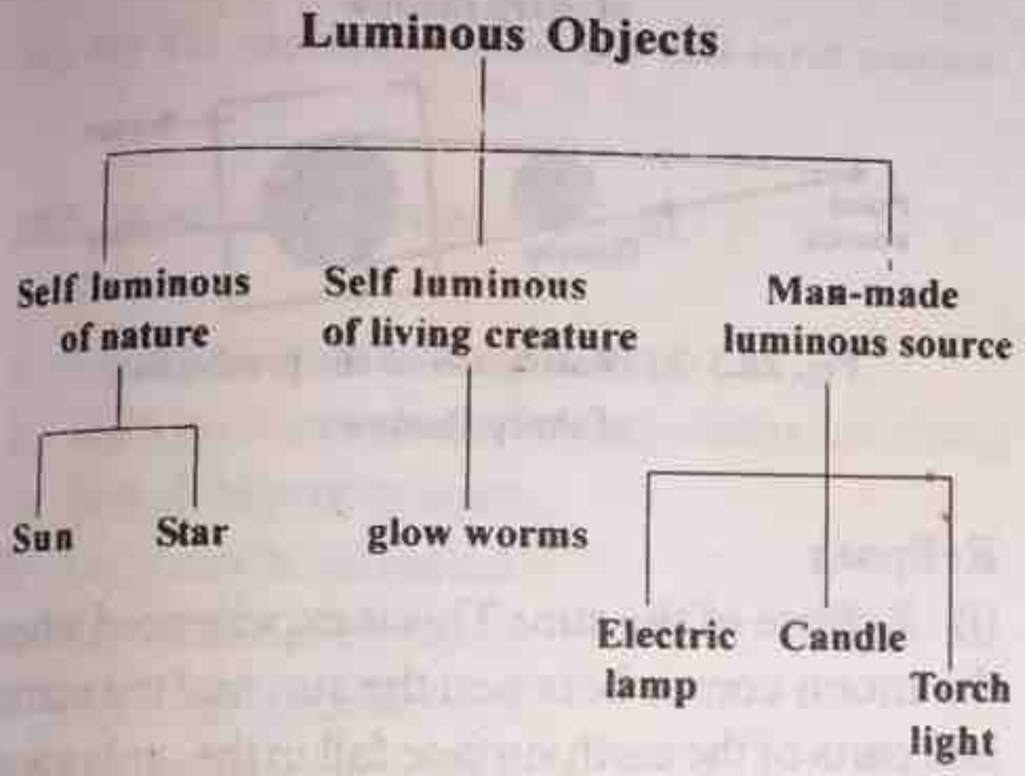
$= 30 \times 0.4$

$= 12\text{m/s}$

28. RECTILINEAR PROPAGATION OF LIGHT

28.1 Sources of Light

A source of light is referred to as the origin of sensation in vision. A light ray is produced from one particular source. The source through which light is produced is called *luminous* objects. It is capable of producing light rays itself.



Luminous objects: These are points or sources through which light rays are produced. Examples are: sun, star (which are referred to as *self-luminous of nature*), fire-fly or glow-worms which are referred to as *self-luminous of living creature*. Electric lamp, candle, torch light, etc, are referred to as *man-made luminous sources*.

Non-luminous objects: These are reflective surfaces which when light falls, produce rays of light. Examples are inner page of white writing paper, a mirror placed in the sun, a signboard placed by the roadside, etc. These objects are classified into:

(i) Transparent objects: These are objects one can see through and light can also pass through them, e.g. white nylon, thin clothes, etc.

(ii) Translucent objects: These are objects that light can pass through but one cannot see through them, e.g. tinted / coloured glasses.

(iii) Opague objects: These are objects that one cannot see through and light cannot pass through e.g. human bodies, walls, etc.

A *ray of light* is the direction or path through which light energy travels, while a *beam of light* is the collection of rays of light.

28.2 Types of Beams

There are three types of beams. These are:
(i) Parallel beams (ii) Convergence beams
(iii) Diverging beams.

1. Convergence beams: They are produced from a large source and meet at a point forming convergent beams.

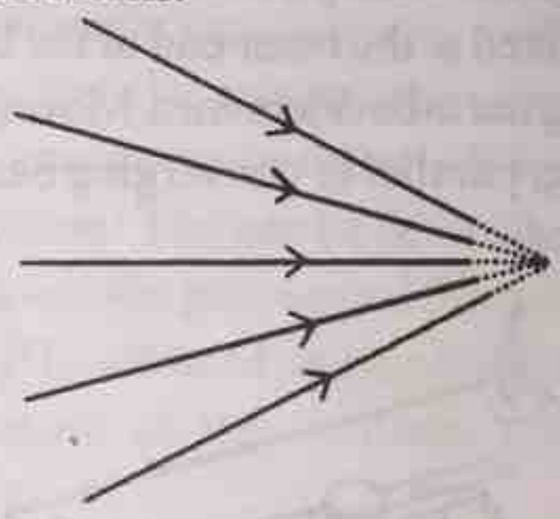


Fig. 28.1 Convergence beams

2. Divergence beams: They are produced from a small source and are scattered, i.e they emerge from a source and diffuse in different directions.

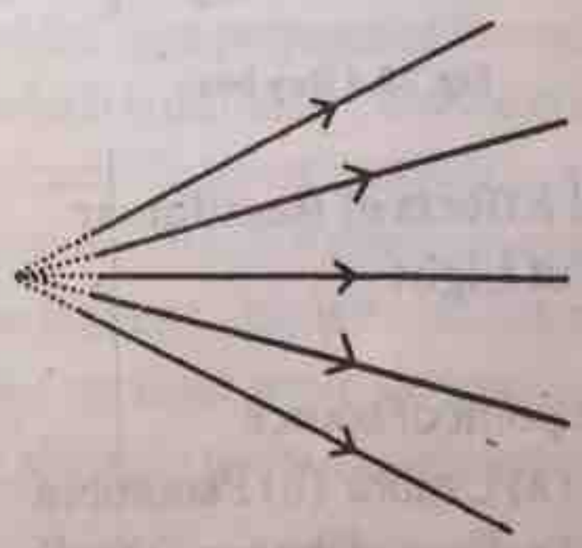


Fig. 28.2 Divergence beams

3. Parallel beams: They are rays of light produced in straight lines.

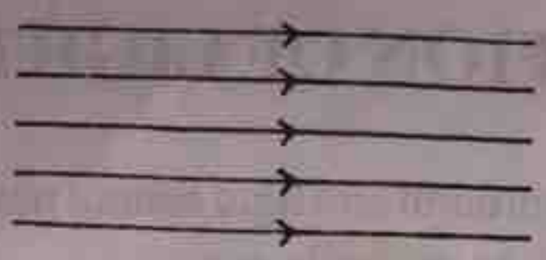


Fig. 28.3 Parallel beams

All rays that are supported with the use of divergence produce a diverging beam of light, e.g. torch light, lantern, etc, but the production of converging beam of light does not require a device, e.g. sunlight. To determine a parallel beam, a ray box is used.

28.3 A Ray Box

To produce a parallel beam of light, a small lamp (L) is placed in a box and a cylinderical converging lens and a parallel but vertical wooden stand are fixed at the other end of the box for the rays coming out to be determined. Moving the lamp, a diverging, parallel or converging beam of rays are obtained.

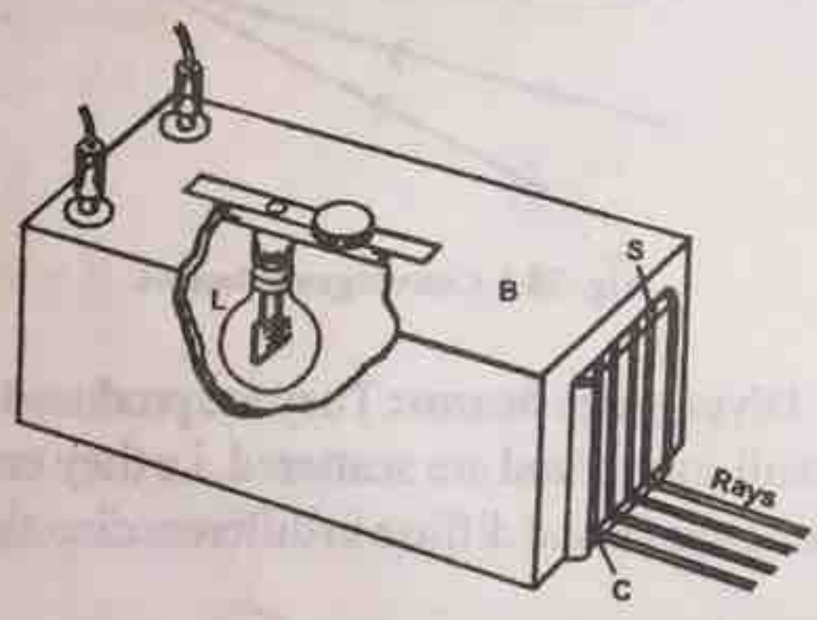


Fig. 28.4 Ray box

28.4 Natural Effects of Rectilinear Propagation of Light

1. Sun as the point of source
2. Shadows: (a) Umbra (b) Penumbra
3. Eclipse: (a) eclipse of the sun (b) eclipse of the moon (c) annular eclipse of the sun.

Shadows: Shadows are due to light travelling in straightlines. They are formed as a result of the reflection of light from an obstacle.

The type of shadow formed depends on the obstacle that light falls on and the size of the luminous object sending out the rays.

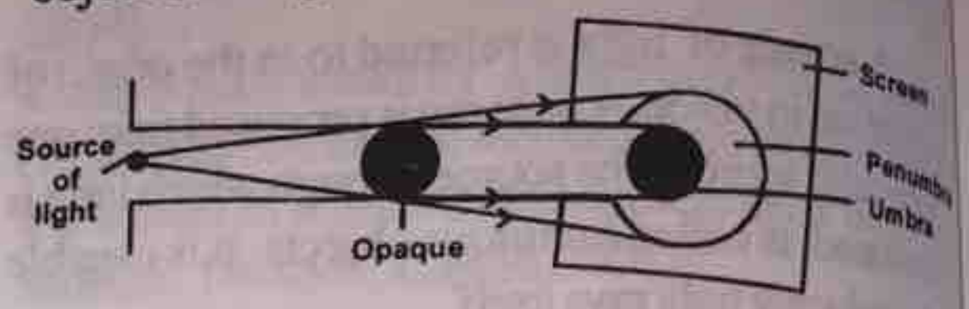


Fig. 28.5 (a) Illustration of the production of sharp shadow

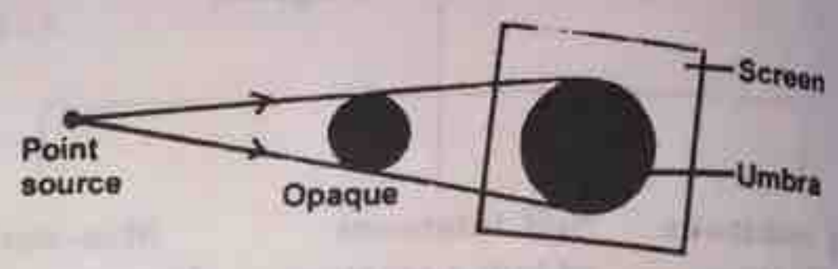


Fig. 28.5 (b) Illustration of the production of sharp shadow

Eclipses

(i) Eclipse of the sun: This is experienced when the moon comes between the sun and the earth, and parts of the earth surface fall in the umbra and penumbera of the moon's shadow.

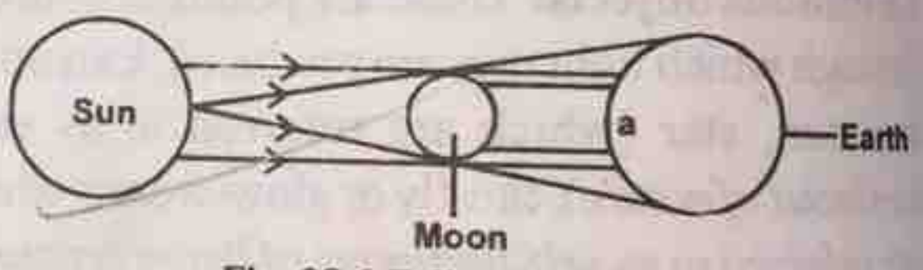


Fig. 28.6 Eclipse of the sun

(ii)Eclipse of the moon: This occurs when the earth comes directly between the sun and the moon. When the moon is on the opposite side of the earth, eclipse of the moon occurs.

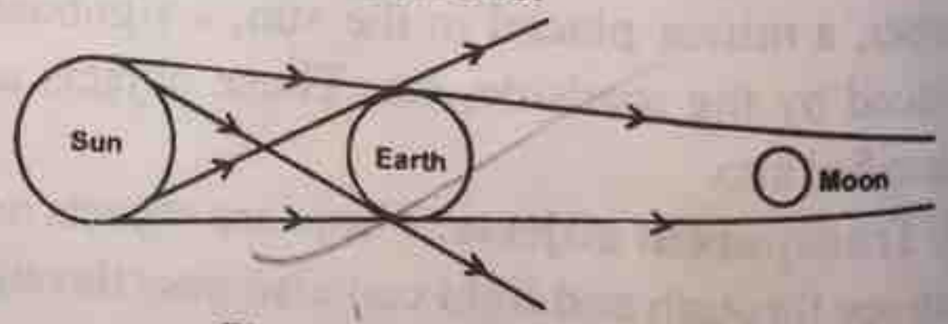


Fig. 28.7 Eclipse of the moon

(iii)Annular eclipse: This occurs when the earth and the moon are in positions and the rays at the edge of the moon are intersected before reaching the earth.

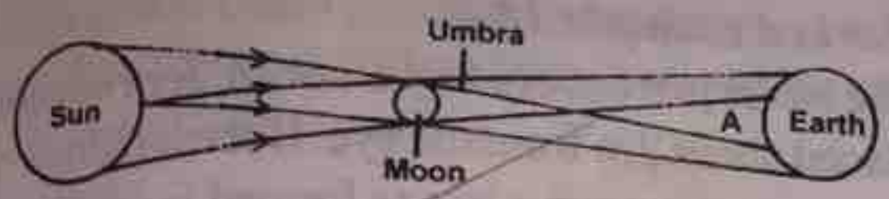


Fig. 28.8 Annular eclipse

Fig. 28.9 The appea rance of the sun from earth position A

28.5 Some Properties of Light

1. Light travels in a straight line.
2. Light produces shadow when obstructed along its path of propagation.
3. Light can be refracted.
4. Light can be refracted.
5. Light can be diffracted.
6. Light can be polarized.

1. Light travels in a straight line (Ray box): This is the first property associated with light waves and can be performed or best explained using a ray box. The box is made up of a bulb, a paper box with open slit at one end. The experiment shows that when the bulb is switched on, rays of light are produced through the opening in a straight line.

Another experiment could be used to prove that light travels in a straight line. The propagated rays could be observed when a lamp is placed in front of three cardboards placed in parallel line but spaced from one another. A tiny rope is passed through the three cardboards. To determine this, an opague substance is placed at the end of the linear propagation where the real image is formed, i.e, the real image shown on the opague substance through this light is confirmed to travel in a straight line. The process of light travelling in a straight line is called *the rectilinear propagation of light.*

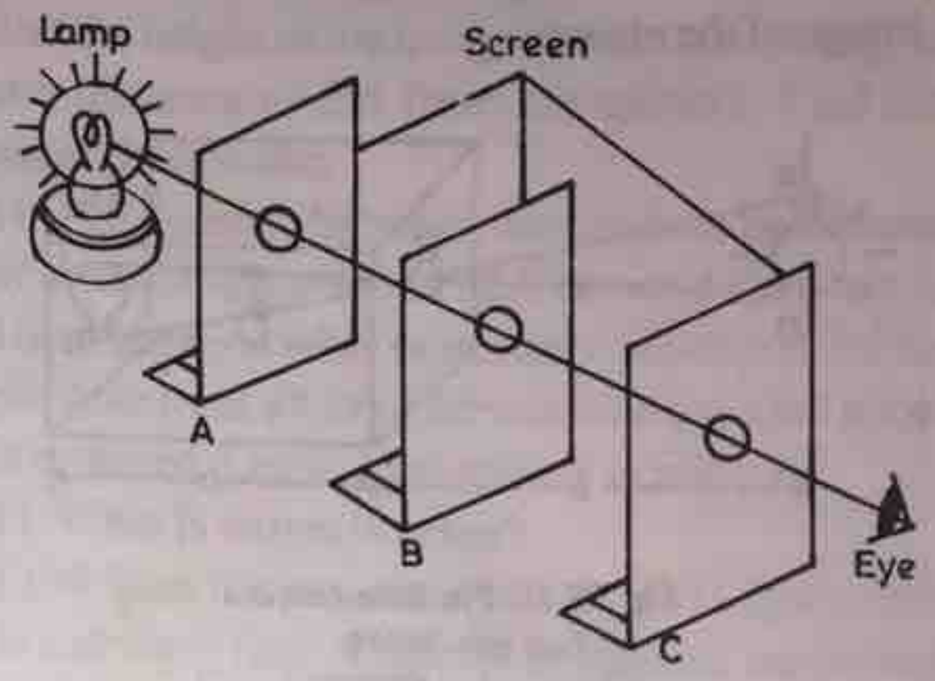


Fig. 28.10 Rectilinear propagation of light.

2. Reflection: This can be defined as the reproduction of light waves when it is incidented at a particular angle into a screen or plane object. The screen could be smooth or has rough surfaces as long as images can be reflected on it.

3. Refraction: This can be defined as the ability of light wave to be propagated from one medium to another. The extent of propagation is determined by the nature of the medium allowing the propagation.

Refractive index can be expressed as the sine of angle at incident to the sine of angle of refraction.

4. Diffraction: This is the ability of a light wave to be further propagated through an opening in an obstructing place along its path of propagation. The energy of the light propagated is much higher than the one which is diffracted. But the energy becomes more appreciable when it travels in a small slit and less appreciable when it travels through a large slit.

5. Polarization: This is the ability of the particles that make up light wave getting adapted to any opening along its path of propagation.

28.6 Pin-hole Camera

The pin-hole camera consists of a closed box or tin having a very tiny hole at the middle and a