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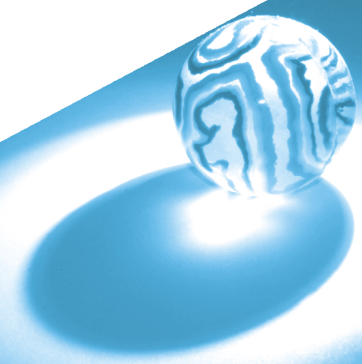
LIGHT : REFLECTION AND REFRACTION



CONTENTS

1.0 INTRODUCTION

Light is a form of energy. It is an indispensable tool to explore the colourful beauty of nature. The light itself is invisible, but we can see all the objects around us in presence of light. A small source of light casts a sharp shadow of an opaque object in its path. This is because the light travels along straight line path. We shall now study the details about the nature of light.

Nature of Light

Physics experiments over the past hundred years have demonstrated that light has a dual nature *i.e.*, light exhibits the properties of both waves and particles. There are two theories about the nature of light.

(a) Wave theory of light

(b) Particle theory of light

According to Wave theory, light consists of electro-magnetic waves which do not require a material medium (like solid, liquid or gas) for their propagation. According to Particle theory, light is composed of particles which propagate in a straight line at a very high speed. The elementary particle that defines light is called 'photon'.

Some of the phenomena of light can be explained only when light is considered as waves and others can be explained only when it is considered to be made up of particles. For example, the phenomena of interference, diffraction and polarization can be explained only when light is considered to be of wave nature. But, these phenomena cannot be explained by the particle theory of light. On the other hand, the phenomena of photoelectric effect can be explained only when light is considered to be made up of particles. The phenomena of reflection and refraction of light can be explained by both particle theory of light and wave theory of light. Thus, light has dual nature. We shall study further details about the nature of light in higher classes.

Terms Related to Light

The following terms are associated with light :

(a) Source ***(b) Medium*** ***(c) Ray***

(a) Source

A source is an object from which light is given out. It may be natural or man-made. For example, sun is the natural source of light whereas a candle, an electric lamp or an oil lamp are man-made sources of light.

The source of light can be classified into two types :

(i) **Luminous :** The objects which emits light are known as luminous objects. Examples – the Sun, the stars, lamp, candle etc.

(ii) **Non-luminous :** The object which does not emits light of its own are known as non-luminous objects. Examples : the Moon, a chair, a book etc.

(b) Medium

A medium is a substance through which light propagates.

There are three types of medium :

(i) **Opaque :** A medium through which light cannot propagate is called opaque medium. Examples – metal, wood etc.

(ii) **Transparent :** A medium through which light propagates easily is called transparent medium. Examples : air, water, glass etc.

(iii) **Translucent :** A medium through which light propagates partially is called translucent medium. Examples : paper, ground glass etc.

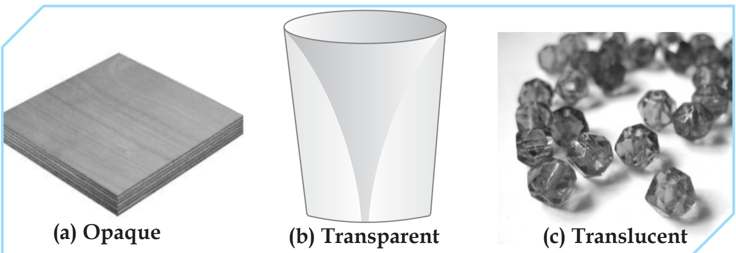


Fig. 1.1 : Different types of medium

(c) Ray

A ray is the straight line path along which light travels. It is represented by an arrow head on a straight line (Fig. 1.2). The arrow head represents the direction of propagation of light. A number of rays combine together to form a beam of light.

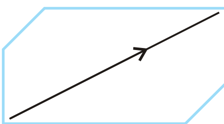


Fig. 1.2 : Ray

There are three types of rays :

(i) **Parallel beam :** When, all the rays of light travels parallel to one another. Then the collection of such rays is called parallel beam. The width of the parallel beam remains constant throughout (Fig. 1.3).

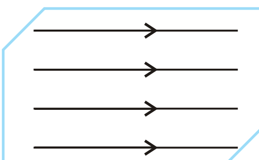


Fig. 1.3 : Parallel beam

(ii) **Convergent beam :** When, all the rays of light coming from a different direction meet at a particular point 'O'. Then the collection of such rays is called convergent beam.

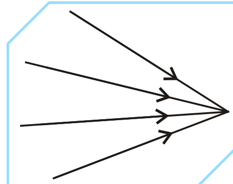


Fig. 1.4 : Convergent beam

The width of the conver-gent beam goes on decreasing as the rays proceed forward (Fig. 1.4).

(iii) **Divergent beam :** When, all the rays of light comes out from a point source 'S' and travel in various direction then the collection of such rays is called divergent beam. The width of the divergent beam goes on increasing as the rays proceed forward (Fig. 1.5).

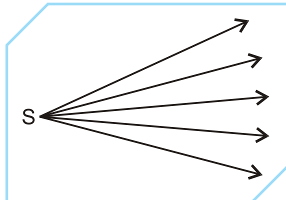


Fig. 1.5 : Divergent beam

1.1 REFLECTION OF LIGHT

When light falls on the surface of an object, some part of it is sent back. The process of returning (or sending back) the light to the same medium after striking a surface of an object, is called reflection of light. This can be explained as follows :

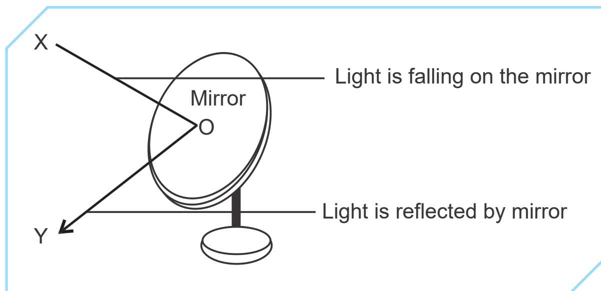


Fig. 1.6 : Reflection of light

When beam of light 'XO' falls on the mirror at a point 'O', it is sent back in the direction of 'OY' (Fig. 1.6). This shows that the mirror has reflected the beam of light falling on it. Most of the objects reflect light which falls on them. The objects having polished, shining surfaces reflects more light than objects having unpolished, dull surfaces. In reflection, the path of light rays changes without any change in the medium.

Types of Reflection

Based on the surface of the object, there are two types of reflection namely,

(a) Regular reflection *(b) Irregular reflection*

(a) Regular Reflection

When the reflecting surface is smooth like plane mirror or highly-polished, the parallel rays of light falling on it are reflected parallel to one another *i.e.*, the reflected ray goes in one particular direction. This type of reflection is known as regular reflection (Fig. 1.7). Images are formed by regular reflection of light.

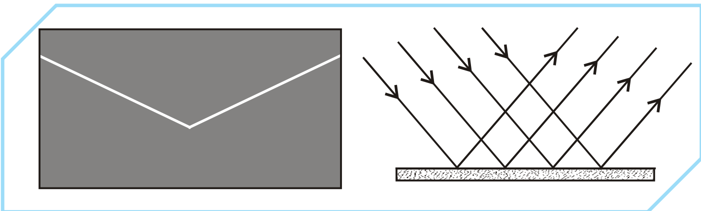


Fig. 1.7 : Regular reflection

For example, a highly polished metal surface and a still water surface also produce regular reflection of light and forms images.

(b) Irregular Reflection

When the reflecting surface is rough and dull, the parallel rays of light falling on it are reflected in different directions, then this type of reflection is called irregular reflection of light (Fig. 1.8).

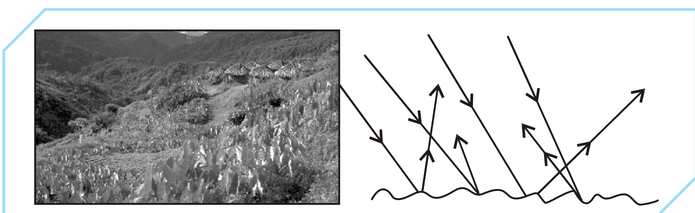


Fig. 1.8 : Irregular reflection

For example, a sheet of papers produces irregular reflection. In irregular reflection of light no image is formed.

Representation of a Plane Mirror

In the Fig. 1.9 below, a plane mirror is represented by a straight line having a number of short, oblique lines on one side. The plane side is the front side of the mirror where reflection of light takes place and the side having short, oblique lines represents the backside of the plane mirror. Silver coating is done on the backside of the plane mirror covered by red paint.

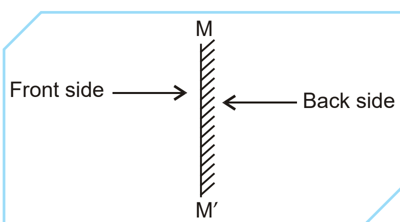


Fig. 1.9 : Plane mirror

Reflection of Light from Plane Surfaces

In order to understand the reflection of light from plane surfaces, (Fig. 1.10) it is necessary to understand the following terms :

(i) Incident Ray

The ray of light which falls on the mirror surface is called the incident ray. Thus, the incident ray shows the direction in which light falls on the mirror.

(ii) Point of Incidence

The point at which the incident ray falls on the mirror is called the point of incidence. Thus, the point of incidence is the point at which the incident ray touches the mirror surface.

(iii) Reflected Ray

The ray of light which is sent back by the mirror is called the reflected ray. Thus, the reflected ray shows the direction in which the light goes after reflection.

(iv) Normal

It is a line at right angle to the mirror surface at the point of incidence. Thus, normal is perpendicular to the mirror at the point of incidence. It is represented by a dotted line in order to distinguish it from the reflected ray and incident ray.

(v) Angle of Incidence

The angle made by the incident ray with the normal at the point of incidence is called the angle of incidence. It is denoted as '*i*'.

(vi) Angle of Reflection

The angle made by the reflected ray with the normal at the point of incidence is called the angle of reflection. It is denoted as '*r*'.

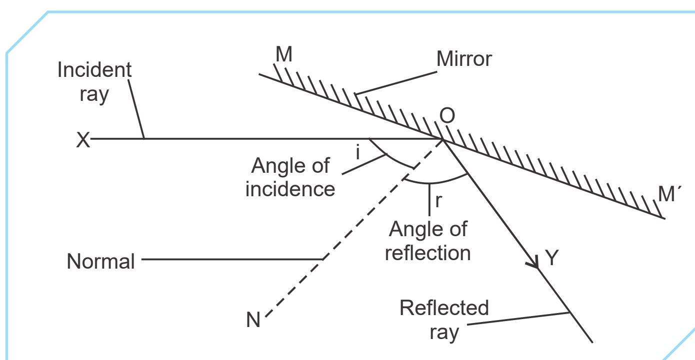


Fig. 1.10 : Reflection of light from a plane surface

Laws of Reflection of Light from Plane Surface

The reflection of light from a plane surface or from a spherical surface takes place according to two laws called the laws of reflection of light. The two laws of reflection of light are as follows :

First Law : According to this law, the incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.

In the Fig. 1.10, XO the incident ray, OY the reflected ray and ON the normal, all lie in the same plane of paper. They neither go down into paper nor come out of the paper.

Second Law : According to this law, the angle of incidence (i) is always equal to the angle of reflection (r), then

$$\angle i = \angle r$$

These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.

If a ray of light is incident normally on a mirror, then the angle of incidence i will be zero and so the angle of reflection r will also become zero according to the second law of reflection.

This shows that if a ray of light incident normally or perpendicularly on a mirror, it is reflected back along the same path. This is because, the angle of incidence as well as the angle of reflection is zero.

In the Fig. 1.11, if a ray of light falls on the plane mirror along the normal NO, then it will be reflected along the same path ON. Thus, the incident ray will be NO and the reflected ray will be ON.

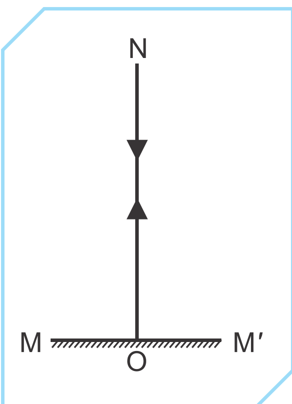


Fig. 1.11 : Incident ray and reflected ray
$\angle i = \angle r = 0°$

Activity 1.1–To compare the characteristics of the image on the two surfaces of spoon.

PROCEDURE

Step 1– Take a large shining spoon.

Step 2– Try to view your face in its curved surface.

Step 3– Do you get the image?

Step 4– Is it smaller or larger?

Step 5– Move the spoon slowly away from your face. Observe the image.

Step 6– How does it change?

Step 7– Reverse the spoon and repeat the activity.

Step 8– How does the image look like now?

Step 9– Compare the characteristics of the image on the two surfaces.

OBSERVATION

(a) Yes, we get the image of our face.

(b) Larger image.

(c) When we move the spoon slowly away from our face, the following observation is made :

As we move the spoon away from our face, the size of image reduces and finally get diminished. The image continues to be real and inverted.

(d) When we reverse the spoon, the curved part is bulged out.

(e) The image of our face is virtual, erect and diminished.

(f) When the spoon is moved away from our face, the image moves away and continues to be virtual, erect and finally it gets diminished to point size.

CONCLUSION

When we see our image in curved surface of spoon the image of our face is real and inverted. But when we see our image in bulged surface of spoon the image of our face is virtual and erect.

Objects and Images

In the study of light, the term 'object' refers to anything which gives out light rays either its own or reflected by it. Examples : a candle, a bulb, a tree etc. The object can be of two types :

(a) Very small objects are called point objects.

(b) Very large objects are called extended objects.

In ray-diagram, the point objects are represented by a 'dot' while the extended objects are represented by "an arrow pointing upwards".

Now let us discuss about the image.

Image is an optical appearance produced when light rays coming from an object are reflected from a mirror (or refracted through a lens)

When we look into a mirror, we see our face. In this case, 'our face' is the 'object' and what we see in the mirror is the 'image'. The image of our face appears to be situated behind the mirror. An image is formed when the light rays coming from an object meet (or appears to meet) at a point, after reflection from a mirror (or refraction through a lens). The images are of two types :

(a) Real images ***(b) Virtual images***

(a) Real Images

The image which can be obtained on a screen is called a real image. Example : In a cinema hall, we see the images of actors and actress on the cinema screen. The real image can be formed on the screen because the light rays actually pass through a real image. The real image can be formed by a concave mirror and a convex lens. Thus, it can be concluded that a real image is formed when light rays coming from an object actually meet at a point after reflection from a mirror or refraction through lens.

(b) Virtual Images

The image which cannot be obtained on a screen is called a virtual image. Example : The image of our face formed by a plane mirror cannot be obtained on the screen. The virtual images are also called as unreal images. The virtual images can be formed by a plane mirror, a convex mirror and a concave lens. A concave mirror and a convex lens form a virtual image only when the object is kept within its focus. Thus, it can be concluded that a virtual image is formed when light rays coming from an object only appears to meet at a point when produced backwards after reflection from a mirror or refraction through lens.

Image Formed in a Plane Mirror

We know that an object gives out a number of light rays in all the directions. But only two light rays coming from the object are used to show the formation of image to keep the ray–diagram simple. In the ray–diagram, the real rays of light are represented by 'solid lines' whereas the virtual rays of light are represented by 'dotted lines'. Similarly the real rays of light can exist only in front of the mirror whereas the virtual rays of light exists or shown behind the mirror or just appear to be coming from behind the mirror.

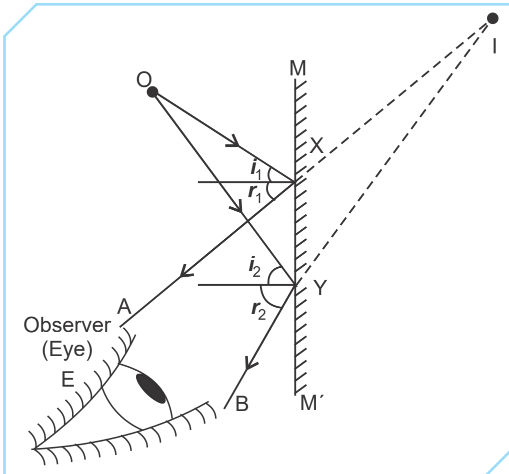


Fig. 1.12 : Formation of image in a plane mirror

In the Fig. 1.12, let 'O' be a small object placed in front of a plane mirror MM' and 'I' be the image formed. Now rays of light 'OX' and 'OY' are coming from the object. The ray 'OX' incident on the plane mirror at 'X' and gets reflected in the direction 'XA' making the angle of reflection r_1 equal to the angle of incidence i_1. Another ray 'OY' incident on the plane mirror at 'Y' and gets reflected in the direction 'YB' making the angle of reflection r_2 equal to angle of incidence i_2.

The two reflected rays 'XA' and 'YB' move away from each other. So they cannot meet on left side. When they are produced backwards in dotted line as shown in the Fig. 1.12, they meet at a point 'I' behind the mirror. When the reflected rays are seen by a person at position E, it looks as if they are coming from the point 'I' behind the mirror. Thus, the point 'I' is the image of the object 'O' formed by a plane mirror. It can be concluded that if our face is at position 'O' in front of the plane mirror, then we will see the image of our face in the mirror at point 'I'.

Note

- The image formed by a plane mirror can be seen only on looking into the mirror, as the light rays do not actually pass through the point 'I', they appear so.

Image of an Extended or Finite Object

We know that an extended object is made up of a very large number of point objects. So, the image will be a collection of the image points corresponding to various points of the object. Now, let us see how a plane mirror forms the image of an extended object.

When an extended object AB is placed in front of a plane mirror MM′, the following steps should be done to find the position of images (Fig. 1.13) :

Step 1– Draw an incident ray 'AX' perpendicular to the mirror. This ray will get reflected back along the same path. So 'XA' is the reflected ray.

Step 2– Draw another incident ray 'AO' striking the mirror at point 'O'. This ray will get reflected along 'OE' making an angle of reflection r_1 equal to the angle of incidence i_1. Thus, OE is the second reflected ray.

Step 3– These two reflected rays XA and OE are produced backwards by dotted lines to meet at point A′.

Step 4– A′ is the virtual image of the top point A of the object.

Step 5– Similarly, draw an incident ray 'BY' perpendicular to the mirror. This ray will get reflected back along the same path. Thus, 'YB' is the reflected ray.

Step 6– Draw another incident ray BO′ striking the mirror at point O′. This ray will get reflected along O′E′, making an angle of reflection r_2 equal to the angle of incidence i_2. So we have reflected ray O′E′.

Step 7– The two reflected rays YB and O′B′ are produced backwards by dotted lines to meet at point B′.

Step 8– The B′ is the virtual image of the bottom point B of the object.

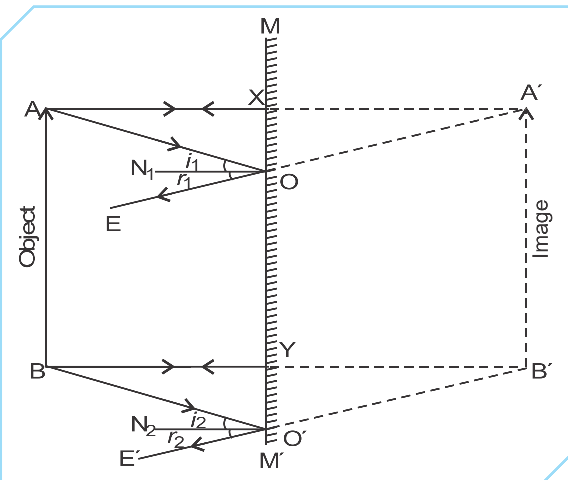


Fig. 1.13 : Image formation of an extended or finite object

In this way, A′B′ becomes the complete image of the object AB formed by the plane mirror. This gives the nature of the image as virtual and erect (direction of image is same as that of object) and the size of the image formed by a plane mirror is equal to that of the object. The image formed in a plane mirror is at the same distance behind the mirror as the object is in front of the mirror.

Lateral Inversion

When we stand in front of a plane mirror, the right side of our body becomes the left side in the image and the left side of our body becomes the right side in the image (Fig. 1.14).

Fig. 1.14 : Our left hand appears to be right hand in the mirror image

This effect of reversing the sides of an object in its image is called lateral inversion. Thus, the image formed in a plane mirror is laterally inverted. This phenomenon will become clear from the following example.

In hospital vans, the word 'AMBULANCE' is written in its mirror image forms as 'ƎƆNAJUBMA' (Fig. 1.15).

Fig. 1.15 : Way of writing Ambulance on the vehicle is an example of lateral inversion

This is because, when we are driving our car and see the hospital van coming from behind in our rear-view mirror, then we would be able to read the laterally inverted image as 'AMBULANCE' and pave way for the van quickly.

Characteristics of Image Formed by the Plane Mirror

The characteristics of image formed by the plane mirrors can be concluded as follows :

(a) The image of an object is always virtual which cannot be caught on the screen.

(b) The image formed in a plane mirror is always erect.

(c) The distance of the image in a plane mirror is as far behind the mirror as the object is in front of the mirror.

(d) The image formed in a plane mirror is laterally inverted.

Uses of Plane Mirror

The plane mirror (Fig. 1.16) is used in :

(a) Bathrooms and dressing tables.

(b) Jewellery shops to make the shop look bigger.

(c) Making periscopes.

Fig. 1.16 : Uses of plane mirror

PAPER - PEN TEST : 1

1. What is light ?
2. State the laws of reflection.
3. Define the following terms : (a) Lateral inversion, (b) Angle of incidence, (c) Angle of reflection, (d) Normal, (e) Incident ray.
4. What are the characteristics of the image formed by a plane mirror ?
5. By giving suitable examples, explain lateral inversion.
6. If a ray of light is incident on a plane mirror at an angle of 30°, then what is the angle of reflection ?
7. Is light visible to you ?
8. How the word 'AMBULANCE' is printed in front of the hospital vans ? Why ?
9. What will be the angle of incidence and angle of reflection if a ray of light is incident normally on a plane mirror ?
10. What will happen to the light which falls on a surface of an object ?
11. What is the nature of light ?
12. Name the following :
    (a) The image formed on a cinema screen.
    (b) The phenomenon in which the right side of an object appears to be left side of the image in a plane mirror.
    (c) The image formed by the actual meeting of reflected rays.
13. Explain the different types of sources of light with an example for each ?
14. Draw a diagram to show how a plane mirror forms an image of a point source of light in front of it.
15. What are the different types of reflection ? Explain with a neat sketch.
16. How would you differentiate between virtual and real images ?
17. If the letter R is placed in front of a plane mirror,
    (a) How would its image look like when it is seen in mirror ?
    (b) What is this phenomenon called ? Define.

Let us now discuss the reflection of light from spherical surface which can converge or diverge the parallel rays falling on them.

Reflection of Light from Curved Surface

Spherical Mirrors

The spherical mirrors have a curved surface therefore, they are also known as curved mirrors. The reflecting surface of a spherical mirror is curved inwards or outwards. A spherical mirror is that mirror whose reflecting surface is a part of a hollow sphere of glass. One side of the spherical mirror is well polished and reflecting and the other side of the spherical mirror is opaque. There are two types of spherical mirrors namely,

(i) Concave Mirror *(ii) Convex Mirror*

(i) Concave Mirror

The spherical mirror in which reflecting surface is curved outwards *i.e.* towards the centre of the sphere is called concave mirror. In other words, the spherical mirror in which the reflection of light takes place at a bent surface (concave surface) is called concave mirror. The other surface of the concave spherical mirror is opaque and non-reflecting. In the concave mirror as shown in the Fig. 1.17 below, the surface A is reflecting surface while the surface B is non-reflecting surface. An example of concave mirror in our daily use is the inner surface of a stainless spoon.

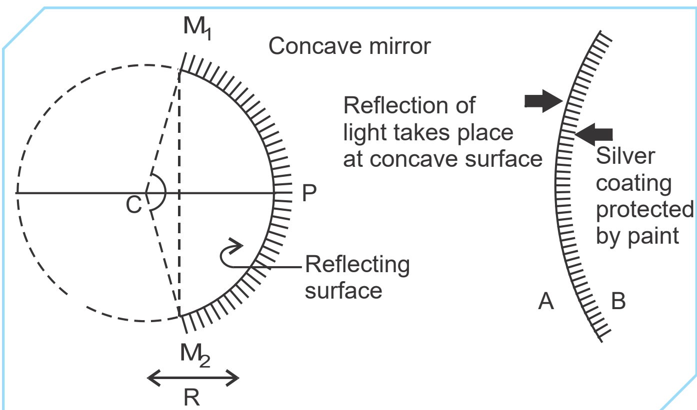


Fig. 1.17 : Concave mirror

(ii) Convex Mirror

The spherical mirror in which reflecting surface is curved inwards *i.e.* away from the centre of the sphere is called convex mirror. In other words, the spherical mirror in which the reflection of light takes place at the bulging surface (convex surface) is called convex mirror. The other surface of the convex spherical mirror is opaque and non-reflecting. In the convex mirror shown in the Fig. 1.18 below, the surface B is reflecting surface while the surface A is non-reflecting surface. An example of convex mirror in our daily use is the outer surface of a steel spoon.

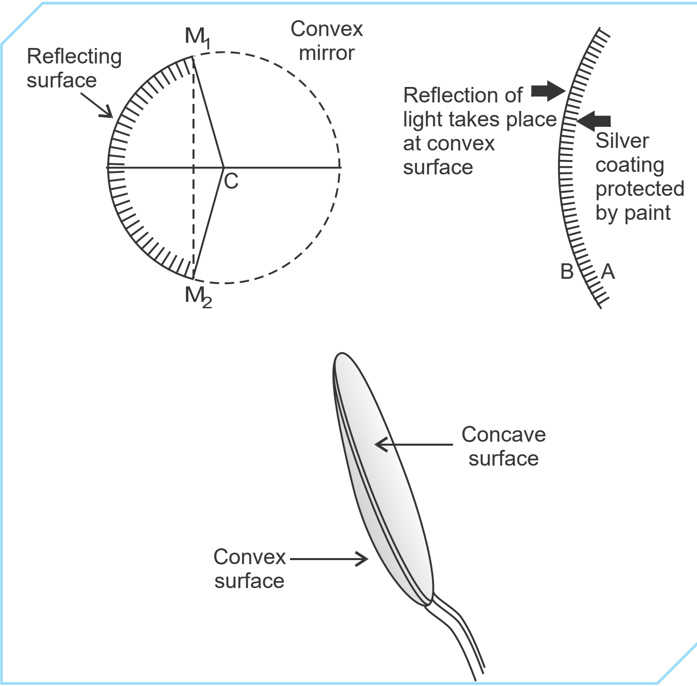


Fig. 1.18 : Convex Mirror

Terms Related to Spherical Mirror

We shall now discuss some of the important terms related to spherical mirror in order to understand the concept of spherical mirror better.

(i) Centre of Curvature

The centre of curvature of a spherical mirror is the centre of the hollow sphere of glass of which the spherical mirror is a part. The centre of curvature is denoted by the letter 'C'. In the Fig. 1.19(a), the 'C' represents centre of curvature of concave mirror and in the Fig. 1.19 (b) the 'C' represents centre of curvature of convex mirror. The centre of curvature is not a part of the mirror. It lies outside its reflecting surface. In the concave mirror, the centre of curvature lies in front of the mirror *i.e.*, the reflecting surface is towards the centre of curvature whereas in the convex mirror, the centre of curvature is behind the mirror *i.e.*, the reflecting surface is on the opposite side of the convex mirror.

(ii) Pole

The pole is the centre of the spherical mirror or the middle point of a spherical mirror. The pole is denoted by the letter 'P'. In the Fig. 1.19(a), the 'P' represents the pole of concave mirror and in the Fig. 1.19(b); the 'P' represents the pole of convex mirror. The pole of a spherical mirror lies on the surface of the mirror.

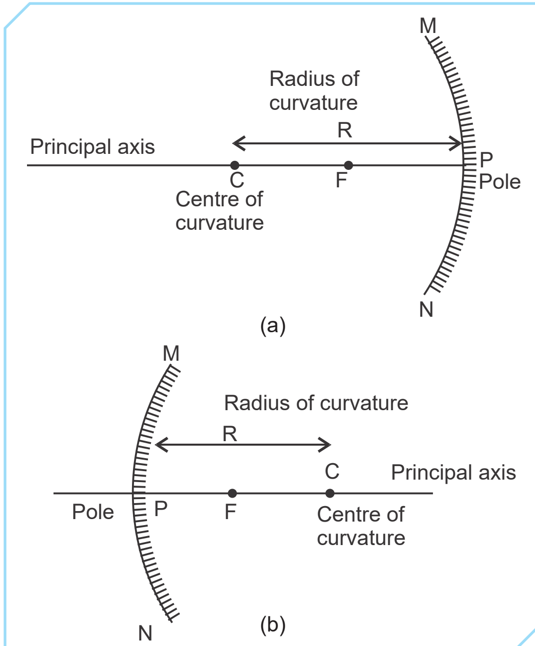


Fig. 1.19 : (a) Various terms related to concave mirror
(b) Various terms related to convex mirror

(iii) Radius of Curvature

The radius of curvature is the radius of the hollow sphere of glass of which mirror is a part. The radius of curvature is denoted by the letter 'R'. In the Fig. 1.19(a), the distance between centre of curvature C and pole of the mirror P represent the radius of curvature of concave mirror and in the Fig. 1.19(b), the distance between centre of curvature C and pole of the mirror P represent the radius of curvature of convex mirror.

(iv) Principal Axis

The principal axis is the straight line passing through the centre of curvature C and pole of the spherical mirror P produced on both sides. The principal axis is normal or perpendicular to the mirror at its pole. In the Fig. 1.19(a), the line passing through the centre of curvature C and pole of the mirror P represent the principal axis of concave mirror and in the Fig. 1.19(b), the line passing through the centre of curvature C and pole of the mirror P represent the principal axis of convex mirror.

(v) Aperture

The part of a mirror from which the reflection of light actually takes place is called the aperture of the mirror. In the Fig. 1.19(a), the distance MN represents aperture of concave mirror and in the Fig. 1.19(b), the distance MN represents aperture of convex mirror.

Principal Focus and Focal Length of a Concave Mirror

The principal focus of a concave mirror is a point on the principal axis at which all the rays of light parallel to the principal axis converge after reflection from concave mirror (Fig. 1.20). Hence, we can say that the principal focus of a concave mirror is a real point which always lies in front of the concave mirror. The principal focus of a concave mirror is denoted by the letter 'F'. Since concave mirror converge the parallel beam of light falling on it, it is also called a converging mirror. The Fig. 1.20 shows the parallel rays falling on the concave mirror are getting reflected and meeting at point focus F on the principal axis.

The focal length of a concave mirror is the distance between the pole P and the principal focus F of the concave mirror. The focal length of a concave mirror is denoted by the letter '*f*'.

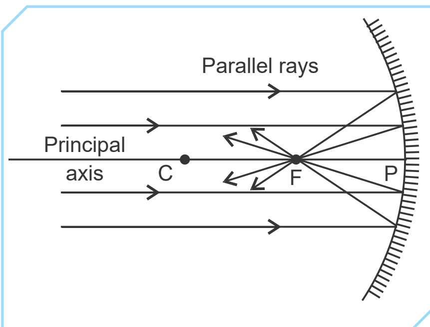


Fig. 1.20 : Principal focus of a concave mirror

Activity 1.2–To determine the Principal focus of a concave mirror

PROCEDURE

Step 1– Hold a concave mirror in your hand and direct its reflecting surface towards the Sun (Fig. 1.21).

Step 2– Direct the light reflected by the mirror on to a sheet of paper held close to the mirror.

Step 3– Move the sheet of paper back and forth gradually until you find on the paper sheet a bright, sharp spot of light.

Step 4– Hold the mirror and the paper in the same position for few minutes.

Step 5– What do you observe?

Step 6– Why?

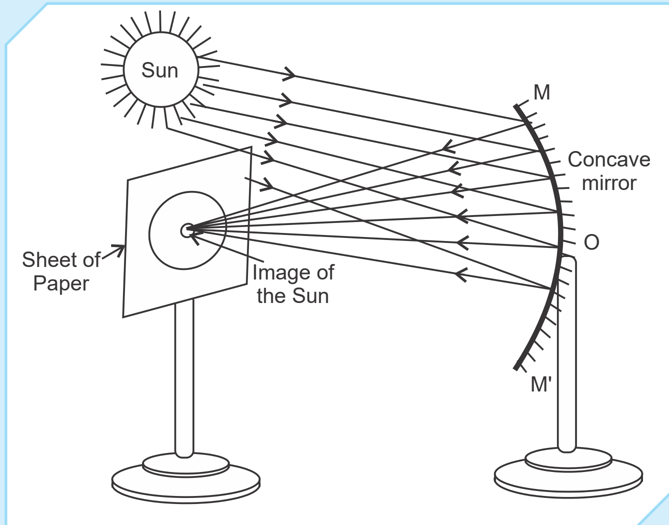


Fig. 1.21 : Image of sun formed by the concave mirror

OBSERVATION

(a) When the sheet of paper is moved back and forth gradually, a bright, sharp spot of light is observed on the paper. This spot is real, point size image of the sun at the focus of the concave mirror.

(b) Holding the mirror and the paper for few minutes in same position, the paper may produce little smoke or burn out.

CONCLUSION

Hence, the focus of the concave mirror is that point at which the image of the sun is formed.

Principal Focus and Focal Length of a Convex Mirror

The principal focus of a convex mirror is a point on its principal axis from which a beam of light rays, initially parallel to the axis, appears to diverge after being reflected from the convex mirror (Fig. 1.22). Hence, we can say that the principal focus of a convex mirror is a virtual point which always lies behind the convex mirror. The principal focus of a convex mirror is denoted by the letter 'F'. Since convex mirror diverge the parallel beam of light falling on it, it is also called a diverging mirror. The Fig. 1.22 shows the parallel rays falling on the convex mirror getting reflected and meeting at point focus F on the principal axis.

The focal length of a convex mirror is the distance between the pole P and the principal focus F of the convex mirror. The focal length of a convex mirror is denoted by the letter '*f*'.

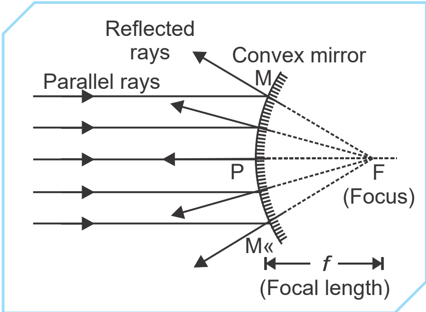


Fig. 1.22 : Convex mirror diverges a beam of light

Relation between Radius of Curvature R and Focal Length of a Spherical Mirror *f*

The focal length of a spherical mirror is equal to half of its radius of curvature *i.e.*, in both concave and convex mirrors, the principal focus F lies at the centre of line joining the pole P of the mirror and centre of curvature C of the mirror.

If 'R' is the radius of the curvature and '*f*' is the focal length of the spherical mirror (convex or concave), then

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

PAPER - PEN TEST : 2

1. Define a spherical mirror.
2. Define the following terms with suitable diagram :
   (a) Aperture (b) Radius of curvature
3. Differentiate between Concave and Convex mirror.
4. Draw a neat labelled sketch showing a convex mirror diverging parallel beam of light rays.
5. Give the relationship between focal length and radius of curvature of a spherical mirror.
6. Out of convex and concave mirror, whose focus is situated in front of the mirror.
7. Define the following terms with suitable diagram :
   (a) Pole (b) Principal axis
   (c) Centre of curvature
8. Draw a neat labelled sketch showing a concave mirror converging parallel beam of light rays.
9. If the focal length of a convex mirror is 18 cm, what is its radius of curvature.
10. Explain an activity to understand the terms related to mirrors.

1.2 RULES FOR TRACING IMAGES FORMED BY CONCAVE MIRRORS

When an object is placed in front of a concave mirror its image is formed at that point where atleast two reflected rays of light meet (or appears to meet).

To obtain the images formed by the concave mirror, the following rules are used.

(a) Rule 1

A ray of light falling on the concave mirror, parallel to principal axis, passes through the principal focus of the mirror after reflection (Fig. 1.23).

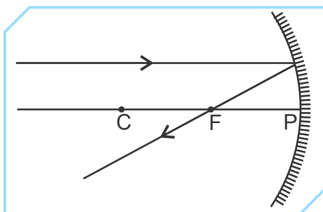


Fig. 1.23

(b) Rule 2

A ray of light passing through centre of curvature of a concave mirror is reflected back along the same path (Fig. 1.24).

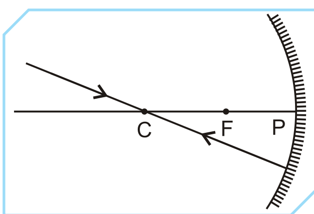


Fig. 1.24

(c) Rule 3

A ray of light passing through focus of a concave mirror becomes parallel to principal axis after reflection (Fig. 1.25).

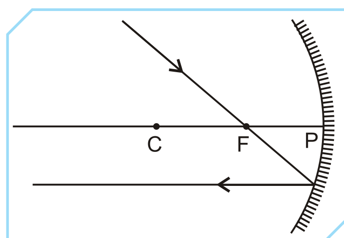


Fig. 1.25

(d) Rule 4

A ray of light incident obliquely at the pole of a concave mirror is reflected obliquely as per laws of reflection (Fig. 1.26).

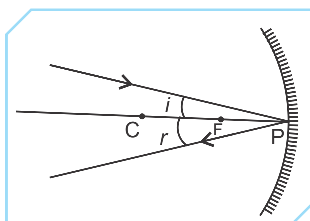


Fig. 1.26

Note

- If a ray of light passes through the centre of curvature of a concave mirror then it is reflected back along the same path. This is because, the ray of light strikes the concave mirror at right angles (90°) to its surface. Thus, the angle of incidence and angle of reflection will be zero.

1.3. IMAGE FORMED BY A CONCAVE MIRROR IN DIFFERENT POSITIONS OF THE OBJECT

The image formed by a concave mirror depends on the position of the object in front of the mirror. We can place the object at various positions from a concave mirror to get different types of images. For example,

(a) Object is at infinity.

(b) Object is at beyond the centre of curvature of a concave mirror.

(c) Object placed at the centre of curvature of a concave mirror.

(d) Object placed between the centre of curvature and focus of a concave mirror.

(e) Object placed at the focus of a concave mirror.

(f) Object kept between the focus and the pole of a concave mirror.

Let us now discuss above cases briefly.

Position 1 : Object is at infinity

In the ray diagram (Fig. 1.27), the object is at a very large distance say at infinity 'A'. Since the object is at a very far distance in front of concave mirror, it cannot be shown in the ray diagram. When two rays from 'A' parallel to each other and inclined at an angle to principle axis, falls on the mirror MN, these rays gets reflected at 'DA' and PA' respectively and meets at a point A' which is the real image of point 'A' of the object. From A', when a perpendicular is drawn to the principal axis of the mirror, we get the image of an object 'AB' at infinity as 'AB'.

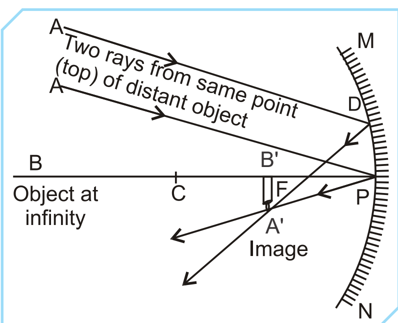


Fig. 1.27 : Ray diagram of image formation when an object is kept at infinity.

Thus, we can conclude that when an object is at infinity, its image will be :

(a) Real and inverted

(b) Much smaller than the object (or highly diminished)

(c) Formed at focus

Position 2 : Object is kept beyond the centre of curvature of a concave mirror

In the ray diagram (Fig. 1.28), the object AB is placed beyond the centre of curvature C of the concave mirror MN perpendicular to the principal axis. When a ray of light from A falls on the mirror along AD parallel

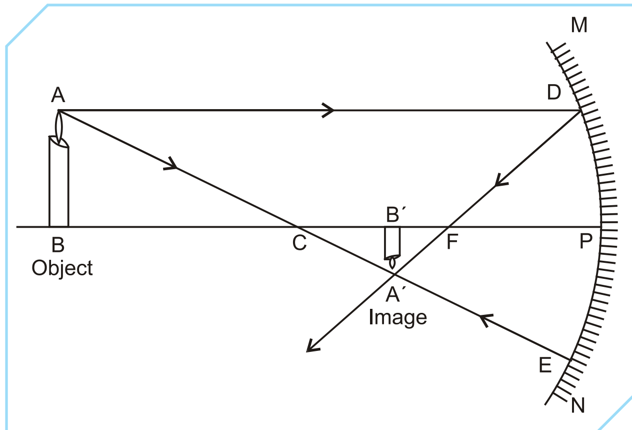


Fig. 1.28 : Ray diagram of image formation when an object is kept beyond the centre of curvature of a concave mirror.

to principal axis, it passes through the focus F of the concave mirror after reflection. Now, when another ray from A falls on the mirror along AE passes through the centre of curvature C of the mirror, it retraces its own path after reflection. The two reflected rays DF and EC meets at A' and is the real image of point A. Drawing a perpendicular to the principal axis of the mirror, we get A'B' as the real image of AB.

Thus, we can conclude that when an object is placed beyond the centre of curvature of a concave mirror, its image will be :

(a) Real and inverted

(b) Smaller in size or diminished

(c) Formed between the focus F and the centre of curvature C of the mirror

Position 3 : Object is placed at the centre of curvature of a concave mirror

In the ray diagram (Fig. 1.29) the object 'AB' is placed at the centre of curvature 'C' of a concave mirror 'MN'. When a ray of light from 'A' falls on the mirror in a direction parallel to the principal axis of the mirror, it gets reflected at 'D' and passes through focus 'F' of the concave mirror, giving us the reflected ray 'DF'. Now, when another ray from 'A' passes through focus 'F' of the concave mirror, it travels along EA′ parallel to the principal axis. The two reflected rays intersect at A′ which is the real image of point 'A' of the object. Thus, A′B′ is the real image of 'AB'.

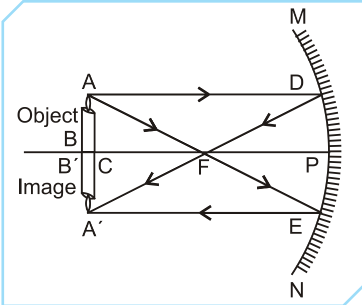


Fig. 1.29 : Ray diagram of image formation when an object is kept at centre of curvature of a concave mirror.

Therefore, we can conclude that when an object is placed at the centre of curvature 'C' of a concave mirror, its image will be :

(a) Real and inverted

(b) Same size as that of object

(c) Formed at the centre of curvature

Position 4 : Object is kept between the centre of curvature and the focus of a concave mirror

In the ray diagram (Fig. 1.30) the object AB is placed between the centre of curvature C and focus F of the concave mirror MN perpendicular to the principal axis. When a ray of light 'AD' from A falls on the mirror along

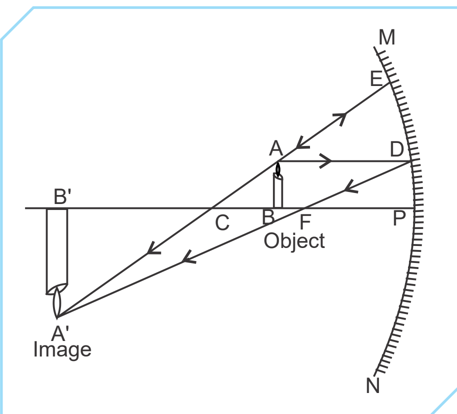


Fig. 1.30 : Ray diagram of image formation when an object is kept between the centre of curvature and focus of a concave mirror.

parallel to the principal axis of the mirror, it gets reflected at D and passes through the focus F of the concave mirror giving us the reflected ray DA′. Now, when another ray from A falls on the mirror along AE passes through the centre of curvature C of the mirror after reflection, it retraces its own path after reflection. The two rays EA and DF meets at A′ and forms the real image A′ of object A. Drawing perpendicular to the principal axis of the mirror, we get A′B′ as the real image of object AB.

Thus, we can conclude that when an object lies between the centre of curvature C and focus F of a concave mirror, its image will be :

(a) Real and inverted

(b) Larger in size than the object (or magnified)

(c) Formed beyond centre of curvature C

Position 5 : Object is placed at the focus of a concave mirror

In the ray diagram (Fig. 1.31), the object 'AB' is placed at the focus 'F' of a concave mirror 'MN' perpendicular to the principal axis. When a ray of light from 'A' falls on the mirror in a direction parallel to the principal axis,

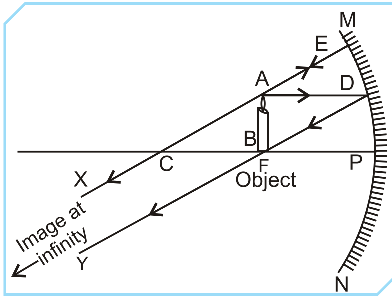


Fig. 1.31 : Ray diagram of image formation when an object is kept at focus of a concave mirror.

it gets reflected at 'D' and passes through the focus 'F' of the mirror forming reflected ray 'DY'. Now, when another ray of light from 'A' falls on the mirror at 'E', it passes through the centre of curvature 'C' of the mirror. This ray retraces its path on reflection giving us the reflected ray 'EX'. The two reflected rays 'AX' and 'BY' are parallel to each other and will intersect or meet at a very off point at infinity. Thus, the image cannot be shown in the ray diagram. But when we put a screen in the path of reflected rays, the image will be shown on the screen.

Thus, we can conclude that when an object is placed at the focus 'F' of a concave mirror, its image will be

(a) Real and inverted

(b) Highly enlarged or magnified

(c) Formed at infinity

Position 6 : Object is kept between the focus and the pole of a concave mirror

In the ray diagram (Fig. 1.32), the object AB is placed between the focus F and the pole P of a concave mirror

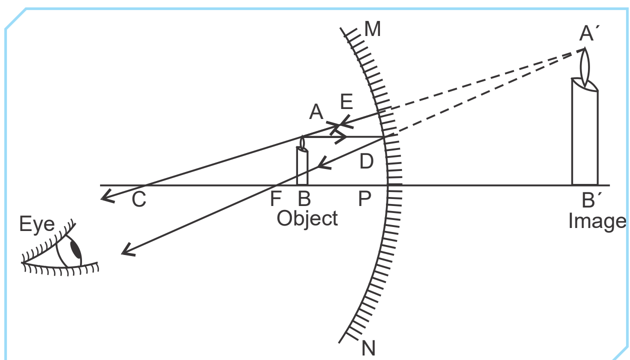


Fig. 1.32 : Ray diagram of image formation when an object is kept between the focus and the pole of a concave mirror.

MN perpendicular to the principal axis. When a ray of light 'AD' from A falls on the mirror parallel to principal axis, it passes through the focus F of the concave mirror after reflection from the concave mirror, giving us the reflected ray DF. Now, when another ray of light from A falls on the mirror along AE it passes through the centre of curvature C of the mirror and retraces its own path after reflection. The two reflected rays EC and DF diverges therefore, do not intersect each other on left side of concave mirror. But when these rays are produced back as shown by the dotted lines, they appear to come from a point A′. Therefore A′ is the virtual image of A.

Drawing a perpendicular to the principal axis of the mirror, we get A′B′ as the virtual image of AB.

Thus, we can conclude that when an object is placed between the focus F and the pole P of a concave mirror, its image will be :

(a) Virtual and erect

(b) Larger than the size of the object (or magnified)

(c) Formed behind the mirror

Summary of the images formed by a concave mirror for different positions of object

S. No.	Position of the Object	Position of the Image	Size of the Image	Nature of the Image
1.	At infinity	At focus	Highly diminished	Real and inverted
2.	Beyond C	Between F and C	Diminished	Real and inverted
3.	At C	At the centre of curvature	Same size as that of object	Real and inverted
4.	Between C and F	Beyond centre of curvature C	Enlarged	Real and inverted
5.	At F	At infinity	Highly enlarged	Real and inverted
6.	Between F and P	Behind the mirror	Enlarged	Virtual and erect

Measuring the Focal Length of a Concave Mirror

It is the fact that "when an object is at infinity from a concave mirror, its image is formed at the focus of the concave mirror, which can be used to measure the focal length of a concave mirror approximately".

The focal length of a concave mirror can be measured as follows :

Take a meter scale and hold it horizontally with its zero ends resting against a wall. Now, holding the concave mirror vertically on the meter scale, move the mirror till a clear, sharp image of a distant object like a window or a tree is formed on the screen. The sharp image of distant object will be formed at focus of the concave mirror. So the distance of screen from the concave mirror gives the approximate value of the focal length of a concave mirror (Fig. 1.33).

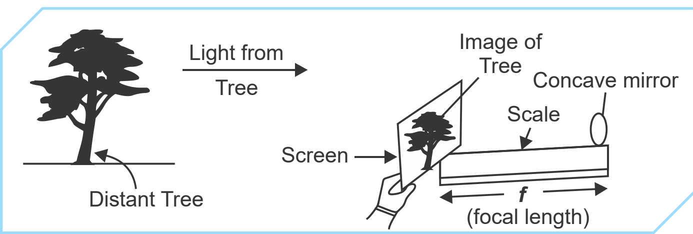


Fig. 1.33 : Arrangement for measuring focal length of a concave mirror

Uses of Concave Mirror

There are some applications of concave mirror (Fig. 1.34) as follows :

(a) The concave mirrors are used in reflecting telescopes.

(b) The concave mirrors are used to observe large images of the teeth of patients by dentists.

When a tooth is within focus of a concave mirror, a magnified image of the tooth is seen in the concave mirror. This helps the doctors to locate the defect in the tooth.

(c) A concave mirror is used as a reflector in torches, head lights of motor vehicles etc., to get powerful parallel beam of light.

When a bulb is placed at the focus of a concave reflector, it produces a bright beam of parallel light rays which helps us to see things in the darkness of night.

(d) A concave mirror is used as a make-up and shaving mirror as it can form erect and magnified image of the face.

When the face is held within the focus of a concave mirror, then an enlarged image of the face is seen in the concave mirror.

(e) The concave mirrors are used to concentrate sunlight to produce heat in solar devices etc.

(f) A concave mirror is used as doctor's head mirror to focus light coming from an object on the body parts like eyes, ears, nose etc., for examining.

Fig. 1.34 : Concave mirror is used for various purposes like, to observe large images of the teeth of patients by dentists, make-up and shaving mirror.

PAPER–PEN TEST : 3

1. Explain the nature of the image when an object is placed between the focus and the pole of a concave mirror.
2. Give any three uses of concave mirror.
3. Explain the nature of the image when an object is placed between the centre of curvature and focus of a concave mirror.
4. How do you measure the focal length of a concave mirror approximately ? Draw necessary ray diagram.
5. Explain the nature of the image when an object is placed beyond the centre of curvature of a concave mirror.
6. What are the possible positions of the object for which we can obtain the image formation by concave mirror ?
7. Explain the nature of the image when an object is placed at the focus of a concave mirror.
8. With the help of labelled ray diagram, explain the rules for tracing images formed by concave mirror.
9. Explain the nature of the image when an object is placed at the centre of curvature of a concave mirror.
10. Draw the ray diagram with respect to concave mirror when the object is placed
    (a) At infinity
    (b) Beyond the centre of curvature
    (c) At the centre of curvature
    (d) Between the centre of curvature and focus
    (e) At the focus

1.4 RULES FOR TRACING IMAGES FORMED BY CONVEX MIRRORS

To find out the position, nature and size of the images formed by a convex mirror, we should remember the paths of the following rays of light.

(a) Rule 1

A ray of light falling on the convex mirror, going fowards its focus becomes parallel to the principal axis after reflection from the mirror Fig. 1.35.

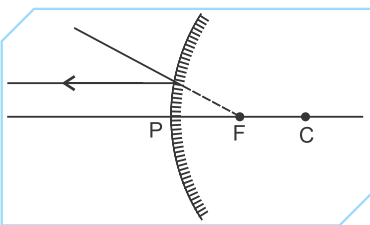


Fig. 1.35

(b) Rule 2

A ray of light going towards the centre of curvature of a convex mirror is reflected back along the same path Fig. 1.36.

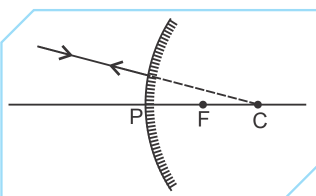


Fig. 1.36

(c) Rule 3

A ray of light going towards the focus of a convex mirror becomes parallel to the principal axis after reflection Fig. 1.37.

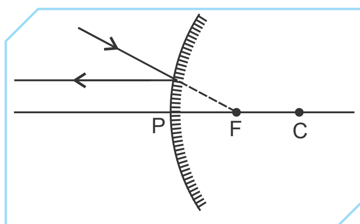


Fig. 1.37

(d) Rule 4

A ray of light which is incident at the pole of a convex mirror is reflected back making the same angle with the principal axis Fig. 1.38.

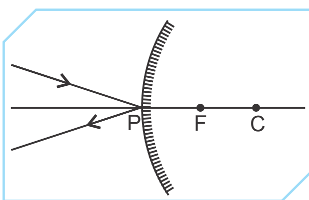


Fig. 1.38

Note

- Since a convex mirror has its focus and centre of curvature behind it, no real rays of light can go behind the convex mirror. Hence all the rays shown behind the convex mirror are virtual and are thus represented by dotted lines.
- Whatever be the position of the object in front of a convex mirror, the image formed by a convex mirror is always behind the mirror and thus the image will be erect, virtual and smaller than the object.

1.5 IMAGE FORMED BY A CONVEX MIRROR IN DIFFERENT POSITIONS OF OBJECT

The image formed by a convex mirror depends on the position of the object in front of the mirror. To find out size, nature, position of image formed by a convex mirror we placed object at.

(a) Infinity

(b) Anywhere between pole P and infinity

Position 1 : Object is kept at Infinity

In the ray diagram (Fig. 1.39), the object AB is at a very, large distance say at infinity. Since the object is at very far distance, it cannot be shown in the ray diagram. The two rays from A, AP and AQ parallel to each other,

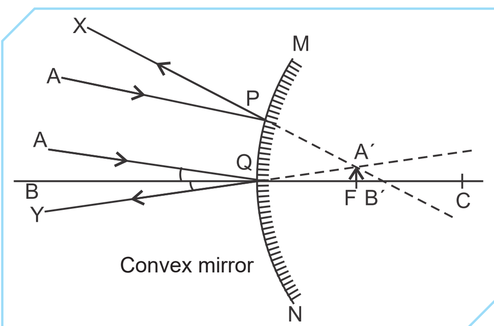


Fig. 1.39 : Ray diagram of image formation when an object is kept at infinity.

but are inclined to principal axis at an angle, the ray AP gets reflected as PX and the ray AQ gets reflected as QY. When these two reflected rays PX and QY are produced backwards by the dotted line, they meet at A′ at focus of convex mirror. Thus A′ is the virtual image of object A. Drawing a perpendicular to the principal axis of the mirror MN, we get A′B′ as the virtual image of AB.

Thus, we can conclude that when an object is at infinity, its image will be :

(a) Virtual and erect

(b) Highly diminished

(c) Formed behind the mirror at focus

Position 2 : Object is kept between infinity and pole

In the ray diagram (Fig. 1.40) , the object AB is placed anywhere between infinity and pole of a convex mirror MN. When a ray of light from A falls on the mirror along AX in the direction parallel to the principal axis of the convex mirror, it gets reflected along XY.

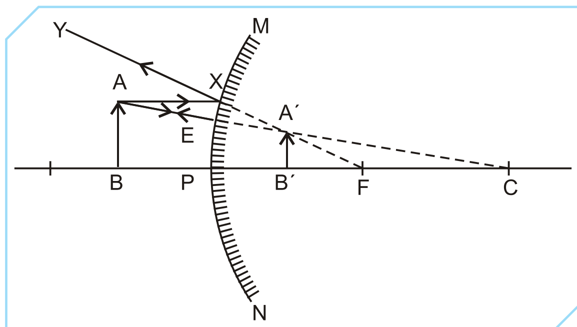


Fig. 1.40 : Ray diagram of image formation when an object is kept in front of pole P of a convex mirror.

Now, according to first rule of image formation by convex mirror, when a ray of light coming parallel to the principal axis of a convex mirror, it appears to be coming from its focus after reflection from the convex mirror. So reflected ray XY appears to be coming from focus F of the convex mirror. Now, another ray of light from A falls on the mirror along AE, towards the centre of curvature C of the convex mirror, retraces its path of reflection at E. When we produce the reflected ray EA backwards the reflected ray EA appears to be coming from centre of curvature C, of the convex mirror. The two reflected ray XY and EA meets at A′ which is the virtual image of object A. When a perpendicular from A′ is drawn to the principal axis of the mirror MN, we get A′B′ as the virtual image of AB at the back of the convex mirror.

Thus, we can conclude that when an object is placed anywhere between infinity and pole of the convex mirror, its image will be :

(a) Virtual and erect

(b) Diminished

(c) Between P and F behind the mirror

Summary of the images formed by convex mirror in different positions of objects

S. No.	Position of the Object	Position of the Image	Size of the Image	Nature of the Image
1.	At infinity	At F behind the mirror	Highly diminished	Virtual and erect
2.	Anywhere between pole P and infinity	Between P and F behind the mirror	Diminished	Virtual and erect

Uses of Convex Mirror

There are some applications of convex mirror as follows :

(a) A convex mirror is used as a reflector in street lamps [Fig. 1.41 (a)].

(b) The convex mirrors are used in vehicles (like cars, trucks and buses) as a rear view mirror [Fig. 1.41 (b)]. Because convex mirror gives an erect, virtual, highly diminished image of distant objects with a wider field of view. Thus, convex mirrors enables driver to view much larger area than would be possible with a plane mirror.

(c) The convex mirrors are also used as shop security mirrors.

(d) Now, a days convex mirrors are being used at the corners of streets in highly accidental prone areas to avoid accidents.


(a)


(b)

Fig. 1.41 : (a) Reflector in street lamps (b) Rear view mirror of vehicles

Difference between a Plane Mirror, a Concave Mirror and a Convex Mirror

In order to distinguish a plane mirror, a concave mirror and a convex mirror without touching them, we need to look at the image of our face in these three mirrors.

(a) In a plane mirror, our face looks normal self as the mirror produces virtual, erect image of the same size of the face.

(b) In concave mirror, our face looks much bigger as the mirror produces a virtual, erect and magnified image of our face when held within the focus of mirror.

(c) In convex mirror, our face looks smaller as the mirror produces a virtual, erect and diminished image of our face.

1.6 SIGN CONVENTION FOR SPHERICAL MIRRORS

In spherical mirrors *i.e.*, concave mirrors and convex mirrors, we use New Cartesian Sign Conventions (Fig. 1.42) for measuring distances. In this convention the principal axis is taken along x–axis and the pole as the origin.

The convention are as follows :

(a) The object is always placed on left side of the mirrors.

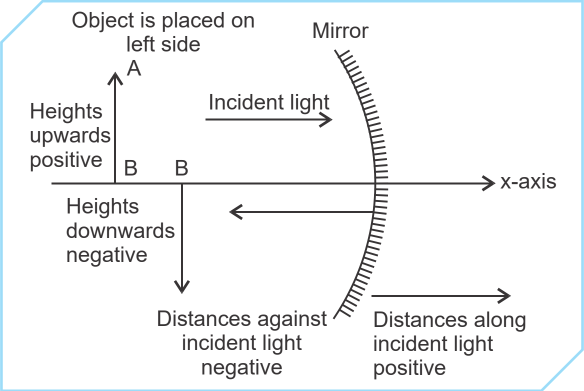


Fig. 1.42 : New Cartesian Sign Conventions for spherical mirror

(b) All the distances parallel to the principal axis are measured from the pole.

(c) The distance measured in the direction of incident light is taken as positive and other side as negative.

(d) The distances measured perpendicular to and above the principal axis along *y*–axis *i.e.*, upwards are taken as positive.

(e) The distance measured perpendicular to and below the principal axis along *y*-axis *i.e.*, downwards are taken as negative.

1.7 MIRROR FORMULA

The relation between object distance, image distance and focal length of a spherical mirror is called mirror formula. This formula is valid for all spherical mirrors for all the positions of the object. The object distance (u) is the distance of the object from the pole of the mirror, the image distance (v) is the distance of the image from the pole of the mirror and the focal length (f) is the distance of principal focus of the mirror from the pole. Then, mirror formula is given as :

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

Now, R is the radius of curvature of the spherical mirror, then

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

Therefore, the mirror formula can also be written as,

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}=\frac{2}{R}$$

Where, u = object distance, v = image distance, f = focal length and R = radius of curvature.

This mirror formula is valid for both type of spherical mirrors.

Note

- Use the New Cartesian Sign Conventions while solving the numerical problems using mirror formula.

Linear Magnification Produced by Spherical Mirrors

The size of the image formed by a spherical mirror depends on the position of the object from the mirror. The image formed by a spherical mirror can be bigger than the object or equal to the object or smaller than the object. The size of the image with respect to the object is given by linear magnification. Thus, we can define linear magnification as :

'The ratio of height of image h_2 to the height of object h_1

$$\text{Magnification} = \frac{\text{Height of image}}{\text{Height of object}}$$

$$m=\frac{h_2}{h_1}$$

We know that the image formed by spherical mirrors may be real or virtual based on the position of the object. Thus, there are following two cases :

Case 1 : When the image is real and inverted *i.e.*, the image lies below the principal axis, the height of the image h_2 is negative and h_1 is positive.

So, $m=\frac{h_2}{h_1}$ = Negative sign

Case 2 : When the image is virtual and erect *i.e.*, the image lies above the principal axis, the height of the image h_2 is positive and h_1 is also positive.

So, $m=\frac{h_2}{h_1}$ = Positive sign

Thus, we can conclude that when magnification, m has negative sign, the image will be real and inverted and when the magnification, m has positive sign, then the image will be virtual and erect.

When the image is magnified or enlarged, *i.e.*, the size of the image is greater than the size of the object, so $h_1 < h_2$ and $m > 1$.

When the image is smaller or diminished *i.e.*, the size of the image is smaller than the size of the object, so $h_1 > h_2$ and $m < 1$.

When the image is of same size as that of the object $h_2 = h_1$, then $m = 1$.

The linear magnification (m) of a spherical mirror is also related to the object distance (u) and the image distance (v). It can be expressed as follows :

$$\text{Magnification} = \frac{\text{Image distance}}{\text{Object distance}}$$

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

SOLVED PROBLEMS BASED ON LINEAR MAGNIFICATION AND MIRROR FORMULA

(a) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ (b) $m=\frac{h_2}{h_1}=-\frac{-v}{u}$

Where 'u' is the object distance, 'v' is the image distance, 'f' is the focal length, 'm' is the linear magnification, 'h_2' is the height of the image, 'h_1' is the height of the object.

1. A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

Solution : Here,

Radius of curvature, R = + 3.00 m;

Object distance, u = – 5.00 m;

Focal length, $f=\frac{R}{2}$

$$f=+\frac{3.00}{2}=+1.50\text{ m}$$

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

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=+\frac{1}{1.50}-\frac{1}{(-5.00)}=\frac{1}{1.50}+\frac{1}{5.00}$$

$$\frac{1}{v}=\frac{5.00+1.50}{7.50}=\frac{6.50}{7.50}$$

$$v=\frac{+7.50}{6.50}=+1.15\text{ m}$$

The image is 1.15 m at the back of the mirror.

$$\text{Magnification, } m=\frac{h_2}{h_1}=-\frac{v}{u}=-\frac{1.15\text{ m}}{-5.00\text{ m}}=+0.23$$

The image is virtual, erect and smaller in size by a factor of 0.23.

2. An object, 4.0 cm in size, is placed at 25.0 cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in

order to obtain a sharp image? Find the nature and the size of the image.

Solution : Here,

Object-size, h_1 = + 4.0 cm

Object distance, u = –25.0 cm

Focal length, f = –15.0 cm

Image distance, v = ?

Height of the image, h_2 = ?

From the mirror formula,

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

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

$$= \frac{1}{-15.0}-\frac{1}{-25.0}$$

$$= -\frac{1}{15.0}+\frac{1}{25.0}$$

$$\frac{1}{v} = \frac{-5.0+3.0}{75.0} = \frac{-2.0}{75.0}$$

$$v = -37.5 \text{ cm}$$

The screen should be placed at 37.5 cm from the mirror. The image is real.

Now, magnification,

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

$$h_2 = -\frac{vh_1}{u} = \frac{(-37.5\,\text{cm})(+4.0\,\text{cm})}{(-25.0\,\text{cm})}$$

Height of the image, h_2 = – 6.0 cm.

The image is inverted and enlarged.

PAPER–PEN TEST : 4

1. Give any three uses of convex mirror.
2. Explain the nature of the image when an object is placed infront of a convex mirror.
3. Why convex mirrors are used as rear view mirror in motor vehicles ?
4. Define linear magnification of spherical mirror.
5. Explain the nature of the image when an object is placed at infinity of a convex mirror.
6. Why convex mirrors are used as shop security mirrors ?
7. Distinguish between a plane mirror, a concave mirror and a convex mirror.
8. What will happen to linear magnification when the image is
   (a) Of same size as that of object
   (b) Smaller than that of the object
   (c) Enlarged than that of the object
9. Give the rules for tracing images formed by the convex mirror with neat sketch of the ray diagram.
10. Why all the rays shown behind the convex mirror are virtual? How are they represented in ray diagram?
11. What are the two possible positions of the object for which we can obtain the image by convex mirror?
12. Draw the ray diagram with respect to convex mirror,
    (a) When the object is at infinity.
    (b) When the object is placed infront of pole of a mirror.

1.8 REFRACTION OF LIGHT

The light rays travels in a straight line while travelling in the same medium having the same density throughout. But, when light rays travel from one medium to another, they change their direction from straight line at the boundary between the two media.

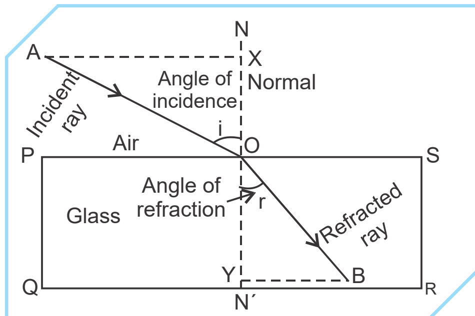


Fig. 1.43 : Refraction of light

For example : When a light ray is allowed to travel from medium 1 *i.e.*, air into another medium 2 *i.e.*, glass, it changes the direction of light (or bends) on entering the glass medium. Hence we can conclude that the straight line path of the light ray in medium 2 is different from the straight line path of the light ray in medium 1. Thus, the bending of ray of light from its original path on entering into another medium is called refraction of light (Fig. 1.43). In other words, we can define refraction of light as,

"The change in the direction of light when it passes from one medium to another."

Let us now explain it more clearly with the help of diagram.

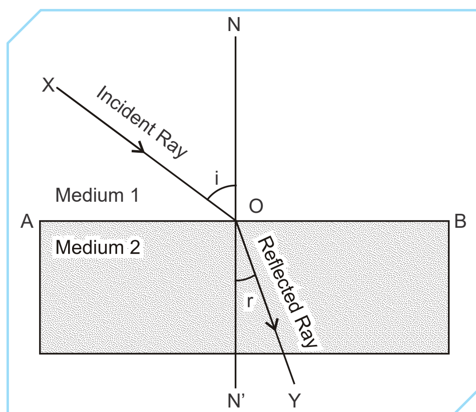


Fig. 1.44 : Refraction of light

In the Fig. 1.44, AB is a plane surface separating medium 2 from medium 1. A ray of light XO travels in medium 1 strikes the boundary AB of two media at O. In medium 2, the ray travels along OY. This ray bends towards the normal NON′ and goes along OY. This change in the path of light occurs at O. Here, XO is called incident ray, OY is called the refracted ray, O is the point of incidence where refraction occurs and NON′ is the normal to the plane surface AB.

The angle between incident ray and normal is called the angle of incidence, represented as *i*,

$$\angle XON = i$$

The angle between refracted ray and normal is called the angle of refraction, represented as *r*,

$$\angle YON' = r$$

We have studied that the angle of reflection is always equal to the angle of incidence. But, in case of refraction, the angle of refraction is never equal to the angle of incidence.

$$\angle i \neq \angle r$$

Effects of Refraction of Light

(a) A coin in a glass tumbler filled with water appears to be raised when seen from above the water.

(b) A pencil partly immersed in water appears to be bent at the interface of air and water.

(c) A lemon kept in water in a glass appears to be bigger than its actual size when viewed from the sides.

In all of the above examples, we can see that the extent of the effect is different for different pair of media. These observations indicate that light does not travel in the same direction in all media. It appears that when travelling obliquely from one medium to another, the direction of propagation of light in the second medium changes.

Activity 1.3–To show that the apparent depth of a coin at the bottom of a bucket filled with water is less than the real depth of the coin in the water.

PROCEDURE

Step 1– Place a coin at the bottom of a bucket filled with water.

Step 2– With your eye to a side above water, try to pick up the coin in one go.

Step 3– Give your result.

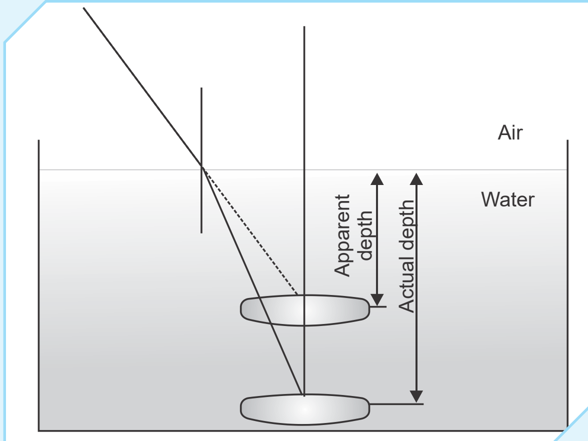


Fig. 1.45 : Apparent depth of a coin at the bottom of a bucket filled with water is less than the real depth of the coin in the water.

OBSERVATION

The coin is not picked in one go. This is because, the coin appears to be raised from its actual position due to the refraction of light (Fig. 1.45). So, when tried to pick up the coin in the water, it seems the coin is else where above the bottom of the bucket.

CONCLUSION

This activity shows that the apparent depth of the coin in water is less than its actual depth in water.

Activity 1.4–To make a coin visible at the bottom of a bucket half filled with water, which was not visible when you look at the coin from one side above the water.

PROCEDURE

Step 1– Place a large shallow bowl on a table and put a coin in it.

Step 2– Move away slowly from the bowl.

Step 3– Stop when the coin just disappears from your sight.

Step 4– Ask a friend to pour water gently into the bowl without disturbing the coin.

Step 5– Keep looking for the coin from your position.

Step 6– Does the coin becomes visible again from your position?

Step 7– How could this happen?

OBSERVATION

(a) Yes.

(b) The increase in real depth of a coin, the distance through which it appears to be raised increases and so the coin placed at the bottom becomes visible.

CONCLUSION

This activity shows that the distance through which an object appears to be raised in water increases with the increase in the real depth of the object.

Causes of Refraction

We know that the speed of light is different in different substances or medium. Thus, when a ray of light travelling in air enters into glass, the speed of the light decreases and so the bending of light or refraction of light takes places at the interface of air and glass. On the other hand, when a ray of light travelling in glass enters into air, the speed of the light increases and so the bending of light or refraction of light takes place at the interface of glass and air. The angle of bending of a ray depends on the difference in the speed of light in the two media.

Note

- Larger the difference in speed of light, larger will be the angle of bending and vice-versa.

Change in Speed of Light Causing Bending of Light

According to wave theory of light, a beam of light made up of light waves travelling in a medium falls at an angle on the boundary of another medium, then one part of the light waves enters into the other medium first and its speed changes first and then the rest of the waves enters the other medium later and so its speed changes later. Thus, the speed of light waves on one side of a beam of light changes a little before then the change in speed of light waves on its other side which causes a change in the direction of light.

Rarer Medium and Denser Medium

A transparent substance through which a light can travel is called an optical medium. It includes air, glass, water, alcohol etc. Since different optical media have different optical densities, the speed of light in different optical media is different. A medium in which the speed of light is more is known as optically rarer medium *i.e.*, less dense medium. Example, air is an optically rarer medium as compared to glass and water. A medium in which the speed of light is less is known as optically denser medium *i.e.*, more dense medium. Example, glass is an optically denser medium than air and water.

Note

- The phenomenon of refraction takes place when the ray of light goes from an optically rarer medium to an optically denser medium or from a optically denser medium to a optically rarer medium.

Refractive Index

We know that a when a ray of light travels at an angle from one medium to another its speed changes, due to which direction of ray of light changes in second medium. The extent to which the change in direction takes place in a given pair of media is expressed in terms of refractive index.

Consider a ray of light traveling from one medium to another, let the speed of light in medium 1 be v_1 and speed of light in medium 2 is v_2. The refractive index of medium 2 with respect to medium 1 is equal to the ratio of speed of light in medium 1 to the speed of light in medium 2. This can be expressed as

$$_{\text{medium 1}}n_{\text{medium 2}} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}}$$

or $$^{1}n_{2} = \frac{v_1}{v_2}$$

where $^{1}n_{2}$ is refractive index of medium 2 with respect to medium 1.

If the medium 1 is vaccum then refreactive index will be.

"The ratio of speed of light in vacuum to the speed of light in the medium."

That is,

$$n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

Where n is the refractive index of the medium

Since the speed of light in air is almost equal to the speed of light in vacuum, therefore, the refractive index of a medium can also be given as

$$\text{Refractive Index} = \frac{\text{Speed of light in air}}{\text{Speed of light in medium}}$$

$$n = \frac{c}{v}$$

Since the refractive index is a ratio of two velocities, it has no units.

A medium with higher value of refractive index is said to be an optically denser medium as compared to the medium with lower value of refractive index. On the other hand, when the value of n is larger, then the value of v is smaller. This shows that in a denser medium, the speed of light is smaller and in a rarer medium, the speed of light is larger.

From the discussion, we can conclude that the refractive index is a characteristic property of the medium, whose value depends on the nature of material of the medium and the colour or the wavelength of light.

The values of refractive index of some of the medium are given below :

S. No.	Material Medium	Refractive Index	S. No.	Material Medium	Refractive Index
1.	Air	1.0003	8.	Fused quartz	1.46
2.	Alcohol	1.36	9.	Ice	1.31
3.	Benzene	1.50	10.	Kerosene	1.44
4.	Canada Balsam	1.53	11.	Rock salt	1.54
5.	Carbon disulphide	1.63	12.	Ruby	1.71
6.	Crown glass	1.52	13.	Sapphire	1.77
7.	Dense flint glass	1.65	14.	Turpentine oil	1.47

Relative Refractive Index

When light passes from one medium (other than vacuum or air) to another medium, then the refractive index of medium 2 with respect to medium 1 is called relative refractive index.

The refractive index of medium 2 with respect to 1,

$$\boxed{{}^1n_2 = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}}}$$

$${}^1n_2 = \frac{n_1}{n_2}$$

$${}^1n_2 = \frac{c/v_1}{c/v_2} = \frac{v_2}{v_1} \quad \left[\because n = \frac{c}{v}\right] \quad ...(1)$$

Similarly, the refractive index of medium 1 with respect to 2,

$$\boxed{{}^2n_1 = \frac{\text{Speed of light in medium 2}}{\text{Speed in light in medium 1}}}$$

$${}^2n_1 = \frac{n_2}{n_1} \quad \left[\because n = \frac{c}{v}\right]$$

$${}^2n_1 = \frac{c/v_2}{c/v_1} = \frac{v_1}{v_2} \quad ...(2)$$

Multiplying (1) and (2), we get

$$\boxed{{}^1n_2 \times {}^2n_1 = \frac{v_2}{v_1} \times \frac{v_1}{v_2} = 1}$$

$$\therefore \quad {}^1n_2 = \frac{1}{{}^2n_1}$$

Absolute Refractive Index

When light is going from vaccum (or air) to another medium, then the value of refractive index is called the absolute refractive index.

Laws of Refraction of Light

The refraction of light on going from one medium to another medium takes place according to two laws which are known as the laws of refraction of light.

(a) First Law

The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

(b) Second Law

The ratio of sine of angle of incidence to the sine of angle of refraction is constant, for the light of a given colour and for the given pair of media. This law is also known as Snell's law of refraction.

$$\frac{\text{sine of angle of incidence}}{\text{sine of angle of refraction}} = \text{Constant}$$

$$\frac{\sin i}{\sin r} = \text{Constant} = n$$

Where, i = angle of incidence
r = angle of refraction
n = refractive index

Conditions for No Refraction

The refraction will not take place under the following two conditions :

Condition 1 : When the refractive index of two media are equal, then the refraction will not take place.

Condition 2 : When the incident ray strikes perpendicular to one media to another media, then light will pass without any refraction.

The Direction of Bending of Light

Based on the above discussion, there are two possible rules which give the direction of bending of a ray of light when it goes from one medium to another medium.

Rule 1 : When a ray of light goes from a rarer medium to a denser medium, it bends towards the normal [Fig. 1.46 (a)].

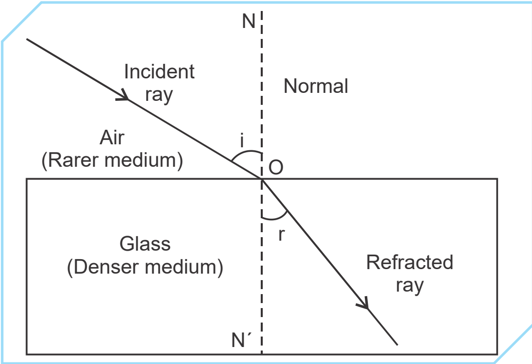


Fig. 1.46 (a) : Rarer to denser medium

Rule 2 : When a ray of light goes from a denser medium to a rarer medium, it bends away from the normal [Fig. 1.46 (b)].

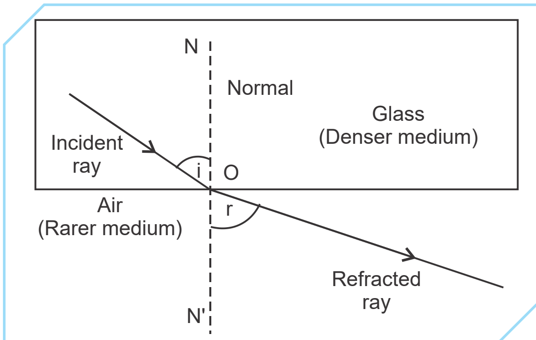


Fig. 1.46 (b) : Denser to rarer medium

Refraction through a Rectangular Glass Slab

When a light ray falls on a glass slab obliquely, it emerges out of the glass slab parallel to its original direction of propagation in which it enters the glass slab. However there is a shift in the path of the incident ray. This shift is called lateral shift or lateral displacement. Thus, lateral shift can be defined as,

"The perpendicular distance between the original path of incident ray and the emergent ray coming out of a glass slab."

It depends on the following factors :

(a) Directly proportional to the thickness of glass slab.
(b) Directly proportional to the incident angle.
(c) Directly proportional to the refractive index of the glass slab.
(d) Inversely proportional to the wavelength of incident light.

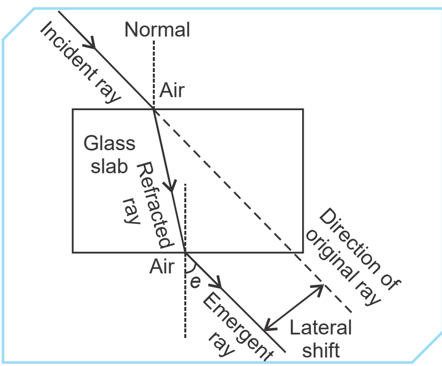


Fig. 1.47 : Thickness of a glass slab is directly proportional to lateral shift

The angle beween emergent ray and normal is called angle of emergence *'e'*.

Activity 1.5–To trace the path of ray of light passing through a rectangular glass slab.

PROCEDURE

Step 1– Fix a sheet of white paper on a drawing board using drawing pins.

Step 2– Place a rectangular glass slab over the sheet in the middle.

Step 3– Draw the outline of the slab with a pencil. Let us name the outline as ABCD.

Step 4– Take four identical pins.

Step 5– Fix two pins, say E and F, vertically such that the line joining the pins is inclined to the edge AB.

Step 6– Look for the images of the pins E and F through the opposite edge.

Step 7– Fix two other pins, say G and H, such that these pins and the images of E and F lie on a straight line.

Step 8– Remove the pins and the slab.

Step 9– Join the positions of tip of the pins E and F and produce the line up to AB.

Step 10– Let EF meet AB at O.

Step 11– Similarly, join the positions of tip of the pins G and H and produce it up to the edge CD.

Step 12– Let HG meet CD at O′.

Step 13– Join O and O′.

Step 14– Also produce EF up to P, as shown by a dotted line (see Fig. 1.48).

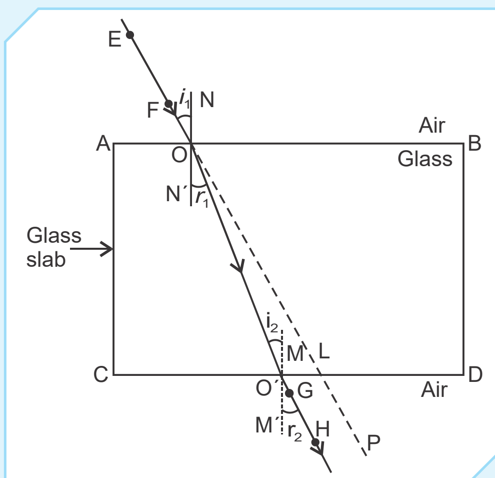


Fig. 1.48 : Path of ray of light passing through a rectangular glass slab

CONCLUSION

The above experiment shows that in refraction through a rectangular slab, the incident ray and the emergent ray of light are parallel to each other.

PAPER–PEN TEST : 5

1. Define Snell's law.
2. What are the two conditions in which no refraction takes place ?
3. Derive an expression for relative refractive index.
4. What are the rules based on the bending of light ?
5. Give an activity to trace the path of ray of light passing through a rectangular glass slab.
6. Define the law of refraction of light.
7. Define relative refractive index.
8. What are the factors on which refractive index depends ?
9. Differentiate between denser and rarer medium.
10. Define optical medium.
11. How the change in the speed of light causes bending of light ?
12. Explain the refraction of light by taking two media as air and water. In the diagram, mark the incident ray, refracted ray, normal and two mediums showing angle of incidence and angle of refraction.
13. What causes refraction ?

1.9 SPHERICAL LENSES

In this section, we shall discuss different types of lens, the formation of images by lenses etc., in detail. Before we do that, we should know the parts involved in lens. Lenses play a very important role in our everyday life. You would have observed some of the people using spectacles for reading, seeing the details of the lines of a person's palm. Lenses are used in spectacles, camera, microscopes, telescopes, film projectors etc. The working of lens is based on the principal of refraction of light rays when they pass through it. Thus, we can define lens

"As a piece of transparent glass bound by two spherical surfaces."

In some cases, both the surfaces of the lens are spherical whereas in some cases, one surface of the lens may be spherical and the other surface may be plane. When a ray of light is passed through a lens, it is refracted twice at the two surfaces of the lens.

Types of Spherical Lens

There are two types of spherical lens namely,

(a) Concave lens ***(b) Convex lens***

(a) Concave Lens

A concave lens is thicker at the edges and thin at the centre, (Fig. 1.49). The concave lens is also called diverging lens, because it diverges the rays of light falling on it. Here, the two surfaces having their own centres of curvature and radii of curvature binds the lens inwards.

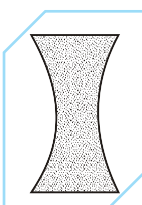


Fig. 1.49 : Concave lens

(b) Convex Lens

A convex lens is thinner at the edges and thick at the centre, (Fig. 1.50). The convex lens is also called converging lens, because it converges the rays of light falling on it. Here, the two surfaces having their own centres of curvature and radii of curvature binds the lens outwards.

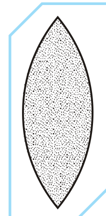


Fig. 1.50 : Convex lens

Terms Related to Spherical Lenses

We shall now discuss some of the important terms related to spherical lenses in order to understand the concept of spherical lenses better (Fig. 1.51, 1.52).

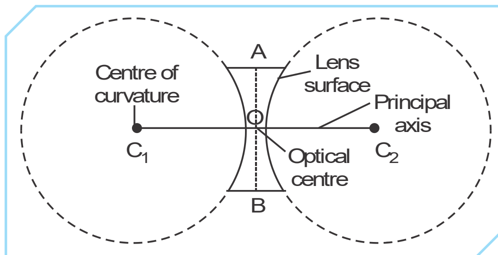


Fig. 1.51 : Terms used for concave lens

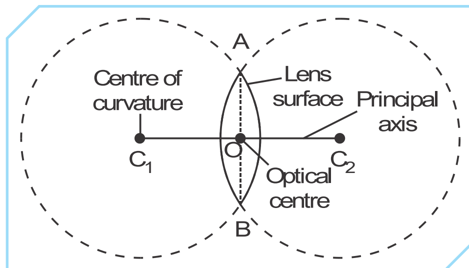


Fig. 1.52 : Terms used for convex lens

(a) Optical Centre

The centre point of a lens is known as its optical centre. It is denoted as 'O'. The rays passing through the optical centre of the lens goes undeviated.

(b) Principal Axis

An imaginary straight line passing through the centres of curvature of a lens is called the principal axis of the lens.

(c) Centre of Curvature

Centre of curvature of a lens is the centre of sphere, from which the lens is formed. Since concave and convex lenses are formed by the combination of two parts of spheres, so they have two centres of curvature. They are denoted as C_1 and C_2.

(d) Aperture

The diameter of the circular edge of the lens is called the aperture of the lens.

Principal Focus and Focal Length of a Concave Lens

Since a concave lens has two surfaces, it has two principal foci or focal points, namely

(a) First principal focus
(b) Second principal focus

When a light ray falls on a concave lens (which appears to converge), gets refracted according to the law of refraction. All the rays after passing through the concave lens diverge and become parallel to principal axis and do not meet at a point. But when the incident rays are produced forwards, they appear to meet at some point. This point is called principal focus (Fig. 1.53). It is represented as F_1. The distance of the first principal focus of the lens from optical centre of the lens is called first focal length of concave lens. It is represented as f_1. Thus, $OF_1 = f_1$.

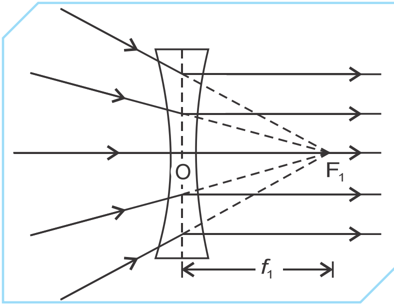


Fig. 1.53 : First principal focus of a concave lens

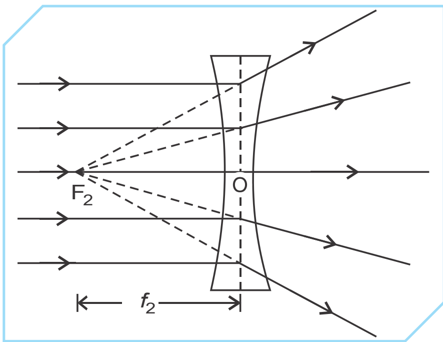


Fig. 1.54 : Second principal focus of a concave lens

Similarly, the second principal focus of a concave lens (Fig. 1.54) is the position of an image on the principal axis of the point when the object is at infinity. It is represented as F_2. The rays from an object parallel to the principal axis, on refraction through concave lens diverge. But on producing backwards, the diverged rays appear to come from F_2 where the image is formed. It is a virtual point. The distance of the second principal focus of the lens from optical centre of the lens is called second focal length of concave lens. It is represented as f_2. Thus, $OF_2 = f_2$.

Before we proceed for different types of images formed by the concave lens, we should know the rules for obtaining the images by the concave lenses.

1.10 RULES FOR TRACING IMAGES FORMED BY CONCAVE LENSES

Rule 1

When a ray of light parallel to principal axis falls on the concave lens, it appears to come from second principal focus of the concave lens after refraction through the lens (Fig. 1.55).

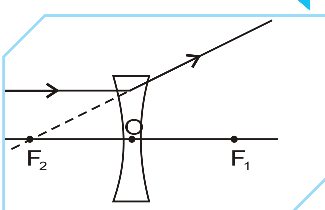


Fig. 1.55

Rule 2

When a ray of light passes through the optical centre of a concave lens, it goes straight after refraction through the lens (Fig. 1.56).

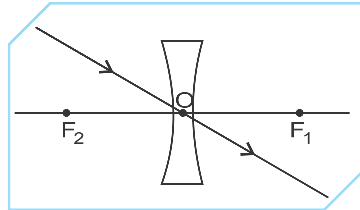


Fig. 1.56

Rule 3

When a ray of light going towards the focus of a concave lens, it becomes parallel to principal axis after refraction through the lens (Fig. 1.57).

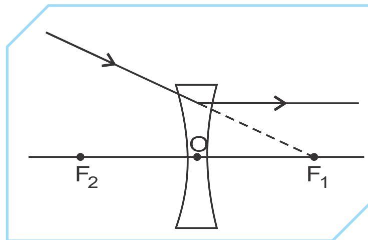


Fig. 1.57

Remembering the rules, we can construct the ray diagrams for finding the position and nature of images formed by concave lens.

1.11 IMAGES FORMED BY CONCAVE LENSES

The image formed by a concave lens depends on the position of the object in front of the lens. There are two main positions of the object for which we can obtain the image. These are :

(a) Object is at infinity.

(b) Object lies between optical centre and infinity.

Let us now discuss the images formed by a concave lens when an object is placed at various positions.

Position 1 : When an object is at infinity

Here, the object is placed at very large distance say at infinity. Since the object is at very far distance, it cannot be shown in the ray diagram. In the ray diagram Fig. 1.58, the two rays AP and AQ from A are parallel to each other. The ray AP gets refracted as PX. The ray AQ gets refracted as QY. When these two refracted rays PX and QY are produced backwards by the dotted line, they meet at F_2 on the same side of the object.

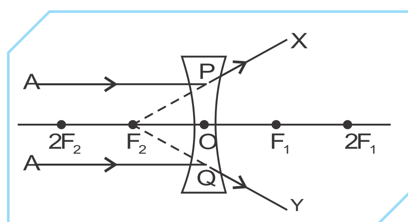


Fig. 1.58 : Ray diagram of image formation when an object is placed at infinity from a concave lens.

Thus, we can conclude that when an object is at infinity, its image will be :

(a) Virtual and erect

(b) Much smaller than object (point size)

(c) Formed at F_2 on the same side of the object.

Position 2 : When an object lies between optical centre and infinity

Here, an object is placed between optical centre and infinity. In the ray diagram Fig. 1.59, the two rays AD and AO from A. The ray AD gets refracted along DE whereas the ray AO passes through optical centre and so remains undeviated. These two rays DE and AO are diverging rays so do not meets but when we produce these rays backwards these two rays meets at A′ which is virtual image of the point A of the object. Drawing A′B′ perpendicular to the principal axis, we get A′B′ as the image of AB.

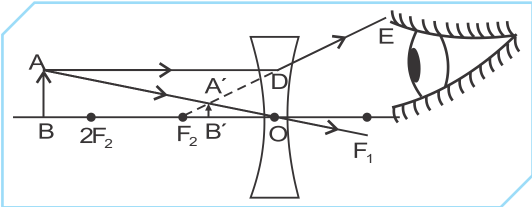


Fig. 1.59 : Ray diagram of image formation when an object lies between optical centre of concave lens and infinity.

Thus, we can conclude that when an object lies between optical centre and infinity, its image will be

(a) Virtual and erect

(b) Smaller in size than the object

(c) Formed between optical centre O and second principal focus F_2.

Summary of images formed by concave lens for different positions of object

S. No.	Position of the Object	Position of the Image	Size of the Image	Nature of the Image
1.	At infinity	At F_2	Highly diminished	Virtual and erect
2.	Anywhere between optical centre and infinity	Between optical centre and F_2	Diminished	Virtual and erect

Uses of Concave Lenses

(a) It is used in spectacles to correct the defect of vision called short sightedness.

(b) It is used as eye lens in Galilean telescopes.

(c) It is used in spy hole in doors.

Principal Focus and Focal Length of a Convex Lens

Since a convex lens has two surfaces, it has two principal foci or focal points, namely

(a) First principal focus ***(b) Second principal focus***

It is a point on the principal axis of the lens, the rays starting from which become parallel to the principal axis after refraction from the lens according to the law of refraction. This point is called first principal focus (Fig. 1.60). It is represented as F_1.

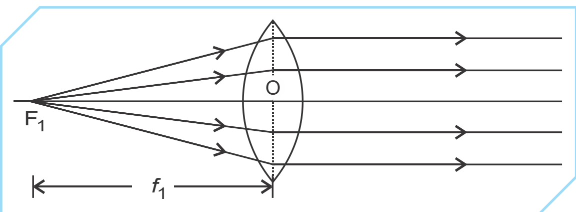


Fig. 1.60 : First principal focus of a convex lens

The distance of the first principal focus of the lens from optical centre of the lens is called first focal length of convex lens. It is represented as f_1. Thus, $OF_1 = f_1$.

Similarly, the second principal focus of a convex lens is the position of an image on the principal axis of the point when the object is at infinity (Fig. 1.61). It is represented as F_2. The rays from an object parallel to the principal axis meet at F_2 where the image is formed. It is a real point. The distance of the second principal focus of the lens from optical centre of the lens is called second focal length of convex lens. It is represented as f_2. Thus, $OF_2 = f_2$.

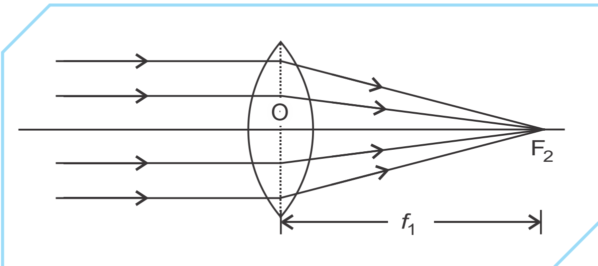


Fig. 1.61 : Second principal focus of convex lens.

Activity 1.6–To determine the principal focus of a convex lens.

PROCEDURE

Step 1– Hold a convex lens in your hand.

Step 2– Direct it towards the Sun.

Step 3– Focus the light from the Sun on a sheet of paper to obtain a sharp bright image of the Sun.

Step 4– Hold the paper and the lens in the same position for a while.

Step 5– Keep observing the paper (Fig. 1.62).

Step 6– What happened ?

Step 7– Why ?

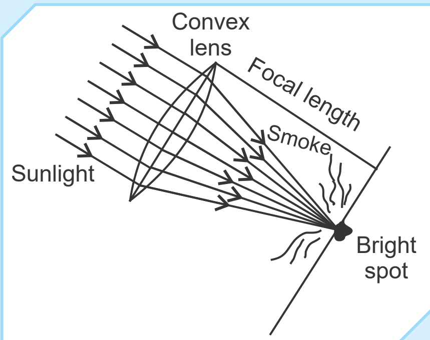


Fig. 1.62 : An experiment to understand the properties of convex lens

OBSERVATION

(a) When a parallel beam of light from a far off object falls on a convex lens, a real, inverted, point size image of the Sun is formed at the focus of the lens.

(b) When the paper and convex lens are held in the same position for some-time, the paper burns out. This is because the heat is produced by the Sun rays when they are concentrated on the spot where image of the Sun is being formed.

CONCLUSION

Hence, the focus of a convex lens is the point at which the image of sun is formed.

Before we proceed for different types of images formed by the convex lens, we should know the rules for obtaining the images by the convex lenses.

1.12 RULES FOR TRACING IMAGES FORMED BY CONVEX LENSES

Rule 1

When a ray of light parallel to principal axis falls on the convex lens, it passes through the second principal focus of the convex lens on refraction (Fig. 1.63).

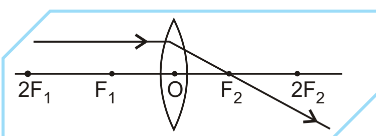


Fig. 1.63

Rule 2

When a ray of light passes through the optical centre of a convex lens, it goes straight after refraction through the lens (Fig. 1.64).

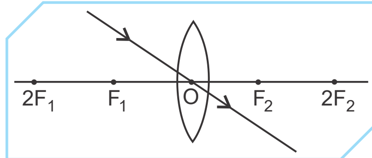


Fig. 1.64

Rule 3

When a ray of light passes through first principal focus, it becomes parallel to principal axis after refraction (Fig. 1.65).

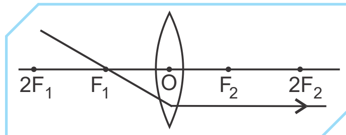


Fig. 1.65

Remembering the rules, we can construct the ray diagrams for finding the position and nature of images formed by convex lens.

Images Formed by Convex Lens

The image formed by a convex lens depends on the position of the object in front of the lens. To get different types of images by a convex lens we can place the object at various positions from a convex lens. For example,

(a) Object is kept at infinity.

(b) Object is placed beyond $2F_1$.

(c) Object is placed at $2F_1$.

(d) Object is placed between F_1 and $2F_1$.

(e) Object is placed at focus F_1 of a convex lens.

(f) Object is kept between the optical centre O and focus F_1 of a convex lens.

Let us now discuss above cases briefly.

Position 1 : When an Object is Placed at Infinity

Here, the object is placed at considerable distance say at infinity. Since the object is at very far distance, it cannot be shown in the ray diagram (Fig. 1.66). When the object is at infinity, the rays parallel to one another but inclined an angle to principal axis falls on the lens. One of these rays gets refracted along P and the other ray passes through the optical centre O goes straight undeviated and these two refracted rays meet at A′, which is a real image of the object A. Drawing A′B′ perpendicular to the principal axis, we get A′B′ as the real image of AB.

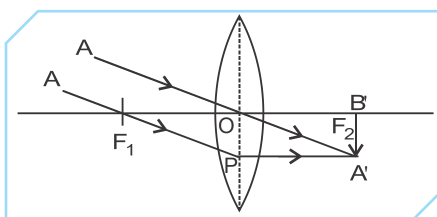


Fig. 1.66 : Ray diagram of image formation when an object is placed at infinity

Thus, we can conclude that when object is placed infinity, its image will be

(a) Real and inverted

(b) Highly reduced or highly diminished

(c) Formed at the focus F_2

Position 2 : When an object is placed beyond $2F_1$

Here, the object is placed at beyond $2F_1$ from the convex lens. In other words, the distance of the object is more than twice the focal length of the lens. In the ray diagram (Fig. 1.67), when a ray of light parallel to the principal axis of the lens from A falls on the lens along AD, it gets refracted by passing through second principal focus F_2. Now, when another ray of light from A falls on the lens along AO through optical centre, it goes straight after refraction. The two refracted rays meet at A′. So A′ is the real image of A. Now draw perpendicular from A′ on principal axis we get A′B′ as the real image of the object AB.

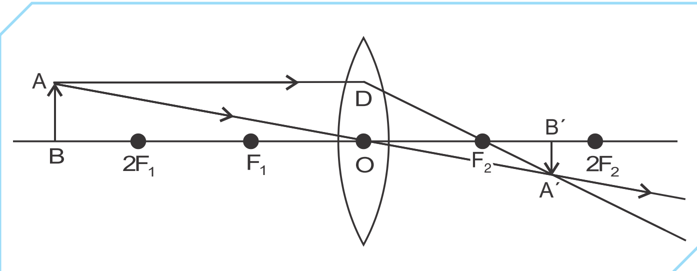


Fig. 1.67 : Ray diagram of image formation when an object is placed beyond the $2F_1$ of a convex lens

Thus, we can conclude that when an object is placed beyond $2F_1$, its image will be

(a) Real and inverted

(b) Diminished or smaller in size than the object

(c) Formed between F_2 and $2F_2$.

Position 3 : When an object is placed at $2F_1$

Here, the object is placed at the distance twice the focal length of the convex lens. In other words, the distance of the object from the convex lens is equal to twice the focal length of the lens. In the ray diagram (Fig. 1.68), when a ray of light parallel to the principal axis of the lens from A falls on the lens along AD, it gets refracted by passing through second principal focus F_2. Now, when another ray of light from A falls on the lens along AO through optical centre, it goes straight after refraction. The two refracted rays meet at A′, which is a real image of the object A. Drawing A′B′ perpendicular to the principal axis, we get A′B′ as the real image of AB.

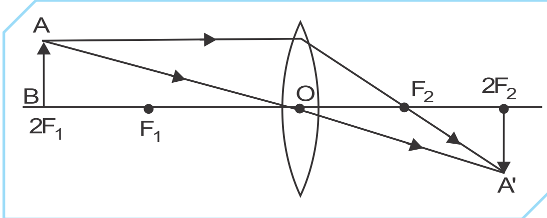


Fig. 1.68 : Ray diagram of image formation when an object is placed at $2F_1$

Thus, we can conclude that when an object is placed at $2F_1$ of a convex lens, its image will be :

(a) Real and inverted

(b) Of same size as object

(c) Formed at 2 F_2

Position 4 : When an object is placed between F_1 and $2F_1$

Here, the object is placed between F_1 and $2F_1$. In the ray diagram (Fig. 1.69), when a ray of light parallel to the principal axis of the lens from A falls on the lens along AD, it gets refracted and passes through second principal focus F_2. Now, when another ray of light from A falls on the lens along AO through optical centre, it goes straight after refraction. The two refracted rays meet at A′, which is a real image of the object A. Drawing A′B′ perpendicular to the principal axis, we get A′B′ as the real image of AB.

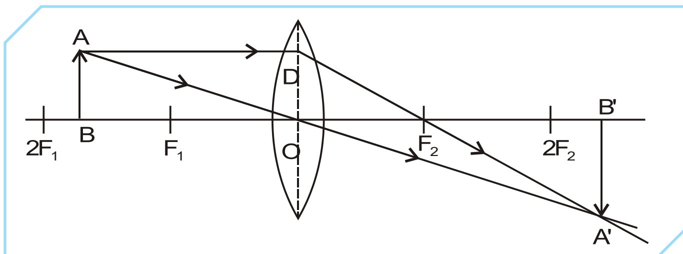


Fig. 1.69 : Ray diagram of image formation when an object is placed between F_1 and $2F_1$

Thus, we can conclude that when an object is placed between F_1 and $2F_1$, its image will be

(a) Real and inverted

(b) Magnified

(c) Formed beyond $2F_2$.

Position 5 : When an object is placed at focus F_1 of a convex lens.

Here, the object is placed focus of a convex lens *i.e.* at a distance equal to the focal length of the lens from the convex lens. In the ray diagram (Fig. 1.70), when a ray of light parallel to the principal axis of the lens from A falls on the lens along AD, it gets refracted by passing through second principal focus F_2. Now, when another ray of light from A falls on the lens along AO through optical centre, it goes straight after refraction. The two refracted rays meet at very large distance from the lens say at infinity. Therefore the image will be a real image of the object.

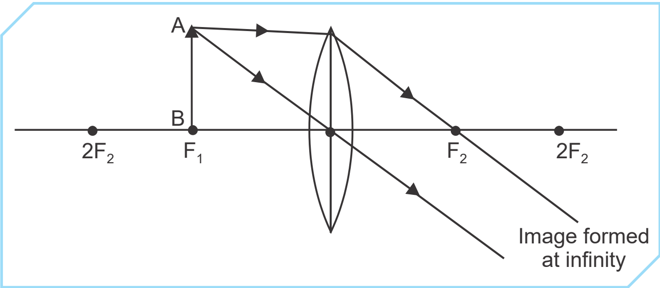


Fig. 1.70 : Ray diagram of image formation when an object is placed at F_1 of a convex lens

Thus, we can conclude that when an object at F_1 of a convex lens, its image will be

(a) Real and inverted

(b) Highly magnified

(c) Formed at infinity

Position 6 : When an object is kept between the optical centre O and F_1 of a convex lens

Here, the object is placed between the optical centre O and F_1 of a convex lens. In the ray diagram (Fig. 1.71), when a ray of light parallel to the principal axis of the lens from A falls on the lens along AD, it gets refracted by passing through second principal focus F_2. Now, when another ray of light from A falls on the lens along AO through optical centre, it goes straight after refraction. These two refracted rays DX and AY are parallel to each other so they do not meet at right hand side of convex lens. When we produce these two rays backwards they meet at A′. So A′ is the virtual image of A. Drawing A′B′ perpendicular to the principal axis, we get A′B′ as the virtual image of AB.

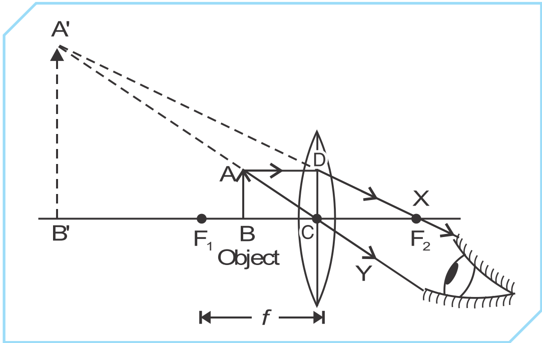


Fig. 1.71 : Ray diagram of image formation when an object is kept between the optical centre O and focus F_1.

Thus, we can conclude that when an object is placed between optical centre O and focus F_1 of a convex lens, its image will be

(a) Virtual and erect

(b) Enlarged or magnified

(c) Behind the object

Summary of Images formed by Convex lens for different Positions of Object

S. No.	Position of the Object	Position of the Image	Size of the Image	Nature of the Image
1.	At infinity	At F_2	Highly diminished	Real and inverted
2.	Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
3.	At $2F_1$	At $2F_2$	Equal or same size	Real and inverted
4.	Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
5.	At F_1	At infinity	Highly magnified	Real and inverted
6.	Between O and F_1	On the same side of the object	Enlarged	Virtual and erect

Measuring the Focal Length of a Convex Lens

It is the fact that "when the object is at infinity, its image is formed at the focus of the convex lens which can be used to measure the focal length of a convex lens approximately" (Fig. 1.72). The focal length of a convex lens can be measured as follows : Put the convex lens in a lens stand and keep it infront of a distant object. Now, put a card board screen behind the lens. By moving towards or away from the convex lens till a clear inverted image of the distant object is obtained on the screen. After obtaining the clear image, measure the distance of the screen from the lens with the help of scale. This distance will be the focal length of the convex lens.

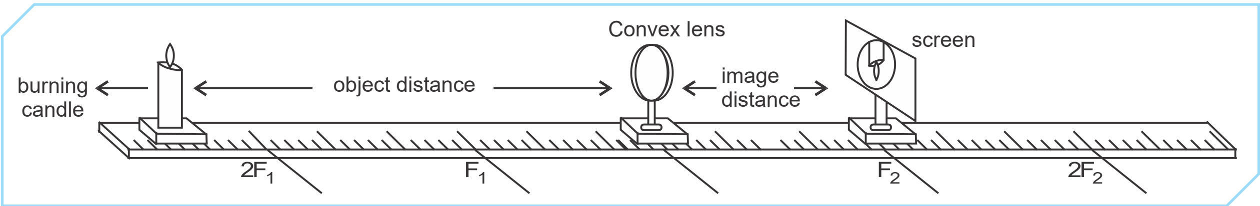


Fig. 1.72 : An experiment to measure the focal length of a convex lens

Uses of Convex Lenses

(i) It is used in spectacles to correct the defect of vision called long sightedness.

(ii) It is used in microscopes, telescopes etc.

(iii) It is used for making a simple camera.

How to differentiate between a convex lens and a concave lens without holding them

On keeping the lens close to the page of a book, if the letters of the book appear enlarged, then it is a convex lens and if the letters of the book appear diminished, then it is a concave lens. This is because a concave lens produces a diminished image for all the positions of the object and convex lens produces an enlarged image, when the object is kept within the focus of convex lens.

PAPER–PEN TEST : 6

1. Define lens and its types.
2. Differentiate between the types of lens.
3. What are the terms related to spherical lenses ?
4. Differentiate between the first principal focus of concave and convex lens.
5. Differentiate between the second focal length of concave lens and convex lens.
6. What are the rules for tracing images formed by concave lens ?
7. What are the two possible positions of the object for which we can obtain image formation by the concave lens ?
8. Mention the uses of concave lenses.
9. Differentiate the second principal focus of convex lens and concave lens.
10. Differentiate the first focal length of concave lens and convex lens.
11. What are the rules for tracing images formed by convex lens?
12. Mention any three possible positions of the object for which we can obtain image formation by the convex lens?
13. Mention the uses of convex lenses.
14. Explain the nature of the image formed by convex lens when an object is place at infinity. Draw the ray diagram.
15. Explain the nature of the image formed by convex lens when an object is placed at focus. Draw the ray diagram.

1.13 SIGN CONVENTION FOR SPHERICAL LENSES

In spherical lenses *i.e.*, concave lens and convex lens, we use New Cartesian Sign Conventions for measuring distances. In this the principal axis is taken along x-axis and the optical centre O as the origin and the object is placed on left side of the lens.

These conventions are as follows (Fig 1.73) :

(a) All the distances are measured from the optical centre of the lens.

(b) The distance measured in the direction of incident ray is taken as positive and other side as negative.

(c) The height perpendicular to the principal axis above x-axis *i.e.*, upwards is taken as positive.

(d) The height perpendicular to principal axis below x-axis *i.e.*, downwards is taken as negative.

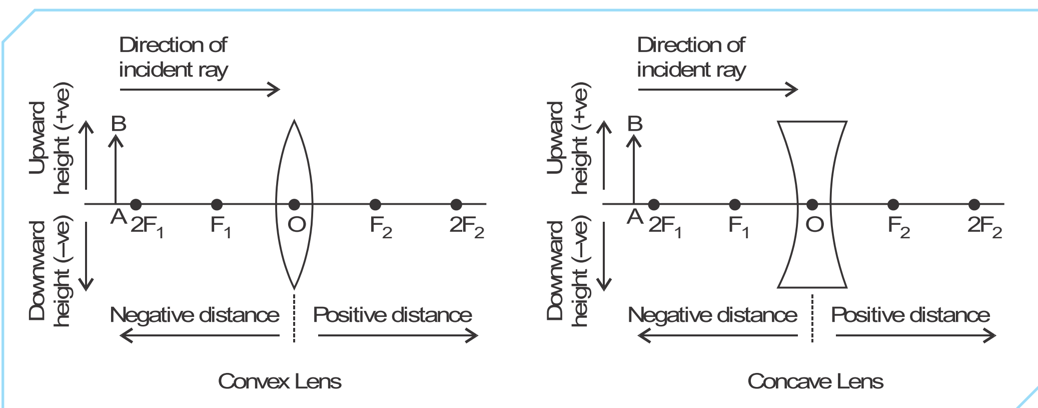


Fig. 1.73 : Sign Convention for Spherical Lenses

On the basis of New Cartesian Sign Convention, the focal length of a convex lens is considered as positive and that of concave lens is considered as negative.

Note

- Use the New Cartesian Sign Conventions while solving the numerical problems using lens formula.

Lens Formula

A formula which gives the relationship between focal length (f) of a lens, object distance (u) and image distance (v) is called lens formula. It can be written as :

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

The lens formula is applicable to both types of spherical lenses. The lens formula for lenses is applicable for all the positions of object from spherical lenses.

Linear Magnification Produced by Spherical Lenses

The size of the image formed by spherical lenses depends on the position of the object from the lens. The image formed by spherical lenses can be bigger than the object or equal to the object or smaller than the object.

The size of the image with respect to the object is given by linear magnification. Thus, we can define linear magnification as,

"The ratio of height of image h_2 to the height of object h_1"

$$\text{Magnification} = \frac{\text{Height of image}}{\text{Height of object}}$$

$$m = \frac{h_2}{h_1}$$

We know that the image formed by spherical lenses may be real or virtual based on the position of the object. Thus, there are following two cases,

Case 1 : When the image is real and inverted *i.e.,* if the image lies below the principal axis, the height of the image h_2 is negative and h_1 is positive.

So, $m = \frac{-h_2}{h_1}$ = Negative sign

Case 2 : When the image is virtual and erect *i.e.,* if the image lies above the principal axis, the height of the image h_2 is positive and h_1 is also positive.

So, $m = \frac{h_2}{h_1}$ = Positive sign

Thus, we can conclude that when magnification, m has negative sign, the image will be real and inverted and when the magnification, m has positive sign, then the image will be virtual and erect.

When the image is magnified or enlarged, the size of the image will be greater than the size of the object, so $h_1 < h_2$ and $m > 1$.

When the image is smaller or diminished, the size of the image will be smaller than the size of the object, so $h_1 > h_2$ and $m < 1$.

When the image is of same size as that of the object $h_2 = h_1$, then $m = 1$.

Notes

- Since a concave lens forms an image which is always smaller or lesser than the object, $m < 1$.
- Since a convex lens forms an image.
  - Less than the size of the object, $m < 1$
  - More than the size of the object, $m > 1$
  - Equal in size of the object, $m = 1$

The linear magnification (m) of a spherical lens can also be related to the object distance (u) and the image distance (v), then

$$\text{Magnification} = \frac{\text{Image distance}}{\text{Object distance}}$$

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

Notes

- The sign of magnification depends on the signs of height of the object and image.
- For concave lens, both h_1 and h_2 are positive, so magnification is also positive.
- For convex lens, when the image is virtual, magnification is positive and when the image is real, the magnification is negative.

SOLVED PROBLEMS BASED ON LINEAR MAGNIFICATION AND LENS FORMULA

(a) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ (b) $m = \frac{h_2}{h_1} = \frac{v}{u}$

Where 'u' is the object distance, 'v' is the image distance, 'f' is the focal length, 'm' is the linear magnification, 'h_2' is the height of the image, 'h_1' is the height of the object.

1. A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens? Also, find the magnification produced by the lens.

Solution : We know that,

A concave lens always forms a virtual, erect image on the same side of the object.

Image-distance v = –10 cm;

Focal length f = –15 cm;

Object distance u = ?

Applying the formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

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

$$\frac{1}{u} = \frac{1}{-10} - \frac{1}{(-15)} = -\frac{1}{10} + \frac{1}{15}$$

$$\frac{1}{u} = \frac{-3+2}{30} = -\frac{1}{30}$$

$$u = -30 \text{ cm}$$

Thus, the object distance is 30 cm.

Magnification

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

$$m = \frac{-10}{-30} = \frac{+1}{3}$$

$$= +0.33$$

The positive sign shows that the image is erect and virtual. The image is one-third of the size of the object.

2. A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

Solution : Here,

Height of the object h_1 = + 2.0 cm;

Focal length f = + 10 cm;

Object distance u = –15 cm;

Image distance v = ?

Height of the image h_2 = ?

Applying the formula,

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

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

$$\frac{1}{v} = \frac{1}{(-15)} + \frac{1}{10} = -\frac{1}{15} + \frac{1}{10}$$

$$\frac{1}{v} = \frac{-2+3}{30} = \frac{1}{30}$$

Therefore, $v = +30$ cm

The positive sign of v shows that the image is formed at a distance of 30 cm on the other side of the optical centre.

Magnification, $m = \frac{h_2}{h_1} = \frac{v}{u}$

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

Height of the image,

$$h_2 = 2.0\left(\frac{+30}{-15}\right) = -4.0 \text{ cm}$$

Magnification,

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

$$m = \frac{+30 \text{ cm}}{-15 \text{ cm}} = -2$$

The negative signs of m and h_2 show that the image is inverted and real. It is formed below the principal axis. Thus, a real, inverted image, 4 cm tall, is formed at a distance of 30 cm on the other side of the lens. The image is two times enlarged.

1.14 POWER OF A LENS

We know that a convex lens converges the light rays falling on it and a concave lens diverges the light rays falling on it.

The power of a lens is a measure of the degree of convergence or divergence of light rays falling on it. When the point of convergence of ray of light lies close to the optical centre of convex lens, it is said to have more converging power or greater power and when the point of convergence of ray of light lies away from the optical centre of convex lens, it is said to have less converging power or lesser power.

Thus, we can conclude that the power of lens depends on its focal length. So, we can define power of lens as,

"The reciprocal of its focal length in metres"

$$\text{Power} = \frac{1}{\text{Focal length of the lens}} \text{ (in metres)}$$

$$\boxed{P = \frac{1}{f}}$$

Hence, the lens of short focal length has more power whereas the lens of long focal length has less power.

For concave lens, focal length (f) is negative and so power (P) is negative.

For convex lens, focal length (f) is positive and so, the power (P) is positive.

"The SI unit of power of a lens is Dioptre. It is denoted as D."

"One dioptre is the power of a lens of focal length one metre."

The power of lens can be measured directly by using dioptometer. This instrument is used by optician to measure the power of spectacle lenses.

Calculating Power of a Lens

To calculate the power of lens, we need to know its focal length. When the focal length of lens is given in centimetres (cm), we need to convert the focal length from centimetres to metres.

Power of a Combination of Lenses

When two lenses of powers p_1 and p_2 are placed in contact with each other, then the combination power P of lenses will be,

$$\boxed{P = p_1 + p_2}$$

Thus,

"If a number of lenses are placed in contact with one another, the power of the combination of lenses is equal to the algebraic sum of the powers of individual lenses."

For example, when a convex lens of power +6D is placed in contact with a concave lens of power –4D, then the power of combination will be

$$P = p_1 + p_2$$

$$P = 6D - 4D = +2\,D$$

The use of combination of lenses increases the sharpness of the image. It is used in cameras, microscopes and telescopes etc., as it is free from many defects.

PAPER–PEN TEST : 7

1. How will you calculate the power of lens when the focal length is given in centimetre?
2. Define one dioptre.
3. Define power of lens.
4. What is the sign for power in concave lens and convex lens ?
5. How will you relate the linear magnification with respect to object distance and image distance?
6. Explain the sign conventions for spherical lenses.
7. Give the lens formula.
8. Define linear magnification of lens.
9. What happens to the magnification of lens, when the image is :
   (i) Real and inverted
   (ii) Virtual and erect
10. Define the power of combination of lenses.

COMPENDIUM

- Light is a form of energy which travels in straight line.
- A small source of light casts a sharp shadow of an opaque object in its path.
- There are two theories about the nature of light : Wave theory of light and Particle theory of light.
- A transparent substance through which a light can travel is called an optical medium.
- A medium through which light cannot propagate is called opaque medium.
- A medium through which light propagates partially is called translucent medium.
- A medium through which light propagates easily is called transparent medium.
- A ray is the straight line path along which light travels. It is represented by an arrow head on a straight line.
- When light falls on the surface of an object, some part of it is sent back. The process of returning (or sending back) of light to the same medium after striking a surface of an object, is called the reflection of light.
- Based on the surface of the object, there are two types of reflection namely, Regular reflection and Irregular reflection
- When the reflecting surface is rough and dull, the parallel rays of light falling on it are reflected in different directions, it is called irregular reflection.
- When the reflecting surface is smooth and polished, the parallel rays of light falling on it are reflected in one direction, it is called regular reflection.
- The ray of light which falls on the mirror surface is called the incident ray.
- The incident ray shows the direction in which light falls on the mirror.
- The point at which the incident ray falls on the mirror is called the point of incidence.
- The ray of light which is sent back by the mirror is called the reflected ray.
- The reflected ray shows the direction in which the light goes after reflection.
- The normal is perpendicular to the mirror at the point of incidence. It is represented by a dotted line in order to distinguish it from the reflected ray and incident ray.
- The angle made by the incident ray with the normal at the point of incidence is called the angle of incidence. It is denoted as 'i'.
- The angle made by the reflected ray with the normal at the point of incidence is called the angle of reflection. It is denoted as 'r'.
- The reflection of light from a plane surface or from a spherical surface takes place according to two laws called the laws of reflection of light.
- The image which can be obtained on a screen is called a real image.

- The image which cannot be obtained on a screen is called a virtual image.
- The image formed in a plane mirror is at the same distance behind the mirror as the object is in front of the mirror.
- The effect of reversing the sides of an object and its image is called lateral inversion.
- The characteristics of image formed by the plane mirrors can be concluded as follows :
  (a) The image of a object is always virtual which cannot be caught on the screen.
  (b) The image formed in a plane mirror is always erect.
  (c) The distance of the image in a plane mirror is as far behind the mirror as the object is in front of the mirror.
  (d) The image formed in a plane mirror is laterally inverted.
- A spherical mirror is that mirror whose reflecting surface is a part of a hollow sphere of glass.
- The spherical mirrors have a curved surface and so are also known as curved mirrors.
- The spherical mirror in which reflecting surface is curved outwards *i.e.,* towards the centre of the sphere is called concave mirror.
- The spherical mirror in which reflecting surface is curved inwards *i.e.,* away from the centre of the sphere is called convex mirror.
- If 'R' is the radius of the curvature and 'f' is the focal length of the spherical mirror (convex or concave), then

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

- Mirror formula

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

- The size of the image formed by a spherical mirror depends on the position of the object from the mirror.
- The size of image formed by a spherical mirror can be bigger than that of object or equal to the size of object or smaller than that of the object.
- The size of the image with respect to the object is given by linear magnification.
- $\text{Magnification} = \dfrac{\text{Height of image}}{\text{Height of object}}$
- When the image is real and inverted *i.e.,* the image lies below the principal axis, the height of the image h_2 is negative and h_1 is positive.

  So, $m = \dfrac{h_2}{h_1}$ = Negative sign
- When the image is virtual and erect *i.e.,* the image lies above the principal axis, the height of the image h_2 is positive and h_1 is negative.

  So, $m = \dfrac{h_2}{h_1}$ = Positive sign
- When the image is magnified or enlarged, the size of the image will be greater than the size of the object.

  So, $h_1 < h_2$ and $m > 1$
- When the image is smaller or diminished, the size of the image will be smaller than the size of the object.

  So, $h_1 > h_2$ and $m < 1$
- When the image is of same size as that of the object $h_2 = h_1$, then $m = 1$.
- The linear magnification (m) of a spherical mirror can also be related to the object distance (u) and the image distance (v),

$$\text{Magnification} = \frac{\text{Image distance}}{\text{Object distance}}$$

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

- The phenomenon of change in the direction of light when it passes from one medium to another is called refraction.
- The angle of bending of a ray depends on the difference in the speed of light in the two media.
- Larger the difference in speed of light, greater will be the angle of bending and vice-versa.
- When a beam of light made up of waves travelling in medium falls at an angle on the boundary of another medium, the speed of light waves on one side of a beam of light changes a little before the change in speed of light waves on its other side causes a change in the direction of light.
- The phenomenon of refraction takes place when the ray of light goes from an optically rarer medium to an optically denser medium or from a denser medium to a rarer medium.
- A medium in which the speed of light is more is known as optically rarer medium *i.e.,* less dense medium.
- A medium in which the speed of light is less is known as optically denser medium *i.e.,* more dense medium.
- $\text{Refractive index} = \dfrac{\text{Speed of light in air or vacuum}}{\text{Speed of light in medium}}$
- Since the refractive index is a ratio of two velocities, it has no units.
- When light passes from one medium (other than vacuum or air) to another medium, then the refractive index of medium 2 with respect to medium 1 is called relative refractive index.

- The refraction of light on going from one medium to another medium takes place according to two laws which are known as the laws of refraction of light.
- When the refractive index of two medium are equal, then the refraction will not take place.
- When the light is incident normally on a boundary, then the refraction will not take place.
- The perpendicular distance between the original path of incident ray and the emergent ray coming out of a glass slab is called lateral shift.
- Lateral shift depends on the following factors :
  (a) Directly proportional to the thickness of glass slab.
  (b) Directly proportional to the incident angle.
  (c) Directly proportional to the refractive index of the glass slab.
  (d) Inversely proportional to the wavelength of incident light.
- A piece of transparent glass bound by two spherical surfaces is called lens.
- A concave lens is thicker at the edges and thin at the centre.
- A convex lens is thinner at the edges and thick at the centre.
- When a light rays falls on a concave lens parallel to one another and also to the principal axis of the lens, it gets refracted according to the law of refraction.
- All the rays after passing through the concave lens diverge and do not meet at a point. But when the refracted rays are produced backwards, they appear to meet at the same point. This point is called principal focus of concave lens.
- The image formed by a concave lens depends on the position of the object in front of the lens.
- When a light rays falls on a convex lens parallel to one another and also to the principal axis of the lens, it gets refracted according to the law of refraction.
- All the parallel rays after passing through the convex lens converge at some point F on the other side. This point is called principal focus of convex lens.
- The image formed by a convex lens depends on the position of the object in front of the lens.
- When the object is at infinity, its image is formed at the focus of the convex lens can be used to measure the approximate focal length of a convex lens.
- Lens formula

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

- $\text{Magnification} = \dfrac{\text{Height of image}}{\text{Height of object}}$
- When the image is real and inverted *i.e.,* the image lies below the principal axis, the height of the image h_2 is negative and h_1 is positive.

  So, $m = \dfrac{-h_2}{h_1}$ = Negative sign
- When the image is virtual and erect *i.e.,* the image lies above the principal axis, the height of the image h_2 is positive and h_1 is negative.

  So, $m = \dfrac{h_2}{h_1}$ = Positive sign
- When the image is magnified or enlarged, the size of the image will be greater than the size of the object.

  So, $h_1 < h_2$ and $m > 1$
- When the image is smaller or diminished, the size of the image will be smaller than the size of the object.

  So, $h_1 > h_2$ and $m < 1$
- When the image is of same size as that of the object $h_2 = h_1$, then $m = 1$.
- $\text{Magnification} = \dfrac{\text{Image distance}}{\text{Object distance}}$

  $$m = \frac{v}{u}$$
- The ability of the lens to converge the light rays falling on it is called the power of lens.
- $\text{Power} = \dfrac{1}{\text{Focal length of the lens}}$

  $$P = \frac{1}{f}$$
- For concave lens, focal length (f) is negative so power (P) is negative.
- For convex lens, focal length (f) is positive and so, the power (P) is positive.
- The SI unit of power is Dioptre. It is denoted as D.
- The power of lens can be measured directly by using dioptremeter.
- One dioptre is the power of a lens of focal length one metre.
- To calculate the power of lens, we need to know its focal length.

EXERCISES (SOLVED)

NCERT IN TEXT QUESTIONS

1. Define the principal focus of a concave mirror.

Ans : Light rays that are parallel to the principal axis of a concave mirror converge at a specific point on its principal axis after reflecting from the mirror. This point is known as the principal focus of the concave mirror.

2. The radius of curvature of a spherical mirror is 20 cm. What is its focal length ?

Solution : Radius of curvature, R = 20 cm

Focal length, $f = \frac{R}{2}$

$\Rightarrow \quad f = \frac{20}{2} = 10$ cm

3. Name the mirror that can give an erect and enlarged image of an object.

Ans : Concave mirror.

4. Why do we prefer a convex mirror as a rear-view mirror in vehicles?

Ans : Convex mirrors gives a virtual, erect, and diminished image of the objects placed in front of them. They are preferred as a rear-view mirror in vehicles because they give a wider field of view, which allows the driver to see most of the traffic behind him.

5. Find the focal length of a convex mirror whose radius of curvature is 32 cm.

Ans : Radius of curvature, R = 32 cm

Focal length, $f = \frac{R}{2}$

$\Rightarrow \quad f = \frac{32}{2}$ cm

$f = 16$ cm

6. A concave mirror produces three times magnified (enlarged) real image of object placed at 10 cm in front of it. Where is the image located?

Solution : Let the height of the object = h

Height of the image, $h' = -3h$ (Image formed is real)

Object distance, $u = -10$ cm

Then, magnification produced by a spherical mirror is given by the relation,

$$m = \frac{h'}{h} = -\frac{v}{u}$$

Substituting the values, we get

$$\frac{-3h}{h} = -\frac{v}{u}$$

$$\Rightarrow \quad -3 = -\frac{v}{-10}$$

$$v = -30 \text{ cm}$$

Here, the negative sign indicates that an inverted image is formed at a distance of 30 cm in front of the given concave mirror.

7. A ray of light travelling in air enters obliquely into water. Does the light ray bend towards the normal or away from the normal? Why?

Ans : The light ray bends towards the normal. When a ray of light travels from an optically rarer medium to an optically denser medium, it gets bent towards the normal. Since water is optically denser than air, a ray of light travelling from air into the water will bend towards the normal.

8. Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass? The speed of light in vacuum is 3×10^8 m/s .

Ans : Speed of light in vacuum, $c = 3 \times 10^8$ m/s

Refractive index of glass, $n_g = 1.50$

Using the formula, $v = \frac{c}{n_g}$, we get

$$v = \frac{3 \times 10^8}{1.5}$$

$$v = 2 \times 10^8 \text{ m/s}$$

9. Find out from below table the medium having highest optical density. Also find the medium with lowest optical density.

Material Medium	Refractive Index	Material Medium	Refractive Index
Air	1.0003	Canada Balsam	1.53
Ice	1.31	Rock salt	1.54
Water	1.33	Carbon disulphide	1.63
Alcohol	1.36	Dense flint glass	1.65
Kerosene	1.44	Ruby	1.71
Fused quartz	1.46	Sapphire	1.77
Turpentine oil	1.47	Diamond	2.42
Benzene	1.50		
Crown glass	1.52		

Ans : Highest optical density = Diamond

Lowest optical density = Air

Optical density of a medium is directly proportional to the refractive index of that medium. A medium which has the highest refractive index will have the highest optical density and vice-versa.

It can be observed from above table that diamond and air respectively have the highest and lowest refractive index. Therefore, diamond has the highest optical density and air has the lowest optical density.

10. You are given kerosene, turpentine and water. In which of these does the light travel fastest? Use the information given in Table. [refer question 9]

Ans : Speed of light in a medium is given by the relation for refractive index (n_m).

Using the formula, $n_m = \frac{c}{v}$

Light will travel the slowest in the material which has the highest refractive index and travel the fastest in the material which has the lowest refractive index. It can be observed from table that the refractive indices of kerosene, turpentine, and water are 1.44, 1.47, and 1.33 respectively. Therefore, light travels the fastest in water.

11. The refractive index of diamond is 2.42. What is the meaning of this statement?

Ans : Using the formula, $n_m = \frac{c}{v}$ where, c is the speed of light in vacuum or air

The refractive index of diamond is 2.42. This means that the ratio of speed of light in vacuum or air to the speed of light in diamond is equal to 2.42.

12. Define 1 dioptre of power of a lens. **Ans :** One dioptre is defined as the power of a lens of focal length 1 metre.

13. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object? Also, find the power of the lens.

Solution : It is given that the image of the needle is formed at a distance of 50 cm from the convex lens. Hence, the needle is placed in front of the lens at a distance of 50 cm.

Object distance, u = –50 cm

Image distance, v = 50 cm

Focal length = f

According to the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Substituting the values, we get

$$\frac{1}{50} - \frac{1}{-50} = \frac{1}{f}$$

$$\frac{1}{50} + \frac{1}{50} = \frac{1}{f}$$

$$\frac{2}{50} = \frac{1}{f}$$

$$\frac{1}{25} = \frac{1}{f}$$

$$f = 25 \text{ cm} = 0.25\text{m}$$

$$P = \frac{1}{f}$$

$$P = \frac{1}{0.25} = +4\text{D}$$

Hence, the power of the given lens is +4 D.

14. Find the power of a concave lens of focal length 2 m.

Ans : Focal length of concave lens, f = –2 m

(Since the focal length of a concave lens is negative).

$$P = \frac{1}{f} = -0.5\text{D}$$

Hence, the power of the given concave lens is - 0.5 D.

NCERT END EXERCISE

1. Which one of the following materials cannot be used to make a lens?

(a) Water (b) Glass

(c) Plastic (d) Clay

Ans : (d)

2. The image formed by a concave mirror is observed to be virtual, erect and larger than the object. Where should be the position of the object?

(a) Between the principal focus and the centre of curvature

(b) At the centre of curvature

(c) Beyond the centre of curvature

(d) Between the pole of the mirror and its principal focus.

Ans : (d)

3. Where should an object be placed in front of a convex lens to get a real image of the size of the object?

(a) At the principal focus of the lens

(b) At twice the focal length

(c) At infinity

(d) Between the optical centre of the lens and its principal focus.

Ans : (b)

4. A spherical mirror and a thin spherical lens each have a focal length of –15 cm. The mirror and the lens are likely to be :

(a) both concave

(b) both convex

(c) the mirror is concave and the lens is convex

(d) the mirror is convex, but the lens is concave

Ans : (a)

5. No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be :

(a) plane (b) concave

(c) convex (d) either plane or convex

Ans : (d)

6. Which of the following lenses would you prefer to use while reading small letters found in a dictionary ?

(a) A convex lens of focal length 50 cm

(b) A concave lens of focal length 50 cm

(c) A convex lens of focal length 5 cm

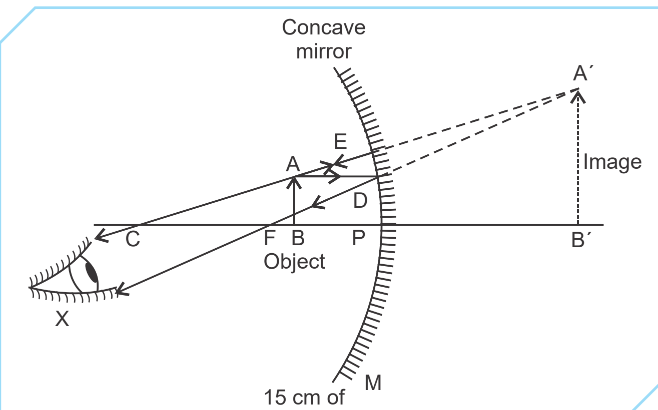
(d) A concave lens of focal length 5 cm

Ans : (c)

7. We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror ? What is the nature of the image ? Is the image larger or smaller than the object ? Draw a ray diagram to show the image formation in this case.

Ans : Since the Focal length is 15 cm, the range of object distance = 0 cm to 15 cm.

A concave mirror gives an erect image when an object is placed between its pole (P) and the principal focus (F). Hence, to obtain an erect image of an object from a concave mirror of focal length 15 cm, the object must be placed anywhere between the pole and the focus. The image formed will be virtual, erect, and magnified in nature, as shown in the given figure.



8. Name the type of mirror used in the following situations. (a) Headlights of a car (b) Side/rear-view mirror of a vehicle (c) Solar furnace

Support your answer with reason

Ans : (a) Concave mirror

(b) Convex mirror

(c) Concave mirror

Explanation :

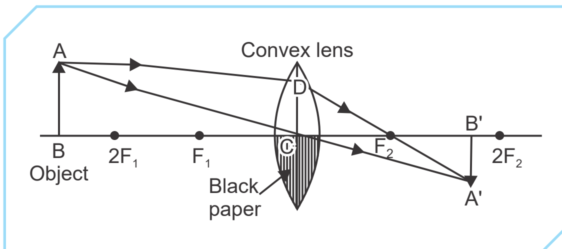
(a) Concave mirror is used in the headlights of a car. This is because concave mirrors can produce powerful parallel beam of light when the light source is placed at their principal focus. This powerful beam of light helps us to see things upto a considerable distance in the darkness of night.

(b) Convex mirror is used in side/rear view mirror of a vehicle. Convex mirrors give a virtual, erect, and diminished image of the objects placed in front of it. Because of this, they have a wide field of view. It enables the driver to see most of the traffic behind him/her.

(c) Concave mirrors are convergent mirrors. That is why they are used to construct solar furnaces. When solar furnace is placed at focus of concave mirror sun rays after reflection from its surface, gets converged at focus with much intense heat and solar furnace gets very hot.

9. One-half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object ? Verify your answer experimentally. Explain your observations.

Ans : The convex lens will form complete image of an object, even if the one half is covered with black paper, because light rays can still pass through optical centre of convex lens. We can verify this by obtaining image of any distant object on a screen by half covered convex lens. This can be more clear by the following ray diagram.



10. An object 5 cm in length is held 25 cm away from a converging lens of focal length 10 cm. Draw the ray diagram and find the position, size and the nature of the image formed.

Solution : Object distance, = –25 cm

Object height, h_1 = 5 cm

Focal length, f = +10 cm

Using the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Substituting the values, we get

$$\frac{1}{v} - \frac{1}{-25} = \frac{1}{10}$$

$$\frac{1}{v} + \frac{1}{25} = \frac{1}{10}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{25}$$

$$\frac{1}{v} = \frac{3}{50}$$

$$v = \frac{50}{3}$$

$$v = 16.67 \text{ cm}$$

The positive value of v shows that the image is formed at the other side of the lens.

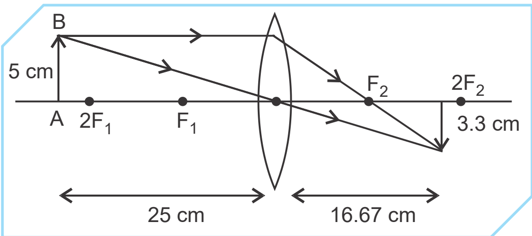
Magnification $m = \frac{h_2}{h_1} = -\frac{v}{u} = -\frac{16.67}{25} = -0.66$

The negative sign shows that the image is real and formed behind the lens.

Magnification $m = \frac{h_2}{h_1}$

$$h_2 = -3.3 \text{ cm}$$

The negative value of image height indicates that the image formed is inverted. The position, size and nature of image are shown in the following ray diagram.



11. A concave lens of focal length 15 cm forms an image 10 cm from the lens. How far is the object placed from the lens ? Draw the ray diagram.

Solution : Focal length of concave lens $f = -15$ cm

Image distance, $v = -10$ cm

According to the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Substituting the values, we get

$$\frac{1}{-10} - \frac{1}{u} = \frac{1}{-15}$$

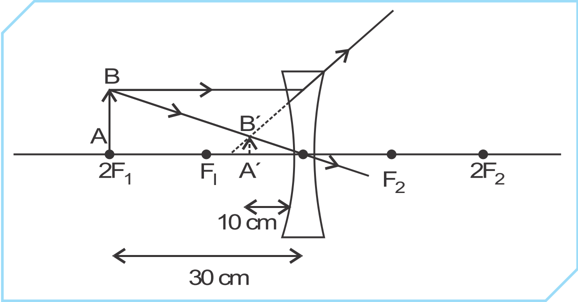
$$-\frac{1}{u} = \frac{-1}{15} + \frac{1}{10}$$

$$-\frac{1}{u} = \frac{-2+3}{30}$$

$$-\frac{1}{u} = \frac{1}{30}$$

$$u = -30 \text{ cm}$$

The negative value of u indicates that the object is placed 30 cm in front of the lens. This is shown in the following ray diagram.



12. An object is placed at a distance of 10 cm from a convex mirror of focal length 15 cm. Find the position and nature of the image.

Solution : Focal length of convex mirror, $f = +15$ cm

Object distance, $u = -10$ cm

According to the mirror formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Substituting the values, we get

$$\frac{1}{v} - \frac{1}{-10} = \frac{1}{15}$$

$$\frac{1}{v} = \frac{1}{15} + \frac{1}{10}$$

$$\frac{1}{v} = \frac{2+3}{30}$$

$$\frac{1}{v} = \frac{5}{30}$$

$$\frac{1}{v} = \frac{1}{6}$$

$$v = +6 \text{ cm}$$

Thus, the image is formed at a distance of 6 cm from the convex mirror. Since the image is formed behind the convex mirror, so image is virtual and erect.

13. The magnification produced by a plane mirror is +1. What does this mean?

Ans : Magnification produced by a mirror

$$m = \frac{\text{Height of image}}{\text{Height of object}}$$

$$1 = \frac{\text{Height of image}}{\text{Height of object}}$$

Height of image = Height of object

Hence, the image formed by the plane mirror is of the same size as that of the object. The positive sign shows that the image formed is virtual and erect.

14. An object 5.0 cm in length is placed at a distance of 20 cm in front of a convex mirror of radius of curvature 30 cm. Find the position of the image, its nature and size.

Solution : Object distance, $u = -20$ cm

Object height, $h_1 = 5$ cm

Radius of curvature, R = 30 cm

Radius of curvature, R = $2 \times f$

Focal length, $f = 15$ cm

According to the mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Substituting the values, we get

$$\frac{1}{v} + \frac{1}{-20} = \frac{1}{15}$$

$$\frac{1}{v} - \frac{1}{20} = \frac{1}{15}$$

$$\frac{1}{v} = \frac{1}{15} + \frac{1}{20}$$

$$\frac{1}{v} = \frac{4+3}{60}$$

$$\frac{1}{v} = \frac{7}{60}$$

$$v = \frac{60}{7} = +8.57 \text{ cm}$$

$$v = 8.57\text{cm}$$

The positive value of v indicates that the image is formed behind the mirror.

Magnification produced by a mirror,

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

$$m = \frac{-v}{u} = -\frac{+8.57}{-20}$$

$$m = +0.42$$

The positive value of magnification indicates that the image formed is virtual and erect.

So, $$m = \frac{h_2}{h_1}$$

$$0.42 = \frac{h_2}{5}$$

$$h_2 = 2.14 \text{ cm}$$

The positive value of image height indicates that the image formed is erect. Therefore, the image formed is virtual, erect, and smaller in size.

15. An object of size 7.0 cm is placed at 27 cm in front of a concave mirror of focal length 18 cm. At what distance from the mirror should a screen be placed, so that a sharp focussed image can be obtained? Find the size and the nature of the image.

Solution : Object distance, $u = -27$ cm

Object height, $h_1 = 7$ cm

Focal length, $f = -18$ cm.

According to the mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Substituting the values, we get

$$\frac{1}{v} + \frac{1}{-27} = \frac{1}{-18}$$

$$\frac{1}{v} = \frac{1}{27} - \frac{1}{18} = \frac{-3+2}{54}$$

$$\frac{1}{v} = \frac{-1}{54}$$

$$v = -54 \text{ cm}$$

The screen should be placed at a distance of 54 cm in front of the given mirror.

Magnification produced by a mirror,

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

$$m = -\frac{v}{u} = -\frac{-54}{-27}$$

$$m = -2$$

The negative value of magnification indicates that the image formed is real.

Also, $$m = \frac{h_2}{h_1}$$

$$-2 = \frac{h_2}{7}$$

$$h_2 = 7(-2) = -14 \text{ cm.}$$

The negative value of image height indicates that the image formed is inverted.

Hence, the image formed is real and inverted, larger than the object.

16. Find the focal length of a lens of power – 2.0 D. What type of lens is this ?

Solution : Power of lens P = $\frac{1}{f}$

$$f = \frac{1}{P} = \frac{1}{-2} = -0.5 \text{ m}$$

A concave lens has a negative focal length. Hence, it is a concave lens.

17. A doctor has prescribed a corrective lens of power +1.5 D. Find the focal length of the lens. Is the prescribed lens diverging or converging ?

Solution : $f = \frac{1}{P} = \frac{1}{1.5} = 0.66$ m.

A convex lens has a positive focal length. Hence, it is a convex lens or a converging lens.

VALUE BASED QUESTIONS (VBQs)

1. Rishika is a student of class X and Ravina is studying in class her. Rishika told Ravina that she would show a magic to her. Rishika had a lens. She focussed the rays of sunlight on the bare arm of Ravina. After few seconds, Ravina felt pain and removed her arm away. Rishika was laughing at Ravina.

(a) Name the type of lens Rishika had.

(b) Why did Ravina feel pain ?

(c) Comment on the behaviour of Rishika.

Ans : (a) Convex lens

(b) When sunlight is focussed on the arm of Ravina, heat is produced. This heat gave the burning sensation to the skin of Ravina's arm, (c) Rishika should not have exploited the ignorance of Ravina. She could have performed this magic on a black paper rather than the arm of Ravina.

2. Vivek Sharma while driving his bike sees a woman behind driving a moped through his rear view mirror. He sees that her saree almost touching the wheels of the vehicle. He stops her and alerts.

What kind of mirror is used as a rear view mirror.

What values you observe in Mr. Sharma ?

Ans : Convex mirror is used as rear view mirror. The values of Vivek Sharma are : (a) concern about others, (b) observation of Traffic rules (c) Responsible citizen.

3. Simran's father Mr. Ram runs a cosmetics and perfumes shop in a crowded market place. Mr. Ram usually complains at home that there is lot of 'shop-lifting' in his shop which was causing loss to him. Simran used to hear such complaints of her father. One day Simran went to the market and purchased two big mirrors of a special kind. She then went to her father's shop and fixed the two big mirrors at two strategic positions inside the shop. Mr. Ram found that after the installation of these mirrors, the shop-lifting almost stopped. He was very happy and thanked Simran for making this possible.

(a) What type of mirrors were fixed by Simran in the shop ?

(b) How did these mirrors help in preventing shop-lifting ?

(c) What values are exhibited by Seema in this episode ?

Ans : (a) Convex mirrors.

(b) Mr. Ram could see the virtual, erect and diminished images of the customers by looking at the two big convex mirrors. In this way, Mr. Ram was able to keep a watch on most of the customers present in the shop (with the help of these, two big convex mirrors) and hence the shop-lifting almost stopped.

(c) The values exhibited by Simran are (i) Knowledge about various types of mirrors (ii) Application of knowledge in everyday situations, and (iii) Desire to solve her father's problem.

4. Jaya a student of class X went to an amusement park along with her younger brother. There, they entered in a small hall having number of large size mirrors. In front of one of the mirrors, they looked very funny. Their faces were normal, their bellies were fat and legs were short. Jaya's younger brother was frightened and tried to hit the mirror with his foot. However, Jaya stopped him to do so.

(a) Name the type of mirror in front of which Jaya and his brother were standing ?

(b) What is the cause of the distortion of their images ?

(c) What values are shown by Jaya ?

Ans : (a) The mirror was the combination of plane, concave and convex mirrors. The top most part was a plane mirror, the middle one was concave and the lower most was convex mirror.

(b) The refraction of light from mirrors distorted their images.

(c) Jaya knew that public or private property should not be damaged. Therefore, she stopped her brother to break the mirror.

HIGHER ORDER THINKING SKILL (HOTS) QUESTIONS

1. How does f change when object distance u from the mirror is changed?

Ans : When u is changed, v changes, but f remains constant. This is because focal length of mirror depends only on radius of curvature of the mirror.

2. Which factors determine the focal length of a lens?

Ans : The focal length of a lens depends on

1. Radii of curvature of the surface of the lens.
2. Nature of material of the lens
3. Nature of medium in which lens is placed

3. The formula for linear magnification of a spherical mirror is $m = \frac{h_2}{h_1} = \frac{-v}{u}$. What determines the sign of m? What is the significance of this sign?

Ans : In the formula $m = \frac{h_2}{h_1} = \frac{-v}{u}$, the sign of m is determined by the signs of h_1 and h_2. When m is positive, the image is virtual and erect. When m is negative, the image is real and inverted.

4. What happens to the power and focal length of a lens when it is dipped in water?

Ans : The focal length of a lens increases and the power gets decreased.

5. How do you find the rough focal length of a convex lens? Is the same method applicable to a concave lens?

Ans : The rough focal length of a convex lens is obtained by forming sharp image of a very distant object on a screen. The distance of the screen from the lens gives us the rough focal length of the lens. This method is not applicable to a concave lens, as image formed by a concave lens is virtual and it cannot be taken on the screen.

EXERCISES (UNSOLVED)

VIVA VOCE QUESTIONS

Split the class into groups and ask them these questions.

1. Which property of light makes a pencil cast a shadow when it is held in front of a light source ?
2. Name the nature of the image seen in a plane mirror.
3. Name the phenomenon in which the right side of an object appears to be the left side of the image in a plane mirror.
4. Where is the image when you look at something in a mirror ?
5. What type of mirror is represented by the front side of a steel spoon ?
6. Where an object should be placed in front of the concave mirror so as to obtain its virtual, erect and magnified image ?
7. Where the image is formed, when the object is placed at infinity in front of a concave mirror ?
8. Name the type of mirror which has negative focal length.
9. Which type of mirror has a wider field of view ?
10. What is the ratio of sine of angle of incidence to the sine of angle of refraction ?

MULTIPLE CHOICE QUESTION

1. The nature of the image formed by the concave mirror when the object is placed between C and F is :

(a) Real and Virtual (b) Real and Inverted

(c) Real and erect (d) Virtual and erect

2. What is not a characteristic of a rear view mirror in a car ?

(a) Convex in nature (b) Concave in nature

(c) They have wider field of coverage

(d) They give a virtual image

3. A piece of red cloth when suitably illuminated may look black, but a piece of black cloth will never appear red. This phenomenon occurs because :

(a) Black cloth reflects only black light

(b) Black absorbs all the colours

(c) Black cloth reflects all colours

(d) Red cloth reflects all colours

4. Consider four mediums P,Q, R and S whose refractive indices are 2.14, 1.99, 2.98, and 2.16 respectively. Assume that if light travels from one medium to another. Calculate the rate of change will be utmost in which medium.

(a) P to Q (b) Q to R

(c) R to S (d) S to P

5. The refractive index (n) of a colourless, volatile, non-polar solvent is 1.24 to the refractive index of a solid ice cube . The unmitigated refractive index of the ice cube is 1.31. Enumerate the unmitigated refractive index of the non-polar solvent.

(a) 1.6522 (b) 1.3241

(c) 1.6244 (d) 1.2401

ASSERTION AND REASON

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

1. Assertion : A ray of light that travels obliquely from one transparent medium into another will change its direction in the second medium.

Reason : Refraction is due to change in the speed of light as it enters from one transparent medium to another.

2. **Assertion :** The refractive index of Kerosene is 1.44 which is optically denser than water.
   Reason : The mass density of kerosene is lesser than water.

BASED ON CONCEPTS

1. Can you measure approximate focal length of concave lens ?
2. Why the linear magnification of a convex lens is either positive or negative ?
3. When a ray of light enters from air to glass, does it bend towards normal ?
4. When a ray of light enters from air to water, which way will it bend ?
5. Is the mirror formula same for convex and concave mirrors?
6. Can a magnified image be formed by a convex mirror?
7. How do you draw normal at any point on a spherical mirror ?
8. If the radius of curvature of a convex mirror is 30 cm, then what is its focal length ?
9. If the focal length of a convex mirror is 12 cm, then what is its radius of curvature ?
10. Can the magnification of a convex mirror be negative ?

PROBLEMS BASED ON NUMERICALS

1. What is the focal length and power of the combination of a convex lens of focal length 40 cm placed in contact with a concave lens of focal length 20 cm?
2. What is the focal length of the converging mirror which forms a real image of height 8 cm of an object of height 2 cm placed 40 cm away from the mirror?

MATCH THE FOLLOWING

1.

S. No.	Column 1	Column 2	Correct Match
1.	Zero curvature	Convex lens of small focal length	
2.	Magnifying glass	Plane glass	
3.	Always virtual and erect image on same side	Plane mirror	
4.	Focal length infinity	Concave lens	

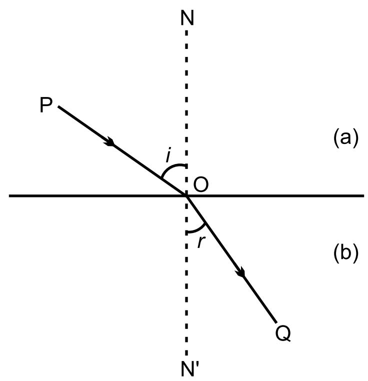
2.

S. No.	Column 1	Column 2	Correct Match
1.	Convergent lens	Convex mirror	
2.	Always diminished image behind the mirror	Image on plane mirror	
3.	Left side object becomes right side in image	Diamond	
4.	Refractive index is maximum	Convex lens	

PARAGRAPH AND TABLE BASED QUESTION

1. Read the following paragraph and answer the following Questions.

   When light ray goes from one transparent medium to another transparent medium, it suffers a change in direaction, into second medium. The extent of the change in direction suffered by the phenomenon of change in the path of light rays when going from one medium to another medium is known as refraction. Ray is a given pair of media can be expressed in terms of refractive index. The refractive index is related to an important physical quantity i.e. relative speed of light in different media.



(a) When light goes from one medium to another, which of the three parameters, frequency, wavelength, velocity change ?

(b) A ray of light in air enters glass. Does it bend towards normal ?

(c) If the same ray enters water. which way will it bend ?

(d) What is the unit of refractive index ?

2. Question number 2 (a)- 2 (d) are based on table given below. Study the table and answer the following questions. The result of image formation of a concave mirror for different positions of the object are given in table.

S. No.	Position of the object	Position of the image	Size of the image
1.	At infinity	At F	Highly diminished
2.	Beyond the centre of curvature	(a)	Diminished
3.	At C	At C	(b)
4.	Between C and F	(c)	Magnified or enlarged
5.	At F	(d)	Highly magnified or infinitely larger

(a) What will be (a) in the table.

(b) What will be (b) in the table.

(c) What will be (c) in the table.

(i) Behind the mirror (ii) Exact at C

(iii) Beyond C (iv) None of these

(d) What will be (d) in the table ?

(i) Behind the mirror (ii) Beyond C

(iii) At infinity (iv) None of these

ANSWERS

VIVA VOCE QUESTIONS

1. Light travels in a straight line.
2. Virtual image.
3. Lateral inversion.
4. Behind the mirror.
5. Concave mirror.
6. Between pole and focus.
7. At focus.
8. Concave mirror.
9. Convex mirror.
10. Snell's law.

MULTIPLE CHOICE QUESTION

1. (c) Real and erect.
2. (b) Concave in nature
3. (b) Black absorbs all the colours
4. (b) Q to R
5. (c) 1.6244

ASSERTION AND REASON

1. (a) A ray of light that travels obliquely from one transparent medium to another will change its direction in the second medium. It is nothing but the process called refraction. This occurs due to change in the speed of light as it enters from one transparent medium to another.
2. (a) We know that the refractive index of kerosene is 1.44 and the refractive index of water is 1.33. It shows that kerosence is optically denser than water. But the mass density of kerosence is lesser than water so, there is no relation between mass density and optical density. Therefore, it clearly defines that an optically denser medium may not posses greater mass density. Thus, the given assertion and reason are true but reason is not the correct explanation of assertion.

BASED ON CONCEPTS

1. No.
2. Because the image formed by a convex lens may be real and inverted for some positions of the object and may also be virtual and erect for some positions.
3. Yes.
4. It will bend towards normal.
5. Yes.
6. No.
7. Normal is the line joining the point A to the centre of curvature of the mirror. A is the any point on a spherical mirror.
8. 15 cm.
9. 24 cm.
10. No.

PROBLEMS BASED ON NUMERICALS

1. – 2.5 D, – 40 cm
2. – 32 cm

MATCH THE FOLLOWING

1.

S. No.	Column 1	Column 2	Correct Match
1.	Zero curvature	Convex lens of small focal length	2
2.	Magnifying glass	Plane glass	1
3.	Always virtual and erect image on same side	Plane mirror	4
4.	Focal length infinity	Concave lens	3

2.

S. No.	Column 1	Column 2	Correct Match
1.	Convergent lens	Convex mirror	4
2.	Always diminished image behind the mirror	Image on plane mirror	1
3.	Left side object becomes right side in image	Diamond	2
4.	Refractive index is maximum	Convex lens	3

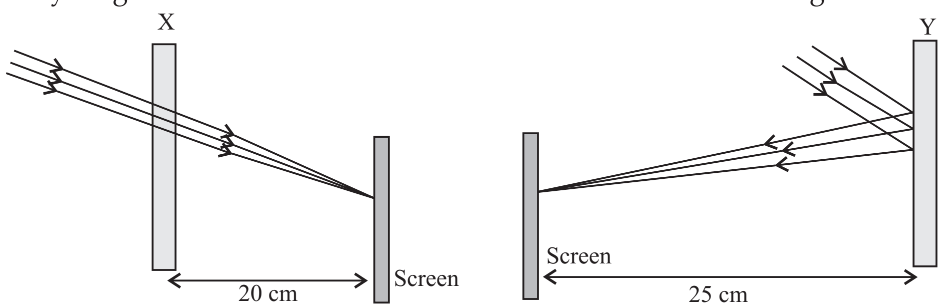
PARAGRAPH AND TABLE BASED QUESTION

1. (a) Two parameters change. They are wavelength and velocity.
(b) Yes, it bends towards normal.
(c) The ray entering water from air will also bend towards normal.
(d) No unit.

2. (a) Between C and F.
(b) Same size.
(c) (iii) Beyond C.
(d) (iii) At infinity.

PREVIOUS YEAR BOARD QUESTIONS

1. Study the given ray diagrams and select the correct statement from the following :



(a) Device X is a concave mirror and device Y is a convex lens, whose focal lengths are 20 cm and 25 cm respectively.
(b) Device X is a convex lens and device Y is a concave mirror, whose focal lengths are 10 cm and 25 cm respectively.
(c) Device X is a concave lens and device Y is a convex mirror, whose focal lengths are 20 cm and 25 cm respectively.
(d) Device X is a convex lens and device Y is a concave mirror, whose focal lengths are 20 cm and 25 cm respectively.

Ans : (d) Device X is a convex lens and device Y is a concave mirror, whose focal lengths are 20 cm and 25 cm respectively.

2. A student obtains a blurred image of a distant object on a screen using a convex lens. To obtain a distinct image on the screen he should move the lens.
(a) away from the screen
(b) towards the screen
(c) to a position very far away from the screen.
(d) either towards or away from the screen depending upon the position of the object.

Ans : (b) towards the screen

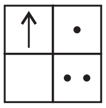
3. A student very cautiously traces the path of a ray through a glass slab for different values of the angle of incidence ($\angle i$). He then measures the corresponding values of the angle of refraction ($\angle r$) and the angle of emergence ($\angle e$) for every value of the angle of incidence. On analysing these measurements of angles, his conclusion would be :
(a) $\angle i > \angle r > \angle e$
(b) $\angle i = \angle e > \angle r$
(c) $\angle i < \angle r < \angle e$
(d) $\angle i = \angle e < \angle r$

Ans : (b) $\angle i = \angle e > \angle r$

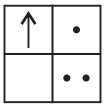
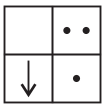
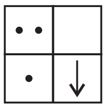
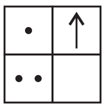
4. Three students A, B and C focussed a distant building on a screen with the help of a concave mirror. To determine focal length of the concave

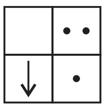
mirror they measured the distances as given below :
Student A : From mirror to the screen
Student B : From building to the screen
Student C : From building to the mirror
Who measured the focal length correctly :
(a) Only A
(b) Only B
(c) A and B
(d) B and C
Ans : (a) Only A

5. If you focus the image of a distant object, whose shape is given below, on a screen using a convex lens.

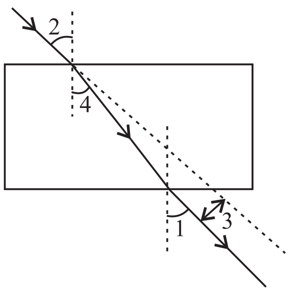


the shape of the image of this object on the screen would be :

(a) 
(b) 
(c) 
(d) 

Ans :
(b) 

6. The correct sequencing of angle of incidence, angle of emergence, angle of refraction and lateral displacement shown in the following diagram by digits 1, 2, 3 and 4 is :



(a) 2, 4, 1, 3
(b) 2, 1, 4, 3
(c) 1, 2, 4, 3
(d) 2, 1, 3, 4
Ans : (b) 2, 1, 4, 3

7. To determine the approximate value of the focal length of a given concave mirror, you focus the image of a distant object formed by the mirror on a screen. The image obtained on the screen, as compared to the object is always :
(a) Laterally inverted and diminished
(b) Inverted and diminished
(c) Erect and diminished
(d) Erect and highly diminished
Ans : (b) Inverted and diminished

8. Suppose you have focused on a screen the image of candle flame placed at the farthest end of the laboratory table using a convex lens. If your teacher suggests you to focus the parallel rays of the sun, reaching your laboratory table, on the same screen, what you are expected to do is to move the :
(a) lens slightly towards the screen
(b) lens slightly away from the screen
(c) lens slightly towards the sun
(d) lens and screen both towards the sun
Ans :
(a) lens slightly towards the screen

9. In your laboratory you trace the path of light rays through a glass slab for different values of angle of incidence ($\angle i$) and in each case measure the values of the corresponding angle of refraction ($\angle r$) and angle of emergence ($\angle e$).
On the basis of your observations your correct conclusion is :
(a) $\angle i$ is more than $\angle r$, but nearly equal to $\angle e$
(b) $\angle i$ is less than $\angle r$, but nearly equal to $\angle e$
(c) $\angle i$ is more than $\angle e$, but nearly equal to $\angle r$
(d) $\angle i$ is less than $\angle e$, but nearly equal to $\angle r$
Ans : (a) $\angle i$ is more than $\angle r$, but nearly equal to $\angle e$

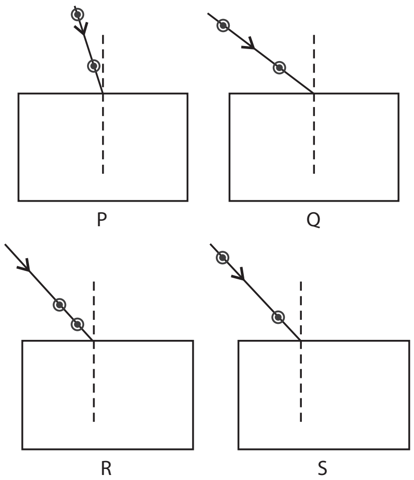
10. A student obtained a sharp image of a candle flame placed at the distant end of the laboratory table on a screen using a concave mirror to determine its focal length. The teacher suggested him to focus a distant building about 1 km far from the laboratory, for getting more correct value of the focal length. In order to focus the distant building on the same screen the student should slightly move the :
(a) mirror away from the screen
(b) screen away from the mirror
(c) screen towards the mirror
(d) screen towards the building
Ans : (c) screen towards the mirror

11. To determine the approximate focal length of the given convex lens by focussing a distant object (say, a sign board), you try to focus the image of the object on a screen. The image you obtain on the screen is always :

(a) erect and laterally inverted
(b) erect and diminished
(c) inverted and diminished
(d) virtual, inverted and diminished

Ans : (c) inverted and diminished

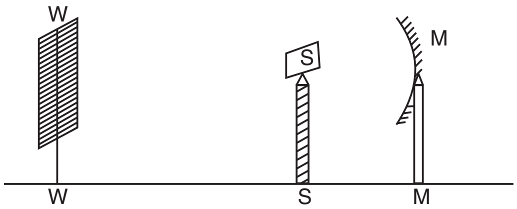
12. Select from the following the best experimental set-up for tracing the path of a ray of light passing through a rectangular glass slab :



(a) P (b) Q
(c) R (d) S

Ans : (d) S

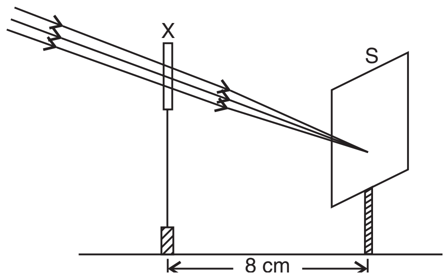
13. A student obtains a sharp image of the distant window (W) of the school laboratory on the screen (S) using the given concave mirror (M) to determine its focal length. Which of the following distance should he measure to get the focal length of the mirror ?



(a) MW
(b) MS
(c) SW
(d) MW – MS

Ans : (b) MS

14. A student used a device (X) to obtain/focus the image of a well illuminated distant building on a screen (S) as shown below in the diagram. Select the correct statement about the device (X).



(a) This device is a concave lens of focal length 8 cm.
(b) This device is a convex mirror of focal length 8 cm.
(c) This device is a convex lens of focal length 4 cm.
(d) This device is a convex lens of focal length 8 cm.

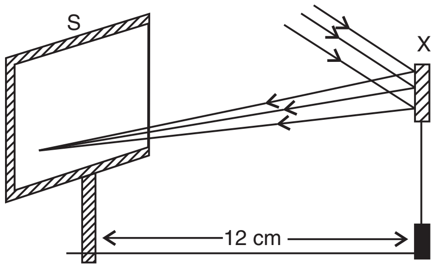
Ans : (d) This device is a convex lens of focal length 8 cm.

15. A student traces the path of a ray of light through a rectangular glass slab for the different values of angle of incidence. He observes all possible precautions at each step of the experiment. At the end of the experiment, on analysing the measurements, which of the following conclusions is he likely to draw ?

(a) $\angle i = \angle e < \angle r$
(b) $\angle i < \angle e < \angle r$
(c) $\angle i > \angle e < \angle r$
(d) $\angle i = \angle e > \angle r$

Ans : (d) $\angle i = \angle e > \angle r$

16. Study the following diagram and select the correct statement about the device 'X' :



(a) Device 'X' is a concave mirror of radius of curvature 12 cm.
(b) Device 'X' is a concave mirror of focal length 6 cm.
(c) Device 'X' is a concave mirror of focal length 12 cm.
(d) Device 'X' is a convex mirror of focal length 12 cm.

Ans : (c) Device 'X' is a concave mirror of focal length 12 cm.

17. A student has obtained a point image of a distant object using the given convex lens. To find the focal length of the lens he should measure the distance between the :

(a) lens and the object only

(b) lens and the screen only

(c) object and the image only

(d) lens and the object and also between the object and the image

Ans : (b) lens and the screen only

18. Four students P, Q, R and S traced the path of a ray of light passing through a glass slab for an angle of incidence 40° and measured the angle of refraction. The values as measured them were 18°; 22°; 25° and 30° respectively. The student who has performed the experiment methodically is

(a) P (b) Q

(c) R (d) S

Ans : (c) R

19. An object is placed at a distance of 30 cm from a concave lens of focal length 15 cm. List four characteristics (nature, position, etc.) of the image formed by the lens.

Ans : Given : u = – 30 cm, f = – 15 cm.

We know that,

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

$$\frac{1}{v}-\frac{1}{(-30)} = \frac{1}{(-15)}$$

$$\frac{1}{v} = \frac{-1}{15}-\frac{1}{30}$$

$$\frac{1}{v} = \frac{-2-1}{30} = \frac{-3}{30} = \frac{-1}{10}$$

$$v = -10 \text{ cm}$$

Characteristics of image :

(a) The image is formed at a distance of 10 cm from the convex lens on the left side.

(b) Image formed is virtual.

(c) Image formed is erect.

(d) The size of the image formed is diminished.

20. A student focuses the image of a candle flame, placed at about 2 m from a convex lens of focal length 10 cm, on a screen. After that he moves gradually the flame towards the lens and each time focuses its image on the screen.

(a) In which direction does he move the lens to focus the flame on the screen?

(b) What happens to the size of the image of the flame formed on the screen?

(c) What difference is seen in the intensity (brightness) of the image of the flame on the screen?

(d) What is seen on the screen when the flame is very close (at about 5 cm) to the lens?

Ans :

(a) He moves the lens away from the screen to focus the image.

(b) Size of the image increases.

(c) The intensity of image decreases as the flame moves towards the lens.

(d) Nothing can be seen as the image formed is virtual.

21. An object is placed at a distance of 15 cm from a convex lens of focal length 20 cm. List four characteristics (nature, position, etc.) of the image formed by the lens.

Ans : Given : u = – 15 cm, f = 20 cm

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

$$\frac{1}{20} = \frac{1}{v}+\frac{1}{15}$$

$$\frac{1}{v} = \frac{1}{20}-\frac{1}{15}$$

$$v = -60 \text{ cm.}$$

Four characteristics of the image formed by the lens are :

(a) Virtual (b) Erect (c) At a distance of 60 cm on the same side of the lens as the object (d) Enlarged image.

22. An object is placed at a distance of 30 cm in front of a convex mirror of focal length 15 cm. Write four characteristics of the image formed by the mirror.

Ans : Given : u = – 30 cm, f = 15 cm.

We know that, $$\frac{1}{v}+\frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{15}+\frac{1}{30} = \frac{2+1}{30} = \frac{3}{30}$$

$$v = 10 \text{ cm}$$

Four properties of the image formed by the given convex mirror are :

(a) Image is always erect.

(b) Image is always small in size.

(c) Image is always virtual.

(d) Image formed is 10 cm behind the mirror between focus and pole.

23. A student places a candle flame at a distance of about 60 cm from a convex lens of focal length 10 cm and focuses the image of the flame on a screen. After that he gradually moves the flame towards the lens and each time focuses the image on the screen.

(a) In which direction-toward or away from the lens, does he move the screen to focus the image?

(b) How does the size of the image change?

(c) How does the intensity of the image change as the flame moves towards the lens?

(d) Approximately for what distance between the flame and the lens, the image formed on the screen is inverted and of the same size?

Ans :

(a) He should move the screen away from the convex lens to focus the image.

(b) The size of the image increases.

(c) The intensity of the image decreases as the flame moves towards the lens.

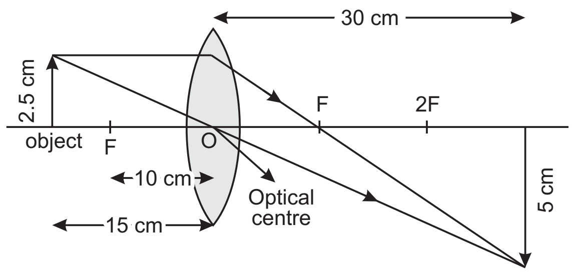
(d) The flame should be placed at 20 cm from the convex lens on its left side.

24. Name the type of mirrors used in the design of solar furnaces. Explain how high temperature is achieved by this device.

Ans : Concave mirror. When a solar furnace is placed at the focus of a large concave mirror called reflectors it focuses a parallel beam of light on the furnace.

25. An object of height 2.5 cm is placed at a distance of 15 cm from the optical centre 'O' of a convex lens of focal length 10 cm. Draw a ray diagram to find the position and size of the image formed. Mark optical centre 'O', principal focus F and height of the image on the diagram.

Ans : The required ray diagram is drawn as follows :



26. "The magnification produced by a spherical mirror is – 3". List four informations you obtain from this statement about the mirror/image.

Ans : Inverted, magnified, real image and the size of the image is three times the size of the object.

27. The refractive indices of glass and water with respect to air are 3/2 and 4/3 respectively. If speed of light in glass is 2×10^8 m/s, find the speed of light in water.

Ans : Refractive index of a medium

$$= \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}}$$

For glass, $\frac{3}{2} = \frac{\text{Speed of light in air}}{2 \times 10^8}$

Speed of light in air $= \frac{3}{2} \times 2 \times 10^8 = 3 \times 10^8$ m/s.

For water, $\frac{4}{3} = \frac{\text{Speed of light in air}}{\text{Speed of light in water}}$

Speed of light in water $= 3 \times 10^8 \times \frac{3}{4}$

$= 2.25 \times 10^8$ m/s.

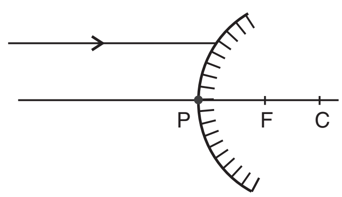
28. State two positions in which a concave mirror produces a magnified image of a given object. List two differences between the two images.

Ans : A concave mirror produces a magnified image when the object is placed in the following positions :

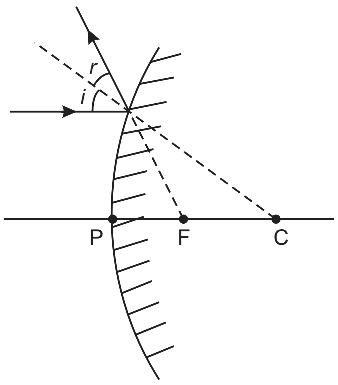
(a) Between its pole and focus : Virtual and erect image is formed.

(b) Between the focus and centre of curvature : Real and inverted image is formed.

29. A ray of light is incident on a convex mirror as shown. Redraw the diagram and complete the path of this ray after reflection from the mirror. Mark angle of incidence and angle of reflection on it.



Ans :



30. What is meant by power of a lens ? What does its sign (+ve or –ve) indicate ? State its S.I. unit. How is this unit related to focal length of a lens ?

Ans : The ability of lens to converge or diverge the light rays is called its power. The positive sign is for converging lens or a convex lens.

The negative sign is for diverging lens or a concave lens. The S.I. unit of power is dioptre.

$$\text{Power} = \frac{1}{\text{Focal length (in metres)}}$$

31. The absolute refractive indices of glass and water are 4/3 and 3/2 respectively. If the speed of light in glass is 2×10^8 m/s, calculate the speed of light in (a) vacuum, (b) water.

Ans :

(a) Given : $n_g = \frac{4}{3}$, $n_w = \frac{3}{2}$, $v_g = 2 \times 10^8$ m/s

We know that,

$$n_g = \frac{c}{v_g}$$

$$\therefore \quad c = n_g v_g$$

$$= \frac{4}{3} \times 2 \times 10^8 = 2.67 \times 10^8 \text{ m/s}$$

(b) Also, $n_w = \frac{c}{v_w}$

$$\therefore \quad v_w = \frac{c}{n_w} = \frac{2.67 \times 2 \times 10^8}{3}$$

$$= 1.78 \times 10^8 \text{ m/s.}$$

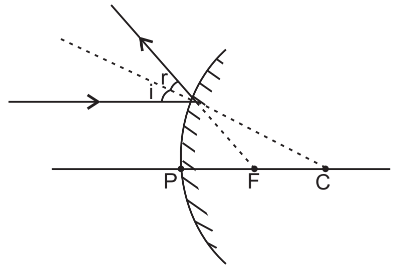
32. A 4 cm tall object is placed on the principal axis of convex lens. The distance of the object from the optical centre of the lens is 12 cm and its sharp image is formed at a distance of 24 cm from it on a screen on the other side of the lens. If the object is now moved a little away from the lens, in which way (towards the lens or away from the lens) will he have to move the screen to get a sharp image of the object on it again ? How will the magnification of the image be affected ?

Ans : Towards the lens.

Magnification decreases.

33. Draw a ray diagram to show the path of the reflected ray corresponding to an incident ray of light parallel to the principal axis of a convex mirror and show the angle of incidence and angle of reflection on it.

Ans :



34. List four characteristics of the images formed by plane mirrors.

Ans : The four characteristics of the images formed by plane mirrors :

(a) Virtual.

(b) Erect.

(c) Same size as the object.

(d) Same distance behind the mirror as the object, in front of the mirror.

(e) Laterally inverted.

35. To find the image-distance for varying object-distances in case of a convex lens, a student obtains on a screen a sharp image of a bright object placed very far from the lens. After that he gradually moves the object towards the lens and each time focuses its image on the screen.

(a) In which direction – towards or away from the lens, does he move the screen to focus the object ?

(b) What happens to the size of image – does it increase or decrease ?

(c) What happen when he moves the object very close to the lens ?

Ans : (a) Away from the lens.

(b) Size of the image increases.

(c) No clear image is formed on the screen.

36. What is the magnification of the images formed by plane mirrors and why ?

Ans : Magnification of the images formed by plane mirrors is 1 because the size of image is equal to the size of object.

37. The absolute refractive index of Ruby is 1.7. Find the speed of light in Ruby. The speed of light in vacuum is 3×10^8 m/s. **[2019]**

Ans : We know that,

Refractive index of ruby (μ)

$$= \frac{\text{Speed of light in air (or vacuum)}}{\text{Speed of light in ruby}}$$

So, $1.70 = \dfrac{3\times10^8}{\text{Speed of light in ruby}}$

or Speed of light in ruby $= \dfrac{3\times10^8}{1.7}$ ms^{-1}

$= 1.76 \times 10^8$ ms^{-1}

Thus, speed of light in ruby is 1.76×10^8 ms^{-1}.

38. List four specific characteristics of the images of the objects formed by convex mirrors.

Ans : The specific characteristics of the images of the objects formed by the convex mirrors are :

(a) Virtual.

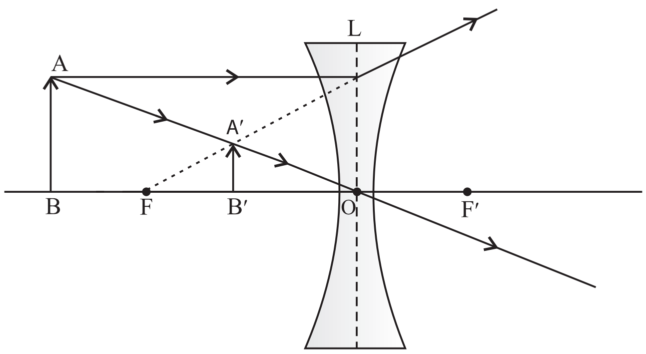
(b) Erect.

(c) Diminished.

(d) Object distance more than image distance.

39. If the image formed by a lens for all positions of an object placed in front of it is always erect and diminished, what is the nature of this lens? Draw a ray diagram to justify your answer. If the numerical value of the power of this lens is 10 D, what is its focal length in the Cartesian system?

Ans : It is a concave lens.



Since, power of a lens is given by the relation

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

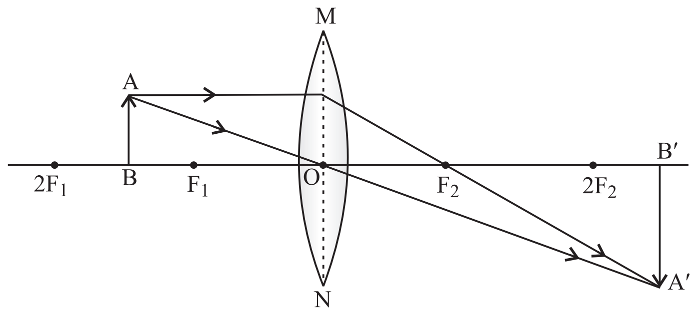
$\because \quad P = 10$ D

$\therefore \quad f = \dfrac{1}{P} = \dfrac{1}{10} = 0.1$ m.

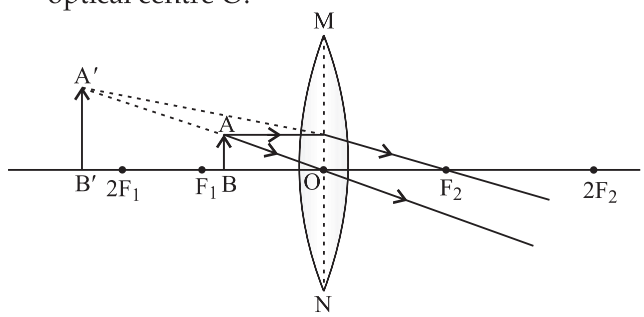
or – 10 cm, as lens is concave lens.

40. Draw ray diagrams to show the formation of three times magnified (a) real, and (b) virtual image of an object by a converging lens. Mark the positions of O, F and 2F in each diagram.

Ans : For real image : To get three times magnified image, the object is placed between F_1 and $2F_1$.



For virtual image : To get three times magnified image, the object is placed between the F_1 and optical centre O.



41. An object 4 cm in height, is placed at 15 cm in front of a concave mirror of focal length 10 cm. At what distance from the mirror should a screen be placed to obtain a sharp image of the object. Calculate the height of the image.

Ans : Given : $u = -15$ cm, $f = -10$ cm

Using the mirror equation,

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

$$\frac{1}{v} - \frac{1}{15} = \frac{-1}{10}$$

$$\frac{1}{v} = \frac{-1}{10} + \frac{1}{15}$$

$$\frac{1}{v} = \frac{-15+10}{150} = \frac{-5}{150}$$

$$v = -30 \text{ cm.}$$

Thus, to obtain a sharp image of the object, the screen should be placed in front of the mirror at a distance of 30 cm.

Now, $\quad m = \dfrac{-v}{u} = \dfrac{\text{Height of image}}{\text{Height of object}}$

$$m = -\left(\frac{-30}{-15}\right) \Rightarrow m = -2$$

$$-2 = \frac{h_i}{4} \Rightarrow h_i = -8 \text{ cm.}$$

$\therefore$ Height of the image is – 8 cm.

42. A 6 cm tall object is placed perpendicular to the principal axis of a concave mirror of focal length 30 cm. The distance of the object from the mirror is 45 cm. Use mirror formula to dertermine the position, nature and size of the image formed. Also draw labelled ray diagram to show the image formation in this case. [2019]

Ans : Given, Height of the object $h_0 = 6$ cm

Focal length, f = –30 cm

Object distance, u = – 45 cm

Image distance, v = ?

Height of image, h_i = ?

We have,

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

$$\frac{1}{-30} = \frac{1}{v} + \frac{1}{-45}$$

$$\frac{-1}{30} + \frac{1}{45} = \frac{1}{v}$$

$$\frac{1}{v} = \frac{-3+2}{90}$$

$$v = 90 \text{ cm}$$

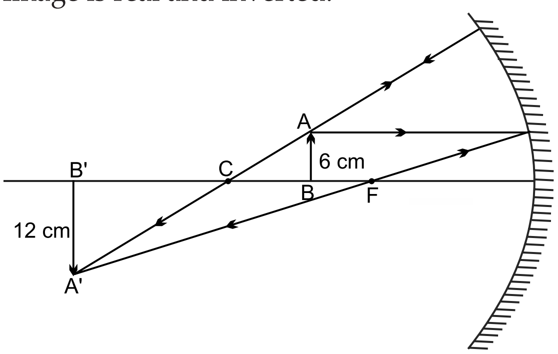
Also, we have $$m = \frac{h_i}{h_o} = \frac{-v}{u}$$

$$\frac{h_i}{6} = \frac{-(-90)}{-45}$$

$$\frac{h_i}{6} = -2$$

$$h_i = -12$$

Image is real and inverted.



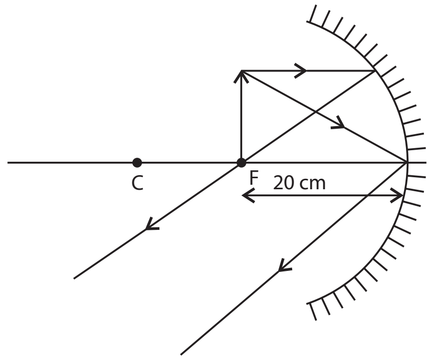
43. The image of an object formed by a mirror is real, inverted and is of magnification – 1. If the image is at a distance of 40 cm from the mirror, where is the object placed ? Where would the image be if the object is moved 20 cm towards the mirror ? State reason and also draw ray diagram for the new position of the object to justify your answer.

Ans : Object position : At C (centre of curvature)

Object distance : 40 cm.

If the object is moved 20 cm towards the mirror then,

Position of the image: At infinity, because the focal length of the mirror is 20 cm. If the object is moved 20 cm towards the mirror then its new position would be at the focus of the mirror.



44. The image of an object formed by a lens is of magnification – 1. If the distance between the object and its image is 60 cm, what is the focal length of the lens ? If the object is moved 20 cm towards the lens, where would the image be formed ? State reason and also draw a ray diagram in support of your answer.

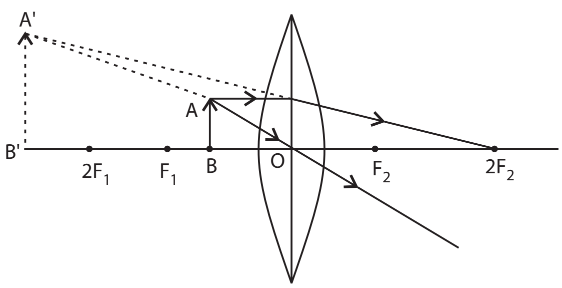
Ans : Magnification = –1, image = inverted, same size. Therefore, object is at 2F and image is also at 2F.

Therefore, distance between u and $v = 4f = 60$ cm.

$\therefore$ $f = 60 \text{ cm}/4 = 15$ cm

Object will be at $2f = 30$ cm.

If the object is shifted towards the lens by 20 cm, the new object distance will be at 10 cm from the lens on the left side. This distance is less than the focal length, and the image formed in this case would be virtual, erect and on the same side.



45. The image formed by a spherical mirror is real, inverted and is of magnification – 2. If the image is at a distance of 30 cm from the mirror, where is the object placed ? Find the focal length of the mirror. List two characteristics of the image formed if the object is moved 10 cm towards the mirror.

Ans : Given : $m = -2$, $v = -30$ cm

We know that, $m = \dfrac{-v}{u}$

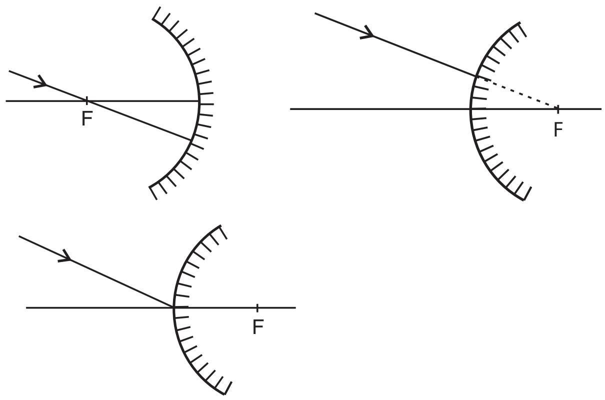
$$-2 = \frac{30}{u}$$

$$u = -15 \text{ cm}$$

Now, $f = \dfrac{uv}{u+v} = \dfrac{-15\times-30}{-15-30} = \dfrac{450}{-45} = -10 \text{ cm}.$

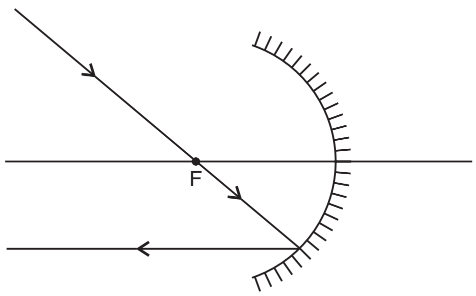
If the object is shifted 10 cm towards the mirror then, u = – 5 cm, *i.e.*, object is between pole and focus, thus image formed will be virtual, erect and magnified.

46. Draw the following diagram, in which a ray of light is incident on a concave/convex mirror, on your answer sheet. Show the path of this ray, after reflection, in each case.

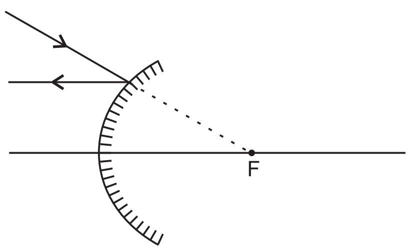


Ans :

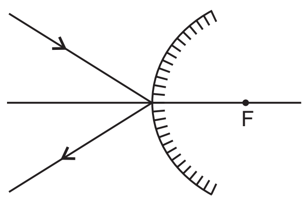
(a)



(b)



(c)

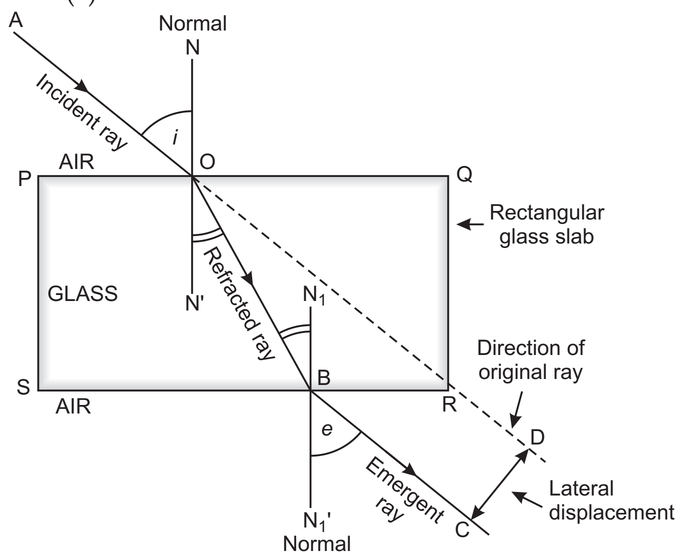


47. (a) Draw a ray diagram to show the refraction of light through a glass slab and mark angle of refraction and the lateral shift suffered by the ray of light while passing through the slab.

(b) If the refractive index of glass for light going from air to glass is 3/2, find the refractive index of air for light going from glass to air.

Ans :

(a)



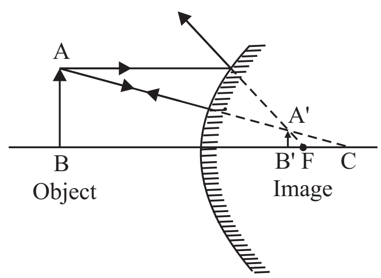
(b) Given, ${}_a n_g = \dfrac{3}{2}$

$$\therefore\ {}_g n_a = \frac{1}{{}_a n_g} = \frac{1}{\frac{3}{2}} = \frac{2}{3}$$

48. If the image formed by a mirror for all positions of the object placed in front of it is always erect and diminished, (i) what type of mirror is it ? Draw a ray diagram to justify your answer. **[2018]**

(ii) Where and why do we generally use this type of mirror ?

Ans : (i) The image formed by a convex mirror for all positions of the object placed in front of it is always erect and diminished.



(ii) Uses of convex mirror :

Convex mirrors are used as rear-view mirrors in vehicles and as shop security mirrors in malls and airports because the image formed in these mirrors is much smaller than the object due to which a convex mirror gives a wide field of view.

49. An object of height 5 cm is placed perpendicular to the principal axis of a concave lens of focal length 10 cm. If the distance of the object from the optical centre of the lens is 20 cm, determine the position, nature and size of the image formed using the lens formula.

Ans : Given : $h_1 = +5$ cm, $f = -10$ cm, $u = -20$ cm

We know that,

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

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-10} - \frac{1}{20} = \frac{-3}{20}$$

Image distance, $v = -\frac{20}{3}$ cm.

The nature of the image is virtual and erect.

Now, magnification, $m = \frac{h_2}{h_1} = \frac{v}{u}$

$$\Rightarrow h_2 = \frac{v}{u} \times h_1 = \frac{-20}{3} \times \frac{1}{-20} \times 5 = \frac{+5}{3}\text{ cm}$$

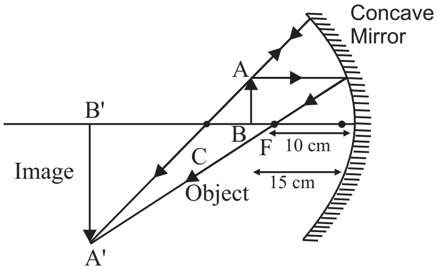
$\therefore$ The size of the image is 1.67 cm.

50. To construct a ray diagram we use two rays of light which are so chosen that it is easy to determine their directions after reflection from the mirror. Choose these two rays and state the path of these rays after reflection from a concave mirror. Use these two rays to find the nature and position of the image of an object placed at a distance of 15 cm from a concave mirror of focal length 10 cm.

Ans :

(a) A ray parallel to the principal axis, after reflection will pass through the principal focus of a concave mirror.

(b) A ray passing through the centre of curvature of a concave mirror, after reflection is reflected back along the same path.



The nature of the image is real and inverted and the position of the image is beyond C.

51. Analyse the following observation table showing variation of image-distance (v) with object-distance (u) in case of a convex lens and answer the questions that follow without doing any calculations :

S.No.	Object-Distance u (cm)	Image-Distance v (cm)
1.	– 100	+ 25
2.	– 60	+ 30
3.	– 40	+ 40
4.	– 30	+ 60
5.	– 25	+ 100
6.	– 15	+ 120

(a) What is the focal length of the convex lens? Give reason to justify your answer.

(b) Write the serial number of the observation which is not correct. On what basis have you arrived at this conclusion?

(c) Select an appropriate scale and draw a ray diagram for the observation at S.No. 2. Also find the approximate value of magnification.

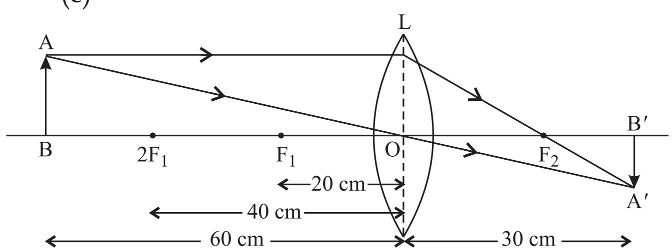
Ans :

(a) From the observation 3, the radius of curvature of the lens is 40 cm as distance of object and the distance of the image is same.

Focal length, $f = \frac{R}{2} = \frac{40}{2} = 20$ cm.

(b) S.No. 6 is not correct as for this observation the object distance is between focus and pole so for such cases the image formed is always virtual but in this case a real image is forming as the image distance is positive.

(c)



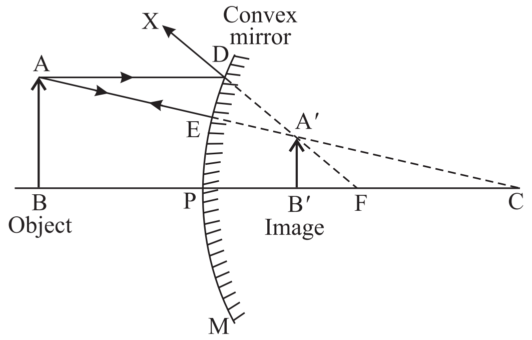
$$\text{Magnification} = \frac{v}{u} = \frac{+30\text{ cm}}{-60\text{ cm}} = -0.5$$

52. (a) If the image formed by a mirror for all positions of the object placed in front of it is always diminished, erect and virtual, state the type of the mirror and also draw a ray diagram to justify your answer. Write one use such mirrors are put to and why ?

(b) Define the radius of curvature of spherical mirrors. Find the nature and focal length of a spherical mirror whose radius of curvature is +24 cm.

Ans : (a) The type of the mirror is convex mirror.

The ray diagram is shown below :



Use of convex mirror : A convex mirror always produces a smaller, virtual and erect image of an object. In convex mirror, the length of the image is shorter than that of the object. Hence, it is used as a side view mirror in vehicles. The convex mirror forms images of vehicles that are spread over a relatively larger area.

(b) **Radius of curvature :**

The distance between the centre of curvature and pole of a spherical mirror is known as radius of curvature.

Given : R = + 24 cm

$$f = \frac{R}{2} = \frac{24}{2} = +12 \text{ cm}$$

The mirror is convex mirror.

53. Analyse the following observation table showing variation of image distance (v) with object distance (u) in case of a convex lens and answer the questions that follow, without doing any calculations :

S.No.	Object distance u (cm)	Image distance v (cm)
1.	- 90	+ 18
2.	- 60	+ 20
3.	- 30	+ 30
4.	- 20	+ 60
5.	- 18	+ 90
6.	- 10	+ 100

(a) What is the focal length of the convex lens? Give reason in support of your answer.

(b) Write the serial number of that observation which is not correct. How did you arrive at this conclusion?

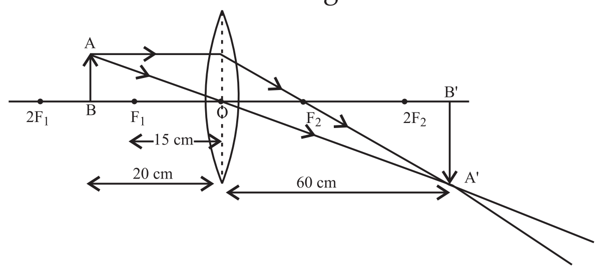
(c) Take an appropriate scale to draw ray diagram for the observation at S. No. 4 and find the approximate value of magnification.

Ans :

(a) From S.No. 3 we can say that the radius of curvature is 30 cm because when an object is placed at the centre of curvature of a convex lens, its image is formed on the other side of the lens at the same distance from the lens. And, we also know that focal length is half of the radius of curvature. Thus focal length of the lens is + 15 cm.

(b) S.No.6 is not correct as the object distance between focus and pole is so far. In such cases the image formed is always virtual but in this case a real image is formed as the image distance is positive.

(c) Approximate value of magnification for object distance – 20 cm and image distance + 60 cm is – 3.



54. (a) To construct a ray diagram we use two rays which are so chosen that it is easy to know their directions after reflection from the mirror. List two such rays and state the path of these rays after reflection in case of concave mirrors. Use these two rays and draw ray diagram to locate the image of an object placed between pole and focus of a concave mirror.

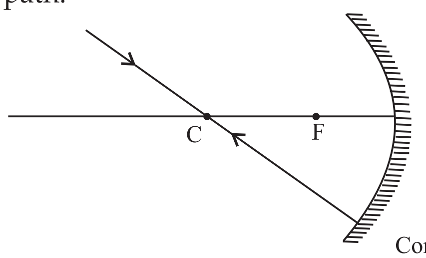
(b) A concave mirror produces three times magnified image on a screen. If the object is placed 20 cm in front of the mirror, how far is the screen from the object?

Ans :

(a) The following rays of light are usually used to locate the images formed by concave mirrors :

The incident ray passess through the centre of curvature :

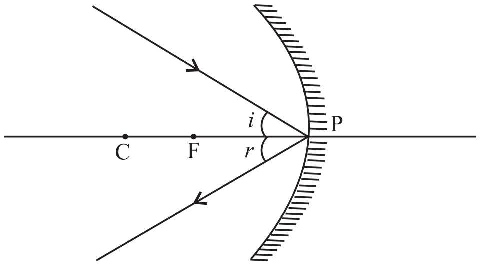
In this case, light after reflecting from the concave mirror moves back along the same path.



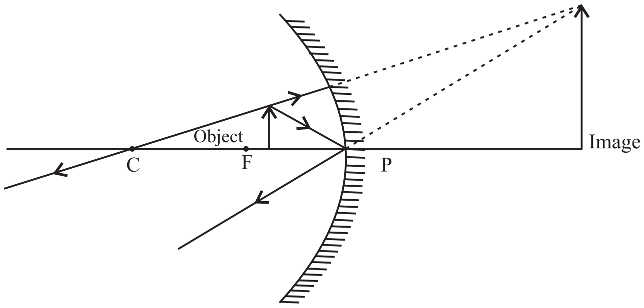
Concave mirror

The ray incident obliquely to the principal axis :

In this case, the incident ray will be reflected back by the reflecting surface of the concave mirror obliquely and making equal angles with the principal axis.



When the object is placed between pole and focus of the concave mirror, image is formed behind the mirror which is virtual, erect and magnified.



(b) Given, $m = -3$ (As image is real)

$u = -20$ cm

$v = ?$

We have, $m = -\frac{v}{u}$

$$-3 = -\left(\frac{v}{-20}\right) \Rightarrow v = -60 \text{ cm}$$

The image is located at a distance of 60 cm in front of the mirror.

Thus, the screen is at a distance of 40 cm from the object.

55. It is desired to obtain an erect image of an object, using concave mirror of focal length of 12 cm.

(a) What should be the range of distance of an object placed in front of the mirror ?

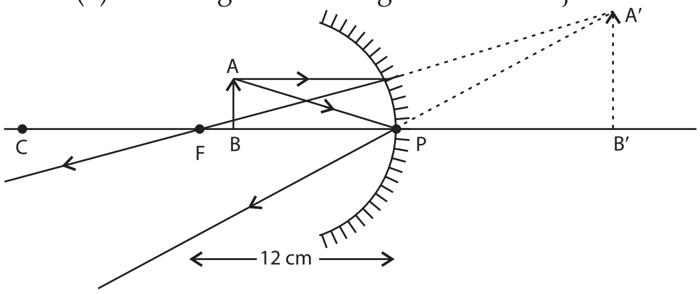
(b) Will the image be smaller or larger than the object. Draw ray diagram to show the formation of image in this case.

(c) Where will the image of this object be, if it is placed 24 cm in front of the mirror ? Draw ray diagram for this situation also to justify your answer.

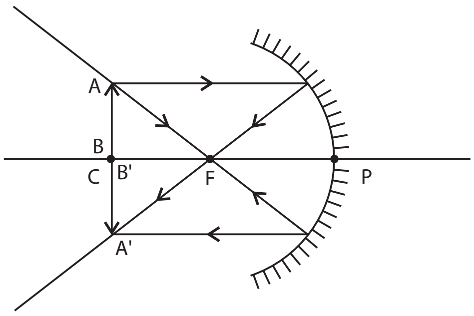
Show the positions of pole, principal focus and the centre of curvature in the above ray diagrams.

Ans : (a) Range of distance should be 0 cm to < 12 cm.

(b) The image will be larger than the object.



(c) Image will be formed at a distance of 24 cm in front of the mirror.



56. (a) Define optical centre of a spherical lens.

(b) A divergent lens has a focal length of 20 cm. At what distance should an object of height 4 cm from the optical centre of the lens be placed so that its image is formed 10 cm away from the lens. Find the size of the image also.

(c) Draw a ray diagram to show the formation of image in above situation.

Ans :

(a) Optical centre is a point on the principal axis of the lens such that a ray of light passing through this point emerges parallel to its direction of incidence.

(b) Given : $f = -20$ cm, $h_o = 4$ cm, $v = -10$ cm

We know that,

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

$$\frac{1}{-20} = -\frac{1}{10} - \frac{1}{u}$$

$$\frac{1}{u} = -\frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{u} = \frac{-2+1}{20} = \frac{-1}{20}$$

$$u = -20 \text{ cm}$$

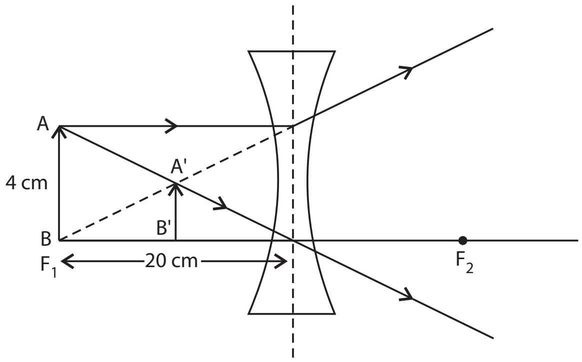
Now, $$m = \frac{h_i}{h_o} = \frac{v}{u}$$

$$\frac{h_i}{4} = \frac{-10}{-20}$$

$$2\,h_i = 4$$

$$\Rightarrow \quad h_i = 2 \text{ cm}$$

(c)



57. (a) Define focal length of a spherical lens.

(b) A divergent lens has a focal length of 30 cm. At what distance should an object of height 5 cm from the optical centre of the lens be placed so that its image is formed 15 cm away from the lens ? Find the size of the image also.

(c) Draw a ray diagram to show the formation of image in the above situation.

Ans :

(a) The distance between the optical centre and focus is called focal length.

(b) Given : $f = -30$ cm, $h_O = 5$ cm, $h_I = ?$, $v = -15$ cm.

We know that, $$\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$$

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

$$\Rightarrow \quad u = \frac{vf}{f-v}$$

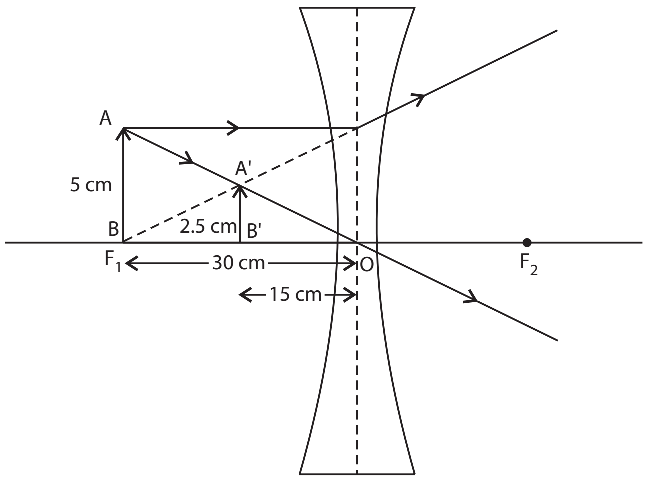
$$= \frac{-15 \times -30}{-30+15} = -30 \text{ cm.}$$

Now, $$m = \frac{v}{u} = \frac{h_I}{h_O}$$

$$\Rightarrow \quad h_I = \frac{v}{u} \times h_O$$

$$= \frac{-15}{-30} \times 5 = 2.5 \text{ cm.}$$

(c)



58. (a) Define focal length of a divergent lens.

(b) A divergent lens of focal length 30 cm forms the image of an object of size 6 cm on the same side as the object at a distance of 15 cm from its optical centre. Use lens formula to determine the distance of the object from the lens and the size of the image formed.

(c) Draw a ray diagram to show the formation of image in the above situation.

Ans :

(a) Focal length is the distance between pole and principal focus of a divergent lens.

(b) Given : $f = -30$ cm, $u = ?$, $v = -15$ cm, $h_1 = 6$ cm, $h_2 = ?$

We know that, $$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

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

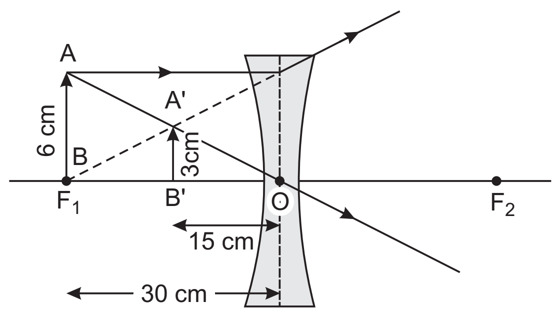
$$\Rightarrow \quad u = \frac{vf}{f-v} = \frac{-15 \times -30}{-30+15}$$

$$= \frac{450}{-15} = -30 \text{ cm.}$$

Now, $$m = \frac{h_2}{h_1} = \frac{v}{u}$$

$$\Rightarrow \quad h_2 = \frac{v}{u} \times h_1 = \frac{-15}{-30} \times 6 = 3 \text{ cm.}$$

(c)



59. (a) Define the following terms in the context of spherical mirrors :

(i) Pole (ii) Centre of curvature

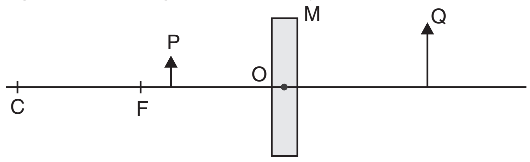
(iii) Principal axis (iv) Principal focus

(b) Draw ray diagrams to show the principal focus of a :

(i) Concave mirror

(ii) Convex mirror

(c) Consider the following diagram in which M is a mirror and P is an object and Q is its magnified image formed by the mirror.



State the type of the mirror M and one characteristic property of the image Q.

Ans :

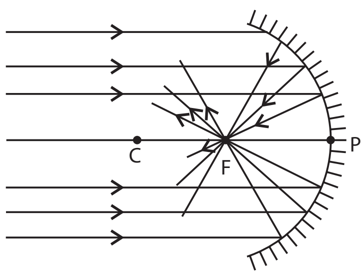
(a) (i) Pole is the centre of the reflecting surface of the mirror.

(ii) Centre of curvature is the centre of the hollow sphere of which the reflecting surface of mirror is a part.

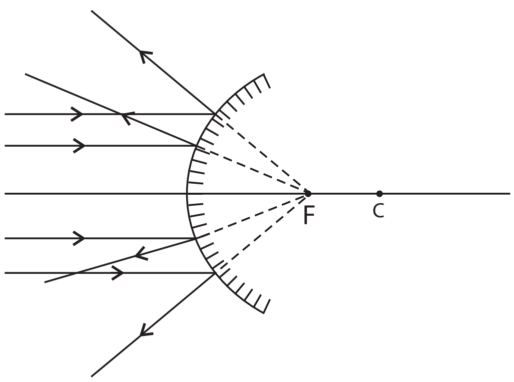
(iii) Principal axis is the straight line passing through the pole and the centre of curvature of a spherical mirror.

(iv) Principal focus : Incident rays parallel to principal axis, after reflection, either converge to or appear to diverge from a fixed point on the principal axis called principal focus of a spherical mirror.

(b) (i)



(ii)



(c) M is a concave mirror and the image is virtual.

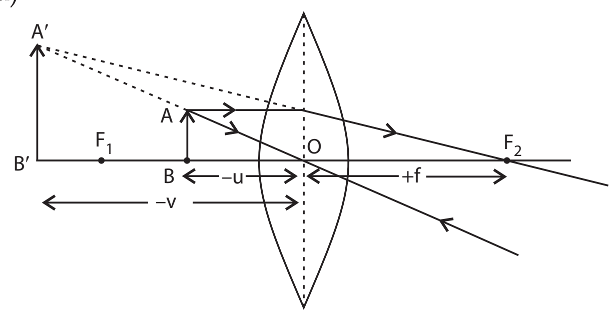
60. (a) Draw a ray diagram to show the formation of image by a convex lens when an object is placed in front of the lens between its optical centre and principal focus.

(b) In the above ray diagram mark the object-distance (u) and the image-distance (v) with their proper signs (+ve or – ve as per the new Cartesian sign convention) and state how these distances are related to the focal length (f) of the convex lens in this case.

(c) Find the power of a convex lens which forms a real, and inverted image of magnification –1 of an object placed at a distance of 20 cm from its optical centre.

Ans :

(a)



(b) The object distance and image distance are marked in the diagram of part (a).

The relation between v, u and f is given by the formula,

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

(c) Given, $m = -1$; $u = -20$ cm; $v = ?$, $f = ?$

We known that, $m = \frac{v}{u}$

$$-1 = \frac{v}{-20}$$

$\therefore$ $v = +20$ cm

Thus object is at 2F.

i.e., $2f = 20$ cm

$\therefore$ $f = \frac{20}{2} = 10 \text{ cm} = 0.1 \text{ m}$

$$P = \frac{1}{f} = \frac{1}{0.1} = +10\text{D}$$

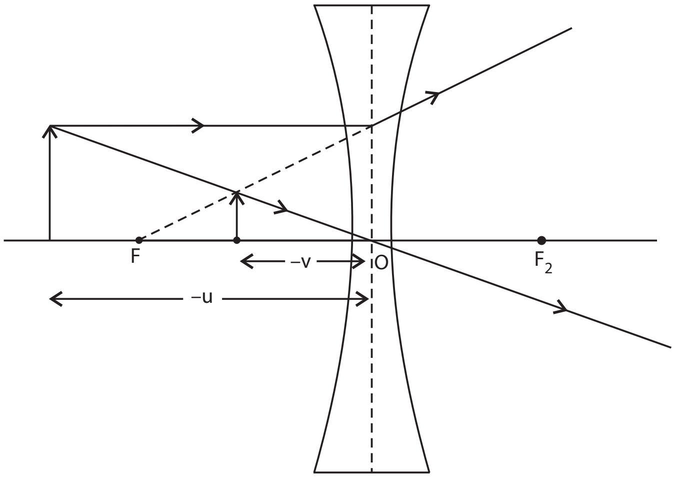
The power of convex lens is + 10 D.

61. (a) Draw a ray diagram to show the formation of image by a concave lens when an object is placed in front of it.

(b) In the above diagram mark the object-distance (u) and the image-distance (v) with their proper signs (+ve or –ve as per the new Cartesian sign convention) and state how these distances are related to the focal length (f) of the concave lens in this case.

(c) Find the nature and power of a lens which forms a real and inverted image of magnification – 1 at a distance of 40 cm from its optical centre.

Ans : (a)



(b) The object distance (u) and image distance (v) are marked in the diagram of part (a).

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

(c) As, m= –1; hence, the lens is convex

Now, $m = \frac{v}{u}$

$\therefore$ $v = -u$

Thus, Object is at 2F.

$2f = 40$ cm

$f = 20$ cm = 0.2 m.

$P = \frac{1}{f} = \frac{1}{0.2} = +5$ D (convex lens)

62. What is meant by power of a lens ? Define its S.I. unit.

You have two lenses A and B of focal lengths +10 cm and –10 cm respectively. State the nature and power of each lens. Which of the two lenses will form a virtual and magnified image of an object placed 8 cm from the lens ? Draw a ray diagram to justify your answer.

Ans : Power of a lens is defined as the reciprocal of its focal length in metres. Its S.I. unit is dioptre.

For lens A :

$f_A = +10$ cm = 0.1 m

Since the focal length is positive, it is a convex lens.

Now, $P_A = \frac{1}{f_A} = \frac{1}{0.1} = +10\,\text{D}.$

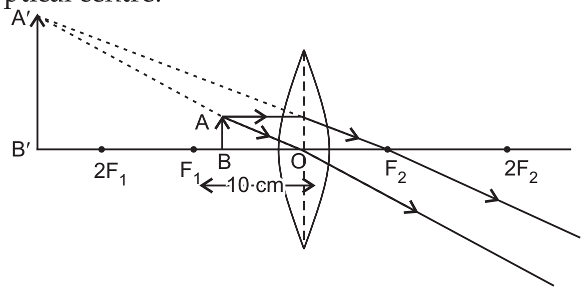
For lens B :

$f_B = -10$ cm = – 0.1 m

Since the focal length is negative, it is a concave lens.

$P_B = \frac{1}{f_B} = \frac{1}{-0.1} = -10\,\text{D}.$

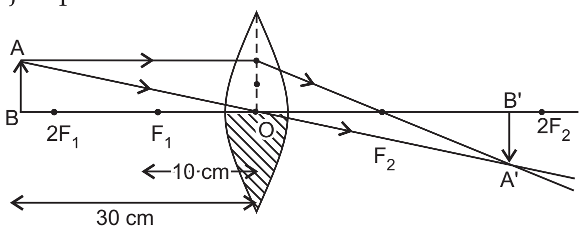
In case of a convex lens, image is virtual and magnified if object is placed between focus and optical centre.



63. One half of a convex lens of focal length 10 cm is covered with a black paper. Can such a lens produce an image of a complete object placed at a distance of 30 cm from the lens ? Draw a ray diagram to justify your answer.

A 4 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image.

Ans : Yes, it can produce an image of a complete object placed at a distance of 30 cm from the lens.



Given : $h_1 = 4$ cm, $f = +20$ cm, $u = -15$ cm

We know that,

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

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} - \frac{1}{15} = \frac{3-4}{60} = \frac{-1}{60}$$

$\therefore$ Image distance, $v = -60$ cm.

The size of the image is 16 cm.

Image will be virtual and erect.

Now, magnification, $m = \frac{h_2}{h_1} = \frac{v}{u}$

$$h_2 = \frac{v}{u} \times h_1 = \frac{-60}{-15} \times 4 = +16\,\text{cm}$$

64. (a) State the laws of refraction of light. Explain the term absolute refractive index of a medium and write an expression to relate it with the speed of light in vacuum. [2018]

(b) The absolute refractive indices of two media 'A' and 'B' are 2.0 and 1.5 respectively. If the speed of light in medium 'B' is 2×10^8 m/s, calculate the speed of light in :

(i) vacuum, (ii) medium 'A'.

Ans :

(a) **Laws of refraction of light :**

(i) Incident ray travelling from one medium to another, bend in such a way that the incident ray, refracted ray and the normal ray at the point of incidence, all lie in the same plane.

(ii) The ratio of sine of angle of incidence to the sine of angle of refraction is constant for a given pair of media.

Absolute refractive index of a medium is the ratio of sin i to sin r.

Absolute refractive index = Speed of light in vaccum/Speed of light in medium

(b) Given : n_A = 2.0, n_B = 1.5, speed of light in medium B = 2×10^8 m/s

(i) $$n_B = \frac{c}{\text{Speed of light in a medium } (v_B)} = \frac{c}{v_B}$$

$$c = n_B \times v_B = 1.5 \times 2 \times 10^8 = 3 \times 10^8 \text{ m/s.}$$

(ii) $$n_A = \frac{c}{v_A}$$

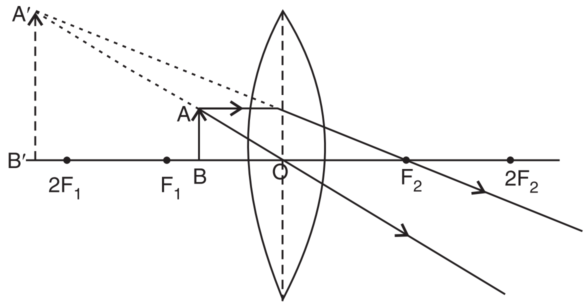
$$v_A = \frac{c}{n_A} = \frac{3\times10^8}{2} = 1.5 \times 10^8 \text{ m/s}$$

65. "A convex lens can form a magnified erect as well as magnified inverted image of an object placed in front of it." Draw ray diagram to justify this statement stating the position of the object with respect to the lens in each case.

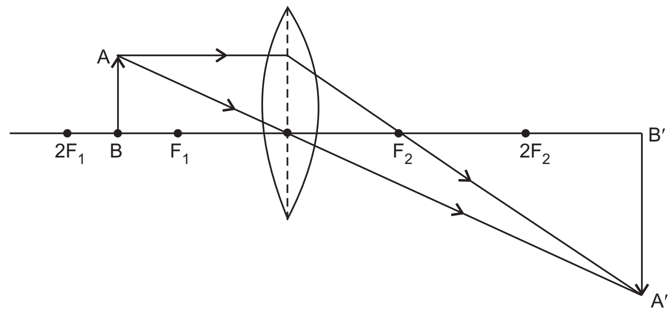
An object of height 4 cm is placed at a distance of 20 cm from a concave lens of focal length 10 cm. Use lens formula to determine the position of the image formed.

Ans :

(a) Image formed is magnified and erect when object is placed between optical centre and focus of a convex lens.



(b) Image formed is magnified and inverted when the object is placed between F and 2F of a convex lens.



Given : u = – 20 cm, f = – 10 cm, v = ?

We know that,

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

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

$$\frac{1}{v} = -\frac{1}{10} - \frac{1}{20}$$

$$\frac{1}{v} = \frac{-2-1}{20} = \frac{-3}{20}$$

$$\therefore \quad v = \frac{-20}{3} \text{ cm.}$$

MOCK TEST-1

Time : 1 : 30 hours Max. Marks : 40

General Instructions :

- All questions are compulsory.
- There is no choice in any of the questions.
- Question numbers 1 to 3 are one mark question. These are to be answered in one word or one sentence.
- Question numbers 4 to 11 are three marks questions. These are to be answered in 50 words each.
- Question numbers 12 to 14 are five marks questions. These are to be answered in 70 words each.

1. When object is placed between infinity and mirror, image formed is diminished and between focus and optical centre on the same side as that of the object. What is the nature of the mirror.

2. Can virtual image be obtained on screen ?
3. What is magnification ?
4. Refractive index of diamond with respect to glass is 1.6 and absolute refractive idex of glass is 1.5. Find out the absolute refractive index of diamond.
5. A Pen when dipped in water in a glass tumbler appears to be bent at the interface of air and water. Will the Pen appear to be bent to the same extent, if instead of water we use liquid like kerosene or turpentine? Support your answer with reason.
6. What are the sign conventions rules for spherical lenses ?
7. What are the uses of concave and convex mirrors ?
8. Distinguish between real and virtual image in a lens ?
9. What is the nature of image of an object when it moved from infinity to the convex lens ?
10. What is magnification of lens ?
11. Refractive index of water is 4/3 and glass is 3/2 with respect to air. What is the refractive index of glass with respect to water ?
12. Size of image of an object by a mirror having a focal length of 20 cm is observed to be reduced to $1/3^{rd}$ of its size. At what distance the object has been placed from the mirror? What is the nature of the image and the mirror?
13. A student focussed the image of a candle flame on a white screen using a convex lens. He noted down the position of the candle, screen and the lens as under on the screen as

Position of the candle = 12 cm
Position of the convex lens = 50 cm
Position of the screen = 88 cm

(a) What is the focal length of the convex lens?
(b) Where will the image be formed if he shifts the candle towards the lens at a position of 31 cm?
(c) What will be the nature of the image formed if he further shifts the candle towards the lens?
(d) Draw ray diagram to show the formation of the image in case (c) as said above.

14. Draw the ray diagrams showing the image formation by a concave mirror when an object is placed.
(a) Between the pole and focus of the mirror.
(b) Between focus and centre of curvature of the mirror.
(c) At centre of curvature of the mirror.
(d) A little beyond centre of curvature of the mirror.
(e) At infinity.

MOCK TEST-2

Time : 1 : 30 hours Max. Marks : 40

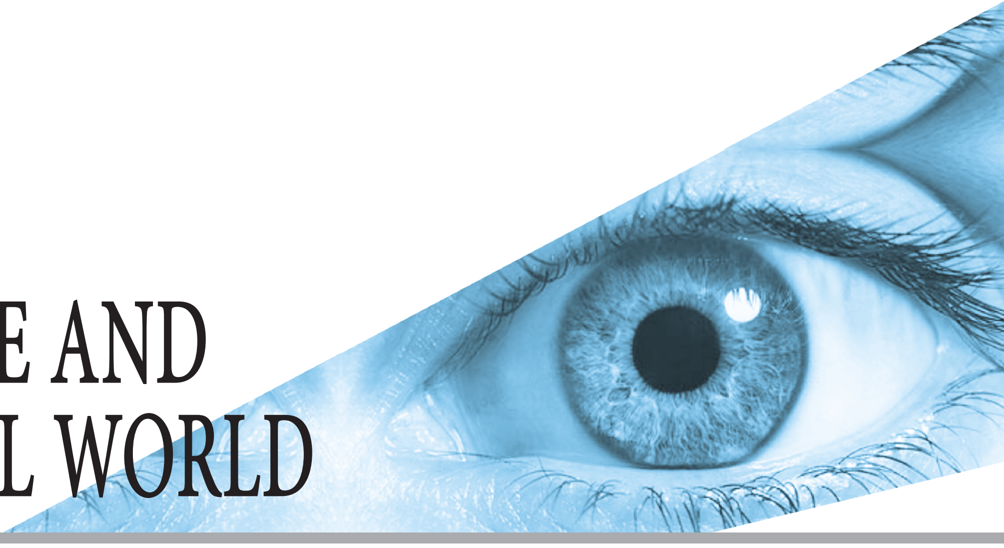
General Instructions :

- All questions are compulsory.
- There is no choice in any of the questions.
- Question numbers 1 to 3 are one mark question. These are to be answered in one word or one sentence.
- Question numbers 4 to 11 are three marks questions. These are to be answered in 50 words.
- Question numbers 12 to 14 are five marks questions. These are to be answered in 70 words each.

1. What is focus ?
2. What is lens formula ?
3. Object is placed between focus and lens, image formed is enlarged and on the same side as that of object. What is the nature of the lens ?
4. What is the power of convex lens of focal length 0.5 m ?
5. How are power and focal length of a lens related? You are provided with two images of focal length 20 cm and 40 cm respectively. Which lens will you use to obtain more convergent light ?
6. What are Cartesian sign conventions used in spherical mirrors ? What is the mirror formula ?
7. Distinguish between plane mirror, convex and concave mirror without touching?
8. Explain with the help of diagram, why pencil partly immersed in water appears to be bent as the water surface.
9. How does the tank appear to a viewer from outside ?
10. What is lens formula ? Give its sign conventions and assumptions.
11. What are the laws of refraction of light ?
12. (a) Define the following :
(i) centre of curvature (ii) pole of concave mirror
(b) State the mirror formula and its magnification.
(c) Using the same find the distance at which an object to be placed for getting a real, inverted and enlarged image at 45 cm using a concave mirror of focal length 20 cm.
13. State and prove the law of refraction.
14. Draw ray diagram showing the image formation by a convex lens when an object is placed.
(a) Between optical centre and focus of the lens.
(b) Between focus and twice the focal length of the lens.
(c) At twice the focal length of the lens.
(d) At infinity.
(e) At the focus of the lens.

2

THE HUMAN EYE AND THE COLOURFUL WORLD



CONTENTS

2.0 INTRODUCTION

In our earlier chapter, we discussed about the position, size and nature of images formed by lenses and refraction of light by lenses. In this chapter, we are going to study about the structure and working of human eye, functions of eye lens, defects of vision and their corrections, splitting of white light, atmospheric refraction, scattering of light by atmosphere and the refraction of light through a glass prism.

Let us discuss first about the structure and working of the human eye.

2.1 STRUCTURE OF THE HUMAN EYE

We know that our eye is one of the most important, valuable and sensitive sense organs. The human eye uses light and enables us to see the colourful world, beautiful nature and the natural phenomenon around us and so we can say it is God gifted optical instrument. It is like a photographic camera that uses light enabling us to see the beautiful and colourful world around us. The structure of the human eye involves the following parts namely, cornea, iris, pupil, eye lens, ciliary muscles, retina, optic nerve and eye ball.

We shall now discuss each part in detail.

(a) Cornea

The cornea is the outermost part of the eye *i.e.*, front part of the eye. It is a transparent part of eye which bulges outwards forming convex shape. It acts as window of the eye. The main function of cornea is to allow the light to enter into the eye.

(b) Iris

It is found just behind the cornea. It is flat, coloured, ring shaped membrane and thus can be compared to coloured diaphragm. The iris has muscles and coloured pigments. The colour of the eye depends on the colour of these pigments. The iris has a hole in the centre. This hole is called the pupil. The main function of the iris is to control and regulate the amount of light entering the eye by adjusting the size of the pupil.

(c) Pupil

It is the hole found in the middle of the iris. It appears black as no light is reflected from it. When the intensity of light is bright, the pupil contracts *i.e.*, become small allowing only small amount of light to enter into the eyes. When the intensity of light is dim, the pupil expands *i.e.*, become large allowing more amount of light to enter into the eyes. The function of pupil is to control and regulate the light entering the eye (Fig. 2.1).

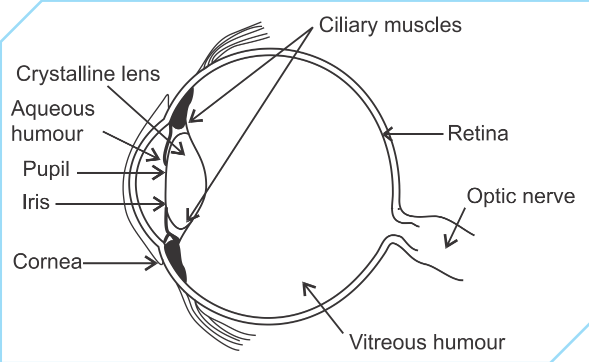


Fig. 2.1 : The human eye

Let us look into an example, (Fig. 2.2) when we go from a bright light to a dark room, at first we cannot see our surroundings clearly. But, after short time, we would be able to see the surroundings. This is because in bright light, the pupil of our eye is small. So, when we enter the dark room, a very little light enters our eye and we cannot see properly. But later, the pupil of our eye expands and becomes large, allowing more light to enter our eye enabling us to see.

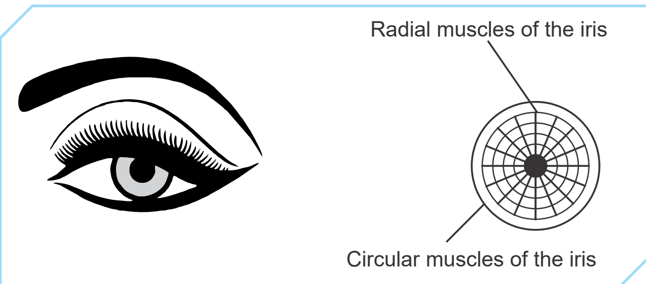


Fig. 2.2 : In the bright light the pupil of the eye contracts

On the other hand, when we go from a dark room into bright room or when we light a bright lamp in dark room we feel glare in our eyes (Fig. 2.3). This is because, in dark room the p upil of our eye is large, so when we light up a bright light, a large amount of light enters our eyes and we feel the glare. Gradually, the pupil of our eye contracts resulting in less amount of light entering our eyes allowing us to see clearly. Thus, we can conclude that, the iris also protects our eyes from the glare of bright light.

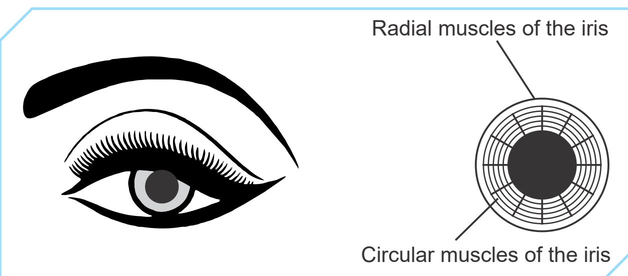


Fig. 2.3 : In the dark the pupil of the eye expands

(d) Eye Lens

The eye lens is found behind the pupil. It is a crystalline double convex lens made up of transparent, fibrous, soft and flexible jelly like substance. Due to its flexibility, it has the ability to change its shape to focus the light on to the retina. It is held in position by suspensory ligaments. One end of the suspensory ligaments is attached to the eye lens while the other end is attached to the ciliary muscles. The main function of the eye lens is to focus the images of the objects on the retina.

(e) Ciliary Muscles

These muscles hold the eye lens in position. When the ciliary muscles contract, the eye lens becomes thick and the focal length of the lens decreases. When the ciliary muscles relax, the eye lens becomes thin and the focal length of the lens increases. Thus, we can say that the focal length of the eye lens can be changed by changing the shape of ciliary muscles. The difference between camera and the eyes is that the focal length of the convex lens used in the camera is fixed while the focal length of the convex lens inside the eyes can be changed due to ciliary muscles.

(f) Retina

The retina is found behind the eye lens and at the back part of the eye. The retina of the eye can be compared to the film in a camera. The image of an object is formed on the retina. Thus, the retina acts as a light sensitive screen to obtain the image of the objects. It is a delicate membrane containing number of light sensitive cells called rods and cones (Fig. 2.4). The rod type cells respond to the intensity or brightness of light while the cone type cells respond to the colour of the light. The main function of these cells is to convert light energy into electrical impulses or signals.

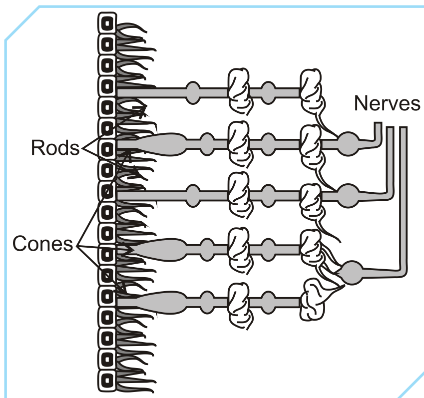


Fig. 2.4 : Cones and rods in the retina

(g) Rods

These are rod shaped cells found in the retina of an eye which are sensitive to dim light. These cells are important for vision in dim light *i.e.,* during night. They do not mediate colour vision. We can observe these cells in large numbers in nocturnal animals like owls where rods help them to see properly during night (Fig. 2.5).


Fig. 2.5 An owl has large number of rod cells in the retina

(h) Cones


Fig. 2.6 : Bees have cone cells in the retina

These are cone shaped cells found in the retina of an eye which are sensitive to bright light. These cells function only in bright light and not in dim light. These are capable of colour vision. We can observe this during our travel at night that it becomes impossible to see colours of cars on the road. For example, bees have cone shaped cells in the retina which are sensitive to ultra-violet light.

When a person cannot differentiate different colours, he is said to be colour blind. This is because, the retina of the eye of such a person does not possess some cone shaped cells. This defect is common in males than in females (Fig. 2.6).

(i) Optic Nerve

The nerve fibres coming from the retina are called optic nerve. These carry electrical impulse to the brain.

(j) Blind Spot

The least sensitive spot on the retina is called the blind spot (Fig. 2.7). This means that at the junction of the optic nerve and retina, there is a region in which no light sensitive cells *i.e.,* absence of rods and cones makes the vision impossible at that spot. It is the place where the optic nerve enters the eye ball. When the image of an object falls on the blind spot, it cannot be observed by the eye.

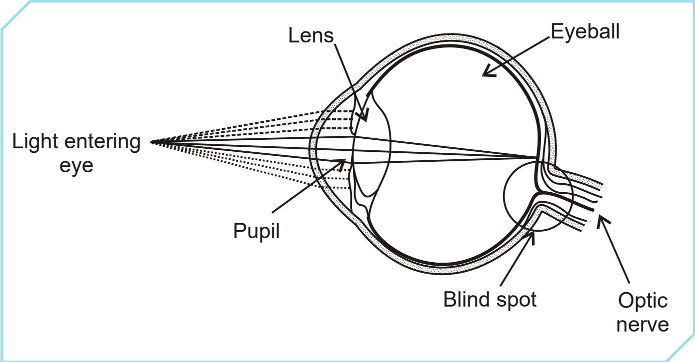


Fig. 2.7 : Blind spot is the least sensitive spot on the retina of the eye

(k) Eye Lid

The eye lid is located in front of the human eye. It acts as a shutter in a camera. The light can enter our eyes only when the eye lid is open. Thus, no light enters our eyes when the eye lids are closed.

(l) Aqueous Humour

The space between the cornea and eye lens is filled with a transparent, watery and viscous liquid called aqueous humour.

(m) Vitreous Humour

The space between eye lens and retina is filled with a jelly like substance called vitreous humour.

Working of the Eye

The light rays from the object enter the eye through cornea and fall on the eye lens through the pupil. Being convex, the eye lens forms a real, inverted and smaller image of the object on the retina. Due to this, the light sensitive cells *i.e.,* rods and cones in the retina get activated and produce electrical signals in the form of nerve impulses. These nerve impulses are sent to brain through optic nerves. The brain processes this information and gives us the sensation of vision. Though the image formed on the retina is inverted, our mind interprets the image as in upright position as that of an erect object.

The human eye is like a camera but the difference between camera and human eye is that in human eye, a real and inverted image of an object is formed on the retina by the convex lens (eye lens) whereas in camera, the convex lens (camera lens) forms a real and inverted image of the object on the light sensitive photographic film.

Note

- The rays of light from a distant object *i.e.*, at infinity are parallel to one another when they reach the eye. (Fig. 2.8).
- The rays of light from a nearby object are diverging when they reach the eye. (Fig. 2.9)

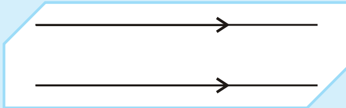


Fig. 2.8 : Parallel rays

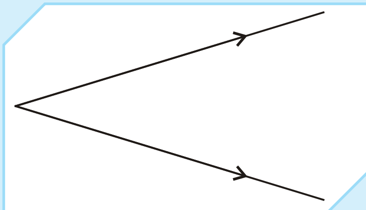


Fig. 2.9 : Diverging rays

Persistence of Vision

The most important characteristic of human eye is the persistence of vision. The image of any object formed on the retina persists for about $\frac{1}{16}$ of a second. The image of the object neither be permanent nor fades away. This is called persistence of vision (Fig. 2.10). We can thus, define persistence of vision as :

"The continuance of sensation of eye for some-time even after the removal of the object."

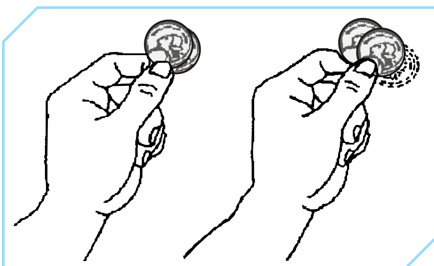


Fig. 2.10 : An example of persistence of vision

We can observe this in projection of motion pictures *i.e.,* cinematography. In motion picture, the sequence of still pictures taken by a movie camera is projected on the screen at the rate of about 24 images per second. The successive impressions of the images on the screen appear to merge to give us the feeling of the moving image *i.e.,* movie.

Let us now discuss the power of accommodation of the eye.

Power of Accommodation of Eye

The eye has the ability to observe the objects clearly located at different distances from the eye. A normal eye can see the distant objects as well as the nearby objects clearly. This is done by changing the focal length of its lens by the ciliary muscles. The ciliary muscles have the ability to change the thickness of the soft and flexible eye lens, thereby changing the focal length of the eye lens.

Let us now discuss how the focal length of the eye lens changes to see distant as well as nearby objects.

When we look at a distant object, (Fig. 2.11) the ciliary muscles are relaxed. This pulls the suspensory ligaments which in-turn pulls the eye lens. This stretches the eye lens and becomes thin. The thin eye lens has large focal length and small converging power. This converging power is sufficient to converge the parallel rays of light coming from a distant object to form the image on the retina. Thus, the eye is said to be unaccommodated because it is the relaxed state of the eye.

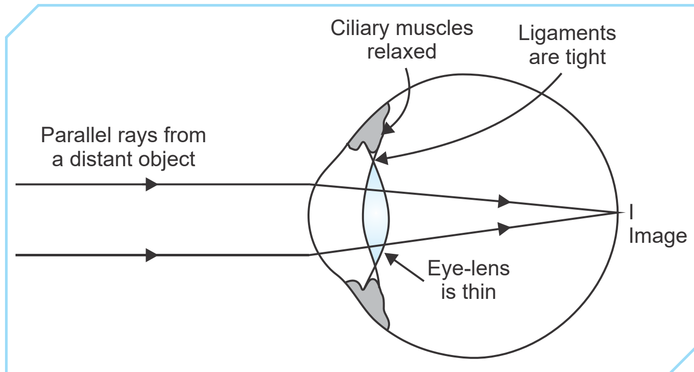


Fig. 2.11 : An eye focussed on a distant object

When we look at nearby objects (Fig. 2.12), the ciliary muscles contract and make the suspensory ligaments loose. This makes the eye lens bulgy and thick. The thick eye lens has small focal length and large converging power. This large converging power converges the diverging light rays coming from the nearby objects to form an image on the retina. Thus, the eye is said to be accommodated because the eye lens becomes more convex to focus the nearby objects.

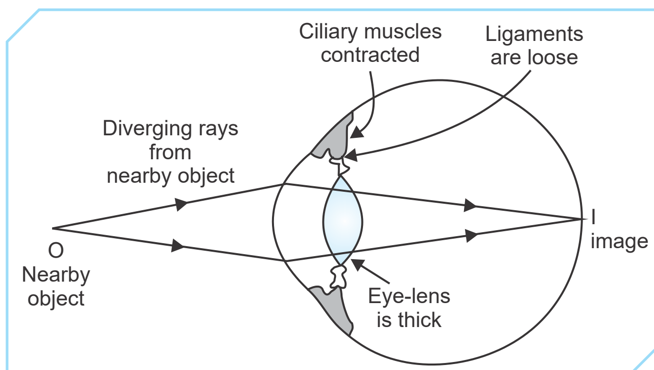
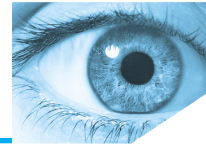


Fig. 2.12 : An eye focussed on a nearby object

Thus, we can define the accommodation as :

"The ability of the eye to focus the distant objects as well as the nearby objects on the retina by changing the focal length of its lens."



Range of Vision

The most distant point at which an object can be seen clearly is called far point. Thus, for a normal eye the far point lies at infinity (Fig. 2.13). This means that a normal eye has a power to accommodate the objects present at infinity. On the other hand, when the object is too close, the lens cannot curve enough to focus the image on the retina and so the image becomes blurred. Thus, the point at closest distance at which an object can be seen clearly by the eye is called near point of the eye. In other words, the distance of the near point of a normal eye is called least distance of distinct vision. For normal eye, the value of least distance of distinct vision is 25 cm. It is represented by '*d*'.

Fig. 2.13 : We can see the distant objects, like mountains, clouds, sky because the far point of our eye is at infinity.

Thus, we can define the range of vision as

"The distance between the near point and the far point."

The maximum power of accommodation of the eye for a person having normal vision is,

$$P = \frac{100}{f} = \frac{100}{d} = \frac{100}{25} = 4\ D$$

Note

- When any one of the structure of eye involved in transmission of light malfunctions, the visual functioning is disturbed.
- When we read a printed page by holding it very close to the eyes, we feel strain in the eyes and see a blurred image. This is because, the focal length of eye lens cannot be decreased below a minimum limit with the help of ciliary muscles.

PAPER–PEN TEST : 1

1. Describe the working of the human eye.
2. What do you understand by the term 'power of accommodation' ?
3. How does the eye adjusts itself to deal with varying light intensity?
4. Name the light sensitive cells which : (a) work in dim light, (b) detect colour ?
5. What happens when you walk from a dark room into sunlight and again back into the dark room ?
6. Mention the function of ciliary muscles and iris of the human eye.
7. Give reasons : "We cannot see our seats first when we enter a darkened cinema hall from a bright light, but slowly they become visible".
8. How the amount of light entering the eye is controlled ?
9. Why our night vision is comparatively poor compared to the night vision of an owl ?
10. What is the range of vision of a normal human eye ?

2.2 DEFECTS OF VISION

When a person cannot focus the image of an object properly on the retina, then the vision of a person becomes blurred. This makes the person to have a defective vision. Thus, we can define defect of vision as,

"When the person cannot see either the distant objects or nearby object or both clearly and comfortably, it is called defect of vision."

Common Defects of Eye

There are three common defects of the eye. These include :

(a) ***Myopia or short-sightedness***

(b) ***Hypermetropia or long-sightedness***

(c) ***Presbyopia or old sight***

We shall now study these defects of eye, their causes and corrections by using suitable spherical lenses either concave or convex lenses in the form of glasses or spectacles.

(a) Myopia

Myopia means short sightedness *i.e.*, the short sight of the person is normal and the long sight of the person is defective. Thus, we can define myopia as :

"The defect of the human eye in which a person can see the objects lying at short distances clearly but cannot see the far objects distinctly."

A myopic child sitting on the back benches in the class cannot read what is written on blackboard, but can read the book comfortably. Thus, we can also say that a myopic person has no problem in reading and writing, but he cannot see clearly the objects beyond a particular distance. Thus, the far point of an eye suffering from myopia is less than infinity (Fig. 2.14). In a myopic eye, the image of a distant object is formed in front of the retina not at the retina itself (Fig. 2.15).

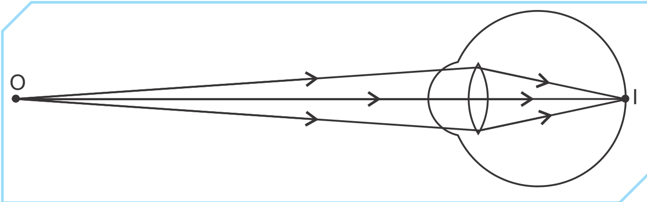


Fig. 2.14 : Far point of a myopic eye.

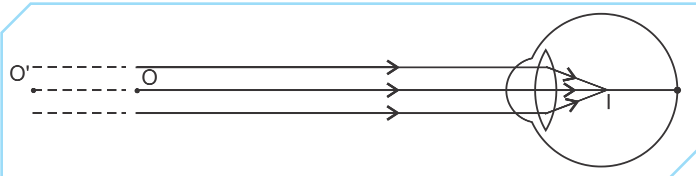


Fig. 2.15 : Myopic eye

Causes of the Myopia

This defect may arise due to

(i) Decrease in the focal length of the eye lens.

(ii) The size of the eye ball becomes too long.

Correction

To correct a myopic eye, the person is allowed to wear spectacles with concave lens of suitable power or focal length (Fig. 2.16).

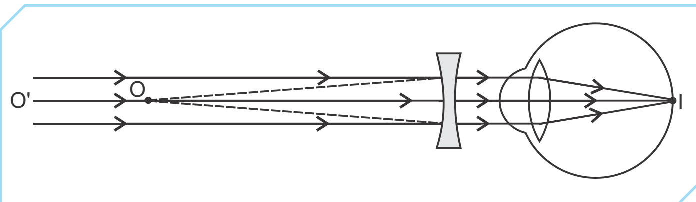


Fig. 2.16 : Correction for myopia

When a concave lens or diverging lens of suitable power is placed in front of the myopic eye, then the parallel rays of light coming from the distant object are first diverged by the concave lens. Thus, the concave lens forms a virtual image of the distant object at the far point of the myopic eye which can be easily focused by the eye lens to form an image on the retina.

Note

- The concave lens used for correcting myopia should be of focal length that it produces a virtual image of the distant object at the far point of the myopic eye.
- The main object of using concave lens is to reduce the converging power of the eye lens.

Calculation of Focal Length and Power of a Concave Lens to Correct Myopia

We know that the concave lens is used to correct short sightedness which diverges the light rays entering the eye from infinity. Assume that distance of far point of myopic eye be 'd' and focal length of concave lens be 'f'. Here, the object is seen at infinity, and the image is formed at a distance 'd'.

$$\therefore \quad u = \infty \text{ and } v = -d$$

From the lens formula,

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

On substituting the values, we get

$$\frac{1}{-d} - \frac{1}{\infty} = \frac{1}{f} \qquad \left[\because \frac{1}{\infty} = 0\right]$$

$$\frac{1}{f} = -\frac{1}{d}$$

$$\therefore \quad \boxed{f = -d}$$

Hence, the focal length of concave lens used for correcting the myopic eye is equal to the distance of far point of the myopic eye.

Knowing the focal length of the concave lens, its power can be calculated.

Let us take an example to calculate the power of concave lens to correct myopia.

SOLVED PROBLEMS BASED ON LENS FORMULA

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

Where 'u' is the object distance in centimetre, 'v' is the image distance in centimetre and 'f' is the focal length in centimetre.

1. The far point of a myopic person is 80 cm in front of the eye. What is the nature and power of the lens required to correct the defect?

Solution : Myopia is corrected by using a concave lens. So, the person requires concave lens.

The far point of the myopic person is 80 cm.

Here,

The object distance $(u) = \infty$

The image distance (v) = – 80 cm

Using the formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Substituting the values, we get

$$\frac{1}{-80} - \frac{1}{-\infty} = \frac{1}{f}$$

$$-\frac{1}{80} - 0 = \frac{1}{f}$$

$$-\frac{1}{80} = \frac{1}{f}$$

$$f = -80 \text{ cm}$$

Thus, the focal length of the required concave lens is – 80 of or – 0.8 m. In order to calculate power, we need to use the formula,

$$\text{Power} \qquad P = \frac{1}{f\left(\text{in metre}\right)}$$

Substituting the value of f, we get

$$P = \frac{1}{-0.8}$$

$$= -\frac{10}{8}$$

$$= -1.25 \text{ D}$$

The power of concave lens required is –1.25 D.

(b) Hypermetropia

Hypermetropia means long sightedness *i.e.*, the long sight of the person is normal and the short sight of the person is defective. Thus, we can define hypermetropia as,

"The defect of the human eye in which a person can see the objects lying at long distances clearly, but cannot see the nearby objects distinctly."

A hypermetropic person has problem in reading and writing *i.e.*, he cannot see distinctly the objects lying closer than a certain distance but he can see clearly the objects beyond a particular distance. Thus, the least distance of distinct vision is no longer at 25 cm. Its near point is more than 15 cm away (Fig. 2.17).

In a normal eye, the rays from the near point are focussed on the retina is 25 cm. In a hypermetropic eye, the rays from the normal near point are focussed at a point beyond retina of the eye (Fig. 2.18). So the objects lying at near point are not seen clearly.

Causes of the Hypermetropia

The hypermetropic eye is caused by the following two defects :

(i) Increase in the focal length of the eye lens.

(ii) The size of the eye ball becomes too short.

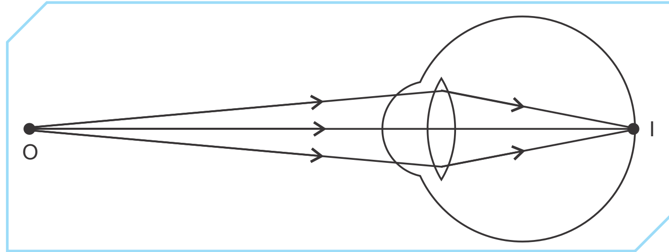


Fig. 2.17 : Near point of hypermetropic eye

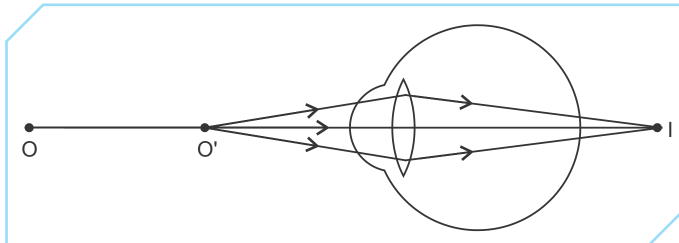


Fig. 2.18 : Hypermetropic eye

Correction

To correct a hypermetropic eye, the person is allowed to wear spectacles with a convex lens of suitable power or focal length (Fig. 2.19).

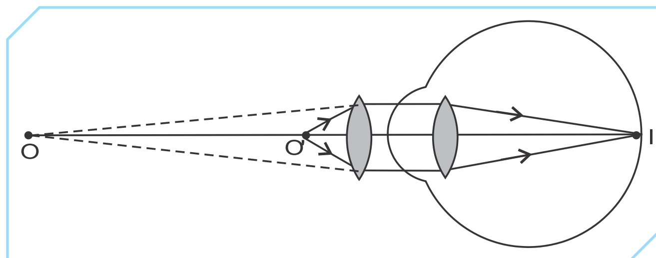


Fig. 2.19 : Correction for hypermetropia

When a convex lens or converging lens of suitable power is placed in front of the hypermetropic eye, then the diverging rays of light coming from the nearby object are first converged by this convex lens. Thus, the convex lens forms a virtual image of the nearby object (lying at O') at the point O of the hypermetropic eye which can be easily focused by the eye lens to form an image on the retina.

Note

- The convex lens used for correcting hypermetropia should be of focal length that it produces a virtual image of the nearby object at the near point of the hypermetropic eye.
- The main object of using convex lens is to increase the converging power of the eye lens.

Calculation of Focal Length and Power of a Convex Lens to Correct Hypermetropia

We know that the convex lens is used to correct long sightedness which converges the light rays entering the eye from the near point. Assume that distance of nearby point of hypermetropic eye be 'd' and focal length of concave lens be 'f', since the object is seen at near point, $u = -25$ cm and $v = -d$

From the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

On substituting, we get

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

$$\frac{1}{f} = -\frac{1}{25} + \frac{1}{-d}$$

Knowing the focal length of the convex lens, its power can be calculated.

SOLVED PROBLEMS BASED ON LENS FORMULA

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

Where 'u' is the object distance in centimetres, 'v' is the image distance in centimetres and 'f' is the focal length in centimetres.

1. The near point of a hypermetropic eye is 1 m. What is the nature and power of the lens required to correct this defect? [Assume that the near point of the normal eye is 25 cm]

Solution : The eye defect, hypermetropia can be corrected by using a convex lens.

Here,

The object distance (u) = – 25 cm

The image distance (v) = – 1 m = – 100 cm

Using lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

On substituting the values, we get

$$\frac{1}{-100} - \frac{1}{-25} = \frac{1}{f}$$

$$-\frac{1}{100} + \frac{1}{25} = \frac{1}{f}$$

$$\frac{-1+4}{100} = \frac{1}{f}$$

$$\frac{3}{100} = \frac{1}{f}$$

$$f = \frac{100}{3}$$

$$f = 33.3 \text{ cm}$$

The focal length of the convex lens required is +33.3 cm.

In order to calculate power, we need to use the formula,

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

On substituting the value of f, we get

$$\text{P} = \frac{1}{+0.33}$$

$$\text{P} = +\frac{100}{33}$$

$$\text{P} = +3.0 \text{ D}$$

The power of convex lens required is +3.0 D.

(c) Presbyopia

In old age, the ciliary muscles become weak and the eye lens becomes rigid losing its power of accommodation. Due to this, an old person cannot see the nearby objects clearly leading to the defect called presbyopia. Thus, we can define presbyopia as,

"The defect in which an old person cannot see the nearby objects clearly due to loss of power of accommodation of eye."

In other words, we can say that presbyopia is a kind of hypermetropia. It is also called old sight.

Causes of Presbyopia

The defect of presbyopia arises due to ageing of a person. Actually the cause of presbyopia is :

(i) Gradual weakening of the ciliary muscles.

(ii) Diminishing flexibility of the eye lens.

Correction

Presbyopia is basically long sightedness but it arises in old people due to the eye lens losing flexibility. It can be corrected by using a convex lens.

Sometimes in this a person may suffers from both the defects *i.e.,* myopia and hypermetropia as the eye loses its power of accommodation. The defect can be corrected by using bifocal lens (Fig. 2.20). In this lens, the upper part consists of concave lens used for distant vision and the lower part of the bifocal lens consists of convex lens used for nearby objects.

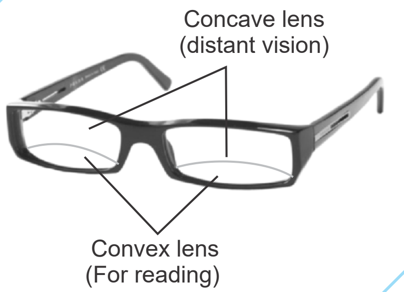


Fig. 2.20 : Spectacles having bifocal lens

(d) Cataract

Another defect of the eye which comes in old age is cataract. The defect is developed when the eye lens of a person becomes cloudy due to the formation of a membrane over it (Fig. 2.21). The defect of the cataract leads to :

- Decrease in vision of the eye gradually.
- Result in total loss of vision of the eye.

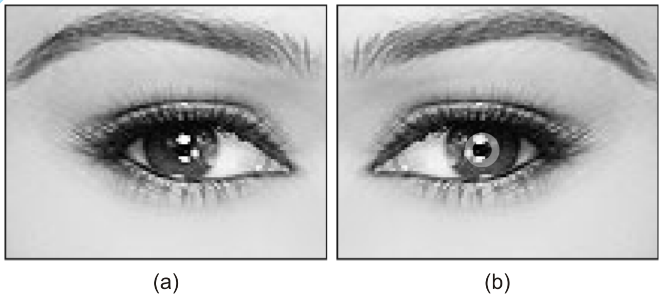


Fig. 2.21 : (a) Normal, clear lens (b) Lens clouded by cataract

Correction

The cataract can be rectified after getting surgery in which the cloudiness layer is removed and the lens is replaced with new artificial lens.

PAPER–PEN TEST : 2

1. Mention any two defects of eye which can be corrected by using spectacles.
2. Explain with the help of ray diagram, how hypermetropia defect is corrected by lens.
3. What is presbyopia ?
4. Give any two causes of myopia defect.
5. What is short sightedness ?
6. How would you calculate the power of convex lens to correct hypermetropia ?
7. Explain with the help of ray diagram, how myopia defect is corrected by lens.
8. Give any two causes of hypermetropia defect.
9. What is the far point and near point of a person suffering from myopia and hypermetropia respectively ?
10. How would you calculate the power of concave lens to correct myopia ?

2.3 REFRACTION OF LIGHT THROUGH A PRISM

A homogenous, transparent refracting medium bounded by at least two non-parallel surfaces inclined at some angle is called a prism. A triangular glass prism is a transparent object made up of glass having two triangular bases and three rectangular lateral surfaces [Fig. 2.22 (a)]. The opposite sides of a triangular prism are not parallel to one another. They are inclined at an angle to one another. The angle between its opposite faces is called the angle of the prism. Generally a triangular glass prism is represented by drawing a triangle in ray diagrams. [Fig. 2.22 (b)].

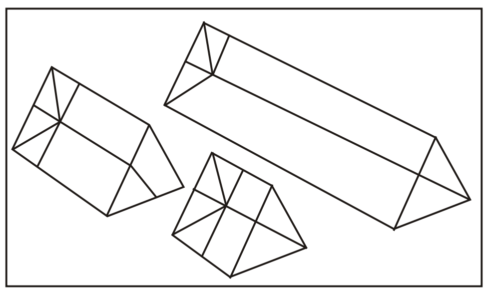
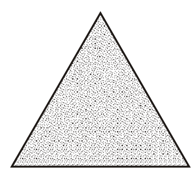



Fig. 2.22 : (a) Triangular glass prism (b) A triangular prism is represented by a triangle in ray diagrams

In refraction of a light through a glass prism, the emergent ray is not parallel to the incident ray. This is because, the opposite faces of the glass prism are not parallel to one another. Thus, in refraction through a glass prism the emergent ray is deviated from its original direction by a certain angle.

Let us illustrate an activity to trace the path of light rays through a glass prism.

Activity 2.1–To trace the path of light rays through a glass prism

PROCEDURE

Step 1– Place a prism on a white sheet of paper with the triangular base on the sheet and trace its boundary ABC.

Step 2– Fix two pins T and S on one side (Fig. 2.23).

Step 3– Place the prism on the boundary ABC.

Step 4– Looking through the other side fix two more pins Q and R in such a way that the all four pins appear to be in the same line.

Step 5– Remove the pins and mark their positions.

Step 6– Join TS and RQ and extend them to meet the faces of the prism at P and O respectively.

Step 7– Join PO.

Step 8– TP represents the incident ray, PO represents the refracted ray and OR represents the emergent ray which is bent towards the base.

Step 9– Let NN′ and MM′ be the normal at the points P and O respectively.

Step 10– Let *i* be the angle of incidence and *r* the angle of refraction.

Step 11– If the incident ray TP is extended forward and the emergent ray RO backwards, they meet at K, forming the angle OKL.

Step 12– Measure the angle OKL. This angle is called the angle of deviation.

Step 13– Measure the angle of incidence *i* and the angle of deviation.

Step 14– Record these angles in the observation table.

Step 15– Repeat this for different values of angle of incidence.

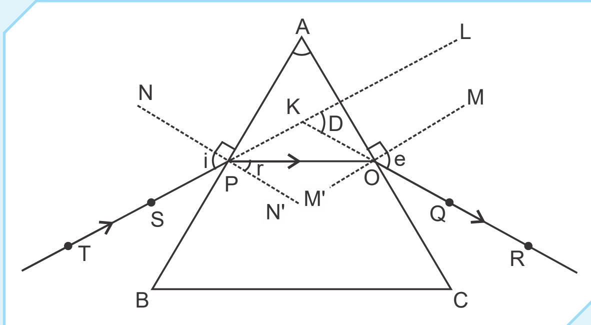


Fig. 2.23 : Refraction of light through the prism

Where, TP – Incident ray, PO – Refracted ray, OR – Emergent ray, $\angle A$ – Angle of prism, $\angle i$ – Angle of incidence, $\angle r$ – Angle of refraction, $\angle e$ – Angle of emergence and $\angle D$ – Angle of deviation.

OBSERVATION

In this experiment, the emergent ray OR is not parallel to the incident ray TP. There has been a deviation in the path of light on passing through the prism. When the incident ray TP is drawn towards L by a dotted line from P, it cuts the line TL at point K. Thus, the original direction of the ray of light is TL but after passing through the prism, it deviates from its path and goes in the direction KR. The angle between the incident ray and emergent ray is called angle of deviation. The angle LKR is the angle of deviation [Angle of deviation is the angle by which an incident ray deviates].

CONCLUSION

We can conclude that the peculiar shape of the glass prism makes the emergent ray bend with respect to the incident ray.

2.4 DISPERSION OF LIGHT

Newton in 1665 discovered that white light consists of a mixture of seven colours *i.e.,* lights of seven colours. In this experiment, Newton passed a beam of white light through a triangular prism, the white light splits to form a band of seven colours which is caught on a white screen. Thus, when a beam of white light is passed through a glass prism, the band of seven colours is formed on a white screen (Fig. 2.24). The seven colours of the spectrum are Red, Orange, Yellow, Green, Blue, Indigo and Violet. The seven colours of the spectrum can be denoted by the word 'VIBGYOR' where V stands for violet, I for indigo, B for blue, G for green, Y for yellow, O for orange, and R for red.

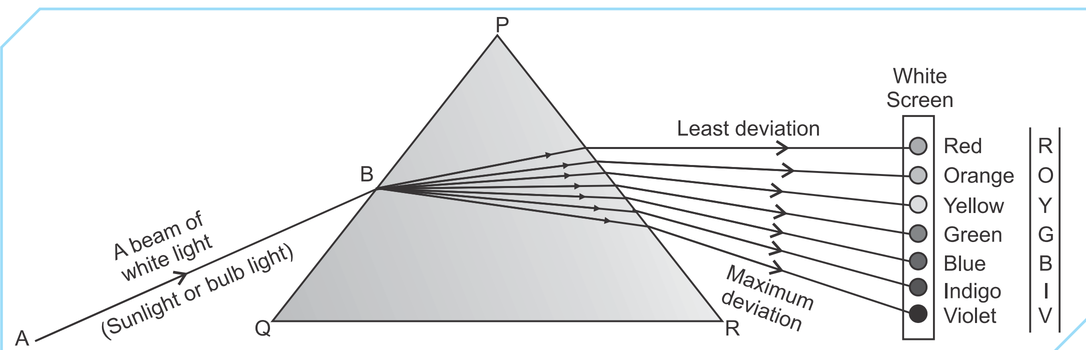


Fig. 2.24 : A white light splits into lights of seven colours after passing through the prism

Let us perform an experiment to find out the dispersion of white light.

When a beam of white light passes through a glass prism, the white light splits to form a broad patch of seven colours on a white screen placed on the other side of the prism (Fig. 2.25). When the glass prism is kept on its base, the red colour will be at the top and violet colour at the bottom of the spectrum. Thus, the splitting of white light into seven colours on passing through a transparent medium like a glass prism is called dispersion of light.

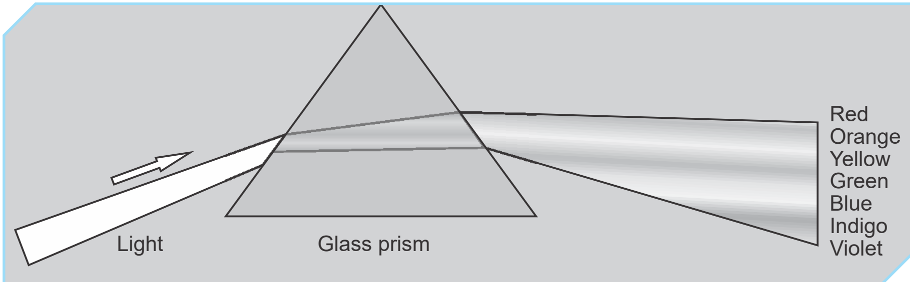


Fig. 2.25 : Experiment shows white light is made up of light of seven colours

The formation of spectrum of seven colours shows that white light is made up of lights of seven different colours mixed together. The dispersion of white light takes place because the colours of white light travel at different speeds through a glass prism. The amount of bending or refraction of light depends on the speed of the coloured light in glass.

The refractive index of glass is different for different colours, so when white light falls on the glass prism each colour is refracted at a different angle. The red colour has the maximum speed in glass prism and so the red colour deviates the least. On the other hand, the violet colour has the minimum speed in glass prism and so the violet colour deviates the most. The order of the colours formed in the increasing frequency is Red, Orange, Yellow, Green, Blue, Indigo and Violet.

Let us now perform an activity to show the phenomenon of dispersion of light by glass prism.

Activity 2.2–To show the phenomenon of dispersion of light by glass prism

PROCEDURE

Step 1– Take a thick sheet of cardboard and make a small hole in its middle.

Step 2– Allow the sunlight to fall on the hole.

Step 3– Now, take a glass prism and allow the light from the hole to fall on one of its faces (Fig. 2.26).

Step 4– Turn the prism slowly until the light that comes out of it appears on a nearby screen.

Step 5– Note down your observation.

Step 6– Why does this happen?

Step 7– Note the colours that appear at the two ends of the colour band.

Step 8– What is the sequence of colours that you see on the screen?

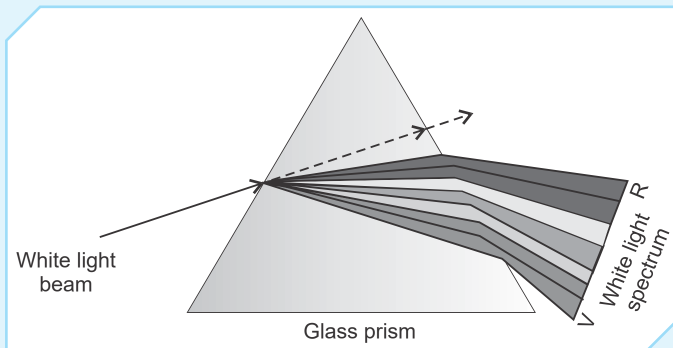


Fig. 2.26 : Dispersion of white light by the glass Prism

OBSERVATION

(a) You will find a beautiful band of seven different colours.

(b) Colour sequence is Violet, Indigo, Blue, Green, Yellow, Orange and Red.

CONCLUSION

The prism has probably split the incident white light into a band of seven different colours. Different colours of light bend by different angle with respect to the incident ray as they pass through the prism.

Visible Spectrum

We know that every colour of visible spectrum has its own characteristic wavelength and so have characteristic frequency. The table shows the characteristic wavelength and frequency.

S. No.	Colour	Wavelength	Frequency
1.	Red	7900 Å	3.80×10^{14} Hz
2.	Orange	6000 Å	5.00×10^{14} Hz
3.	Yellow	5800 Å	5.17×10^{14} Hz
4.	Green	5400 Å	5.56×10^{14} Hz
5.	Blue	4800 Å	6.25×10^{14} Hz
6.	Indigo	4500 Å	6.67×10^{14} Hz
7.	Violet	4000 Å	7.50×10^{14} Hz

The table shows that the violet colour has minimum wavelength and so has maximum frequency. On the other hand, the red colour has maximum wavelength and so has minimum frequency. Thus, we can conclude that a spectrum in which different colours occupy their own distinct positions without any overlapping is called a pure spectrum. On the other hand, a spectrum in which different colours overlap with one another is called an impure spectrum.

Recombination of the Spectrum of White light

Newton passed the beam of light dispersed by a glass prism through another identical glass prism. The second prism is held in a position along the first prism but in opposite direction. He found a beam of white light emerging from the other side of the second prism. Thus, he concluded that the first prism dispersed white light into seven colours and the second prism which received it, recombines them to form original white light (Fig. 2.27). This takes place due to angular dispersion produced by the second prism which is equal and opposite to the angular dispersion produced by the first prism. Thus, Newton suggested that the sunlight is made up of seven colours.

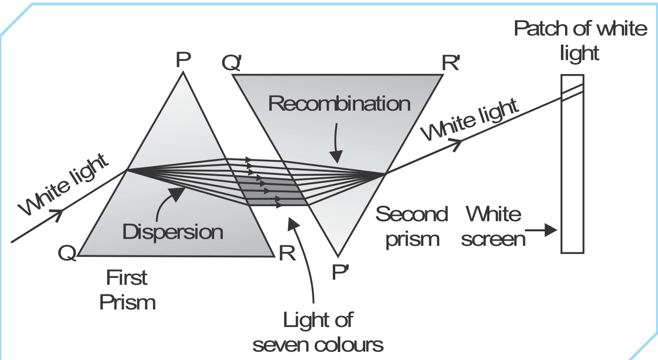


Fig. 2.27 : Recombination of the spectrum of white light

We can observe rainbow as the dispersion of sunlight in nature.

Rainbow

We know that the rainbow is an arch of seven colours visible in the sky produced by the dispersion of sunlight by rain drops in the atmosphere (Fig. 2.28). It is an example of spectrum formed by the dispersion of sunlight provided by the nature in the form of rainbow.

Fig. 2.28 : Rainbow

We can see the rainbow in the sky when the sun is shining and it is raining at the same time. When we stand with our back towards sun and rain in front of us, we can see the rainbow. This is because a rainbow is always formed in the direction opposite to the sun.

During or after rain, a large number of tiny raindrops remain suspended in air. When sunlight falls on these droplets, it gets refracted and dispersed in the atmosphere, thereby each raindrop acts as a tiny glass prism splitting the sunlight into a spectrum of seven different colours. Since raindrops act like prisms, when white sunlight enters and leaves these raindrops, the coloured rays in white light are refracted by different amounts and so an arch of seven colours *i.e.,* rainbow is formed.

Let us now discuss the formation of rainbow (Fig. 2.29).

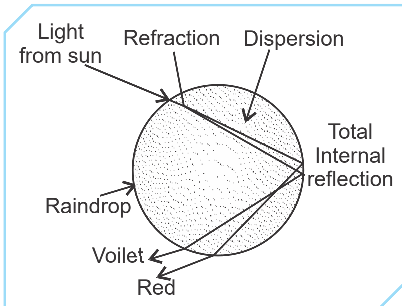


Fig. 2.29 : Rainbow formation

When a ray of sunlight enters the raindrop at a point, it undergoes refraction and dispersion to form a spectrum. This spectrum undergoes total internal reflection at a point within the raindrop and finally refracted out of the raindrop at another point. This spectrum produced by the raindrops is seen from the earth. In the rainbow, the red colour is seen at the top whereas the violet colour is seen at the bottom.

Note

- We can see a rainbow on a sunny day by looking at the sky through a water fountain or through a water fall. The only condition is that our back must be towards the sun.

PAPER–PEN TEST : 3

1. Name the seven different colours seen in a rainbow.
2. Demonstrate how white light is composed of a number of colours.
3. Explain refraction and dispersion with the help of diagram.
4. Explain how the colours of the spectrum combine to form white light.
5. Define dispersion of white light.
6. What do you understand by the term ‘spectrum’?
7. Explain the formation of rainbow in the sky with the help of diagram.
8. What are the conditions required for the formation of a rainbow in the sky?
9. Define rainbow.
10. What will happen when a second triangular glass prism is placed upside down behind the first glass prism?

We know that the atmosphere have air everywhere. But do you know that whole air is not at the same temperature. The atmosphere also involve in refraction. We shall discuss it in detail.

2.5 ATMOSPHERIC REFRACTION

In the atmosphere, some layers of air may be cold and some may be hot or warm. The cool air layers of the atmosphere behave as an optically denser medium while the hot or warm air layers of the atmosphere behave as an optically rarer medium. Thus, in the same atmosphere, we have air layers having different optical densities. When light goes from one medium to another medium having different optical densities, then refraction of light rays takes place (Fig. 2.30).

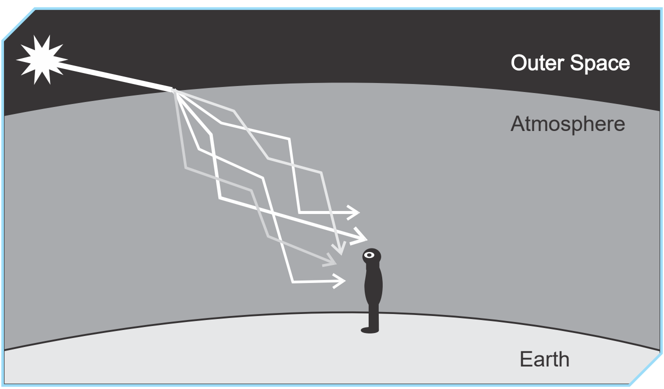


Fig. 2.30 : Refraction of light takes place due to difference in optical densities

Thus, light coming from stars and entering earth’s atmosphere passes from rarer to denser medium, it results in multiple refractions before reaching the earth’s surface. This is called atmospheric refraction. Thus, we can define atmospheric refraction as

“The phenomenon of bending of light on passing through different layers of earth’s atmosphere.”

Let us look into an example of atmospheric refraction.

When we look at objects through the hot air over a fire, the objects appear to be moving slightly. This is because the air just above the fire becomes hotter and forms an optically rarer layer. But the cool air above it forms an optically denser layer. Thus, the objects coming through hot and cold air layers have different optical densities due to refraction of light taking place randomly, the objects appear to be moving.

Let us describe some of the optical phenomena in nature, taking place due to atmospheric refraction of light.

Twinkling of Stars

We know that stars are independent sources of light situated very far away from the earth. In other words, stars emit their own light and due to which the stars shine in the night sky. When we look at the stars at night, we can observe that the intensity of light from the stars changes continuously *i.e.*, it appears bright and the next moment it appears dim. Due to this, we say that the stars twinkle at night. The twinkling of stars takes place due to atmospheric refraction (Fig. 2.31).

Let us explain this phenomenon.

When the light from the star enters the earth’s atmosphere, it undergoes refraction. The continuously changing atmosphere refracts the light from the star by different amount from one moment to the next. Thus, when the atmosphere refracts more starlight to us, we can see the stars appears to be bright and when the atmosphere refracts less light to us, we can see the stars appears to be dim.

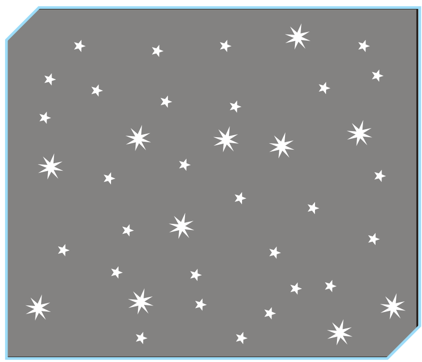


Fig. 2.31 : Twinkling of stars is an example of Atmospheric refraction

Thus, the starlight on reaching our eyes increases and decreases continuously due to atmospheric refraction, making stars appear to twinkle at night.

In other words, since the stars are very small in size and are far away from the earth and so the continuous changing of atmosphere causes variations in the intensity of light coming from the star. Due to which the stars appear to be twinkling.

Planets do not Twinkle

The stars are very small in size and are far away from the earth. So, it can be considered as a point source of light. The continuous changing of the atmosphere causes variations in the light coming from the star due to which the stars appear to be twinkling. On the other hand, the planets are bigger in size and are closer to the earth. So, it can be considered as a collection of a large number of point sources of light. Some point sources produces dimming effect and other produces brighter effect so, the total variation in the amount of light entering our eye will average out to zero. Thus, the twinkling effect is nullified and planets do not appear to twinkle.

Stars Seem Higher than they actually are

The light from the star is refracted as, it leaves the space or vacuum and enters the earth's atmosphere. Since we have studied earlier that the air higher up in the sky is rarer and near the earth is denser, therefore as the light from the star comes down, the dense air refracts the light more. Due to this refraction of star's light, the stars appear to be at a higher position (Fig. 2.32).

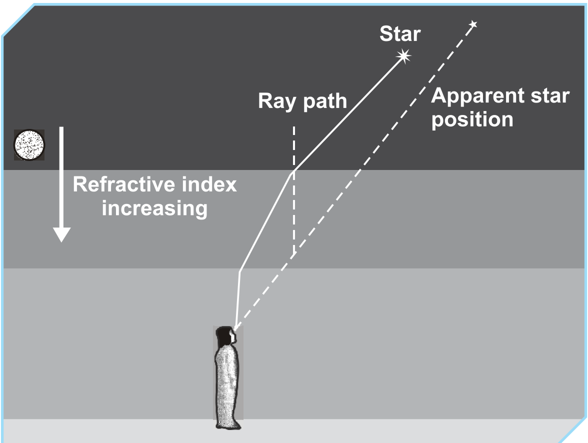


Fig. 2.32 : Stars seem to be higher in the sky than they actually are due to atmospheric refraction

Since the atmosphere bends the starlight towards the normal, the apparent position of the star is slightly different from its actual position.

The star appears slightly above than its actual position when viewed near the horizon. Further, this apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary. Since the stars are point-sized sources of light, the path of rays of light coming from the star goes on varying slightly and the apparent position of the star fluctuates.

Advance Sunrise and Delayed Sunset

We can see the sun about two minutes before the actual sunrise and two minutes after the actual sunset because of atmospheric refraction (Fig. 2.33). Let us first discuss the atmospheric refraction in sunrise.

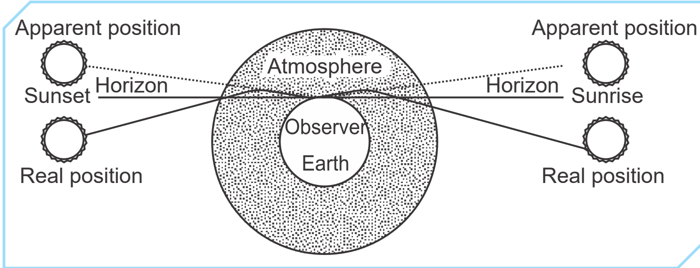


Fig. 2.33 : Effect of atmospheric refraction at sunrise and sunset

The actual sunrise takes place when the sun is just above the horizon due to refraction of sunlight, we can see the rising sun about two minutes before it is actually above the horizon. This can be explained as follows : When the sun is slightly below the horizon, the light from the sun travels from less dense air to more dense air and so get refracted downwards as it passes through the atmosphere. Thus, the sun appears to be raised above the horizon when actually it is slightly below the horizon.

Let us illustrate this with an example.

As we move above the earth's surface, the density of air goes on decreasing. Thus, the light from the sun entering the earth's atmosphere passes from rarer medium to denser medium and bends towards the normal every-time. Therefore, the sun which is below the horizon appears to rise just above the horizon. The difference in time involved is two minutes. Thus, we can conclude that the sun appears to rise two minutes earlier.

It is also due to the atmospheric refraction that we can still see the sun for about two minutes even after the sun has set below the horizon. The sun which has already gone below the horizon appears to be just above the horizon due to atmospheric refraction. The difference in time involved is two minutes.

In this way, the length of each day increases by four minutes due to atmospheric refraction. But if earth has no atmosphere, then this effect will not take place.

Note

- The sun appears flattened or oval at sunrise and sunset due to atmospheric refraction.

PAPER–PEN TEST : 4

1. Define atmospheric refraction.
2. Why planets do not twinkle at night ?
3. What causes atmospheric refraction ?
4. By how much time, the day would have been shorter if the earth had no atmosphere ? Justify.
5. Why do stars seem higher than they actually are ? Illustrate.

6. Draw a diagram to illustrate the effect of atmospheric refraction at sunset.
7. Why do stars twinkle at night ?
8. Name any three effects produced by the atmospheric refraction.
9. If we look at the objects through the hot air over a fire, the objects appear to be moving slightly. Why ?
10. Draw a diagram to illustrate the effect of atmospheric refraction at sunrise.

2.6 SCATTERING OF LIGHT

The word 'Scattering of light' refers to 'throw light in various directions'. The particles which scatter light is known as scatterers. When sunlight enters the earth's atmosphere, the atoms and molecules of different gases in the atmosphere absorb this light and re-emit it in all directions. This phenomenon is known as scattering of light. The scattering of light involves bouncing off radiation by atoms or molecules through the medium they are travelling. Thus, we can conclude that scattering is the phenomenon of change in the direction of light on striking an atom, a molecule, a water droplet or a dust particle etc.

Lord Rayleigh studied scattering experimentally (Fig. 2.34) and established that the intensity of scattered light varies inversely as the fourth power of the wavelength of incident light. He also found that, when the size of scatterer is much less than the wavelength of light, then scattering is valid but when the size of scatterer is much larger than the wavelength of light, then the scattering is not valid. The colour of scattered light depends on the size of scattering particles.

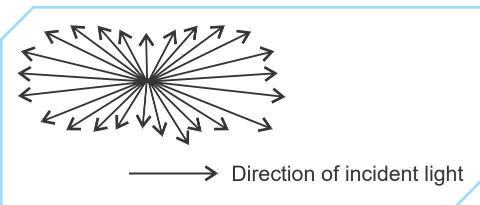


Fig. 2.34 : Rayleigh scattering

Have you ever noticed, when a beam of sunlight enters a dusty room? What do you observe? Similarly while trekking in forest, have you ever noticed sunlight passing through the canopy? What do you observe ? Is both the observation due to the same phenomenon ? Let us discuss.

Tyndall Effect

"The scattering of light by particles in its path is called Tyndall effect."

We can observe the Tyndall effect when a beam of sunlight enters a dusty room through a window, then its path becomes visible to us (Fig 2.35). This is because, the tiny dust particles in the room scatter the beam of light all around the room.

Fig. 2.35 : Tyndall effect

Another example of Tyndall effect is that when sunlight passes through the canopy of a dense forest, the tiny water droplets in the mist scatter the sunlight.

In 1859, Tyndall discovered that when white light is passed through a clear liquid having small suspended particles, then the blue colour of the white light having shorter wavelength is scattered more than the red colour having longer wavelength. Since blue light has shorter wavelength, it gets scattered more easily than the red light which has longer wavelength.

Colour of the Scattered Light depends on the Size of the Scattering Particles

We know that the earth's atmosphere is a heterogeneous mixture of particles. The particles may be larger or smaller. These particles include dust particles, water droplets, air molecules such as nitrogen and oxygen gas etc.

When the white light from the sun hits the large particles present in the atmosphere, the light gets scattered in different directions. The different colours of white light are reflected by the dust and water particles. Due to this, the scattered light appears white. Thus, we can say that when the white sunlight falls on larger particles present in the atmosphere, it gets scattered and appears white.

On the other hand, when the white light from the sun hits the smaller particles such as nitrogen and oxygen gas molecules, it is not scattered as white light. The air molecules scatter mainly the lower wavelengths of light *i.e.*, blue shades (Fig. 2.36).

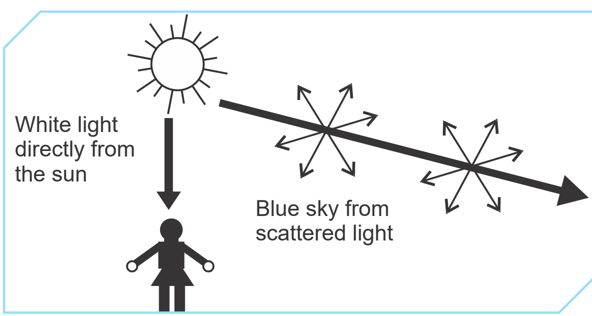


Fig. 2.36 : Colour of scattered light depends on the size of the scattering particles

Thus from the above discussion, we can conclude that the colour of the scattered light depends on the size of the scattering particles in the atmosphere.

Fig. 2.37: Scattering of sunlight

Some phenomenon occuring in nature can be explained by the scattering of light (Fig. 2.37).

Blue Colour of the Sky

When sunlight passes through the atmosphere, most of the light having longer wavelengths does not scatter much. But the light of shorter wavelength gets scattered all around the sky by air molecules present in the atmosphere. Some of this scattered blue light enters our eyes and so, the sky looks blue (Fig. 2.38). Thus, we can say that the sky appears blue due to the molecules in air which scatter the blue part of the sunlight easily than the red light or other shades.

Fig. 2.38 : Sky appears blue due to the scattering of blue light more than the other colour of the sunlight

If the earth had no atmosphere, then there would have been no scattering of sunlight and so there would have been no light entering our eyes. Due to this, the sky would look dark and black to us. Astronauts found the sky appears dark and black in outer space. This is because, there is no atmosphere in the outer space to scatter the sunlight.

Note

- Only a little of the blue light present in the white sun light is scattered by the atmosphere which makes the sky appear blue. Most of the blue light remains unscattered due to which the composition of sunlight remains unaltered. Thus, the direct sunlight from the blue sky still appears white.

Red Colour of Danger Signals

We know that the danger signal lights are red in colour. This is because all colours are scattered much more than that of red light (Fig. 2.39). The red colour being least scattered, remains confined around the signal and so illuminates the signal significantly. Thus, the danger signal can be seen from far off distances. Another advantage of the red light is that it is least scattered by smoke or fog. Hence red signals are visible even through smoke or fog.

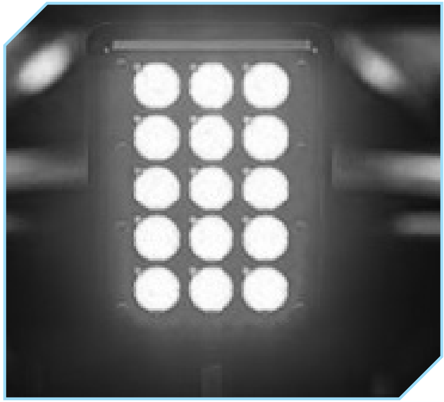


Fig. 2.39 : Red colour is used for danger signal as it is scattered least as compared to other colours of light

Colour of the Sun during Sunrise and Sunset

The sun and the surroundings appear red during sunrise and sunset (Fig. 2.40). This is because, during the time of sunrise and sunset, the sun is near the horizon and so the light from the sun has to travel greatest distance through the atmosphere to reach us. During this travel, most of the shorter wavelengths present in it get scattered and only the longer wavelength *i.e.,* red colour is left out which makes the sun appears red.

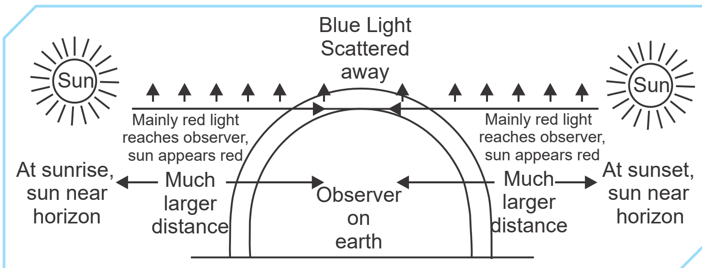


Fig. 2.40 : Colour of the sun changes to red during sunrise and sunset due to scattering

Let us perform an activity to understand the blue colour of the sky and the reddish appearance of the sun during the sunrise or sunset.

Activity 2.3–To understand the blue colour of the sky and the reddish appearance of the sun during the sunrise or sunset by Tyndall effect.

PROCEDURE

Step 1– Place a strong source (S) of white light at the focus of a converging lens (L_1). This lens provides a parallel beam of light.

Step 2– Allow the light beam to pass through a transparent glass tank (G) containing clear water.

Step 3– Then allow the beam of light to pass through a circular hole (H) made in a cardboard.

Step 4– Obtain a sharp image of the circular hole on a screen (XY) using a second converging lens (L_2), as shown in Fig. 2.41.

Step 5– Dissolve about 200 g of sodium thiosulphate (hypo) in about 2 litre of clean water taken in the tank.

Step 6– Add about 1 to 2 ml of concentrated sulphuric acid to the water.

Step 7– Note down your observation.

Step 8– Observe the colour of the transmitted light from the fourth side of the glass tank facing the circular hole.

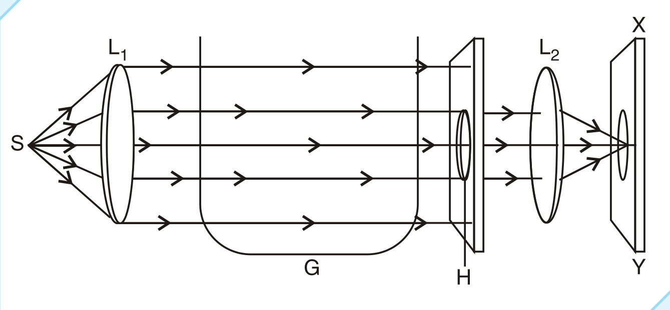


Fig. 2.41 : An experimental setup to observe the scattering of light in a colloidal solution

OBSERVATION

(a) Fine microscopic sulphur particles precipitating in about 2 to 3 minutes.

(b) The blue light is formed from the three sides of the glass tank.

(c) The colour of the transmitted light from the fourth side of the glass tank facing the circular hole is first orange red and then bright crimson red.

CONCLUSION

(a) The blue light from the three sides of the glass tank is due to the scattering of short wavelengths by minute colloidal sulphur particles.

(b) The colour obtained on the screen from the fourth side of the glass tank facing the circular hole is red because mainly the red colour of the beam of white light reaches the screen after passing the colloidal sulphur solution in the glass tank as the blue colour being scattered and hence eliminated on the way.

Sun Appears White when it is Overhead in the Sky

When the sun is overhead, then the light coming from the sun has to travel a shorter distance through the atmosphere to reach us. During this short travel, a little of blue colour of the white light is scattered. Since the light coming from the overhead sun has almost all its component colours in right proportion, therefore the sun in the sky overhead appears white to us (Fig. 2.42).

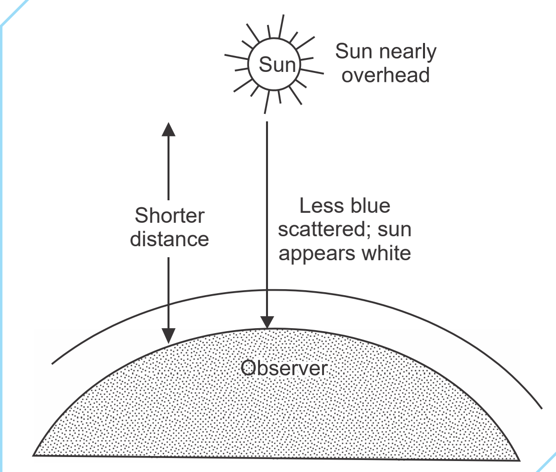


Fig. 2.42 : Sun appears white when it is overhead in the sky

PAPER–PEN TEST : 5

1. Explain Tyndall effect with an example.
2. With the help of diagram explain an activity for observing the scattering of light in a colloidal solution of sulphur to show how the sky appears blue and appearance of sun red at sunrise and sunset.
3. Why the sun overhead at noon appears white ?
4. The danger signal are red in colour. Why ?
5. Why the sky appears black to an astronaut ?
6. The sky appears blue on a clear day. Why ?
7. Mention any two effects produced by scattering of light by the atmosphere.
8. What happens when a beam of sunlight enters a dusty room through a window ?
9. The colour of the scattered light depends on the size of the scattering particles in the atmosphere. Justify.
10. Why the sun appears red at sunrise and sunset ?

COMPENDIUM

- Our eye is one of the most important sense organ.
- The human eye uses light and enables us to see the colourful world, beautiful nature and natural phenomenon.
- The structure of the human eye involves the following parts namely, cornea, iris, pupil, eye lens, ciliary muscles, retina, optic nerve and eye ball.
- The cornea is the outermost part of the eye.
- The main function of cornea is to allow the light to enter the eye.
- The iris has muscles and coloured pigments.
- The iris has a hole in the centre called pupil.
- The main function of the iris is to control and regulate the amount of light entering the eye by adjusting the size of the pupil.
- The pupil appears black as no light gets reflected from it.
- When the intensity of light is bright, the pupil contracts *i.e.,* allow only small amount of light to enter into the eyes.
- When the intensity of light is dim, the pupil expands *i.e.,* allow more amount of light to enter into the eyes.
- The eye lens has the ability to change its shape to focus the light to the retina.
- The main function of eye lens is to focus the images of the objects on the retina.
- The focal length of eye lens can be changed by changing the shape of ciliary muscles.
- The difference between camera and the eyes is that the focal length of the convex lens used in the camera is fixed while the focal length of the convex lens inside the eyes can be changed with the help of ciliary muscles.
- The retina of the eye can be compared to the photographic film in a camera.
- The retina is a delicate membrane containing number of light sensitive cells called rods and cones.
- The rod shaped cells respond to the intensity or brightness of light while the cone shaped cells respond to the colour of the light.
- The main function of these cells is to convert light energy into electrical impulses or signals.
- The rod shaped cells found in the retina of an eye which are sensitive to dim light can be observed in nocturnal animals.
- The cone shaped cells are found in the retina of an eye which are sensitive to bright light.
- Bees have cone shaped cells in the retina which are sensitive to ultraviolet light.
- When a person cannot differentiate between colours then he is said to be suffering from colour blindness.
- The nerve fibres from retina are called optic nerve.
- The optic nerves carry electrical impulse to the brain.
- The least sensitive spot on the retina is called the blind spot.
- When the image of an object falls on the blind spot, it cannot be seen by the eye.
- The eye lids act as a shutter in a camera.
- The space filled between the cornea and eye lens with a viscous liquid is called aqueous humour.
- The space filled between eye lens and retina with a jelly substance is called vitreous humour.
- The continuance of sensation of eye for sometime even after the removal of the object is called persistence of vision.
- The ability of the eye to focus on the distant objects as well as on the nearby objects on the retina by changing the focal length of its lens is called the power of accommodation of eye.
- The most distant point at which an object can be seen clearly is called far point of the eye.
- The point at closest distance at which an object can be seen clearly by the eye is called near point of the eye.
- The distance of the near point of a normal eye is called least distance of distinct vision.
- For normal eye, the value of least distance of distinct vision is 25 cm.
- The ability to see is called vision or eye sight.
- When a person cannot see either the distant objects or nearby objects or both, clearly and comfortably, it is called defect of vision.
- There are three common defects of vision which includes, (a) Myopia or short-sightedness, (b) Hypermetropia or long-sightedness, (c) Presbyopia or old sight.

- Myopia or short-sightedness is that defect of vision due to which a person can see nearby objects clearly but cannot see distant objects distinctly.
- The myopia is caused by the following two reasons :
  - Decrease in the focal length of the eye lens.
  - The size of the eye ball becomes too long.
- To correct a myopic eye, the person should wear spectacles with a concave lens of suitable power or focal length.
- Hypermetropia or long sightedness is that defect of vision due to which a person can see distant objects clearly but cannot see nearby objects distinctly.
- The hypermetropia is caused by the following two reasons :
  - Increase in the focal length of the eye lens.
  - The size of the eyeball becomes too short.
- To correct a hypermetropic eye, the person should wear spectacles with a convex lens of suitable power or focal length.
- The defect in which an old person cannot see the nearby objects clearly due to loss of power of accommodation of eye is called presbyopia or old sight.
- The cause of presbyopia is :
  - Gradual weakening of the ciliary muscles.
  - Diminishing flexibility of the eye lens.
- Presbyopia can be corrected by using bifocal lens.
- The cataract defect is developed when the eye lens of a person becomes cloudy due to the formation of a membrane over it.
- The defect of the cataract leads to (a) Decrease in the vision of the eye gradually, and (b) Total loss of vision of the eye.
- The cataract can be rectified after getting surgery done on the eye in which the cloudy layer is removed and eye lens is replaced with new artificial lens.
- A homogenous, transparent refracting medium bound by atleast two non-parallel surfaces inclined at some angle is called a prism.
- A triangular glass prism is a transparent object made up of glass having two triangular ends and three rectangular sides.
- The angle between its opposite faces is called the angle of the prism.
- The splitting of white light into seven colours on passing through a transparent medium like a glass prism is called dispersion of light.
- The order of the colours formed in the increasing frequency is Red, Orange, Yellow, Green, Blue, Indigo and Violet.
- The rainbow is an arch of seven colours visible in the sky produced by the dispersion of sunlight by rain drops in the atmosphere.
- When light goes from one medium to another medium having different optical densities, then refraction of light rays takes place.
- The phenomenon of bending of light on passing through different layers of earth's atmosphere is called atmospheric refraction.
- The twinkling of stars takes place due to atmospheric refraction.
- Planets do not twinkle at night.
- When sunlight enters the earth's atmosphere, the atoms and molecules of different gases in the atmosphere absorb this light and re-emit it in all directions. This process is known as scattering of light.
- The colour of scattered light depends on the size of scattering particles.
- The scattering of light by particles in its path is called Tyndall effect.
- When the sunlight strikes the larger particles present in the atmosphere, the scattered light appears white.
- The sky appears blue due to the molecules in air which scatter the blue part of the sunlight much more easily than the red light or other shades.
- Astronauts find the sky dark and black in outer space.
- The sun and the surroundings appear red at sunrise and at sunset.
- Sun appears white when it is overhead in the sky.

EXERCISES (SOLVED)

NCERT IN TEXT QUESTIONS

1. What is meant by power of accommodation of the eye?

Ans : The ability of the eye to focus on the distant objects as well as on the nearby objects on the retina by changing the focal length of its lens is called the power of accommodation of the eye.

2. A person with a myopic eye cannot see objects beyond 1.2 m distinctly. What should be the type of the corrective lens used to restore proper vision?

Ans : In this case, the person is unable to see a distant object. Hence, this person is suffering from myopia. So, a concave lens will help in restoring his proper vision.

3. What is the far point and near point of the human eye with normal vision?

Ans : For the normal vision, the far point of the human eye is at infinity and the near point is at 25 cm from the eye.

4. A student has difficulty in reading the blackboard while sitting in the last row. What could be the defect the child is suffering from? How can it be corrected?

Ans : Since the child is unable to see a distant object, he may be suffering from myopia. This defect can be corrected by using concave lens of suitable power.

NCERT END EXERCISE

1. The human eye can focus objects at different distances by adjusting the focal length of the eye lens. This is due to.

(a) Presbyopia (b) Accommodation

(c) Near-sightedness (d) Far-sightedness

Ans : (b)

2. The human eye forms the image of an object at its :

(a) Cornea (b) Iris

(c) Pupil (d) Retina

Ans : (d)

3. The least distance of distinct vision for a young adult with normal vision is about :

(a) 25 m (b) 2.5 cm (c) 25 cm (d) 2.5 m

Ans : (c)

4. The change in focal length of an eye lens is caused by the action of the.

(a) Pupil (b) Retina

(c) Ciliary muscles (d) Iris

Ans : (c)

5. A person needs a lens of power – 5.5 D for correcting his distant vision. For correcting his near vision he needs a lens of power +1.5 D. What is the focal length of the lens required for correcting (a) distant vision, and (b) near vision?

Solution : (a) For distant vision,

Power (P) = –5.5 D

Using the formula, $P = \frac{1}{f}$

Substituting the value of P, we get

$$f = -\frac{1}{5.5} = -0.18 \text{ m}$$

Hence, the focal length of the required lens for distant vision = –0.18 m. The minus sign indicate that it is a concave lens.

(b) For near vision,

Power (P) = +1.5 D

Using the formula, $P = \frac{1}{f}$

Substituting the value of P, we get

$$f = \frac{1}{1.5} = 0.67 \text{ m}$$

Hence, the focal length of the required lens for near vision = + 0.67 m. The plus sign indicate that it is a convex lens.

6. The far point of a myopic person is 80 cm in front of the eye. What is the nature and power of the lens required to correct the problem?

Solution : The person is suffering from an eye defect called myopia. In this defect, the image is formed in front of the retina. Hence, a concave lens is used to correct this defect of vision.

The object distance (u) = ∞

The image distance (v) = –80 cm = – 0.8 m

Using the formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Substituting the values, we get

$$-\frac{1}{0.8} - \frac{1}{\infty} = \frac{1}{f}$$

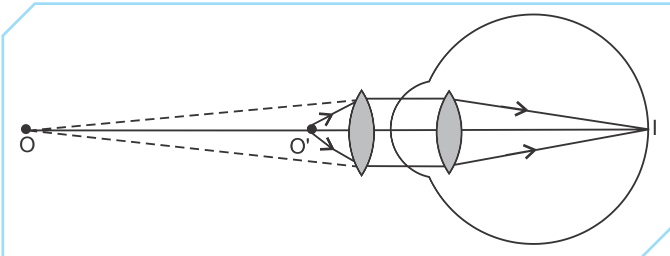
$$-\frac{1}{0.8} - 0 = \frac{1}{f}$$

$$\frac{1}{f} = -\frac{1}{0.8} = -1.25 \text{ D}$$

A concave lens of power –1.25 D is required by the person to correct his defect.

7. Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1 m. What is the power of the lens required to correct this defect? Assume that the near point of the normal eye is 25 cm.

Solution : Hypermetropia can be corrected by using a convex lens of appropriate power. The ray diagram is as follows :



Given,

The object distance, $(u) = -25$ cm $= -0.25$ m

The image distance $(v) = -1$ m

Using the formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Substituting the values, we get

$$-\frac{1}{1} - \frac{1}{(-0.25)} = \frac{1}{f}$$

$$\frac{1}{f} = 3 \text{ m}$$

$$\Rightarrow \qquad f = \frac{1}{3} \text{ m}$$

We know that,

$$\text{Power (P)} = \frac{1}{f}$$

$$\text{(P)} = \frac{1}{1/3} = 3 \text{ D}$$

A convex lens of power + 3 D is required to correct the defect.

8. Why is a normal eye not able to see clearly the objects placed closer than 25 cm?

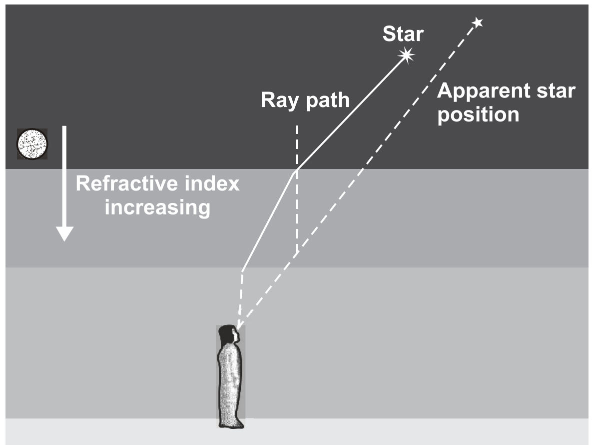
Ans : The normal eye is not able to see clearly the objects placed closer than 25 cm because the focal length of eye lens cannot be decreased beyond a certain minimum length.

9. What happens to the image distance in the eye when we increase the distance of an object from the eye?

Ans : In human eyes, the image is always formed at the retina. So, when we increase the distance of an object from the eye, there is no change in the image distance inside the eye.

10. Why do stars twinkle?

Ans : When the light from the star enters the earth's atmosphere from rarer medium to denser medium, it undergoes refraction. The continuously changing atmosphere refracts the light from the star by different amount from one moment to the next. Thus, when the atmosphere refracts more star light to us, we can see that the stars appear to be bright and when the atmosphere refracts less light to us, we can see that the stars appear to be dim.



Since, the atmosphere bends starlight towards the normal, the apparent position of the star is slightly different from its actual position. The star appears slightly above than its actual position when viewed near the horizon. Further, this apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary. Since the stars are very distant and are point-sized sources of light, the path of rays of light coming from the star goes on varying slightly and fluctuates the apparent position of the star and the amount of starlight. Thus, the light of the star, on reaching our eyes, increases and decreases continuously due to atmospheric refraction and making stars appear to twinkle at night.

11. Explain why the planets do not twinkle.

Ans : 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. Hence, the planets do not twinkle.

12. Why does the Sun appear reddish early in the morning?

Ans : This is because, at the time of sunrise, the sun is near the horizon and so the sunlight has to travel a large distance through the atmosphere to reach us. During this travel, most of the shorter wavelength's lights present in it are scattered out from our line of sight and only red light having larger wavelength is able to reach our eye due to less scattering. Hence the sun appear reddish early in the morning.

13. Why does the sky appear dark instead of blue to an astronaut?

Ans : There is the vacuum in the space and hence no particle is available for scattering of light. In the absence of scattering, none of the colours from the visible spectrum reach the viewer's eye and the sky appears dark to the astronaut.

VALUE BASED QUESTIONS (VBQs)

1. Mala and Kala are friends studying in the same class V sitting on the last bench. Mala was finding difficulty in reading the blackboard when they are sitting on the last bench. Mala was depressed fearing that she may turn blind. Kala asked her not to worry and explained her difficulty to her parents. Mala accompanied by her parents visited a doctor. The doctor prescribed spectacles of suitable power for Mala. Mala smiled and thanked Kala.

Read the above passage and answer the following questions :

(a) Name the eye defect Mala is suffering from.

(b) What could be the cause of this defect?

(c) If the far point of Mala is 50 cm, then what is the power of the lens she should use to enable her to see the blackboard?

(d) What values are displayed by Kala?

Ans :

(a) Mala is suffering from myopia or short sightedness.

(b) Two possible causes of this defect are :

- Increases in the size of the eyeball.
- Decrease in the focal length of eye lens.

(c) Here, $u = \infty$ and $v = -50$ cm $= -0.5$ m

We know that,

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

$$\frac{1}{f} = \frac{1}{-0.5} - \frac{1}{\infty}$$

$$f = -\frac{1}{2}\text{ m}$$

Now, $$P = \frac{1}{f} = \frac{1}{-\frac{1}{2}} = -2\text{ D}$$

(d) Kala has displayed the value of concern for her friend.

2. Ram and Shyam are friends studying in Class X. Ram can read a book keeping it at normal distance of about 25 cm while Shyam has to keep the book about 50 cm from his eyes. Shyam felt it is a natural defect of his eyes, which cannot be corrected. But Ram was smarter. He explained Shyam that there must be a treatment for this problem and so asked him to take his parents to visit a doctor. The doctor, on checking, prescribed him spectacles of suitable power and his vision with that spectacles become normal.

Read the above passage and answer the following questions :

(a) What defect was there in the vision of Shyam?

(b) What could be the causes of this defect?

(c) Calculate the nature and power of the lens prescribed by the doctor if the near point of the Shyam is 50 cm. Assume that the near point of the normal eye is 25 cm.

(d) What are the values of life displayed by Ram?

Ans :

(a) Shyam is suffering from Hypermetropia or Long sightedness.

(b) Two possible causes of this defect are :

- Decrease in size of the eye ball.
- Increase in focal length of eye lens.

(c) Hypermetropia can be corrected by using a convex lens.

Here, $u = -25$ cm and $v = -50$ cm

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

$$= \frac{1}{-50} + \frac{1}{25} = \frac{1}{50}$$

$$f = 50\text{ cm}$$

$$\text{Power (P)} = \frac{100}{f} = \frac{100}{50} = 2\text{ D}$$

(d) Ram has displayed concern for the health of Shyam who is his friend. His awareness has helped Shyam to get the problem treated. Ram proved that "a friend in need is a friend indeed."

3. Gaurav, a Physics teacher was explaining to his students in class X about human eyes. He told that our eyes can live even after our death by donating them. After we die, one pair of our eyes can give vision to two corneal blind people. Eye donors may belong to any sex or any age group. People suffering from diabetes, hypertension, asthma or any other non-communicable disease can donate eyes. Eye banks have been established for this purpose, where you can pledge to donate your eyes after your death.

Read the above passage and answer the following questions :

(a) Why is the pledge necessary?

(b) Can people who have been using spectacles or those who have been operated for cataract donate their eyes?

(c) What values are displayed by Gaurav ?

Ans :

(a) The eyes have to be removed from your dead body and then implanted in two corneal blind people. Your permission in the form of pledge is essential. In fact, the pledge is to be signed in the presence of your near and dear ones, who will be in charge of the body.

(b) Yes, people who have been using spectacles or those who have been operated for cataract can donate their eyes.

(c) The values displayed by Gaurav are awareness, concern for blind people and motivational skill.

4. Newton in 1665 discovered that white light consists of a mixture of seven colours. In this experiment, Newton passed a beam of white light through a triangular prism, the white light splits to form a band of seven colours which is caught on a white screen. Thus, when a beam of white light is passed through a glass prism, the band of seven colours is formed on a white screen. The seven colours of the spectrum are Red, Orange, Yellow, Green, Blue, Indigo and Violet. The seven colours of the spectrum can be denoted by the word 'VIBGYOR' where V stands for violet, I for indigo, B for blue, G for green, Y for yellow and O for orange and R for red.

Read the above passage and answer the following questions :

(a) Name the phenomenon explained in the paragraph.

(b) What is the cause of the phenomenon?

(c) Give an example of this phenomenon.

(d) What value is taught by this phenomenon?

Ans : (a) Dispersion.

(b) The cause of dispersion is that different colours of white light having different wavelengths deviate through different angles on passing through the prism. So, they split on coming out from the prism.

(c) Rainbow is the best example of dispersion of sunlight in nature.

(d) The phenomenon of dispersion teaches us universal brotherhood. There is such a huge variety of people in the universe. There should be no distinction on the basis of colour, cast, creed, religion and so on. As we are part of one family, we should live like brothers with no hatred or violence against each other.

HIGHER ORDER THINKING SKILL (HOTS) QUESTIONS

1. Where in nature can you find evidence that white sunlight is made up of different colours?

Ans : Rainbow formation in the sky is the evidence that white sunlight is made up of different colours.

2. Does myopia or hypermetropia imply necessarily that the eye has partially lost its ability of accommodation? If not, what is the cause of these defects of vision?

Ans : No, a person may have normal ability of accommodation and yet he may be myopic or hypermetropic. In fact, myopia may arise when length of eye ball is elongated and hypermetropia may arise when length of eye ball gets shortened.

3. Ram can read a book clearly only if he holds it at an arm's length from him. Name the defect of vision if he is an old man.

Ans : He is suffering from Presbyopia.

4. When we increase the distance of an object from the eye, what happens to the image distance in the eye ?

Ans : For a normal eye, image distance in the eye is fixed, being equal to distance of retina from the eye lens. When we increase the distance of an object from the eye, the focal length of eye lens is changed on account of accommodating power of the eye, so as to keep the image distance constant.

5. Ahmed cannot distinguish between red and green colour. Why? Does he have normal vision?

Ans : Ahmed who is blind to red and green colour may be deficient in cone shaped cells having red and green pigment in the retina of his eyes. It is a genetic disorder and not a refractive defect of vision. So, he may not have normal vision.

6. Radha can read a magazine clearly only if she holds it at an arm's length. Name the defect of vision if she is a young girl.

Ans : She is suffering from Hypermetropia.

NUMERICAL PROBLEMS

1. Parthiv with normal near point (25 cm) reads a book with small print using a magnifying glass, a thin convex lens of focal length 5 cm. What are the closest and farthest distances at which he can read the book viewing through the magnifying glass?

Solution : Here, $f = 5$ cm, u =?

For the closest distance, $v = -25$ cm

Using the formula,

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

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

$$=\frac{1}{5}+\frac{1}{25}=\frac{6}{25}$$

$$u=\frac{-25}{6}\text{ cm}=-4.17\text{ cm}$$

The closest distance at which Parthiv can read the book is –4.17 cm.

For the farthest distance, $v'=\infty$, $u'=?$

Using the formula,

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

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

$$=\frac{1}{5}-\frac{1}{\infty}=\frac{1}{5}$$

$$u'=-5\text{ cm}$$

The farthest distance at which Parthiv can read the book is – 5 cm.

2. For a normal eye, the far point is at infinity and near point is at 25 cm in front of the eye. The cornea of the eye provides a converging power of about 40 D and the least converging power of eye lens behind the cornea is about 20 D. Calculate the range of accommodation of normal eye.

Solution : To observe objects at infinity, the eye uses its least converging power

Power of the eye lens is given as

$$P = 40 + 20 = 60\text{ D.}$$

$$\Rightarrow \quad f=\frac{100}{P}\text{ cm}$$

$$=\frac{100}{60}\text{ cm}$$

$$=\frac{5}{3}\text{ cm}$$

To focus an object at the near point,
Object distance (u) = $-d$ = –25 cm.
Focal length of the eye lens
= Distance between the eye lens and the retina
= Image distance.

Using the formula,

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

Substituting the values, we get

$$\frac{1}{f'}=\frac{3}{5}+\frac{1}{25}=\frac{16}{25}$$

$$f'=\frac{25}{16}\text{ cm}$$

$$\text{Power (P')}=\frac{100}{f'}=\frac{100}{25/16}=64\text{ D}$$

Power of eye lens (P') = 64 – 40 = 24 D

Hence, the range of accommodation of the eye lens is from 20 D to 24 D.

EXERCISES (UNSOLVED)

VIVA VOCE QUESTIONS

1. What is the value of power of accommodation of a normal eye?
2. What happens to the focal length of eye lens for a myopic eye?
3. What is the value of the least distance of distinct vision of a normal eye of an adult?
4. What is the name given to a light consisting of a single wavelength only?
5. How many refraction a ray of light suffers while passing through a glass prism?
6. What is the name given to the band of seven colours of white light?
7. Who discovered the dispersion of white light into seven colours on passing through a glass prism?
8. What is the name given to a light consisting of more than one wavelength?
9. What is the phenomenon of splitting of white light into seven colours?
10. What happens to the focal length of eye lens for a hypermetropic eye?

MULTIPLE CHOICE QUESTION

1. The image formed by the retina of the human eye is :

(a) Virtual and erect (b) Real and inverted
(c) Virtual and inverted (c) Real and erect

2. The light- sensitive cell present on the retina and is sensitive to the intensity of light is :

(a) Cones (b) Rods
(c) Both rods and cones (c) None of these

3. The part of the eyes refracts light entering the eye from external objects ?

(a) Lens (b) Cornea

(c) Iris (c) Pupil

4. Which of the following colours is least scattered by fog, dust or smoke ?

(a) Violet (b) Blue

(c) Red (c) Yellow

5. How many images are seen when a ray of light gets reflected by two plane mirrors which are set up at an unknown angle between them that the ray undergoes a deviation of 200° ?

(a) 2 (b) 3

(c) 4 (c) 5

ASSERTION AND REASON

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If both assertion and reason are false.

1. Assertion : The image of a distant object is formed in front of the retina and not at the retina itself.

Reason : The excessive curvature of the eye lens is a defect of myopia.

2. Assertion : The power of accommodation of the eye usually increases with ageing.

Reason : Presbyopia arises due to the gradual strengthening of the ciliary muscles.

NAME THE FOLLOWING

Split the students in your classroom into three groups and ask the following questions.

1. The device used to split white light into seven colours.

2. The angle between the directions of incident ray and emergent ray of light coming out of the glass prism.

3. The colour for which the angle of deviation while passing through the prism, is maximum.

4. The type of lens used to correct Myopia.

5. The scatterer present in the atmosphere.

6. The colour of light which is scattered the least.

7. The phenomenon due to which the stars twinkle.

8. The type of lens used to correct hypermetropia.

9. The defect of vision if human eye can see distant objects clearly but cannot see the near objects clearly.

10. The colour for which the angle of deviation while passing through the prism is minimum.

MATCH THE FOLLOWING

Ask students to match the following :

S. No.	Column A	Column B	Correct Match
1.	Twinkling of stars	Corrected by convex lens	
2.	Hypermetropia	Far point comes closer to the eye	
3.	Cataract	Atmospheric Refraction	
4.	Myopia	Opaque membrane over eye lens	

BASED ON NUMERICAL PROBLEMS

Ask students to work out these problems based on the concept.

1. If the far point of Raju, a myopic person is 4 m, then how would you calculate the power of the lens he requires to look at the stars?

2. If Ram, a myopic person uses spectacles of power –0.5 D, then what will be the distance of far point of his eye?

3. Mala can see the objects lying between 25 cm and 100 cm from her eye. Her vision can be corrected by using lens of power – 0.1 D. Is the statement true or false?

PARAGRAPH AND TABLE BASED QUESTION

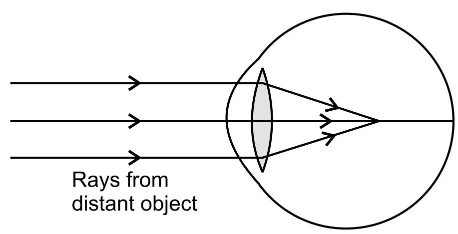
1. Read the following paragraph and answer the following questions.

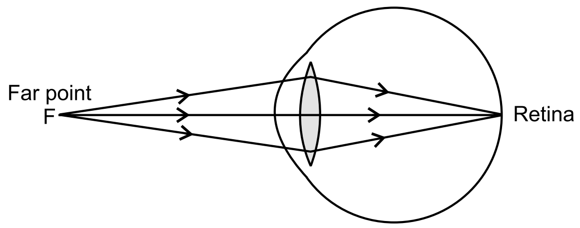
The causes of myopia are :

(A) The eyeball gets elongated and the focal length of the eye lens becomes too short or power of eye lens becomes too high.

(B) By elongation of eye ball, we mean that the distance between the eye lens and retina is increased when the distance becomes more than the focal length of the lens, the eye lens cannot form a sharp image of the distant object on the retina but forms an image in front of it as shown in the figure.

(C) The focal length of the eye lens is too short. If focal length of the eye lens is short, it will form a sharp image of the distant object in front of the retina and not over it.





(a) Is eye lens made of glass ?

(b) A myopic person uses specs of power 0.2 D. What is the distance of far point of his eye ?

(c) Which lens is used for correcting a myopic eye ?

(i) Convex lens (ii) Concave lens
(iii) Bifocal lens (iv) None of these

(d) The human eye forms the image of an object at its :

(i) Cornea (ii) Pupil
(iii) Iris (iv) Retina

2. Question number 2(a)-(d) are based on table given below. study the table and answer the following questions.

White light is a mixture of seven colours i.e., violet, indigo, blue, green, yellow, orange and red. Every colour has its own characteristic wavelength. Different colours with their wavelengths are given below in the table:

S. No.	Colour	Wavelength
1.	Red	7900Å
2.	Orange	6000Å
3.	Yellow	5800Å
4.	Green	5400Å
5.	Blue	4800Å
6.	Indigo	4500Å
7.	Violet	4000Å

The phenomenon of splitting white light into seven colours when it passes through a glass prism is called dispersion of white light.

(a) Name the phenomenon occurring in nature due to dispersion of light.

(b) Light of two colours A and B pass through a glass prism. A deviates more than B from its path of incidence. Which colour has a higher speed in the prism.

(c) Choose the correct option.

(i) Each colour of light travels with same speeds in a given medium

(ii) Each colour of light travels with different speeds in a given medium

(iii) Only red colour of light travels with fast speed in a given medium

(iv) All of the above.

(d) The speed of light depends upon :

(i) Frequency (ii) Wavelength
(iii) Density (iv) None of these

ANSWERS

VIVA VOCE QUESTIONS

1. 4 dioptre.
2. Decrease in the focal length of the eye lens.
3. 25 cm.
4. Monochromatic light.
5. Two.
6. Spectrum.
7. Sir Issac Newton.
8. Polychromatic light.
9. Dispersion of white light.
10. Increase in the focal length of the eye lens.

MULTIPLE CHOICE QUESTION

1. (b) Real and inverted
2. (b) Rods
3. (b) Cornea
4. (c) Red
5. (b) 3

ASSERTION AND REASON

1. (a) A person with myopia can see nearby objects clearly but cannot see distant object distintly. A person with this defect may see clearly upto a distance of a few metres.
   In a myopic eye, the image of a distant object is formed in front of the retina but not at the retina itself. This defect may arise due to excessive curvature of the eye lens.
   Thus, both assertion and reason are true and reason is the correct explanation of assertion.
2. (d) The power of accoummodation of the eye usually decreases with ageing and presbyopia arises due to the gradual weakening of the ciliary muscles. Thus, both assertion and reason are false.

NAME THE FOLLOWING

1. Glass prism.
2. Angle of deviation.
3. Violet colour.
4. Concave lens.
5. Atoms or molecules or dust particles.
6. Red colour.
7. Atmospheric refraction.
8. Convex lens.
9. Hypermetropia or long sightedness.
10. Red colour.

MATCH THE FOLLOWING

S. No.	Column A	Column B	Correct Match
1.	Twinkling of stars	Corrected by convex lens	3

2.	Hypermetropia	Far point comes closer to the eye	1
3.	Cataract	Atmospheric Refraction	4
4.	Myopia	Opaque membrane over eye lens	2

BASED ON NUMERICAL PROBLEMS

1. Here,

Object distance, $u = \infty$

Image distance, $v = -4$ m

We know that,

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

$$\frac{1}{f} = \frac{1}{-4} - \frac{1}{\infty}$$

$$\frac{1}{f} = \frac{-1}{4}$$

$$f = -4 \text{ m}$$

Now, $P = \frac{1}{f}$

Substituting the values, we get

$$P = \frac{1}{-4} = -0.25 \text{ D}$$

2. Here,

Power (P) = – 0.5 D

Let x be the distance of the far point.

Using the formula, $f = -x$

$$P = \frac{1}{f}$$

$$P = -\frac{1}{x}$$

$$x = -\frac{1}{P}$$

$$= \frac{-1}{-0.5}$$

$$= 2 \text{ m}$$

3. Here,

The distance of far point (x) = 100 cm

Focal length (f) = – x = –100 cm

Using the formula, $P = \frac{100}{f}$

Substituting the values, we get

$$P = \frac{100}{-100} = -1 \text{ D}$$

The statement is wrong.

PARAGRAPH AND TABLE BASED QUESTION :

1. (a) No, eye lens is not made of glass. It is made of fibrous jelly like meterial.

(b) P = – 0.2 D

$$f = \frac{1}{p} = \frac{1}{-0.2} = -5\text{m}$$

Distance of far point of his eye is 5m.

(c) (ii) Concave lens.

(d) (iv) Retina.

2. (a) Rainbow.

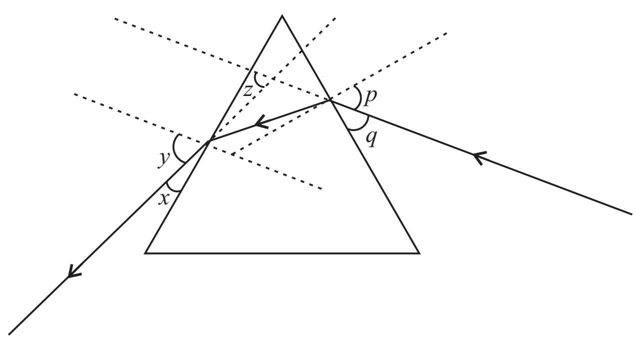
(b) Colour B has higher speed than that of colour A.

(c) (ii) Each colour of light travels with different speeds in a given medium.

(d) (ii) Wavelength.

PREVIOUS YEAR BOARD QUESTIONS

1. Study the following ray diagram



In this diagram, the angle of incidence, the angle of emergence and the angle of deviation respectively have been represented by

(a) y, p, z

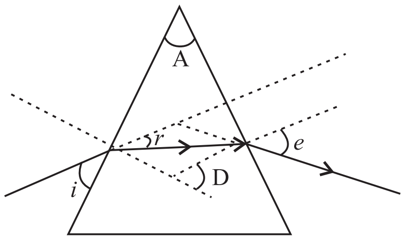
(b) x, q, z

(c) p, y, z

(d) p, z, y

Ans : (c) p, y, z

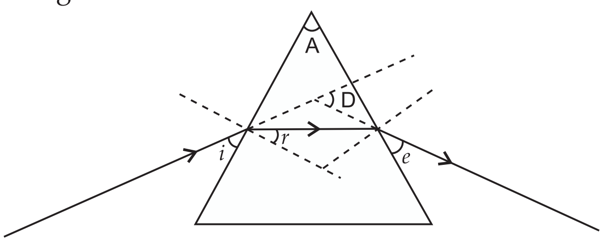
2. In the following diagram the correctly marked angles are :



(a) ∠ A and ∠ e (b) ∠ i, ∠ A and ∠ D
(c) ∠ A, ∠ i and ∠ e (d) ∠ A, ∠ r and ∠ D

Ans : (a) ∠ A and ∠ e

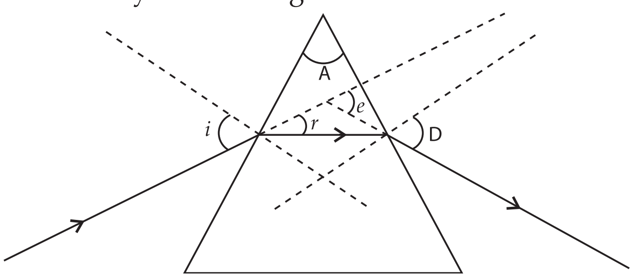
3. In the following ray diagram the correctly marked angle are :



(a) ∠i and ∠e (b) ∠A and ∠D
(c) ∠i, ∠e and ∠D (d) ∠r, ∠A and ∠D

Ans : (d) ∠r, ∠A and ∠D

4. Study the following figure in which a student has marked the angle of incidence (∠i), angle of refraction (∠r), angle of emergence (∠e), angle of prism (∠A) and the angle of deviation (∠D). The correctly marked angles are :



(a) ∠A and ∠i (b) ∠A, ∠i and ∠r
(c) ∠A, ∠i, ∠e and ∠D (d) ∠A, ∠i, ∠r and ∠D

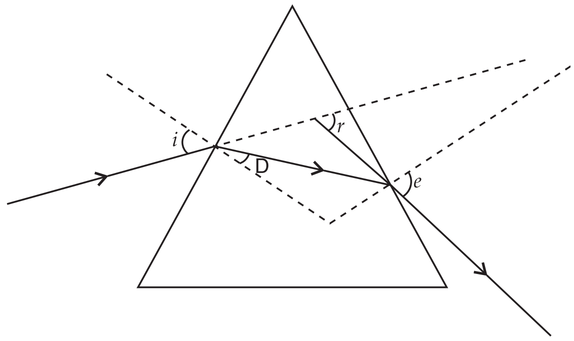
Ans : (a) ∠A and ∠i

5. A student traces the path of a ray of light through a triangular glass prism for different values of angle of incidence. On analysing the ray diagrams, which one of the following conclusions is he likely to draw ?

(a) The emergent ray is parallel to the incident ray.
(b) The emergent ray bends at an angle to the direction of the incident ray.
(c) The emergent ray and the refracted ray are at right angles to each other.
(d) The emergent ray is perpendicular to the incident ray.

Ans : (b) The emergent ray bends at an angle to the direction of the incident ray.

6. After tracing the path of a ray of light through a glass prism a student marked the angle of incidence (∠i), angle of refraction (∠r), angle of emergence (∠e) and the angle of deviation (∠D) as shown in the diagram. The correctly marked angles are :



(a) ∠i and ∠r (b) ∠i and ∠e
(c) ∠i, ∠e and ∠D (d) ∠i, ∠r and ∠e

Ans : (b) ∠i and ∠e

7. When do we consider a person to be myopic or hypermetropic ? List two cause of hyoermetropia. Explain using ray diagrams how the defect associated with hypermetropic eye can be corrected. **[2019]**

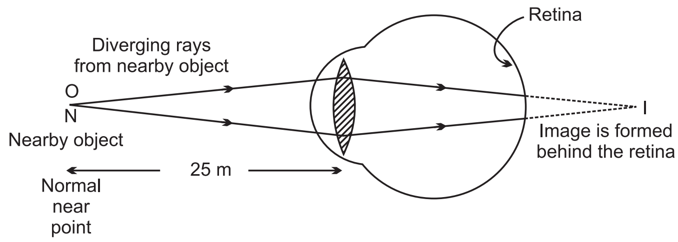
Ans : Myopia is the defect in vision in which a person cannot see the distant objects clearly whereas cannot see nearby objects clearly.

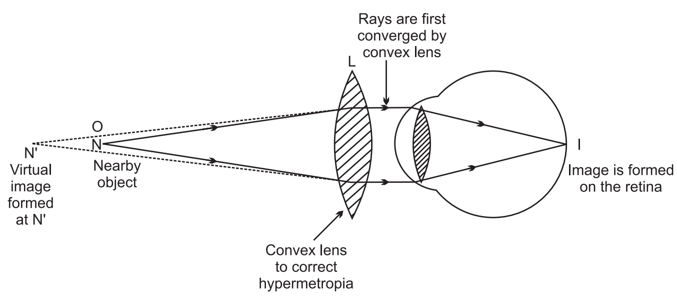
Hypermetropia is caused due to :

(i) Decrease in converging power of eye-lens.

(ii) Too short eye ball.

In a hypermetropic eye, the image of nearby object lying at normal near point N (at 25cm) is formed behind the retina.



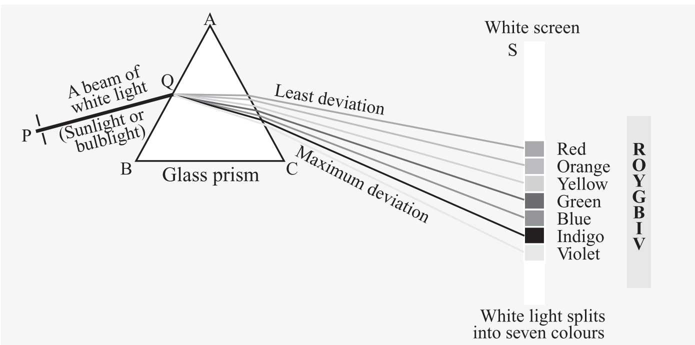


Hypermetropic eye can be corrected using convex lenses. When a convex lens of suitable power is placed in front of hypermetropic eye, then the diverging rays of light from the object are converged first by the convex lens used. This form a virtual image of the object at another near point N′.

Now, the rays can be easily focused by the eye lens to form an image on retina.

8. What is 'dispersion of white light' ? State its cause. Draw a ray diagram to show the dispersion of white light by a glass prism.

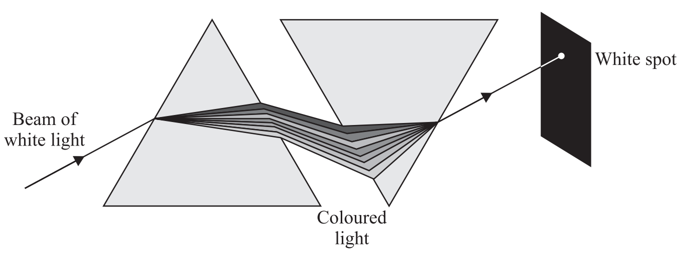
Ans : The splitting of beam of light into its seven constituent colours, when it passes through a glass prism, is called the dispersion of light.



When a beam of white light enters a prism, it gets refracted at point and splits into its seven constituent colours *i.e.* violet, indigo, blue, green, yellow, orange and red *i.e.* VIBGYOR. This splitting of light rays occurs because of the different angles of bending for each colour and this different angles of bending occurs because different component of light faces different refractive indices when passing through the glass prism. When a beam of sunlight is allowed to fall on one of the rectangular surfaces of the glass prism, we obtain a coloured spectrum with red and violet colour at its extremes.

9. What is "dispersion of white light" ? Draw a labelled diagram to illustrate the recombination of the spectrum of white light. Why is it essential that the two prisms used for the purpose should be identical and placed in an inverted position with respect to each other ?

Ans : The phenomenon of splitting of white light into its constituent colours on passing through a prism is known as the dispersion of white light.



It is essential that the two prisms used for the purpose should be identical and placed in an inverted position with respect to each other so that the second prism completely nullifies the dispersion caused by the first prism and we get pure white light.

10. Due to gradual weakening of ciliary muscles and diminishing flexibility of the eye lens a certain defect of vision arises. Write the name of this defect. Name the type of lens required by such persons to improve the vision. Explain the structure and function of such a lens.

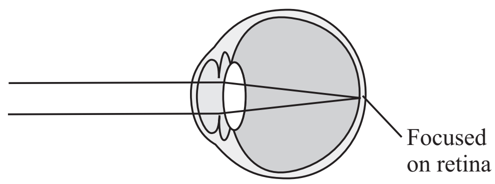
Ans : The defect caused due to gradual weakening of ciliary muscles and diminishing flexibility of the eye lens is presbyopia. Presbyopia is the defect of eye in which a person cannot see nearby objects comfortably and distinctly without corrective eye glasses. A presbyopic eye has its near point greater than 25 cm and is gradually increases as the eye becomes older. The type of lens required by such person to improve the vision is bifocal lens.

A bifocal lens consists of both convex lens and concave lenses. The convex lens used in bifocal lens is used to correct hypermetropia (far sightedness) and concave lens is used to correct myopia (short sightedness).

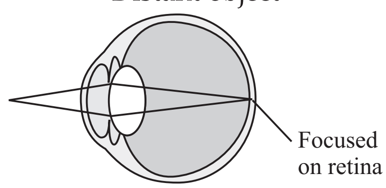
11. Write about power of accommodation of human eye. Explain why the image distance in the eye does not change when we change the distance of an object from the eye?

Ans : The ability of the eye to adjust its focal length is called power of accommodation.

The focal length of the human eye can change *i.e.* increase or decrease, depending on the distance of objects and due to this the image distance in the eye does not change. When we change the distance of an object from the eye, it is the ciliary muscles that modify the curvature of the lens to change its focal length.



Distant object



Near object

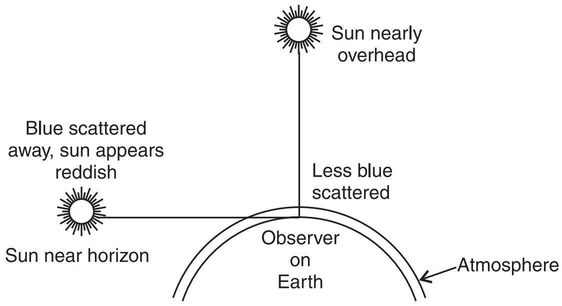
12. What is meant by scattering of light ? The sky appears blue and the sun appears reddish at sunrise and sunset. Explain these phenomena with reason.

Ans : Scattering of light is the phenomenon of spreading of light by minute particles in a medium. The sky appears blue because the blue colour of sunlight scatters much more strongly than the red colour by particles in atmosphere due to its shorter wavelength.

At sunrise and sunset most of the blue light and shorter wavelength light is scattered away by the particles in the atmosphere as the light from the sun near the horizon passes through thick layers of air and larger distance. The light that reaches us is of longer wavelength giving a reddish appearance.

13. With the help of a labelled diagram, explain why the sun appears reddish at the sunrise and the sunset.

Ans :



At the time of sunrise and sunset, when the sun is near the horizon, the sunlight has to travel the greatest distance through the atmosphere to reach us. During this long journey of sunlight, most of the shorter wavelength blue colour present in it is scattered out and away from our line of sight. So, the light reaching us directly from the rising sun or setting sun consists mainly of longer wavelength red colour due to which the sun appears red.

14. (a) A student suffering from myopia is not able to see distinctly the objects placed beyond 5 m. List two possible reasons due to which this defect of vision may have arisen. With the help of ray diagrams. Explain.

(i) Why the student is unable to see distinctly the objects placed beyond 5 m from his eyes.

(ii) The type of the corrective lens used to restore proper vision and how this defect is corrected by the use of this lens.

(b) If, in this case, the numerical value of the focal length of the corrective lens is 5 m, find the power of the lens as per the new Cartesian sign convention.

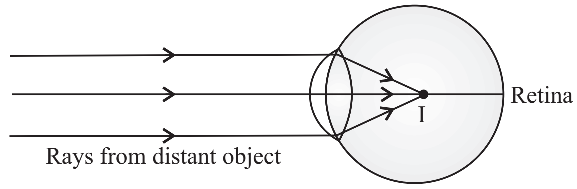
Ans :

(a) Two possible reason due to which this defect of vision may have arisen are

(1) increase in curvature of the lens.

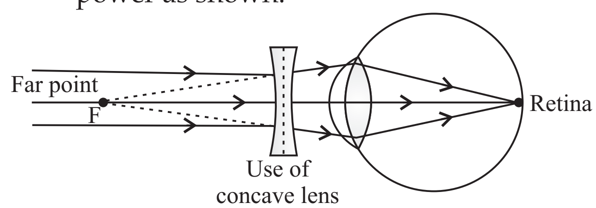
(2) increase in length of the eyeball.

(i) A myopic eye has its far point nearer than infinity. It forms the image of a distant object in front of its retina as shown below :



In the given case student's far point in 5 m. So, image of the object placed beyond 5 m from his eyes is formed in front of the retina and hence appears blurred. That is why the student is unable to see distinctly the objects placed beyond 5 m from his eye.

(ii) Since a concave lens has an ability to diverge incoming rays, it is used to correct this defect of vision. The image is allowed to form at the retina by using a concave lens of suitable power as shown.



(b) Power, $P = \dfrac{1}{f(\text{m})}$

$$P = -\frac{1}{5} = -0.2 \text{ D.}$$

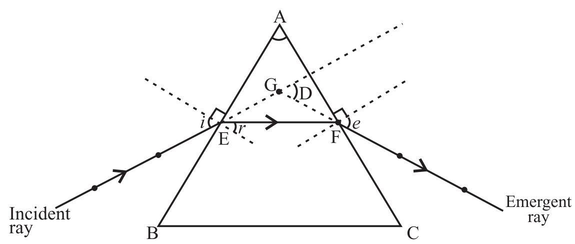
15. (a) Draw a ray diagram to explain the term angle of deviation.

(b) Why do the component colours of incident white light split into a spectrum while passing through a glass prism, explain.

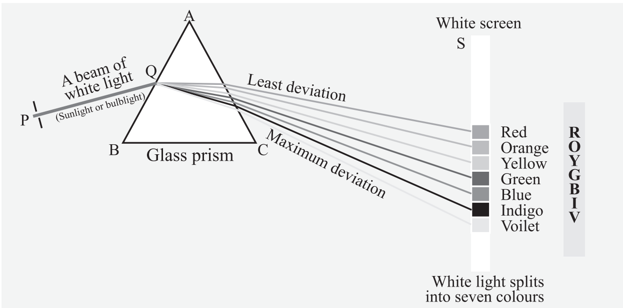
(c) Draw a labelled ray diagram to show the formation of a rainbow.

Ans :

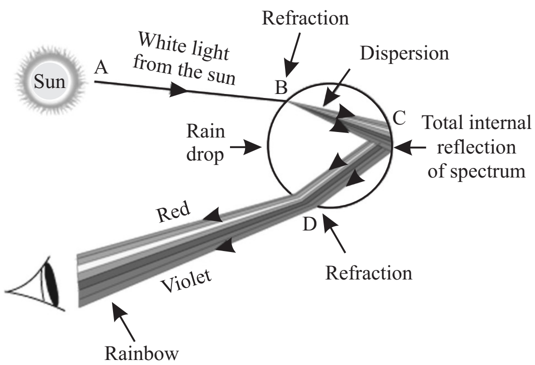
(a) The emergent ray bends at an angle to the direction of the incident ray and the angle between them is known as angle of deviation D.



(b) The splitting up of white light into its constituent colours on passing through a refracting medium like a glass prism is called dispersion of light. The dispersion of white light occurs because different colours of light bend through different angles with respect to the incident ray, as they pass through a prism. The red light bends the least while the violet the most as shown below.



(c)



The given diagram shows the formation of rainbow in the sky.

16. What is atmospheric refraction ? Use this phenomenon to explain the following natural events.

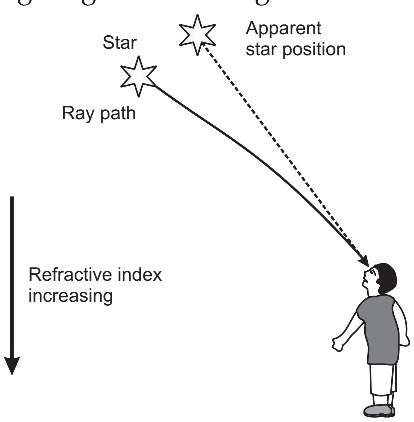
(a) Twinkling of stars

(b) Advanced sunrise and delayed sunset.

Draw diagrams to illustrate your answers.

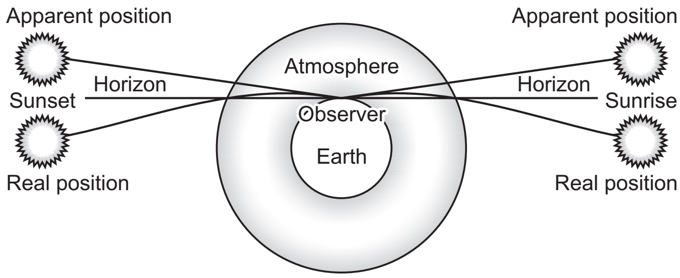
Ans : Atmospheric refraction : Refraction of light caused by the earth's atmosphere due to change in the refractive indices of different layers.

(a) **Twinkling of stars :** Stars are distant point sized source of light. The path of the rays of light coming from the star goes on varying due to atmospheric refraction slightly. Thus apparent position of the stars fluctuates and the amount of star light entering the eye flickers giving the twinkling effect.



(b) **Advanced sunrise :** When the sun is slightly below the horizon, light rays coming from the sun travel from the rarer to denser layer of air. Because of atmospheric refraction of light, light appears to come from a higher position above the horizon. Thus sun appears earlier than actual sunrise.

Delayed sunset : Same reason, as similar refraction occurs at the sunset.



17. (a) Write the function of each of the following parts of human eye : Cornea; iris; crystalline lens; ciliary muscles. **[2018]**

(b) Millions of people of the developing countries of world are suffering from corneal blindness. These persons can be cured by replacing the defective cornea with the cornea of a donated eye. A charitable society of your city has organised a campaign in your neighbourhood in order to create awareness about this fact. If you are asked to participate in this mission how would you contribute in this noble cause ?

(i) State the objective of organising such campaigns.

(ii) List two arguments which you would give to motivate the people to donate their eyes after death.

(iii) List two values which are developed in the persons who actively participate and contribute in such programmes.

Ans : (a) **Cornea :** Refracts the rays of light falling on the eye.

Iris : Controls the size of the pupil.

Crystalline lens : Focuses the image of the object on the retina.

Ciliary muscles : Holds the eye lens and adjusts its focal length.

(b) (i) These campaigns are organised to make people aware and realise their duties towards society.

(ii) Following arguments can be given :

- One person can give sight to two people.
- Our eyes can live even after our death.

(iii) **Values :** Concern for others, Social welfare.

18. Write the importance of ciliary muscles in the human eye. Name the defect of vision that arises due to gradual weakening of the ciliary muscles in old age. What type of lenses are required by the persons suffering from this defect to see the objects clearly ?

Akshay, sitting in the last row in his class, could not see clearly the words written on the blackboard. When the teacher noticed it, he announced if any student sitting in the front row could volunteer to exchange his seat with Akshay. Salman immediately agreed to exchange his seat with Akshay. He could now see the words written on the blackboard clearly. The teacher thought it fit to send the message to Akshay's parents advising them to get his eyesight checked.

In the context of the above event, answer the following questions :

(a) Which defect of vision is Akshay suffering from ? Which type of lens is used to correct this defect ?

(b) State the values displayed by the teacher and Salman.

(c) In your opinion, in what way can Akshay express his gratitude towards the teacher and Salman ?

Ans : Ciliary muscles modify the curvature of the eye lens to enable the eye to focus objects at varying distances.

The defect of vision that arises due to gradual weakening of the ciliary muscles in old age is presbyopia and it can be corrected by using a bifocal lens.

(a) Akshay is suffering from myopia or near sightedness and it can be corrected by using a concave lens.

(b) Values showed are concern and caring.

(c) By thanking the teacher and Salman.

19. (a) A student is unable to see clearly the words written on the black board placed at a distance of approximately 3 m from him. Name the defect of vision the boy is suffering from. State the possible cause of this defect and explain the method of correcting it.

(b) Why do stars twinkle ? Explain. **[2018]**

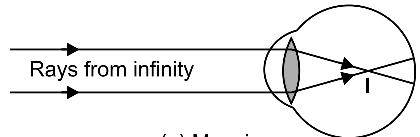
Ans : (a) The boy is suffering from myopia.

This defect is caused :

(i) due to increase in length of eyeball, and

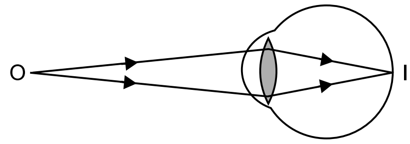
(ii) decrease in focal length of eye lens, when the eye is fully relaxed.

Correction : The image of a distant object (i,e., at infinity) is formed in front of the retina of eye suffering from myopia as shown in figure (a).



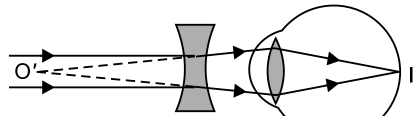
(a) Myopic eye

As the image of the object lying at infinity is not formed on the retina of the eye, so such object can not be seen clearly by the myopic eye. The far point of such an eye is near to the eye as shown in fig. (b).



(b) Far point of a myopic eye

This defect can be corrected by using a concave lens (minus powered) of suitable focal length. So, a man suffering from this defect wears spectacles having concave lens of suitable focal length. The concave lens diverges the rays of light entering the eye from infinity. Hence, this lens makes the rays of light appear to have come from the far point(O') of the defective eye as shown in figure (c).



(c) Correction of myopia

(b) The twinkling of a star is due to atmospheric refraction of starlight. The atmospheric refraction occurs in a medium of gradually changing refractive index.

Since the atmosphere bends starlight towards the normal, the apparent position of the star is slightly different from its actual position. This apparent position of the star is slightly different position of the star is not stationary, but keeps on changing slightly, as the physical conditions of the earth's atmosphere are not stationary. Since the stars are very distant, they approximate point- sized sources of light. As the path of light rays coming from the star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers i.e., the star sometimes appear brighter, and at some other time, fainter, which is the twinkling effect.

MOCK TEST -1

Time : 2 : 30 hours Max. Marks : 50

General Instructions :

- All questions are compulsory.
- There is no choice in any of the questions.
- Question numbers 1 to 3 are one mark questions. These are to be answered in one word or one sentence.
- Question numbers 4 to 18 are three marks questions. These are to be answered in 50 words each.
- Question number 19 is five marks question. It is to be answered in 70 words.

1. When two prisms, one up and one down in contact, receive white light, what colour of light will emerge out?
2. A man wearing glasses of focal length +1 m cannot see objects clearly beyond 1 m. What is the defect in the eye ?
3. Mention the role of iris.
4. What are the causes of myopia ?
5. Why planets do not twinkle ?
6. How does ciliary muscle of human eye help in the functioning of the eye ?
7. The near point of a hypermetropic person is 75 cm. If the person uses glasses having power +1.0 D, then calculate the distance of distinct vision for him.
8. Explain the formation of rainbow with neat ray diagram.
9. Why the sun is seen about two minutes before actual sunrise ? Illustrate your answer with neat sketch.
10. Draw two diagrams to explain refraction and dispersion.
11. Answer the following questions :
    (a) What do you understand by the term 'presbyopia'?
    (b) Mention any two causes of this defect.
    (c) How is it corrected?
12. An eye has a far point of 2 m.
    (a) What type of lens would he require to increase the far point to infinity?
    (b) Calculate the power of lens.
    (c) What is the defect?
13. Explain how a normal eye can see objects lying at various distances clearly.
14. How the amount of light entering the eye is controlled?
15. Describe the working of human eye.
16. (a) What are light sensitive cells?
    (b) Where are they found?
    (c) Give the functions of each.
17. Why is it impossible to make out the colour of cars on the road at night?
18. Differentiate between myopia and hypermetropia.
19. Explain an activity to understand the blue colour of the sky and the reddish appearance of the Sun at sunrise or sunset.

MOCK TEST -2

Time : 2 : 30 hours Max. Marks : 50

General Instructions :

- All questions are compulsory.
- There is no choice in any of the questions.
- Question numbers 1 to 3 are one mark questions. These are to be answered in one word or one sentence.
- Question numbers 4 to 18 are three marks questions. These are to be answered in 50 words each.
- Question number 19 is a five marks question. It is to be answered in 70 words.

1. When light rays pass from air into glass prism, do they refract towards or away from the normal ?
2. Which among the two scatters more easily : Light having shorter wavelength or light having longer wavelength ?
3. Name one defect of vision which cannot be corrected by any type of spectacle lens.
4. What is Tyndall effect ? Explain it with an example.
5. Why are danger signal lights red in colour ?
6. Why spectrum of colours is not observed when light passes through a glass ?
7. In an investigation by CBI, it was important to discover whether the victim was having short sightedness or long sightedness. How do you think it would be possible to identify this with the help of spectacles?
8. Why our night vision is relatively poor as compared to the night vision of an owl?
9. What happens to our eye when we enter a darkened cinema hall from bright room? Explain with a neat sketch.
10. Give the function of pupil and iris.
11. Draw a diagram to show how an eye can focus the nearby object by changing the thickness of its lens.
12. How the eye adjusts itself with the light of varying intensity?
13. Explain clearly why a person who lost eye sight of one eye is at a disadvantage compared to the normal person who has two good eyes?
14. Draw a ray diagram showing the path of light rays through a glass prism.
15. Explain how rain drops in the atmosphere act like many small prisms.
16. Illustrate with neat diagram why do stars seem higher than they actually are?
17. Explain how the colour of scattered light depends on the size of scattering particles.
18. Explain why the sky is blue in colour?
19. Give an activity with a neat diagram to show an arrangement for observing the scattering of light in a colloidal solution.