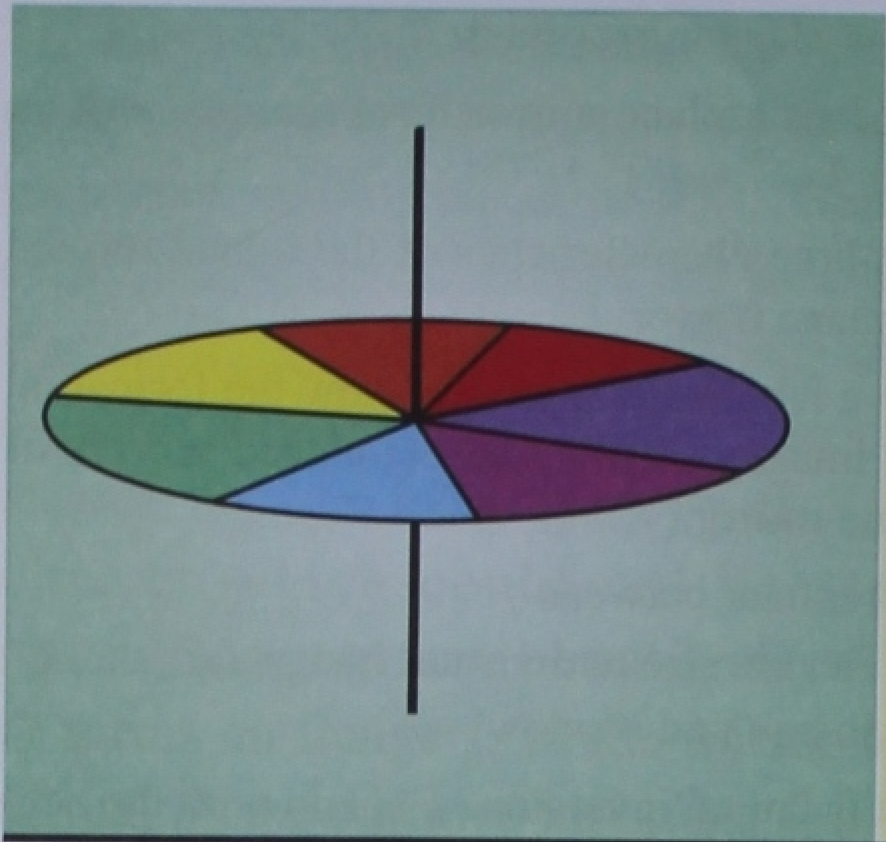


7 Reflection of Light — Spherical Mirrors

SYLLABUS

1. Spherical mirrors : convex and concave mirrors, centre of curvature, pole, radius of curvature, principal axis, focus of a concave miror.
2. Image formation by a concave mirror for different positions of the object – drawing ray diagrams for the same.
3. Image formation by a convex mirror – its focus – ray diagrams.
4. Some uses of curved mirrors.
   - Formation of an image by a curved mirror – changes observed using objects of different heights, different distances from the mirror; can the image be obtained on a screen? (E).
   - Formation of images by a concave mirror (D).
5. Dispersion of light.

Spherical mirrors : Mirrors that are made by silvering the pieces of glass, which are the part of a hollow sphere, are called spherical mirrors (see Fig. 7.1).

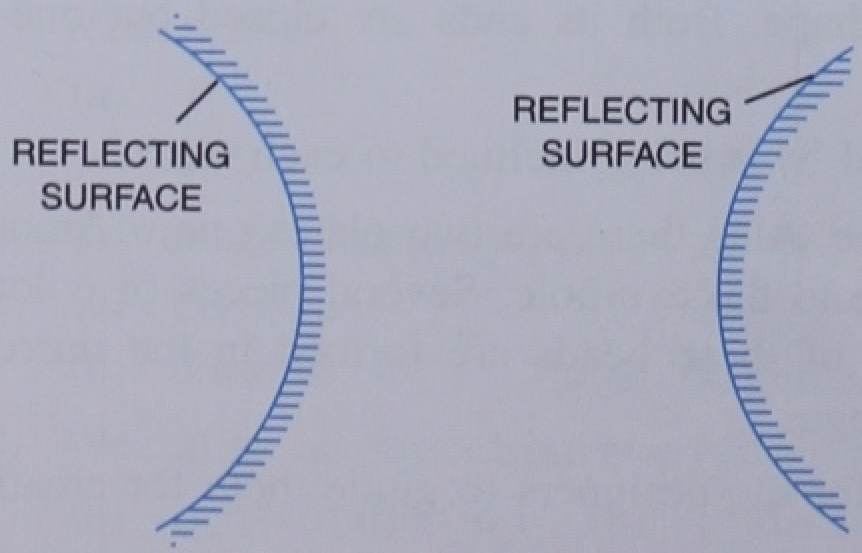


Fig. 7.1 Curved mirrors

Spherical mirrors may have a concave reflecting surface or a convex reflecting surface. Accordingly, spherical mirrors are of two types.

(i) Concave mirror : A spherical mirror whose inner hollow concave surface is the reflecting surface [Fig. 7.2 (a)] is called *concave mirror.*

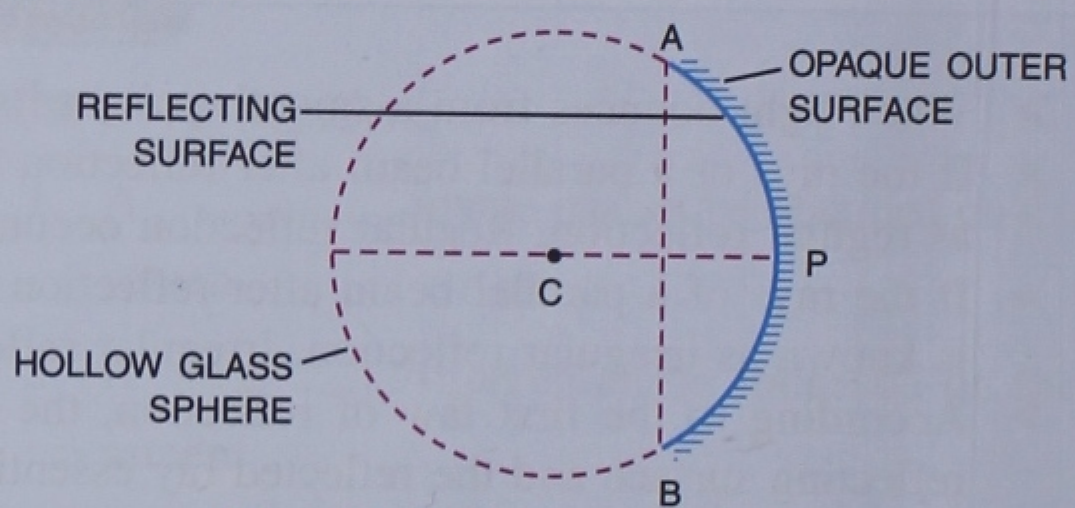


Fig. 7.2 (a) Concave mirror

(ii) Convex mirror : A spherical mirror whose outer surface is the reflecting surface [Fig. 7.2 (b)] is called *convex mirror.*

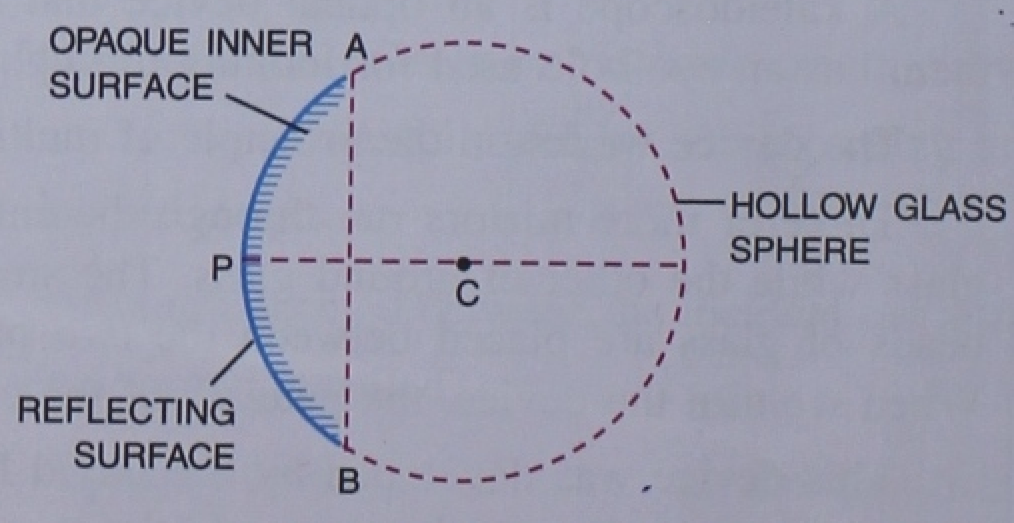


Fig. 7.2 (b) Convex mirror

Terms Related to Spherical Mirrors

1. **Aperture :** The surface of a spherical mirror which is exposed to light for reflection is called its *aperture*. It is shown by MPM′ (Fig. 7.3).
2. **Pole :** The geometric centre of a spherical surface of the mirror is known as the **pole** of the mirror. It is the mid-point of the aperture of the mirror and is denoted by P (Fig. 7.3).
3. **Centre of curvature :** The geometric centre of the hollow sphere of which the mirror is a part is called the *centre of curvature*. It is denoted by C.
4. **Radius of curvature :** The radius of the sphere of which the mirror is a part is known as the *radius of curvature* (PC) of the mirror. It is always denoted by 'R'.
5. **Principal axis :** The straight line passing through the centre of curvature and the pole of a spherical mirror is called the *principal axis* (PX).
6. **Focus or focal point :** If a beam of light parallel to the principal axis falls on a concave mirror, all the rays after reflection meet at one point on the principal axis. This point is called the *focus of the concave mirror*. It is always represented by F (Fig. 7.4).

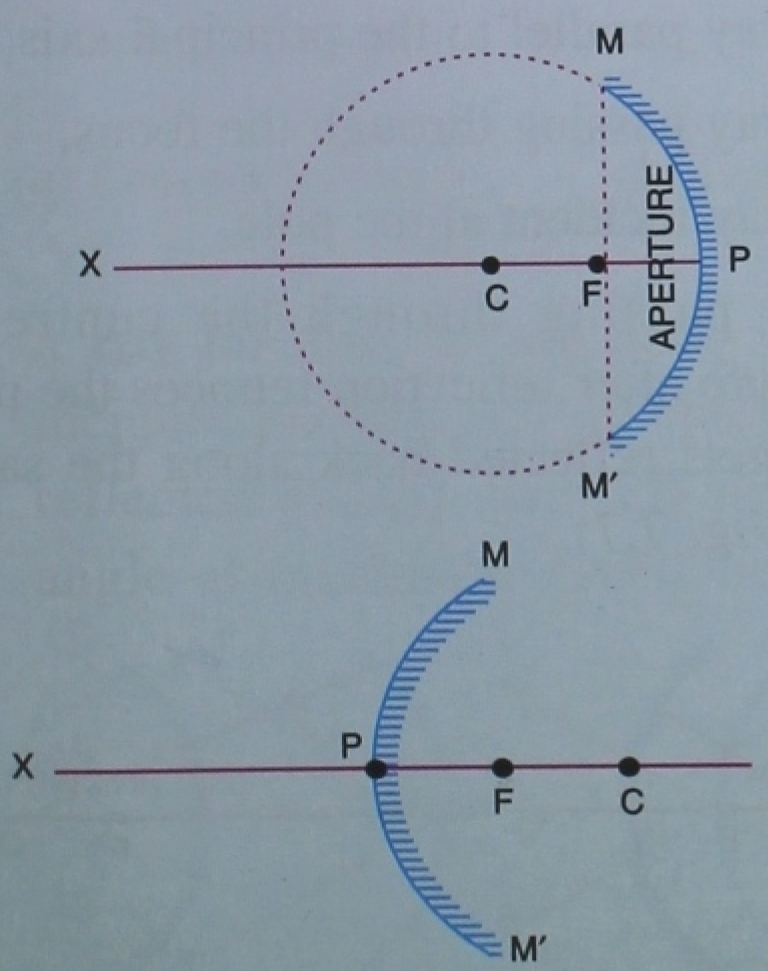


Fig. 7.3

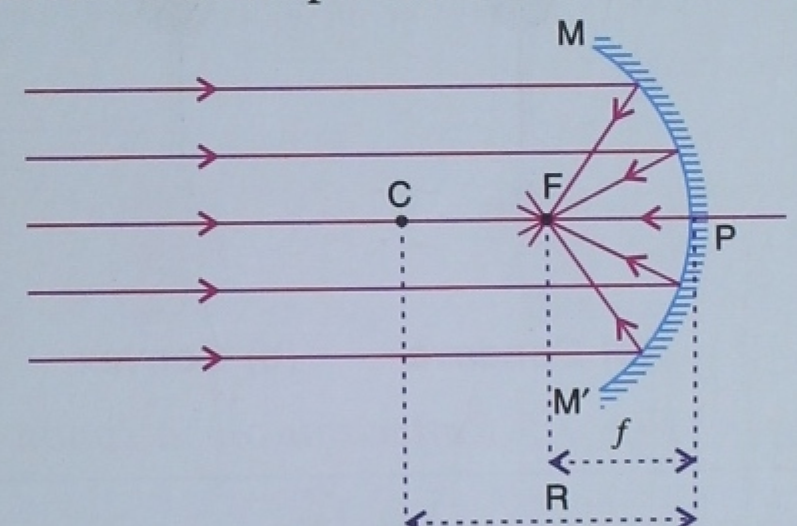
Similarly, if a beam of light parallel to the principal axis falls on a convex mirror, all the rays after reflection diverge. If the reflected rays are extended backwards, they appear to diverge from a point on the principal axis. This point is called the *focus of the convex mirror*. It is also represented by F.

Focus F is always the mid-point of the straight line joining the pole (P) and centre of curvature (C).

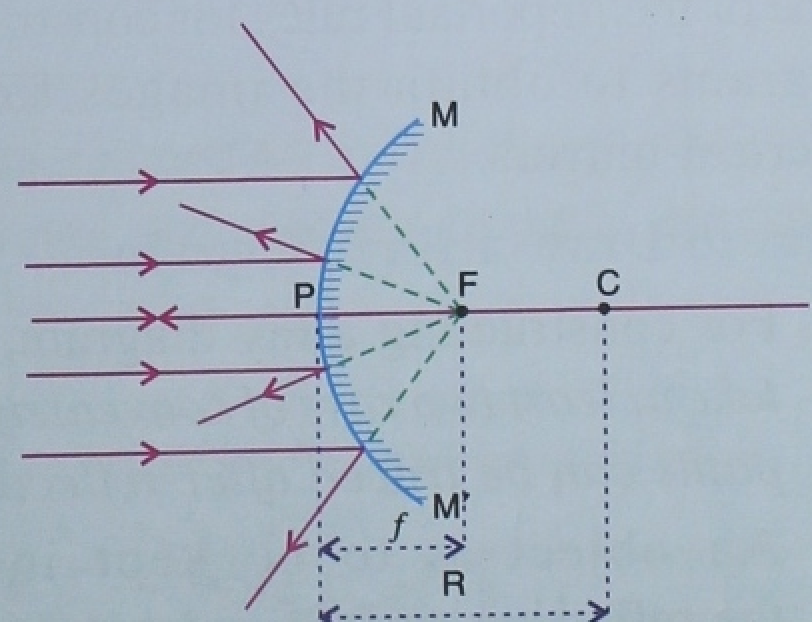
7. **Focal length :** The distance between the pole (P) and the focus (F) is called the *focal length* and is denoted by *f*.

If f is the focal length and R is the radius of curvature, then, $f = \frac{R}{2}$ or $R = 2f$.

This relation is true for both concave and convex mirrors of small aperture and small curvature.



A concave mirror is also called a converging mirror as the parallel rays converge to meet at the focus after reflection.



A convex mirror is called a diverging mirror as the parallel rays appear to diverge from the focus after reflection.

Fig. 7.4 Focal length of concave and convex mirrors

ACTIVITY 1

Images formed by a spherical spoon

Take a polished steel spoon. The inside of the spoon is curved inwards and has a concave shape while the outside of the spoon is curved outwards and has a convex shape. Now, hold the spoon in such a way that the inside of the spoon (concave side) is closer to you. See your image [Fig. 7.5(a)]. How does your image look like ? It is erect and magnified. Keep the spoon at different distances and observe the images.

Now hold the spoon with its outside towards your face, see Fig.7.5(b). Hold it at different distances and observe the images. You will observe erect and diminished images of yours as you move the spoon away.

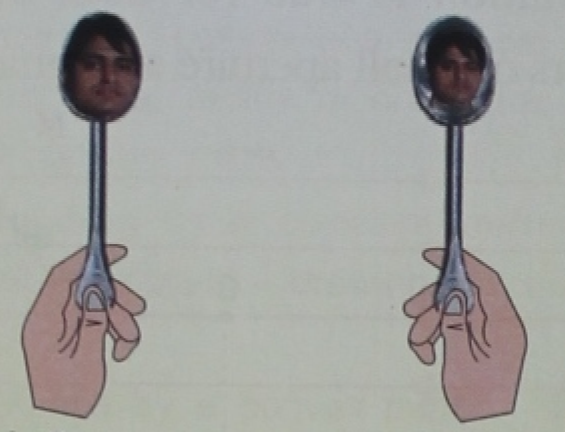


Fig. 7.5 Reflection on a spoon

IMAGE FORMATION BY MIRRORS

A **ray diagram** gives us an idea about the formation of images by a mirror. Following are some of the important rules for constructing ray diagrams to obtain the images formed by spherical mirrors.

Rules to Draw a Ray Diagram

1. For constructing a ray diagram, *we must take at least two rays of convenience whose paths can be traced after reflection.*
2. An object is to be kept infront of the reflecting surface and **not** on the back side.
3. An object is always to be kept on the principal axis such that it is perpendicular to the principal axis and its foot touches the principal axis.

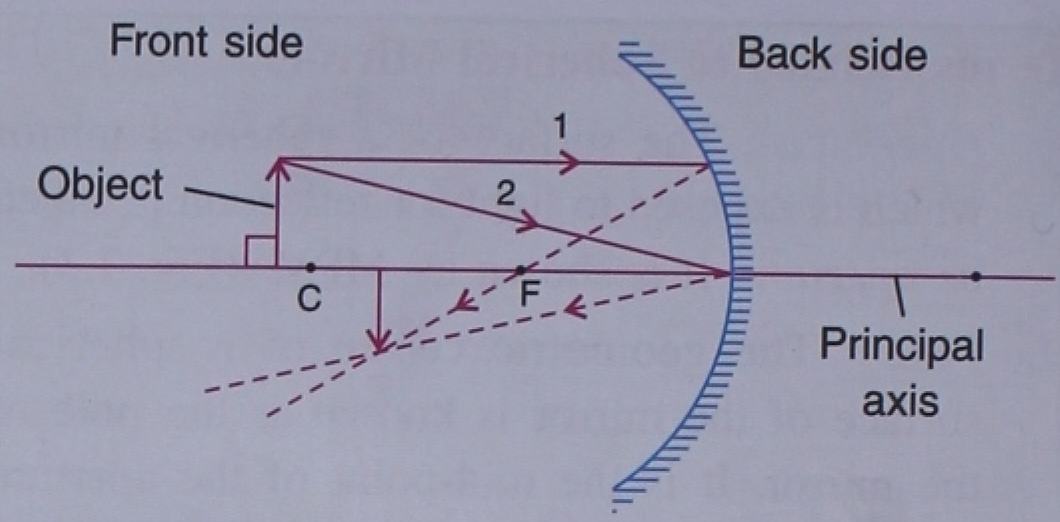


Fig. 7.6

CONVENIENT RAYS FOR THE CONSTRUCTION OF IMAGE BY RAY DIAGRAM

In order to obtain the position and nature of the image formed after reflection from a spherical mirror, we consider at least *two* rays incident on the mirror from the same point of the object. Although from a point of the object, an infinite number of rays travel in all directions, *two* rays are chosen according to convenience. Any *two* of the following rays are taken as the convenient incident rays.

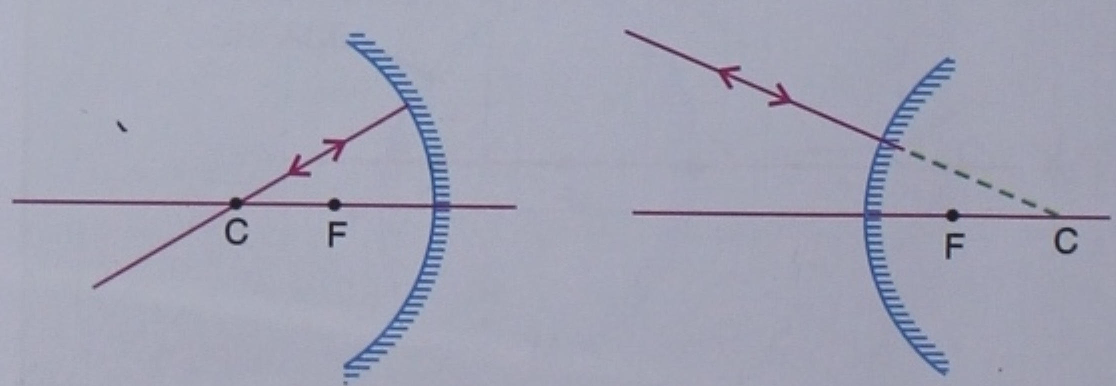
(1) A ray passing through the centre of curvature,

(2) A ray parallel to the principal axis,

(3) A ray passing through the focus,

(4) A ray incident at the pole.

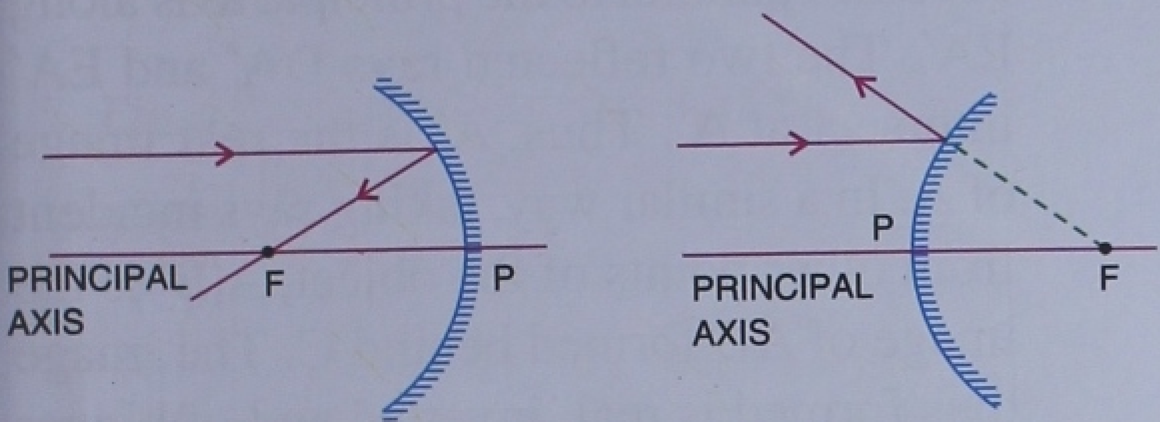
1. A ray passing through the centre of curvature after reflection retraces the path *i.e.* it gets reflected back along the same path (Fig. 7.7).



(a) Concave mirror *(b) Convex mirror*

Fig. 7.7

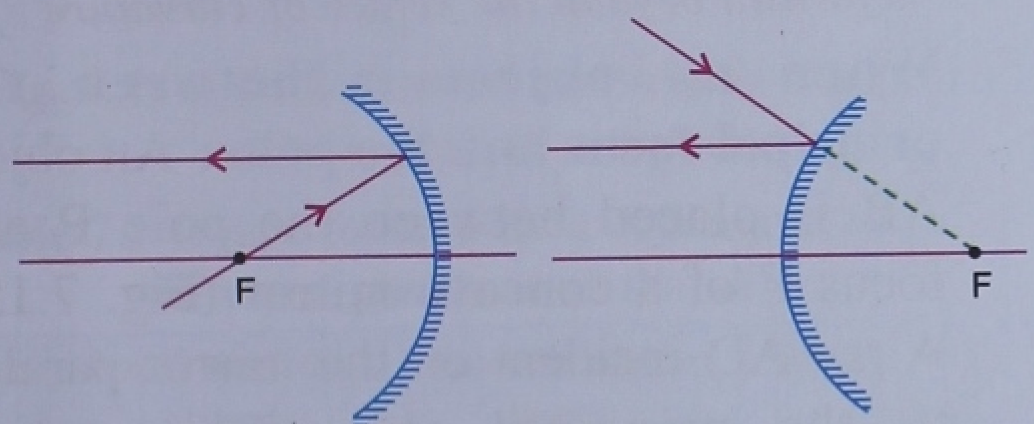
2. A ray parallel to the principal axis after reflection passes through the principal focus if the mirror is concave (Fig. 7.8a) and appears to diverge from the principal focus if the mirror is convex (Fig. 7.8b).



(a) Concave mirror *(b) Convex mirror*

Fig. 7.8

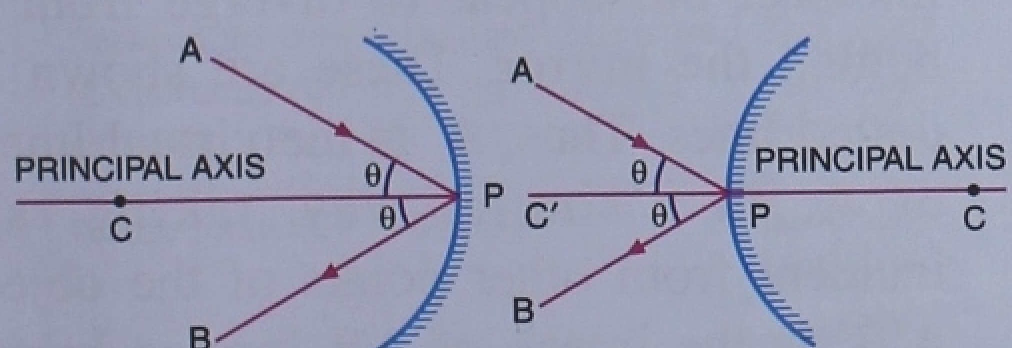
3. A ray passing through the principal focus in the case of a concave mirror or approaching towards the focus in the case of a convex mirror, is reflected parallel to the principal axis (see Fig. 7.9).



(a) Concave mirror *(b) Convex mirror*

Fig. 7.9

4. *A ray incident at the pole :* A ray AP incident at the pole P of the mirror gets reflected along a path PB such that the angle of incidence ∠APC or ∠APC′ is equal to the angle of reflection ∠BPC or ∠BPC′ (Fig. 7.10). In this case, principal axis itself is normal at pole P.



(a) Concave mirror *(b) Convex mirror*

Fig. 7.10 Reflection of a ray incident at the pole

IMAGES FORMED BY CONCAVE MIRRORS

1. **When an object is at infinity :** When an object is at infinity, the image is formed at focus. It is a real, inverted and highly diminished image (Fig. 7.11).

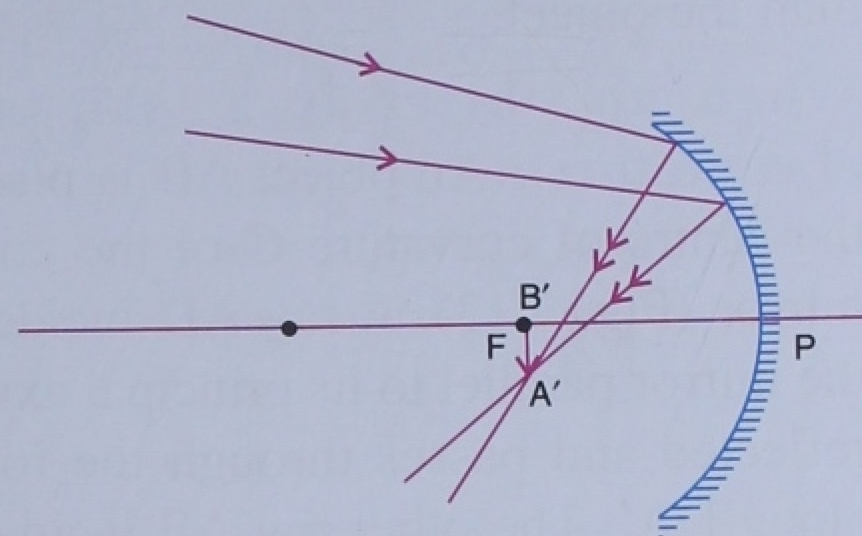


Fig. 7.11 A real, inverted and highly diminished image A′B′ is formed when the object is at infinity

2. **When an object is beyond the centre of curvature :** An object AB is placed beyond the centre of curvature C of the concave mirror (Fig. 7.12). A ray AD is incident on the mirror parallel to the principal axis. This ray after reflection passes through the focus F along DA′. The other ray AE passing through the centre

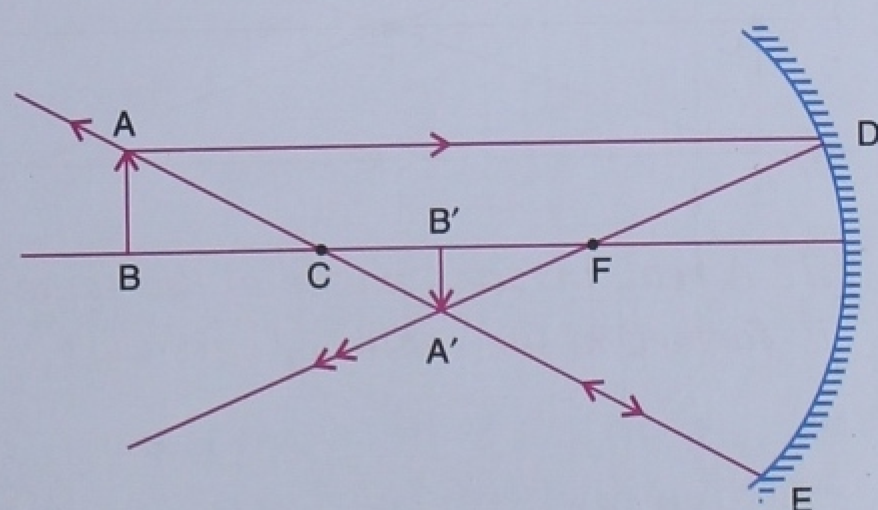


Fig. 7.12 A real, inverted and smaller image is formed between centre of curvature and focus

of curvature C gets reflected and retraces its path (*i.e.*, it gets reflected along EA). The two reflected rays DA′ and EA intersect at A′. Thus, A′ is the real image of the point A. When we take rays incident from other points of the object, we will find that A′B′ is the image of AB which is between C and F. The image formed is real, inverted and of smaller size than the object.

3. **When an object is at the centre of curvature :** An object AB is placed at the centre of curvature C of the concave mirror (Fig. 7.13). A ray AD incident on the mirror parallel to its principal axis gets reflected and passes through the focus F along DA′. The other ray AE incident on the mirror through the focus F gets reflected and becomes parallel to the principal axis along EA′. The two reflected rays DA′ and EA′ intersect at point A′. Hence, A′ is the real image of the point A. In the same way, taking rays incident from other points of the object, A′B′ is the image of AB formed at C. The image formed is real, inverted and of the same size as that of the object.

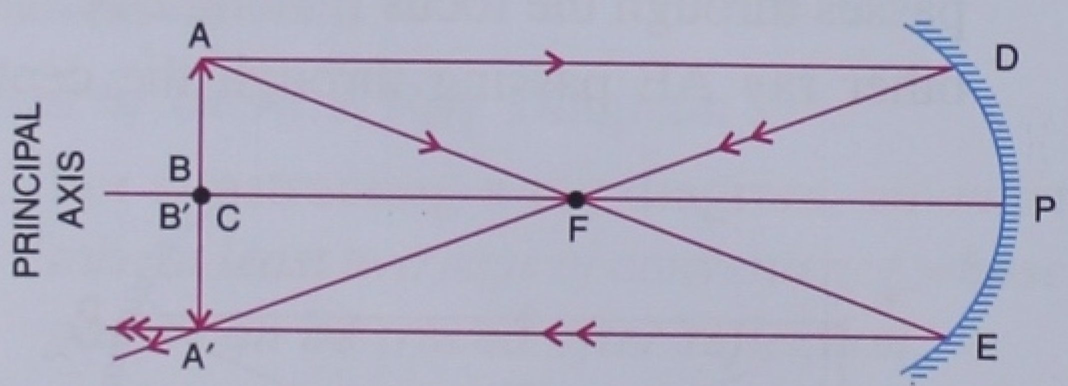


Fig. 7.13 A real, inverted image of the same size is formed at the centre of curvature

4. **When an object is between the centre of curvature and the principal focus :** An object AB is placed between focus F and the centre of curvature C of the concave mirror (Fig. 7.14). A ray AD incident on the mirror parallel to the principal axis gets reflected and passes through the point F along DA′. The other ray AE passing through the focus gets reflected and becomes parallel to the principal axis along EA′. The two reflected rays DA′ and EA′ intersect at A′. Thus, A′ is the real image of A. In a similar way, taking rays incident from other points of the object, A′B′ is the image of AB formed behind C. The image thus formed is real, inverted and of bigger size than the object.

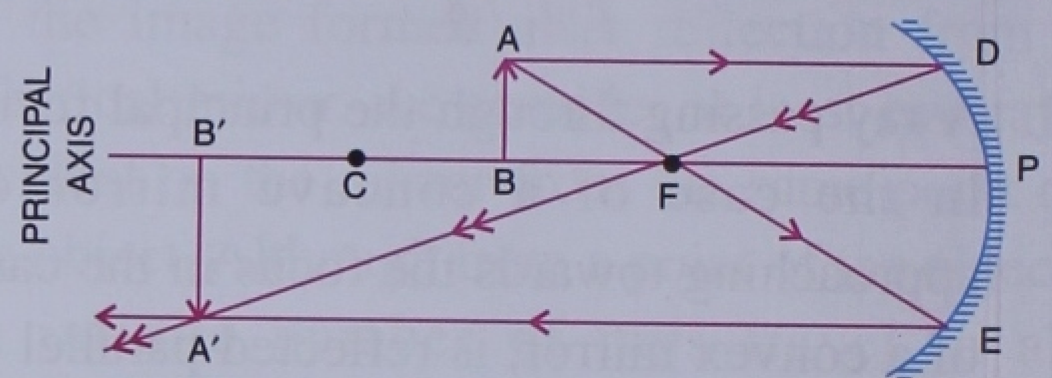


Fig. 7.14 A real, inverted and magnified image is formed beyond the centre of curvature

5. **When an object is between the principal focus and the pole :** An object AB is placed between the pole P and focus F of a concave mirror (Fig. 7.15). A ray AD incident on the mirror parallel to the principal axis after getting reflected, passes through the focus F along DF. The other ray AE passing through the centre of curvature C of the mirror gets reflected and retraces its path (*i.e.*, it gets reflected as EA). The two reflected rays DF and EA do not actually intersect but appear to diverge from A′ behind the mirror. These are shown by dotted lines. Thus, A′ is the virtual image of A. In a similar way, taking rays incident from other points of the object, A′B′ is the image of AB formed behind the mirror. The image formed is virtual, erect and of bigger size than the object.

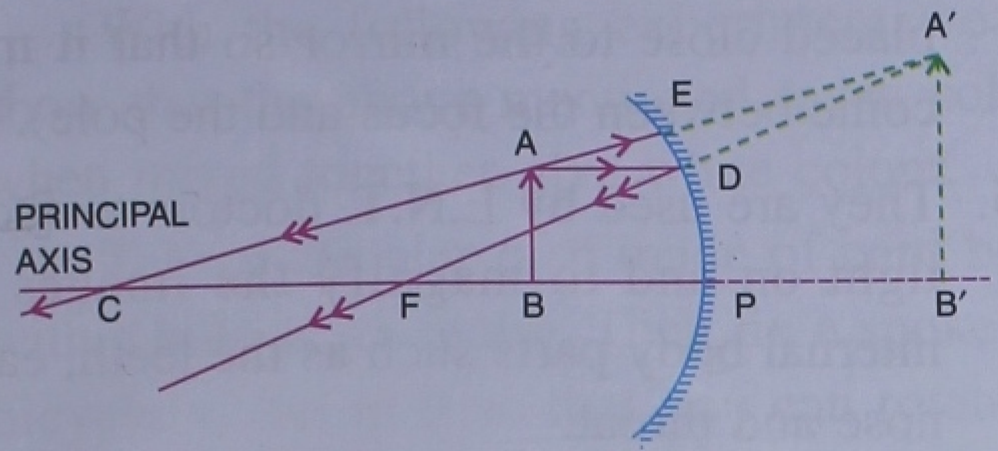


Fig. 7.15 A virtual, erect and bigger image is formed behind the mirror

6. **When an object is at the principal focus :** When an object is at the principal focus, the image thus formed is at infinity. It is real, inverted and highly magnified (Fig. 7.16).

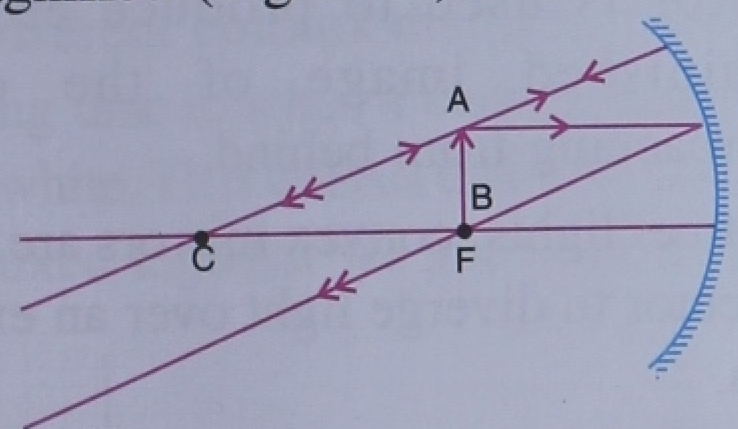


Fig. 7.16 A real, inverted and highly magnified image is formed at infinity

Table 7.1 Image formed by a concave mirror for different positions of the object

No.	Position of the object	Position of the image	Nature of the image
1.	At infinity	At focus (F)	Real, inverted and diminished
2.	Beyond the centre of curvature (C)	Between focus (F) and the centre of curvature (C)	Real, inverted and smaller than the object
3.	At the centre of curvature (C)	At the centre of curvature (C)	Real, inverted and of same size
4.	Between the centre of curvature (C) and focus (F)	Beyond the centre of curvature (C)	Real, inverted and bigger than the object
5.	At the focus (F)	Infinity	Real inverted and highly magnified.
6.	Between the focus (F) and pole (P)	Behind the mirror	Virtual, erect and enlarged

Images Formed by Convex Mirrors

An object AB is placed in front of a convex mirror. A ray AD incident on the mirror and parallel to the principal axis gets reflected and appears to diverge from focus F along DA_1. The other ray AE passing towards the centre of curvature C gets reflected and retraces its path (*i.e.* it gets reflected back along EA). The two reflected rays DA_1 and EA do not actually meet but appear to diverge from at A′ behind the mirror as shown by the dotted lines. Thus A′ is the virtual image of the point A. In a similar way, taking rays incident from other points of the object, A′B′ is the image of AB.

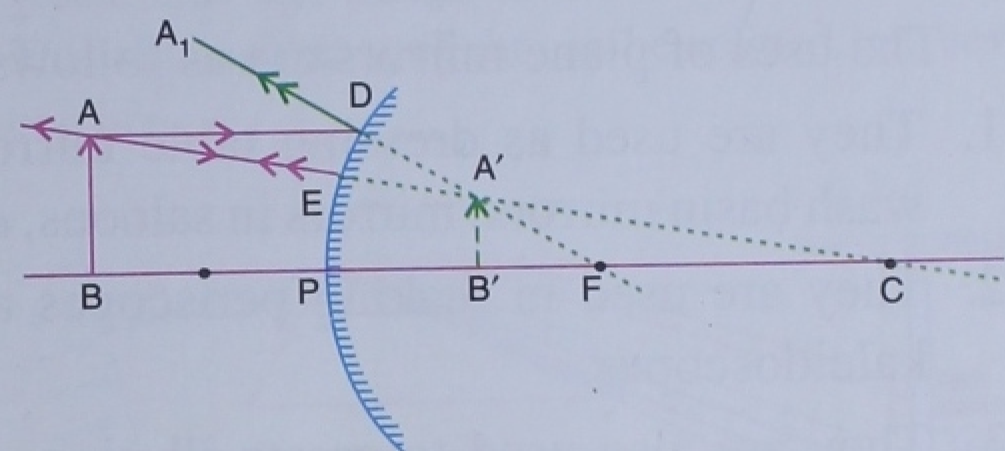


Fig. 7.17 A virtual, erect and smaller image is formed between F and P in the case of a convex mirror

We must note here that as the object is brought closer to the mirror, the image moves towards the mirror. Its size gets enlarged (but always remains smaller than the size of the object). It is virtual, erect and diminished and is always formed between the pole and focus.

Position, size and nature of image formed by a convex mirror

No.	Position of the object	Position of the image	Size of the image	Nature of the image
1	At *infinity*	At *focus*	*Diminished* to a point	*Virtual* and *upright*
2.	At any other point	Between *focus and pole*	*Diminished*	*Virtual* and *upright*

Do You Know ?

How spherical mirrors amuse you ? When convex and concave mirrors are suitably combined, they produce funny distorted images of an object. We see such mirrors placed in **'Fun Fairs'** and **Exhibitions**. These funny images not only make you laugh but also entertain you.

USES OF MIRRORS

Given below are the uses of plane mirrors, concave mirrors and convex mirrors.

Plane Mirrors

The uses of plane mirrors are as follows :

1. They are used as dressing table mirrors, wash basin mirrors, mirrors in saloons, *etc.*
2. They are used in making periscopes and kaleidoscopes.
3. They are also used to create illusion and special effects.

Concave Mirrors

The uses of concave mirrors are as follows :

1. They are used as reflectors in torch light, head light of cars, light-house headlights, searchlights, *etc.*
2. For converging solar radiations in solar cookers to generate adequate heat for cooking purposes, concave mirrors are used.
3. Concave mirrors of large size are used in telescopes.
4. They are used as shaving mirrors and as make-up mirrors to see an enlarged and erect image of the face (the face must be placed close to the mirror so that it may come between the focus and the pole).
5. They are used by E.N.T. doctors to focus light on and to magnify the images of internal body parts such as the teeth, ears, nose and throat.
6. In floodlight, a bright bulb is positioned between focus F and pole P of a concave mirror to obtain a divergent beam.

Convex Mirrors

The uses of convex mirrors are as follows :

1. In rear-view mirrors of cars, a convex mirror is used to produce erect and diminished image of the objects approaching from behind.
2. In street lights, convex mirrors are used as reflector to diverge light over an extended area.
3. Convex mirrors are used as vigilance mirrors in big shops and departmental stores.

DISPERSION OF LIGHT

Have you ever noticed a rainbow in the sky? **A rainbow is arch-shaped.** It appears usually after a heavy rain fall in the morning or evening when the sun is in the horizon. It is formed when white light from the sun passes through tiny prism like water droplets and splits into different colours. This phenomenon of splitting of white light or any polychromatic light into different components of colours is called dispersion of light. The set of colours formed on splitting of white light is called the spectrum of white light. They are seen in the order VIBGYOR, *i.e.*; violet, indigo, blue, green, yellow, orange and red.

With the following experiment we can show that the above mentioned seven colours when mixed together give white colour.

Take a circular disc made of card board with a hole at its centre. Then fix a spoke of a bicycle wheel in it so that you can rotate the circular disc easily. Now mark seven lines from the centre of the disc to its periphery to get seven equal sectors on the circle as shown in Fig. 7.18. Colour the triangles violet, indigo, blue, green, yellow, orange and red respectively. Now, holding the spoke in your hand, rotate the disc. While the motion of the disc is slow, we can see the different colours distinctly. But when the rotating disc reaches a certain speed it appears to be white. This tells us that when seven colours are mixed together we get white colour.

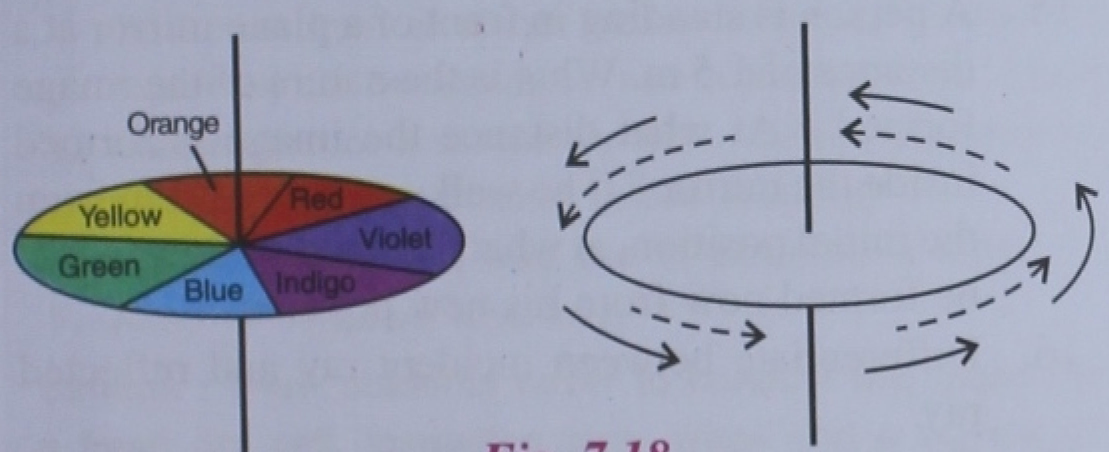


Fig. 7.18

ACTIVITY 2

Take a glass prism. It has two triangular sides. Take a cardboard and make a fine hole in it. Do this experiment in a room where you get a beam of sunlight from a window. Close the window in such a way that you get sunbeam into the room. Place the prism on a table with its base facing you. Make sure the room is dark enough. Through the hole in the cardboard, allow the sunbeam to fall on the prism at a slant. Now look from the other side. You will see a band of seven colours called the spectrum. If you allow the spectrum to fall on a white screen you will see the seven colours. You will see the red colour at the top of the spectrum and the violet at the bottom. In between, you will see orange, yellow, green, blue and indigo in the order of VIBGYOR. This tells us that sunlight can be splitted into seven colours.

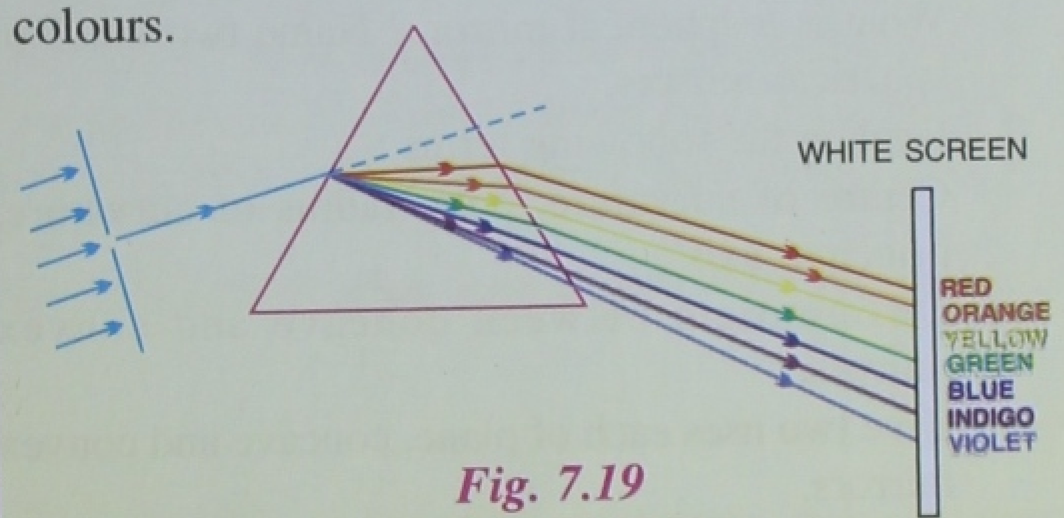


Fig. 7.19

TEST YOURSELF

A. Tick the correct answer :

1. The image formed by a plane mirror is
   (a) Virtual (b) Inverted
   (c) Diminished (d) Real
2. An object is visible to us due to
   (a) Regular reflection (b) Regular refraction
   (c) Irregular reflection (d) None of these
3. A spherical mirror whose outer surface is a reflecting surface is a
   (a) Convex mirror (b) Concave mirror
   (c) Convex lens (d) Concave lens
4. Shaving mirror is a
   (a) Convex lens (b) Concave lens
   (c) Convex mirror (d) Concave mirror
5. The centre of a spherical mirror is called
   (a) Aperture (b) Principal axis
   (c) Radius of curvature (d) Pole
6. A body which does not allow any light to pass through it is called
   (a) A polished surface (b) Opaque body
   (c) Transparent body (d) Translucent body

7. The angle of incidence on a plane mirror is 30°. The angle of reflection is
   (a) 15° (b) 60°
   (c) 30° (d) 0°

B. Write true or false :

1. A concave mirror converges the light rays, but a convex mirror diverges them.
2. The focal length of a convex mirror is equal to its radius of curvature.
3. A virtual image formed by a spherical mirror is always erect and situated behind the mirror.
4. If we use a convex mirror as rear view mirror, we get a virtual and diminished image.
5. If we place our face very close to a concave mirror, we get a diminished and virtual image.
6. A ray of light passing through the centre of curvature is reflected back along the same path in the case of a concave mirror.

C. Answer the following :

1. What is a spherical mirror ? Name two kinds of spherical mirrors.
2. Explain the following terms :
   Centre of curvature, pole, radius of curvature, principal axis.
3. Differentiate between concave and convex mirrors.
4. Give two uses each of plane, concave and convex mirrors.
5. How is a spherical mirror used to converge a beam of light to a point ? Name the type of mirror used.
6. What are the important rules for drawing ray diagrams for image formation by a concave mirror ?
7. What is a real image ? Name the mirror used to obtain the real image of an object. What should be the position of the object relative to the mirror ?
8. For a concave mirror, draw a ray diagram for all the possible positions of the object.
9. Name the mirror which always forms an erect and virtual image. What is the size of the image as compared to that of the object ?
10. Draw a ray diagram to show the formation of an image of an object placed between the focus and the centre of curvature of a concave mirror.
11. Name the mirror which forms an erect, virtual and enlarged image of an object. What is the position of the object relative to the mirror ?
12. A driver uses a convex mirror as a rear-view mirror. Explain the reason with the help of a ray diagram.
13. A concave mirror is used as a shaving mirror. Explain the reason with the help of a ray diagram.
14. Without touching the surface, how would you distinguish between a plane mirror, a convex mirror and a concave mirror ?
15. A person is standing in front of a plane mirror at a distance of 1·5 m. What is the nature of the image formed ? At what distance the image is formed inside the mirror ? If he walks away by 1·5 m from the initial position, at what distance the image will be formed now from his new position ?
16. Differentiate between incident ray and reflected ray.
17. How is a spherical mirror used to diverge a beam of light from a point ? Name the type of mirror used.

RECAPITULATION

- A plane mirror produces an erect, virtual and laterally inverted image. The size of the image is the same as that of the object and the image distance is same as the object distance from the mirror.
- A real image is formed by the actual meeting of reflected rays and can be formed on the screen. The real image is always inverted.
- A virtual image is formed by producing the reflected rays behind the mirror and cannot be formed on the screen. The virtual image is always erect.
- Spherical mirrors are of two types : (i) concave and (ii) convex.
- In a spherical mirror, if the inner hollow surface is the reflecting surface, it is called a concave mirror and if the outer bulging surface is the reflecting surface, it is called a convex mirror.
- The pole of a mirror is the geometric centre of its spherical surface.
- The centre of curvature of a mirror is the centre of the sphere of which the mirror is a part.
- The radius of curvature (R) of a mirror is double the focal length (f) *i.e.* $R = 2f$.
- A convex mirror always forms a virtual, erect and diminished image between the pole and the principal focus.
- The nature and position of an image formed by a concave mirror depends on the position of the object in front of mirror.