LIGHT

CONTENTS

INTRODUCTION

- Light is a form of energy, (optical energy) which helps us in seeing objects by its presence.
- Light is an electromagnetic wave & travels in a straight line with the speed 3×10^8 m/s in vacuum & changes when it travels from one medium to another.
- The wavelength (λ) of light changes when it goes from one medium to another.
- The frequency (f) of the light wave remains the same in all media.
- Light gets reflected back from polished surfaces, such as mirrors, polished metal surfaces, etc.
- Light undergoes refraction (bending) when it travels from one transparent medium to another.

SOURCES OF LIGHT

- The objects which emit (give) light are called **luminous objects**. It may be natural or man-made. Sun is a natural source of light and electric lamp, and oil lamp, etc. are man-made source of light.
- The **Non-luminous objects** do not emit light. However, such objects become visible due to the reflection of the light falling on them. Moon does not emit light & becomes visible due to the reflection of the sunlight falling on it.

MEDIUM OF LIGHT

Substance through which light propagates or tends to propagate is called a medium of light.

According to the medium of light objects are divided into three parts.

(i) Transparent object :

Bodies that allow light to pass through then i.e. transmit light through them, are called transparent bodies.

Ex. Glass, water, air etc

(ii) Translucent object :

Bodies that can transmit only a part of light through them are called translucent objects.

Ex. Froasted or ground glass, greased paper , paraffin wax etc.

(iii) Opaque object :

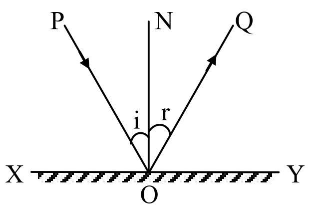
Bodies that do not allow light to pass through them at all are said to be opaque objects

Ex. Chair, desk etc.

➢ REFLECTION OF LIGHT

When light rays are incident on an opaque polished surface (medium), these are returned back in the same medium. This phenomenon of returning of ray of light in the same medium, is called **reflection** of light.

◈ SOME ASSOCIATED TERMS



- **Reflecting surface :** The surface from which the light is reflected, is called the reflecting surface. In diagram, XY is the reflecting surface. (**Actually** XY is the section of a reflecting surface, made by the plane of the book page which is perpendicular to it.)
- **Point of incidence :** The point on the reflecting surface at which a ray of light strikes, is called the point of incidence. In diagram, O is the point of incidence.
- **Normal :** A perpendicular drawn on the reflecting surface at the point of incidence, is called the normal. In diagram, NO is the normal.
- **Incident ray :** The ray of light which strikes the reflecting surface at the point of incidence is called the incident ray. In diagram, PO is the incident ray.
- **Reflected ray :** The ray of light reflected from the reflecting surface from the point of incidence, is called the reflected ray. In diagram, OQ is the reflected ray.
- **Angle of incidence :** The angle that the incident ray makes with the normal, is called the angle of incidence. It is represented by the symbol i. In diagram, angle PON is the angle of incidence.
- **Angle of reflection :** The angle that the reflected ray makes with the normal, is called the angle of reflection. It is represented by the symbol r. In diagram, ∠QON is the angle of reflection.

➢ LAWS OF REFLECTION & NATURE OF IMAGE

◈ **First law :** The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.

Second law : The angle of reflection (∠r) is always equal to the angle of incidence (∠i).

i.e., $\angle r = \angle i$

(For normal incidence, $i = 0$, $r = 0$. The ray is reflected back along normal).

◈ NATURE OF IMAGE

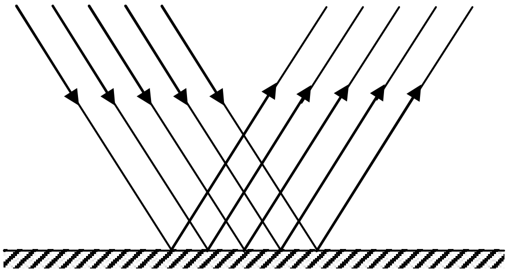
Incident rays starting from a point object, and reflected from a mirror, either actually meet at or appear to come from a point. The other point is called the **image** of the point object.

Real Image	Virtual Image
1. A real image is formed when two or more reflected rays meet at a point in front of the mirror.	1. A virtual image is formed when two or more rays appear to be coming from a point behind the mirror.
2. A real image can be obtained on a screen.	2. A virtual image cannot be obtained on a screen.
3. A real image is inverted with respect to the object.	3. A virtual image is erect with respect to the object.

➢ REGULAR & DIFFUSED REFLECTION

◈ Regular Reflection :

In this reflection, parallel beam of light goes parallel after reflection from plane surface.
This reflection follows the laws reflection.

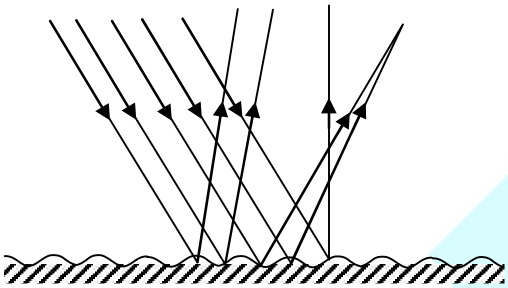


Regular reflection

- **IRREGULAR REFLECTION OR DIFFUSED REFLECTION :**

  In this reflection, parallel beam of light goes random after reflection from a rough surface.

  This reflection also follows the laws of reflection.

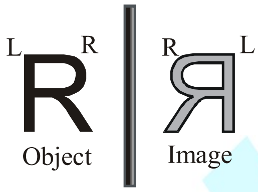


Irregular or diffused reflection

- **Note :** Laws of reflection are always valid no matter whether reflection is regular or irregular.

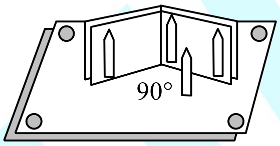
CHARACTERISTICS OF THE IMAGE FORMED BY PLANE MIRROR

- **Size :** size of the image is same as that of object.
- **Upright or Erect :** Image formed erect with respect to object.
- **Image distance :** It will be same as that of object distance.
- **Lateral inversion :** If you move your right hand, it will appear as if the left hand of your image is moving. If you keep a printed page in front of a plane mirror, the image of the letters appear erect but inverted laterally, or sideways. Such an inversion is called lateral inversion.



MULTIPLE REFLECTION

Number of images formed by combination of plane mirrors depends upon angle between mirrors.



If there are two plane mirrors inclined to each other at an angle 90° , the number of images of a point object formed are 3.

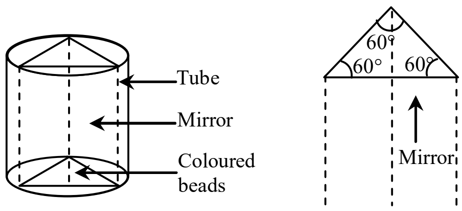
- **KALEIDOSCOPE**

  This is a structure made up of three plane mirrors in which all the plane mirrors are joint along the length and arranged at an angle of 60º as shown in figure.

  A cardboard tube is wrapped around the mirrors to form a tublar structure. One end of this tube is pasted with transparent sheets with some multi coloured beads or pieces of broken bangles in between these sheets. Another and is closed with a plane transparent sheet.

  When we observe through the transparent end with rotating the tube beautiful coloured pattern.

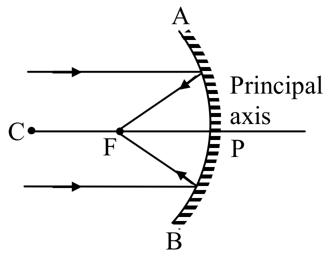
  The above pattern is because of multiple reflection of light rays coming from small beads and pieces of bangles.



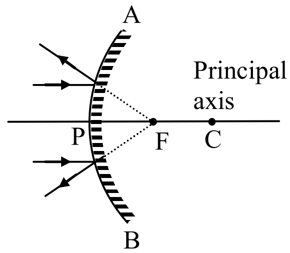
➢ REFLECTION FROM SPHERICAL MIRROR

There are two types of spherical mirrors:

(i) Concave mirror :



(ii) Convex mirror :



◈ SOME ASSOCIATED TERMS

- **Pole :** The centre of the spherical surface of the mirror is called the pole of the mirror. It lies on the surface. In diagram, P is the pole of the mirror.

- **Centre of curvature :** The centre of the spherical shell, of which the mirror is a section, is called centre of curvature of the mirror. It lies outside the surface. Every point on mirror surface lies at same distance from it. In diagram, C is the centre of curvature of the mirror.

- **Principal axis :** The straight line passing through the pole and the centre of curvature of the mirror, is called principal axis of the mirror.

- **Principal focus :** It is a point on the principal axis of the mirror, such that the rays incident on the mirror parallel to the principal axis after reflection, actually meet at this point (in case of a concave mirror) or appear to come from it (in case of a convex mirror). In diagram, F is the principal focus of the mirror.

- **Radius of curvature :** The distance between the pole and the centre of curvature of the mirror, is called the radius of curvature of the mirror. It is equal to the radius of the spherical shell of which the mirror is a section. In diagram, PC is the radius of curvature of the mirror. It is represented by the symbol R.

- **Focal length :** The distance between the pole and principal focus of the mirror, is called the focal length of the mirror. In diagram, PF is the focal length of the mirror. It is represented by the symbol f.

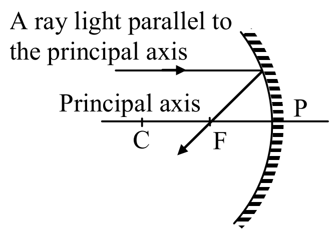
$$f = +\frac{R}{2} \text{ for convex}$$

$$f = -\frac{R}{2} \text{ for concave}$$

➢ RULES OF IMAGE FORMATION BY SPHERICAL MIRROR

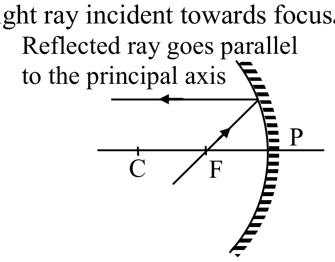
RAY DIAGRAM FOR IMAGE FORMATION FROM CONCAVE MIRROR

(a) *When the light ray incident parallel to the principal axis.*

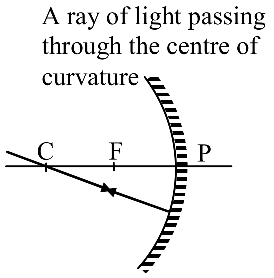


OR

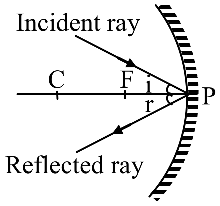
When the light ray incident towards focus**.**



(b) *When the light ray incident towards centre of curvature.*

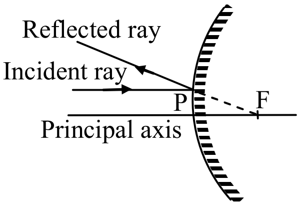


(c) *When the light ray incident on the pole of the mirror.*



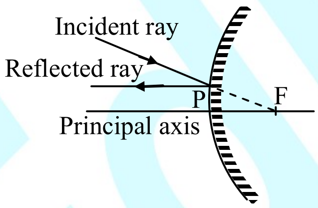
◈ RULES FOR IMAGE FORMATION FROM CONVEX MIRROR

(a) *When the light ray incident parallel to the principal axis.*

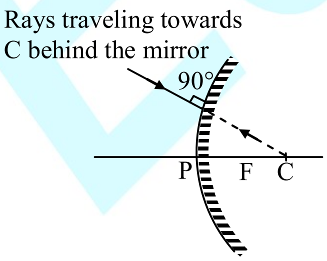


OR

When the light ray incident parallel to the principal axis.



(b) *When the light ray incident on the mirror directing towards centre of curvature.*



➢ REFRACTION OF LIGHT

When light rays travelling in a medium are incident on a transparent surface of another medium they are bent as they travel in second medium.

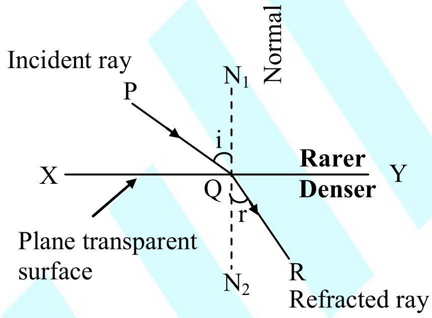


Fig. Refraction of light from a plane transparent denser surface.

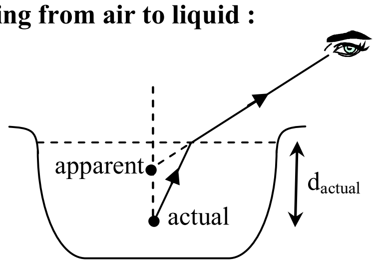
◈ SOME ASSOCIATED TERMS

- **Transparent surface :** The plane surface which refracts light, is called transparent surface. In diagram, XY is the section of a plane transparent surface.
- **Point of incidence :** The point on transparent surface, where the ray of light meets it, is called point of incidence. In diagram, Q is the point of incidence.
- **Normal :** Perpendicular drawn on the transparent surface at the point of incidence, is called normal. In diagram, N_1QN_2 is the normal on surface XY.
- **Incident ray :** The ray of light which strikes the transparent surface at the point of incidence, is called incident ray in diagram PQ is the incident ray.
- **Refracted ray :** The ray of light which travels from the point of incidence into the other medium, is called refracted ray. In diagram, QR is the refracted ray.
- **Angle of incidence :** The angle between the incident ray and the normal on the transparent surface at the point of incidence, is called the angle of incidence. It is represented by the symbol i. In diagram, angle PQN_1 is the angle of incidence.

- **Angle of refraction :** The angle between the refracted ray and the normal on the transparent surface at the point of incidence, is called angle of refraction. It is represented by symbol r. In diagram angle RQN_2 is the angle of refraction.

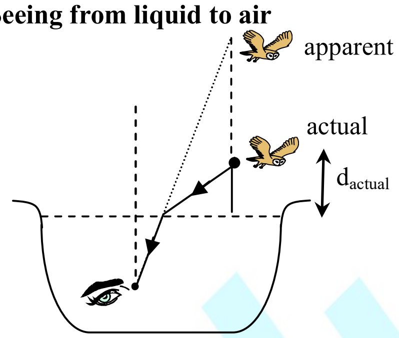
◈ REAL & APPARENT DEPTH & HEIGHT

(A) Seeing from air to liquid :



$$\text{apparent depth from surface} = \frac{d_{actual}}{\mu}$$

(B) Seeing from liquid to air



$$\text{apparent height from surface} = H_{actual} \times \mu$$

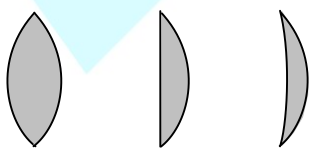
➢ SPHERICAL LENS

A piece of a transparent medium bounded by at least one spherical surface, is called a spherical lens.

- There are two types of spherical lenses:

(i) Convex or Converging Lenses : These are thick in the middle and thin at the edges.

There are three types of convex lenses :



(a) (b) (c)

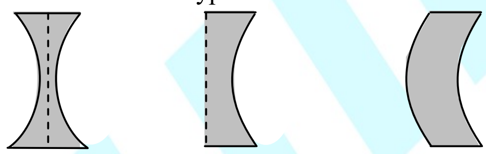
(a) **Double Convex Lens :** It has both the surfaces convex.

(b) **Plano–Convex Lens :** It has one surface plane and the other surface convex.

(c) **Concavo–Convex Lens :** It has one surface concave and the other surface convex.

(ii) Concave or Diverging Lenses : These are thin in the middle and thick at the edges.

There are three types of concave lenses :



(a) (b) (c)

Fig. Three types of concave lenses

(a) **Double Concave Lens :** It has both the surfaces concave. (Fig.)

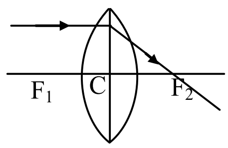
(b) **Plano–Concave Lens :** It has one surface plane and the other surface concave. (fig.)

(c) **Convexo–Concave Lens :** It has one surface convex and the other surface concave. (fig.)

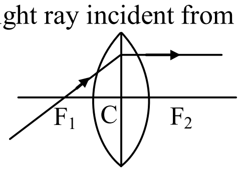
➢ RULES OF IMAGE FORMATION BY SPHERICAL LENS

◈ RAY DIAGRAM FOR IMAGE FORMATION FROM CONVEX LENS

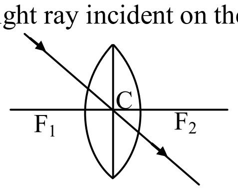
- When light ray incident parallel to principal axis.



- When light ray incident from focus.

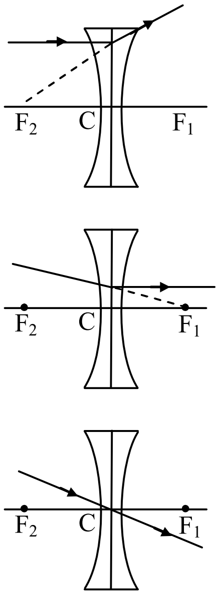


- When light ray incident on the pole.



❖ RAY DIAGRAM FOR IMAGE FORMATION FROM CONCAVE LENS

- When light ray incident parallel to principal axis.



➢ TOTAL INTERNAL REFLECTION

When light travels from a denser medium to a rarer medium and is incident at an angle more than the critical angle for that medium, it is completely returned inwardly in the denser medium. This complete inward return of light is called **total** (complete) **internal** (inward) **reflection** (return).

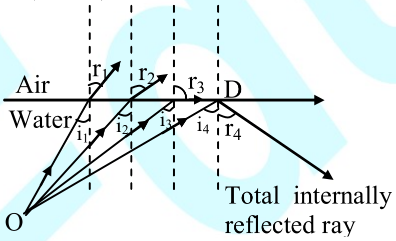


Fig. Total internal reflection.

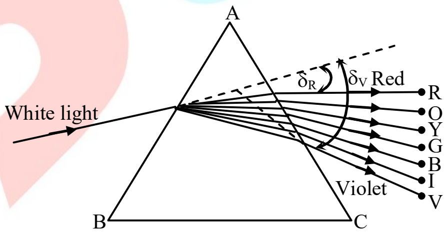
➢ DISPERSION OF WHITE LIGHT BY A GLASS PRISM

When a ray of white light (sunlight) enters a glass prism (denser medium). It emerges out from it broken into seven colours.

This phenomenon, due to which different components of a white light are separated by a denser medium, is called **dispersion** (separation).

- **Explanation :** It is due to different velocities of different components of white light in the denser medium.

White light has seven colours, namely, violet indigo, blue, green, yellow, orange and red (remembered by the word **VIBGYOR**). In air (strictly in vacuum) light waves of all colours have same velocity (3×10^8 m/s). But in a denser medium, their velocities become less and different. Red light waves, being longest in length, travel fastest and have maximum velocity. Violet light waves, being shortest in length, travel slowest and have minimum velocity in the denser medium.



Dispersion of white light by a glass prism

Due to difference in deviation, waves of different colours emerge out from the prism indifferent directions and are said to have been dispersed (separated). When the dispersed white light is made to fall on a white screen, we get a seven coloured band or light. This coloured band is called **spectrum**

➢ HUMAN EYE

It is the most delicate and complicated natural optical instrument which enables us to see the wonderful world of light.

◈ STRUCTURE :

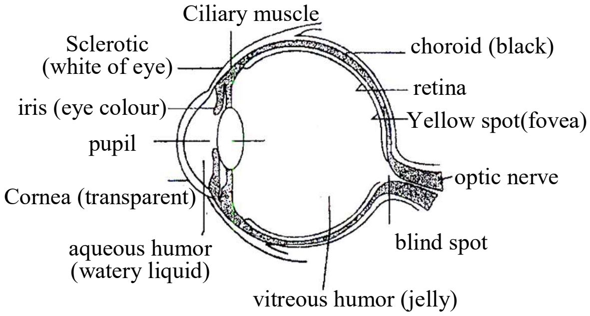
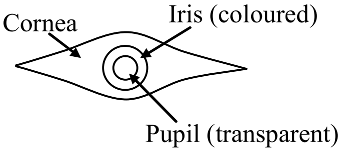


Diagram shows the section of a human eye by a horizontal plane. It is a spherical ball of diameter about 2.5 cm. Its essential parts are described below :

- **Cornea :** It is the front buldged out part of eye ball covered by transparent sclerotic.



Cornea of the eye-front view.

- **Iris :** It is the coloured region under cornea formed by choroid. Its colour differs from person to person.
- **Pupil :** It is central circular aperture in the iris. Its normal diameter is **1 mm** but it can contract in excess light and expand in dim light, by means of two sets of involuntary muscular fibres.
- **Crystalline lens :** It is a double convex lens L immediately behind iris. This is made of transparent concentric layers whose optical density increases towards the centre of the lens.
- **Ciliary muscles :** The lens is connected of the sclerotic by the **ciliary muscles.** These muscles change thickness of the lens by relaxing and exerting pressure.
- **Aqueous humour :** Anterior chamber is filled with a transparent liquid of refractive index. The liquid is called the aqueous humour.
- **Vitreous humour :** Posterior chamber is filled with a transparent watery liquid with little common salt having some refractive index. The liquid is called the vitreous humour.
- **Retina :** It forms innermost coat in the interior of the eye. It consists of a thin membrane which is rich in nerve fibres, containing two kinds of vision cells called **rods** and **cones** and blood vessels. It is sensitive to light, for it is a continuation of the optic nerves. It serves the purpose of a sensitive screen for the reception of the image formed by the lens system of the eye.
  [The **rods** are responsible for colour vision in dim light (**Scotopic vision)**.
  The **cones** are responsible for vision under ordinary day light (**Photopic vision)**.
- **Blind spot :** The blind spot B. It is the spot where the optic nerves enter the eye. It is also slightly raised and insensitive to light, because it is not covered with choroid and retina.

◈ Working (Action of the eye) :

The human eye is like a camera. Its lens system forms an image on a light-sensitive screen called the retina. Light enters the eye through a thin membrane called the cornea. It forms the transparent bulge on the front surface of the eyeball. The eyeball is approximately spherical in shape with a diameter of about 2.3 cm. Most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea. The crystalline lens merely provides the finer adjustment of focal length required to focus objects at different distances on the retina.

We find a structure called *iris* behind the cornea. Iris is a dark muscular diaphragm that controls the size of the pupil. The pupil regulates and controls the amount of light entering the eye. The eye lens forms an inverted real image of the object on the retina. The retina is a delicate membrane having enormous number of light-sensitive cells. The light-sensitive cells get activated upon illumination and generate electrical signals. These signals are sent to the brain via the optic nerves. The brain interprets these signals, and finally, processes the information so that we perceive objects as they are.

DEFECTS OF VISION, SYMPTOMS AND REMEDY (CORRECTION)

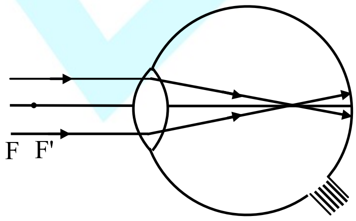
Defects of Vision

The major defects of vision are :

1. Short sightedness or myopia.
2. Long sightedness or hypermetropia.
3. Presbyopic
4. Astigmatism

1. Short sightedness or myopia

- **Symptoms :** Eye cannot see clearly beyond a certain distance. It means that the far point of the defective eye has shifted from infinity to a finite distance ahead.
- **Reasons :** It is so because the image of distant objects is formed in front of the retina. It is shown in fig.



Myopic eye vision.

- **Causes :**

(i) The lens may be **thicker** (more converging) that the normal eye lens.

(ii) The eye ball may be **elongated,**

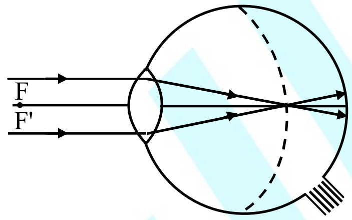


Fig. Elongated eye.

- **Correction :** The extra converging power of eye lens is compensated by using a concave (diverging) lens of proper power (focal length) as shown in fig.

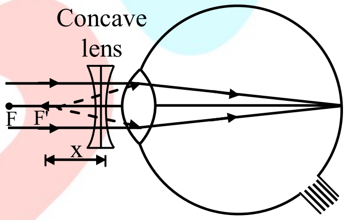
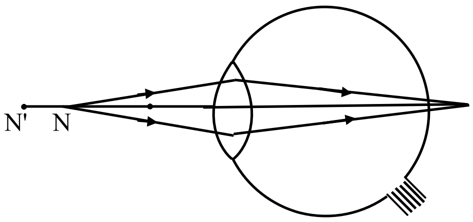


Fig. Myopia corrected by a concave lens

2. Long sightedness or hypermetropia

- **Symptoms :** With this defect eye cannot see clearly within a certain distance. It means that the near point of the defective eye has shifted from 25 cm to some more distance behind (away).
- **Reason :** It is so because the image of near objects is formed behind the retina. It is shown in fig.



Hypermetropic eye vision.

◆ **Causes :**

(i) The eye lens may be **thinner** (less converging) than the normal eye lens.

(ii) The eye ball may be **oval** distance between lens and retina becomes less than that for normal eye.

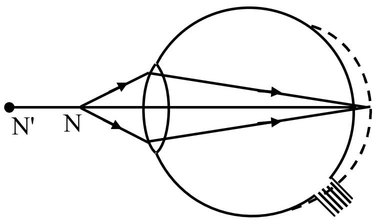


Fig. Oval eye.

◆ **Correction :** The deficiency in converging power of eye lens is compensated by using a convex (Converging) lens of proper power (focal length) as shown in fig.

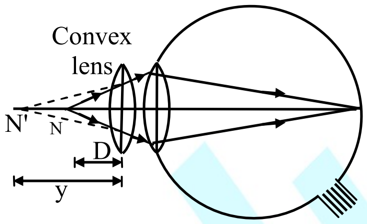


Fig : Hypermetropia corrected by a convex lens.

3. Presbyopic :

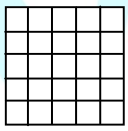
The power of accommodation of the eye usually decreases with ageing. For most people, the near point gradually recedes away. They find it difficult to see nearby objects comfortably and distinctly without corrective eye-glasses. This defect is called **Presbyopia.**

It arises due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye lens. Sometimes, a person may suffer from both myopia and hypermetropia.

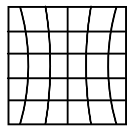
Such people often require bi-focal lenses. A common type of bi-focal lenses consists of both concave and convex lenses. The upper portion consists of a concave lens. It facilitates distant vision. The lower part is a convex lens. It facilitates near vision. These days, it is possible to correct the refractive defects with contact lenses or through surgical interventions.

4. Astigmation :

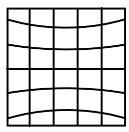
A person suffering from this defect cannot simultaneously focus on both horizontal and vertical lines of a wire gauze.



Normal Wire Gauge



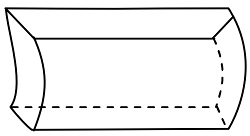
Wire gauge with
distorted vertical lines



Wire gauge with
distorted horizontal lines

This defect arises due to the fact that the cornea is not perfectly spherical

This defect can be corrected by using *cylindrical lens*

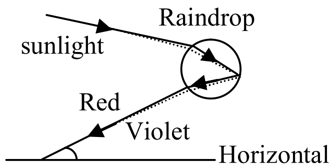


Cylindrical lens

➢ REFRACTION IN NATURE

(A) FORMATION OF RAINBOW

A rainbow is a natural spectrum appearing in the sky after a rain shower. It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere. A rainbow is always formed in a direction opposite to that of the Sun. The water droplets act like small prisms. They refract and disperse the incident sunlight, then reflect it internally, and finally refract it again when it comes out of the raindrop. Due to the dispersion of light and internal reflection, different colours reach the observer's eye.



(B) ATMOSPHERIC REFRACTION

We can observe the apparent random wavering or flickering of objects seen through a turbulent stream of hot air rising above a fire or a radiator. The air just above the fire becomes hotter than the air further up. The hotter air is lighter (less dense) than the cooler air above it, and has a refractive index slightly less than that of the cooler air. Since the physical conditions of the refracting medium (air) are not stationary, the apparent position of the object, as seen through the hot air, fluctuates. This wavering is thus an effect of atmospheric refraction (refraction of light by the earth's atmosphere) on a small scale in our local environment. The twinkling of stars is a similar phenomenon on a much larger scale.

(a) Twinkling of stars :

The twinkling of a star is due to atmospheric refraction of starlight. The starlight, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth. The atmospheric refraction occurs in a medium of gradually changing refractive index.

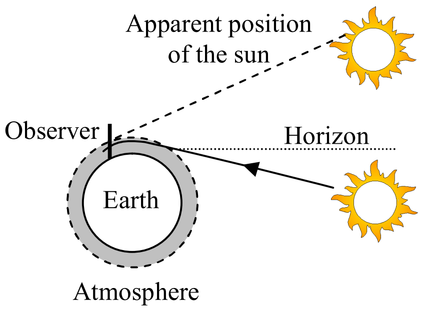
Since the stars are very distant, they approximate point-sized sources of light. As the path of rays of light coming from the star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers – the star sometimes appears brighter, and at some other time, fainter, which is the twinkling effect.

(b) Why don't the planets twinkle?

The planets are much closer to the earth, and are thus seen as extended sources. If we consider a planet as a collection of a large number of point-sized sources of light, the total variation in the amount of light entering our eye from all the individual point-sized sources will average out to zero, thereby nullifying the twinkling effect.

(C) ADVANCE SUNRISE AND DELAYED SUNSET :

Advance sunrise and delayed sunset The Sun is visible to us about 2 minutes before the actual sunrise, and about 2 minutes after the actual sunset because of atmospheric refraction. By actual sunrise, we mean the actual crossing of the horizon by the Sun. figure shows the actual and apparent positions of the Sun with respect to the horizon. The time difference between actual sunset and the apparent sunset is about 2 minutes. The apparent flattening of the Sun's disc at sunrise and sunset is also due to the same phenomenon.



Atmospheric refraction at sunrise and sunset

SCATTERING OF LIGHT

The interplay of light with objects around us gives rise to several spectacular phenomena in nature. The blue colour of the sky, colour of water in deep sea, the reddening of the sun at sunrise and the sunset are some of the wonderful phenomena we are familiar with. The path of a beam of light passing through a true solution is not visible. However, its path becomes visible through a colloidal solution where the size of the particles is relatively larger.

(a) Tyndall effect

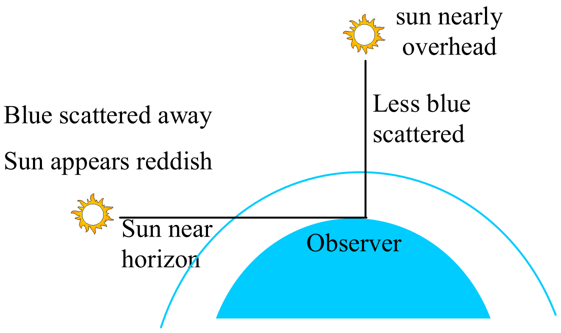
The earth's atmosphere is a heterogeneous mixture of minute particles. These particles include smoke, tiny water droplets, suspended particles of dust and molecules of air. When a beam of light strikes such fine particles, the path of the beam becomes visible. The light reaches us, after being reflected diffusely by these particles. The phenomenon of scattering of light by the colloidal particles gives rise to **Tyndall effect**. This phenomenon is seen when a fine beam of sunlight enters a smoke-filled room through a small hole. Thus, scattering of light makes the particles visible. Tyndall effect can also be observed when sunlight passes through a canopy of a dense forest. Here, tiny water droplets in the mist scatter light. The colour of the scattered light depends on the size of the scattering particles. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelengths. If the size of the scattering particles is large enough, then, the scattered light may even appear white.

- **Why is the colour of the clear sky blue :**

The molecules of air and other fine particles in the atmosphere have size smaller than the wavelength of visible light. These are more effective in scattering light of shorter wavelengths at the blue end than light of longer wavelengths at the red end. The red light has a wavelength about 1.8 times greater than blue light. Thus, when sunlight passes through the atmosphere, the fine particles in air scatter the blue colour (shorter wavelengths) more strongly than red. The scattered blue light enters our eyes. If the earth had no atmosphere, there would not have been any scattering. Then, the sky would have looked dark. The sky appears dark to passengers flying at very high altitudes, as scattering is not prominent at such heights. You might have observed that 'danger' signal lights are red in colour. Do you know why? The red is least scattered by fog or smoke. Therefore, it can be seen in the same colour at a distance.

(b) Colour of the sun at sunrise and sunset

The sky and the Sun at sunset or sunrise appears red. Near the horizon, most of the blue light and shorter wavelengths are scattered away by the particles. Therefore, the light that reaches our eyes is of longer wavelengths. This gives rise to the reddish appearance of the Sun.



◈ MIRAGE OR INFERIOR MIRAGE

It is an optical illusion, seen in deserts at summer noon, due to which an inverted image of a distant tree is seen formed in hot sand below it, as if formed in water. Actually there is no water anywhere.

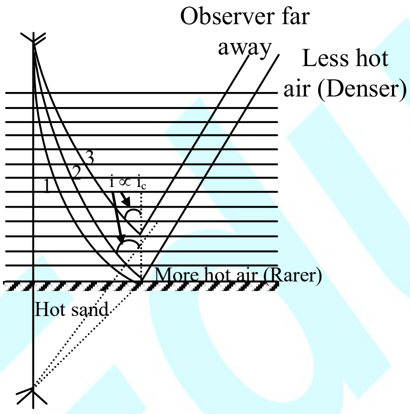


Fig. Mirage in hot desert–Inverted image of tree in hot sand

- **Explanation :** It is due to total internal reflection. At summer noon, in desert, sand becomes hot. The air in its contact becomes very hot and hence rarer. As we move up, air becomes less and less hot, hence less and less rarer. The air can be divided into layers of different optical density (fig.).

For rays (like number 1 ray), incident at small angle at upper most layer, the angle of incidence on lowest layer may not be more than critical angle. These rays are all absorbed by sand.

The ray no. 2 starting from tree top and making a bigger angle since beginning, reaches the lowest layer at bigger angle. The angle of incidence may become just more than the critical angle. The ray is totally reflected upward and outward. All rays on the right of ray no. 2 will start with still bigger angle and will have angle of incidence becoming more than critical angle from upper and upper layers. They are also totally reflected.

◈ LOOMING OR SUPERIOR MIRAGE

It is an optical illusion seen at sea–shore in winter evening, due to which an image of a ship is seen formed in air in sea–sky. The actual ship is nowhere visible.

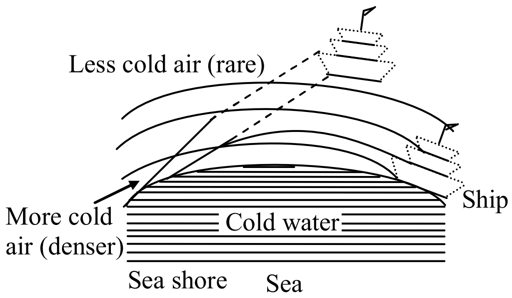


Fig. Looming at cold sea–shore

- **Explanation :** It is due to total internal reflection. In cold evening, over sea–bed sea water becomes too cold. Air layer in its contact is cold and denser. As we go up, air layers become less and less colder and hence rarer. (Fig.)

Rays from invisible ship going upward go from denser to rarer air layers. They are totally reflected downwards and received by an observer at sea–shore. The observer sees an image (virtual) of the ship hanging in the sky.