6 Reflection of Light

When light travelling through a medium (like air) strikes a surface, for example, a wall or a floor, some of it bounces back or travels back into the medium. We call this the reflection of light. All surfaces around us reflect light. That is how we see things. We see things when the light reflected by them enters our eyes.

REGULAR AND DIFFUSE REFLECTION

Though all surfaces reflect light, some do it better than others. Smooth, polished surfaces are better reflectors than rough, dull surfaces. And really smooth surfaces, like that of a mirror, reflect light so well that they let us see clear images of things near them.

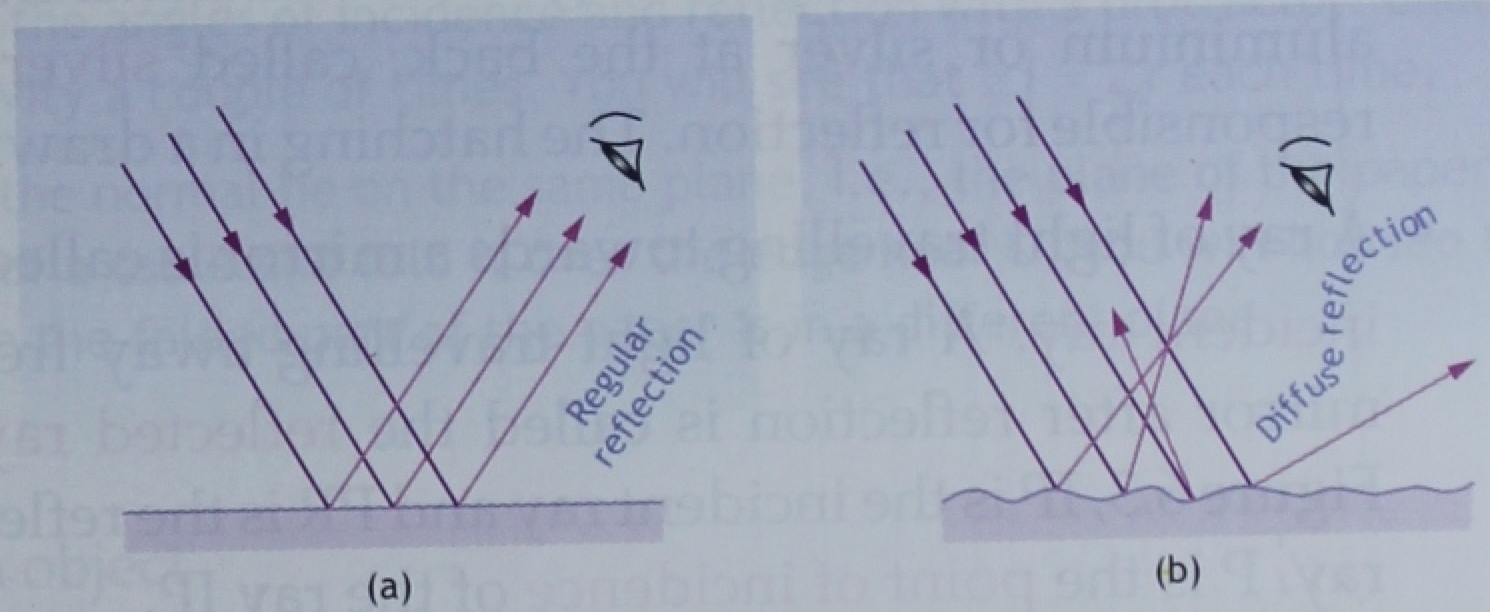


Fig. 6.1 (a) Regular reflection occurs at smooth surfaces, while (b) diffuse reflection occurs at uneven surfaces.

Why is it that smooth surfaces create images, while rough surfaces do not? When a parallel beam of light from an object falls on a smooth surface, it remains parallel after reflection. When this reflected beam enters our eyes, we see a clear image of the object. However, when a beam of light from an object falls on a

Fig. 6.2 The clarity of the image formed by a reflecting surface depends on the smoothness of the surface.

rough surface, the bumps and pits on the surface make the reflected rays travel in different directions. Hence, most of them enter our eyes from slightly different directions, and we see a hazy image or no image at all. Reflection from a smooth surface is called regular reflection, while reflection from an uneven surface is called diffuse reflection.

PLANE MIRRORS

The reflection of light from a perfectly smooth surface, like that of a mirror, follows certain laws. Before we discuss these laws, we must become familiar with the terms and diagrams used in relation to reflection.

Terms Related to Reflection

- A ray of light is a narrow stream of light. It represents the path along which light travels, and is shown by a straight line with a small arrow. The arrowhead indicates the direction in which light travels.
- A mirror is shown by a straight line with hatching on one side. Mirrors have a layer of aluminium or silver at the back, called silvering. It is this layer which is really responsible for reflection. The hatching in a drawing of a mirror represents this layer.
- A ray of light travelling towards a mirror is called the incident ray. A ray of light travelling away from a mirror after reflection is called the reflected ray. In Figure 6.3, IP is the incident ray and PR is the reflected ray. P is the point of incidence of the ray IP.

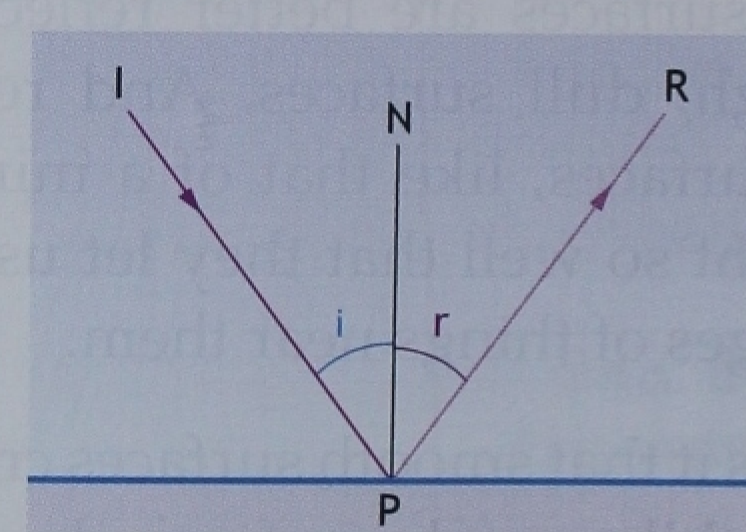


Fig. 6.3

- A line drawn perpendicular to the reflecting surface is called the normal to the surface. PN is the normal in the figure.
- The angle between the incident ray and the normal is called the angle of incidence, while the angle between the reflected ray and the normal is called the angle of reflection. In the figure, i is the angle of incidence and r is the angle of reflection.

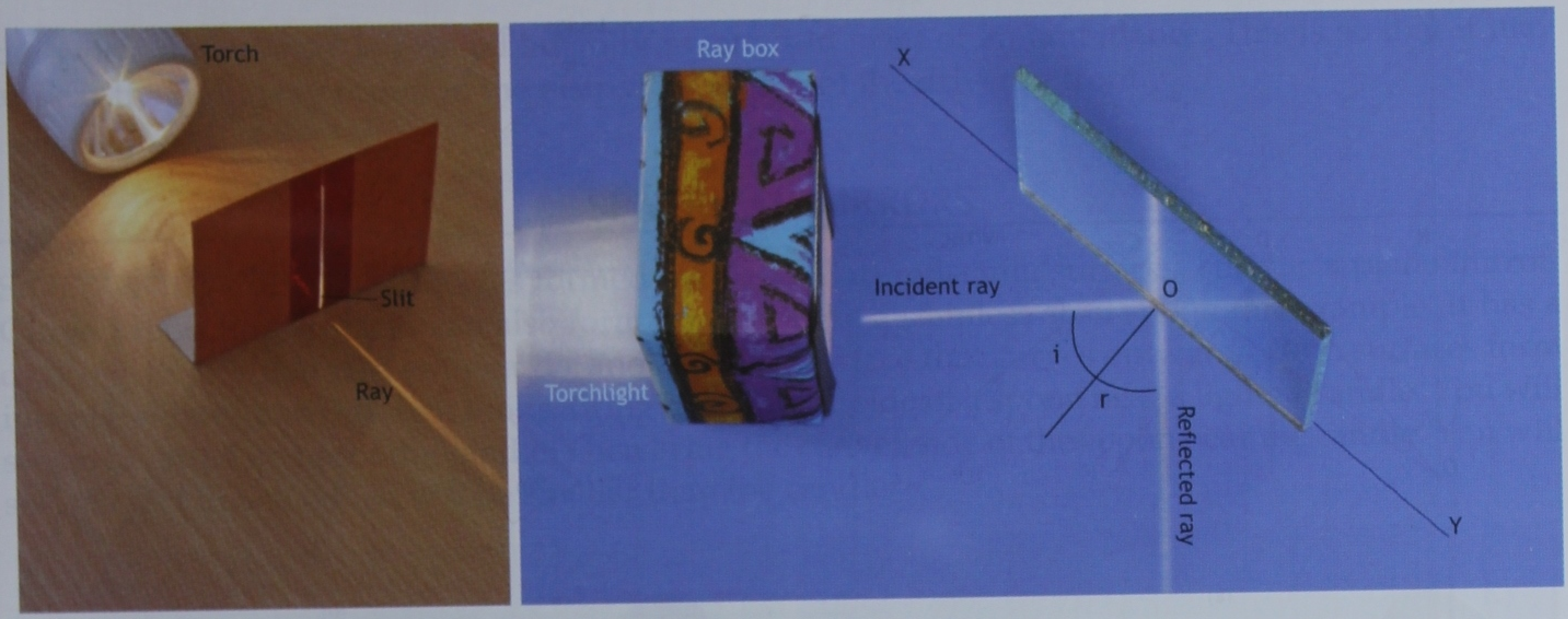
Laws of Reflection

We are now in a position to state the laws of reflection.

1. The incident ray, the normal to the reflecting surface (at the point of incidence) and the reflected ray lie in the same plane.
2. The angle of incidence is equal to the angle of reflection. In Figure 6.3, this would mean $\angle i = \angle r$.

ACTIVITY You can verify the laws of reflection quite easily. All you will need is a mirror, a sheet of paper and a source of rays. You can use a cardboard box to make a source of rays. Cut out one side of the box and cut a window on the opposite side. Make a slit (to get one ray) on a piece of stiff paper and fix it over the window. Shine a torch behind the slit to get a ray.

Now draw a straight line (XY in Figure 6.4) on the sheet of paper. Stand a mirror on the paper with its silvered surface on the line. Let a ray of light from the box fall on the mirror. You will see its reflection. Trace the incident and reflected rays and remove the mirror from the paper. Draw a normal to XY at O, where the



(a) (b)

Fig. 6.4

incident and reflected rays meet. Measure the angles of incidence and reflection with a protractor. Change the angle of incidence and repeat the activity a couple of times. You will see that $\angle i = \angle r$ each time.

The incident ray, the reflected ray and the normal lie on the same plane, i.e., the plane of the paper. If you place the sheet of paper at the edge of a table and fold it over the edge near O, you will not see the reflected ray on the paper. This is because the folded part of the paper is in a different plane.

Image Formed by a Plane Mirror

You may have noticed that when you hold an object in front of a mirror, an image seems to form behind the mirror. What really happens is that light from the object is reflected by the mirror and enters your eyes. The reflected rays *seem* to come from an image behind the mirror. However, if you place a screen at the position where the rays seem to be coming from, you will not see an image. Such an image that cannot be formed on a screen is called a virtual image. Images formed by cameras (for example, the pinhole camera you made), on the other hand, are real images. An image that can be formed on a screen is called a real image.

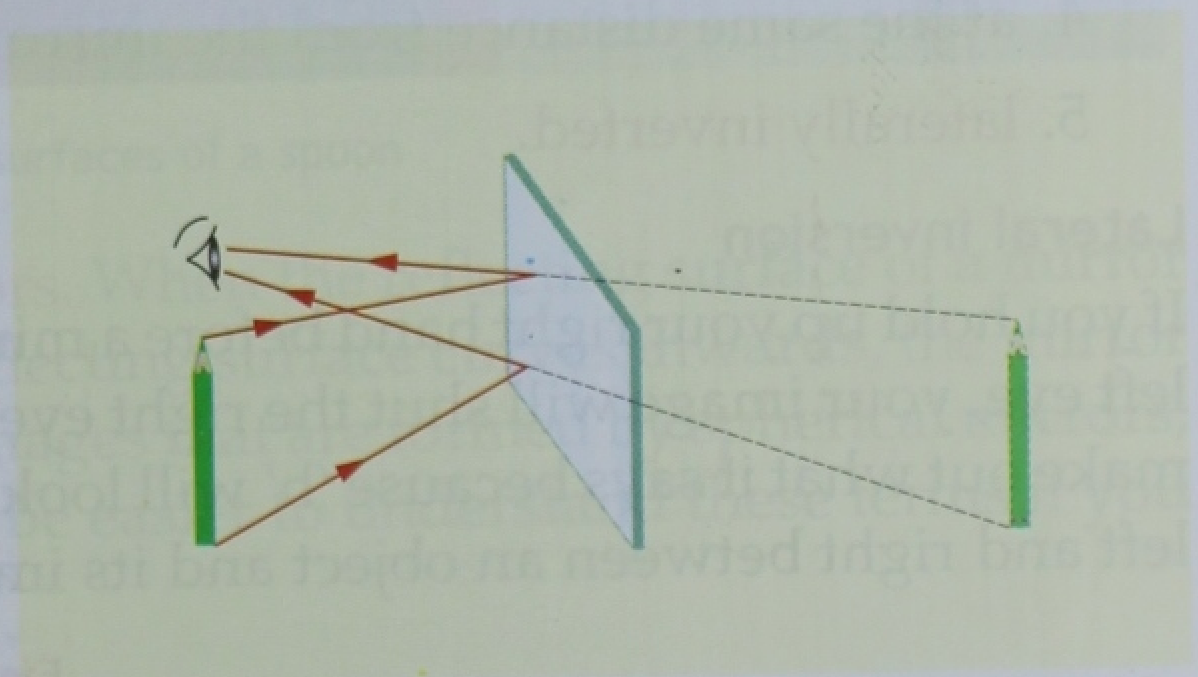


Fig. 6.5 The reflected rays seem to come from an image behind the mirror.

It is possible to locate the position of an image formed by a plane mirror by tracing rays or making a ray diagram. Suppose the object in front of the mirror is very small, like a point. Consider two rays OC and OD from the object incident on the mirror at C and D. They will get reflected along CE and DF. While drawing the reflected rays remember that the angles of incidence and reflection must be equal. If you extend the rays CE and DF backwards, they will meet at the point I. This is the point where these rays seem to be coming from. In other words, this is the image of the object O. You will find that ON = IN. This is always true for an image formed by a plane mirror. We say that for reflection at a plane surface, the image is as far behind the surface as the object is in front of it. If you wish, you can do the activity related to this at the end of the chapter.

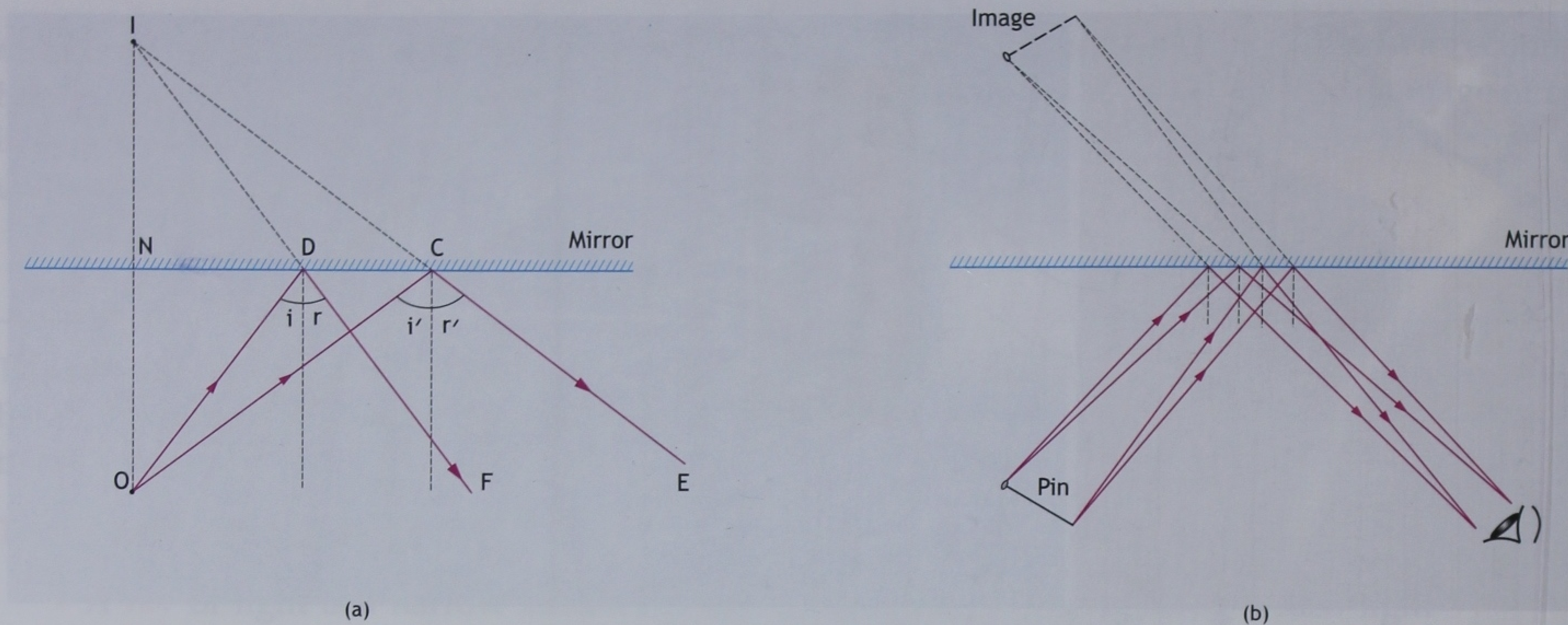


Fig. 6.6 (a) The image is as far behind the mirror as the object is in front of it. (b) The object and the image are of the same size.

You may have noticed that the image formed by a plane mirror is of the same size as the object. This will be clear from Figure 6.6(b), as also from the second activity at the end of the chapter.

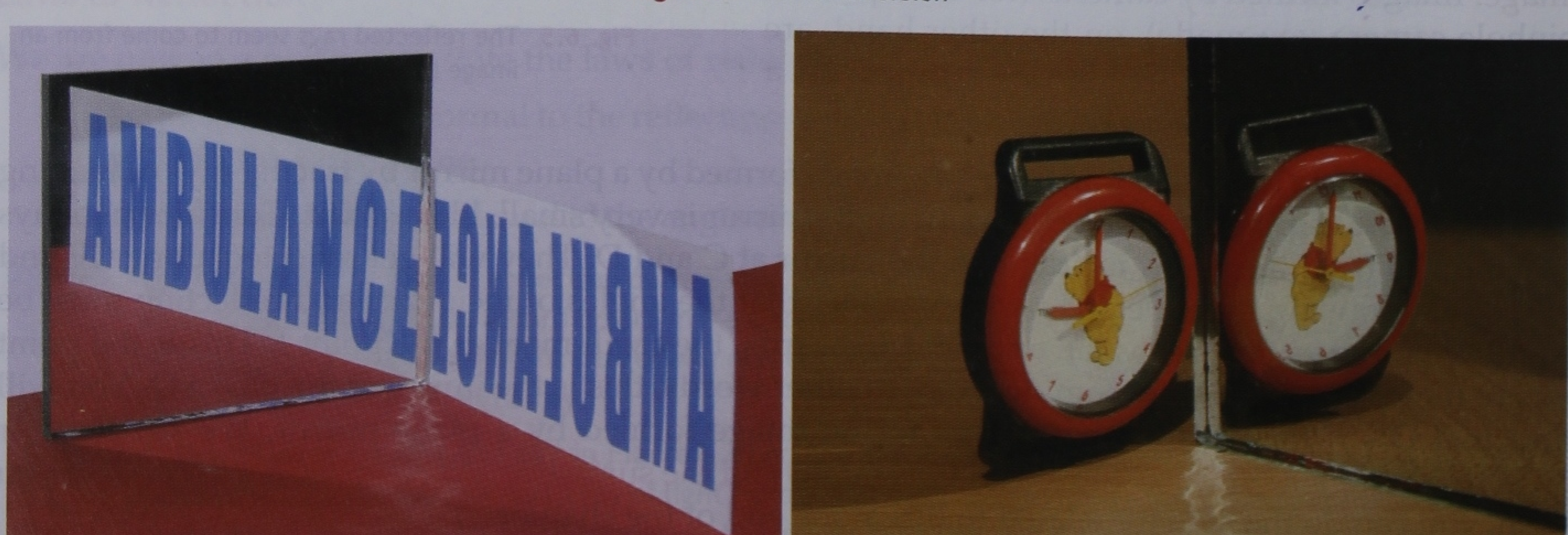
We can now list the characteristics of an image formed by a plane mirror. The image formed by a plane mirror is

1. virtual,
2. erect (a pinhole camera forms an inverted image),
3. of the same size as the object,
4. at the same distance from the mirror as is the object, and
5. laterally inverted.

Lateral inversion

If you hold up your right hand before a mirror, your image will hold up the left hand. If you shut your left eye, your image will shut the right eye. And if you hold up a printed line, you may not be able to make out what it says because 'b' will look like 'd', 'p' will look like 'q', and so on. This interchange of left and right between an object and its image is called lateral inversion. You may have noticed that

Fig. 6.7 Lateral inversion



the word 'ambulance' is printed laterally inverted in front of an ambulance. This is so that it may appear the right way round in the near-view mirror of the driver in front.

SPHERICAL MIRRORS

So far we have discussed images formed by plane (flat) reflecting surfaces, such as a plane mirror. Curved reflecting surfaces can also form images. Take a stainless steel spoon, for example. It has a concave surface that curves inwards, and a convex surface that curves outwards. Both surfaces form images, although of different kinds. Bring the concave side of a spoon near a lighted candle. You will see an inverted image of the candle. Then bring the convex side of the spoon near the candle. You will see an erect image which will be smaller than the candle.

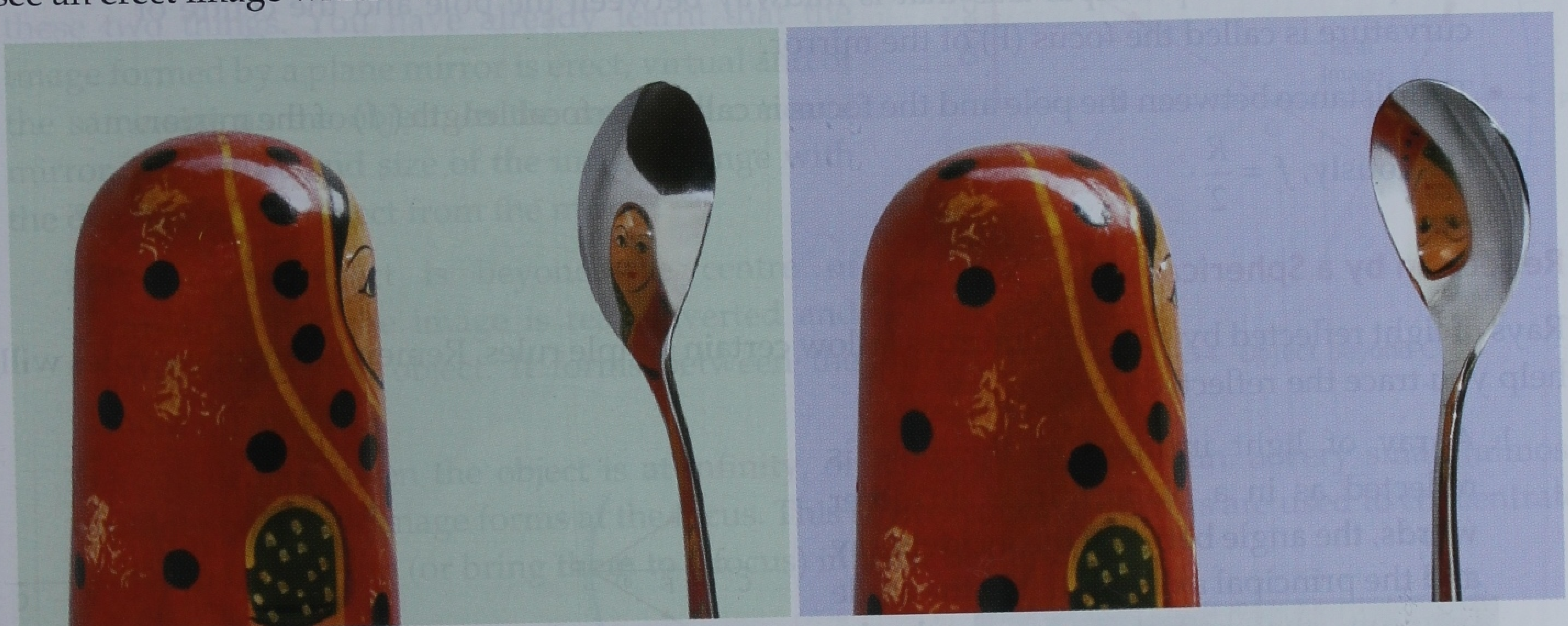
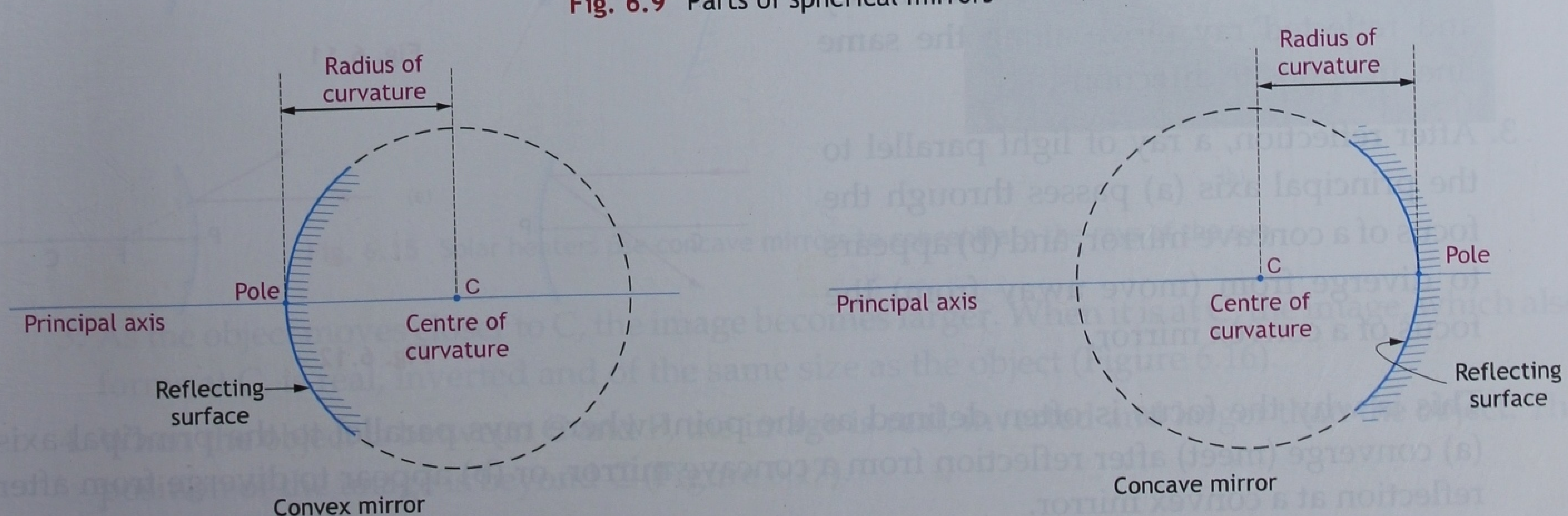


Fig. 6.8 Images formed by the curved surfaces of a spoon

Mirrors with curved surfaces are called spherical mirrors. When the reflecting surface of a mirror bulges outwards, it is called a convex mirror. When the reflecting surface curves inwards, the mirror is called a concave mirror. Before we discuss the kinds of images that are formed by spherical mirrors, we must know a few terms related to such mirrors. It will be easier to understand these terms if you think of a spherical mirror as a part of a hollow sphere.

Fig. 6.9 Parts of spherical mirrors



- The centre of the imaginary sphere of which the mirror is a part is called the centre of curvature, denoted by C.
- The radius of the spherical surface, or of the sphere of which the mirror is a part, is called the radius of curvature, R.
- The centre of the mirror is called the pole of the mirror, denoted by P.
- A diameter of the sphere (of which the mirror is a part) passing through the pole is called the principal axis of the mirror. The principal axis extends beyond the sphere in both directions.
- The point on the principal axis that is midway between the pole and the centre of curvature is called the focus (F) of the mirror.
- The distance between the pole and the focus is called the focal length (f) of the mirror.

  Obviously, $f = \frac{R}{2}$.

Reflection by a Spherical Mirror

Rays of light reflected by spherical mirrors follow certain simple rules. Remembering these rules will help you trace the reflected rays.

1. A ray of light incident at the pole is reflected as in a plane mirror. In other words, the angle between the incident ray and the principal axis is equal to the angle between the reflected ray and the principal axis. This is true for a concave mirror as well as a convex mirror.

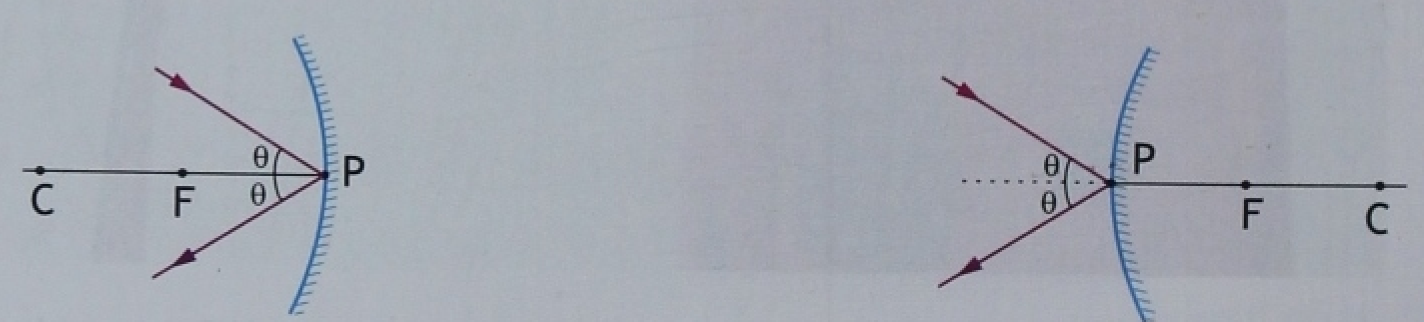


Fig. 6.10

2. A ray of light that (a) passes through the centre of curvature of a concave mirror or (b) moves towards the centre of curvature of a convex mirror, retraces its path after reflection. In other words, the incident ray and reflected ray move along the same line, in opposite directions.

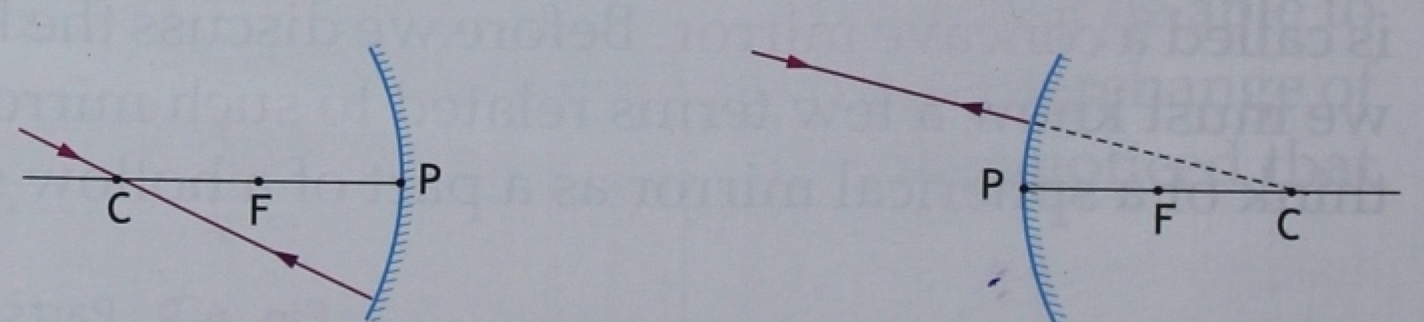


Fig. 6.11

3. After reflection, a ray of light parallel to the principal axis (a) passes through the focus of a concave mirror, and (b) appears to diverge from (move away from) the focus of a convex mirror.

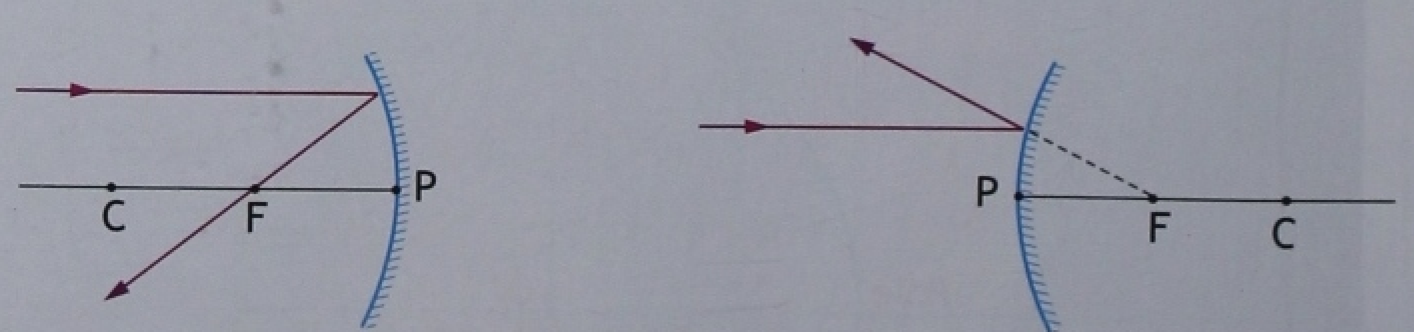


Fig. 6.12

This is why the focus is often defined as the point where rays parallel to the principal axis (a) converge (meet) after reflection from a concave mirror, or (b) appear to diverge from after reflection at a convex mirror.

4. A ray of light (a) passing through the focus of a concave mirror or (b) moving towards the focus of a convex mirror travels parallel to the principal axis after reflection.

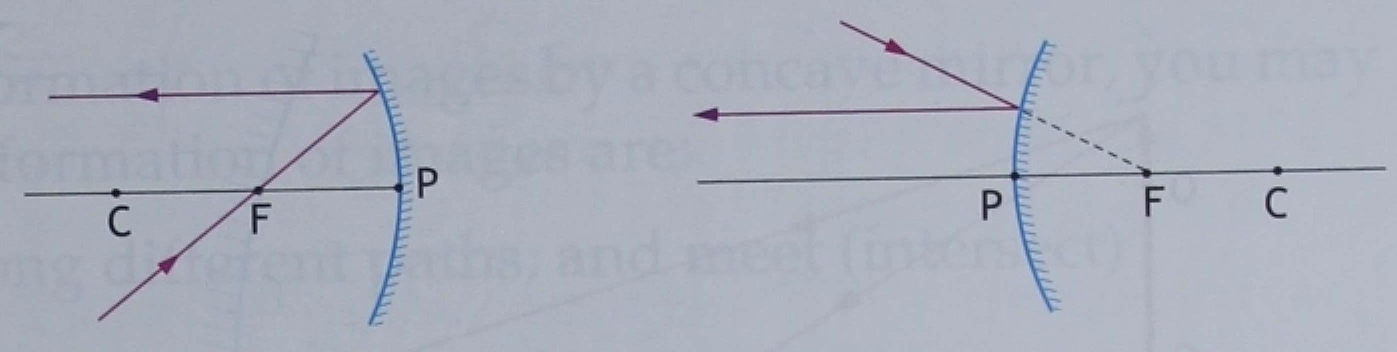


Fig. 6.13

Images Formed by a Concave Mirror

In general, the nature of the image formed by a mirror depends on the nature of the mirror and the position of the object. The position of the image also depends on these two things. You have already learnt that the image formed by a plane mirror is erect, virtual and of the same size as the object. In the case of a concave mirror, the nature and size of the image change with the distance of the object from the mirror.

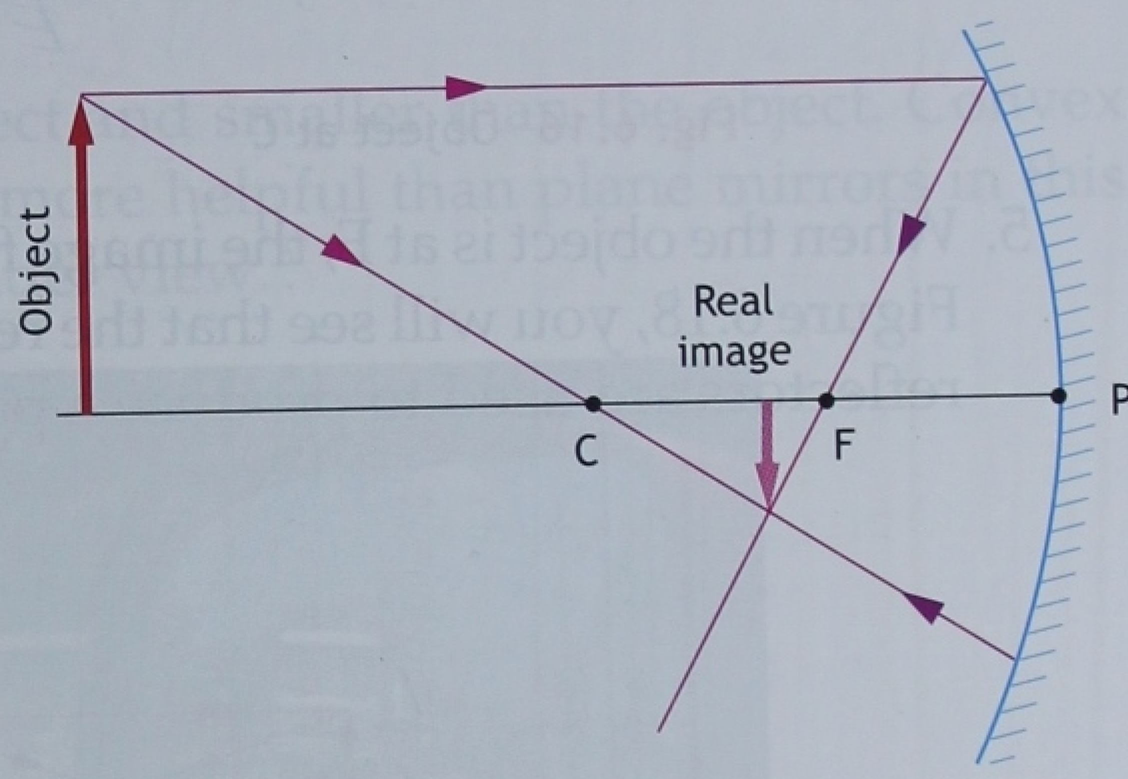
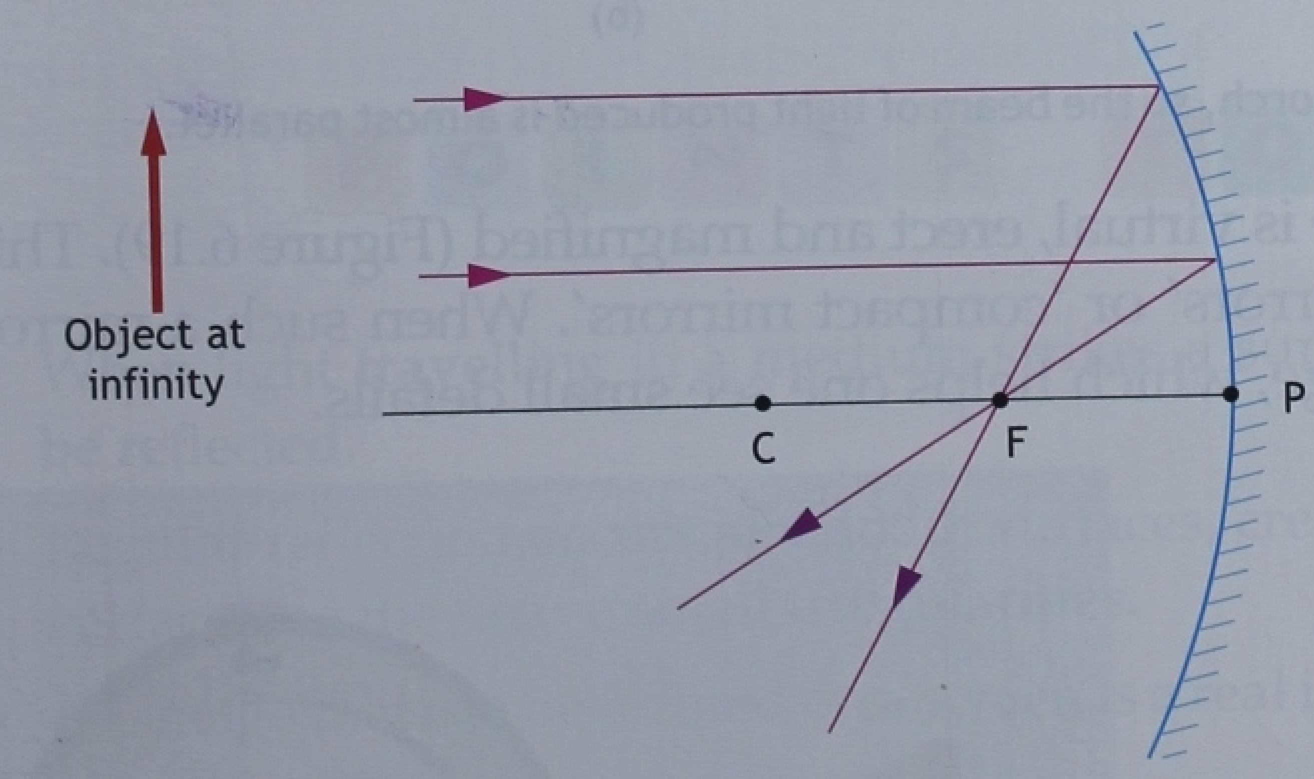


Fig. 6.14 Object beyond C

1. When the object is beyond the centre of curvature (C), the image is real, inverted and smaller than the object. It forms between the focus (F) and C.
2. In particular, when the object is at infinity, or far away, like the sun, a very small (almost point-sized) real image forms at the focus. This is why concave mirrors are used to concentrate the rays of the sun (or bring them to a focus) in solar heaters.



(a)

(b)

Fig. 6.15 Solar heaters use concave mirrors to concentrate the rays of the sun.

3. As the object moves closer to C, the image becomes larger. When it is at C, the image, which also forms at C, is real, inverted and of the same size as the object (Figure 6.16).
4. When the object is between C and F, the image is real, inverted and larger than the object. The position of the image is beyond C (Figure 6.17).

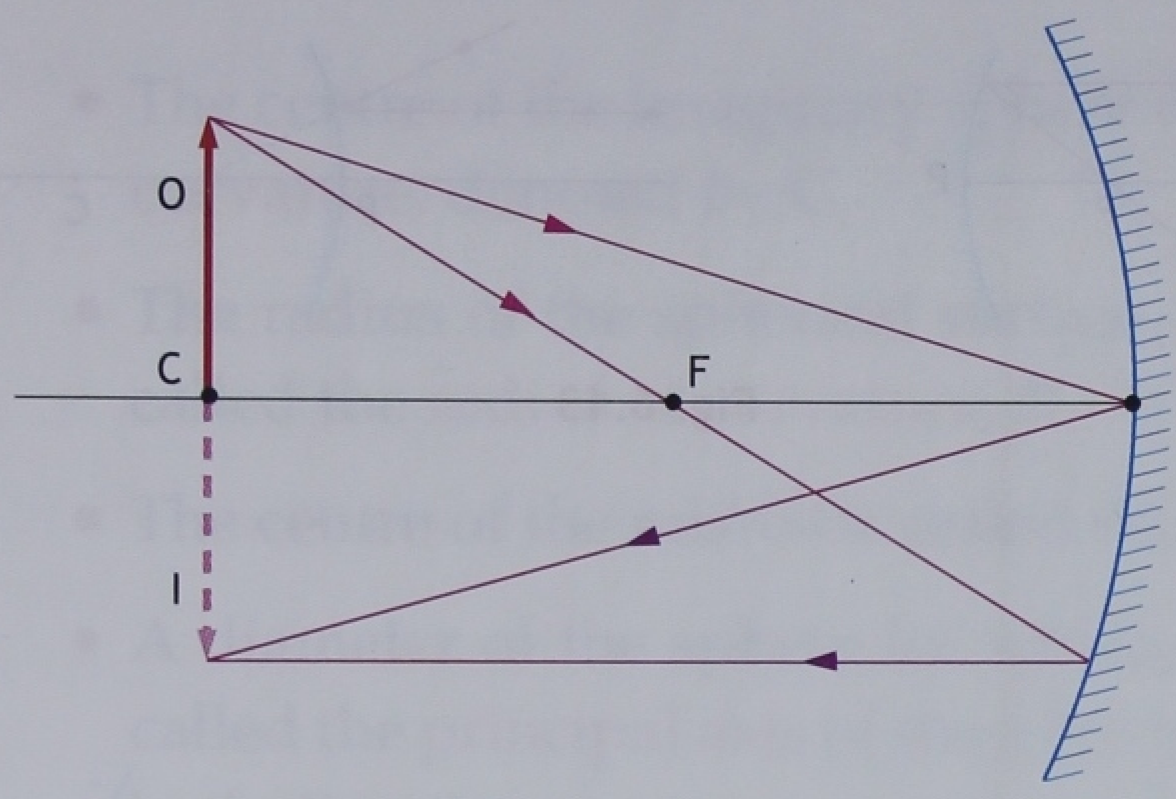


Fig. 6.16 Object at C

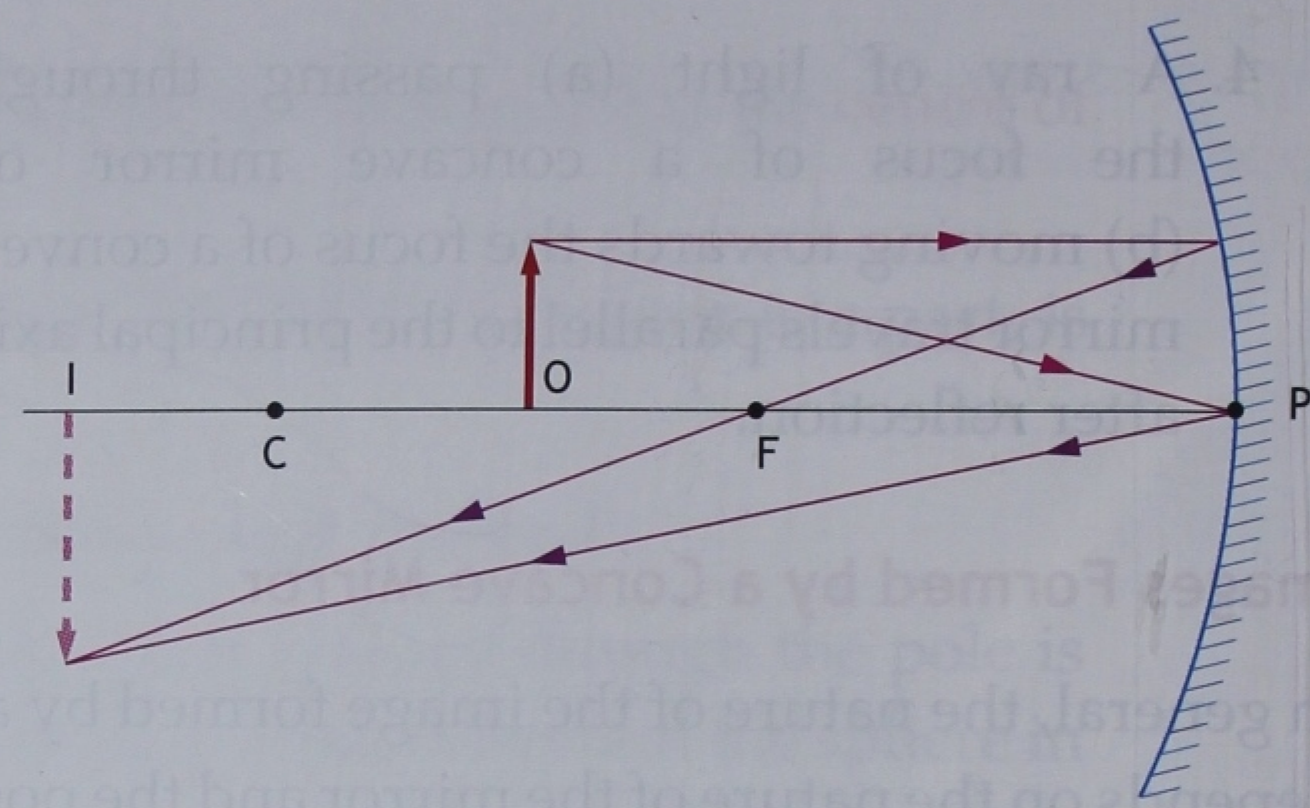


Fig. 6.17 Object between C and F

5. When the object is at F, the image forms at infinity, or it is very far from the mirror. If you look at Figure 6.18, you will see that the reflected rays from the mirror are parallel. This is why concave reflectors are used to produce a parallel beam of light in torches.

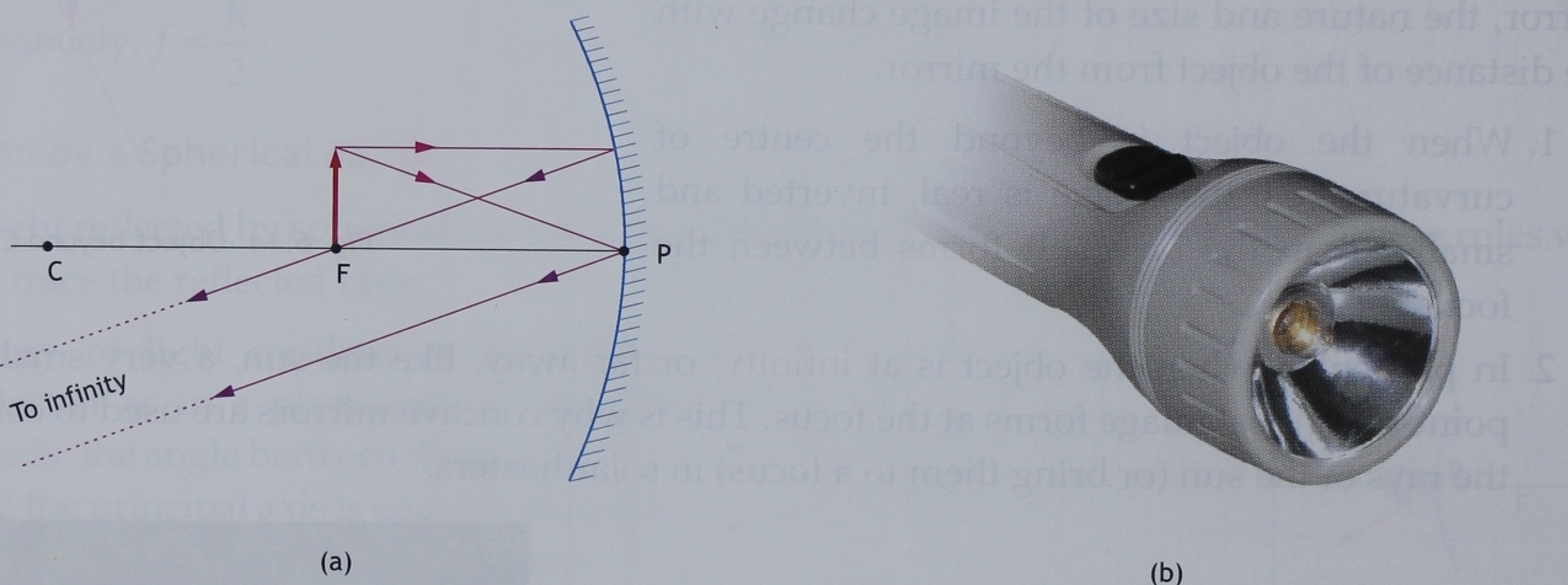


Fig. 6.18 The bulb is at the focus of the reflector in a torch, so the beam of light produced is almost parallel.

6. When the object is between F and P, the image is virtual, erect and magnified (Figure 6.19). This is why concave mirrors are used as 'shaving mirrors' or 'compact mirrors'. When such a mirror is held close to the face, it produces a larger image, which helps one see small details.

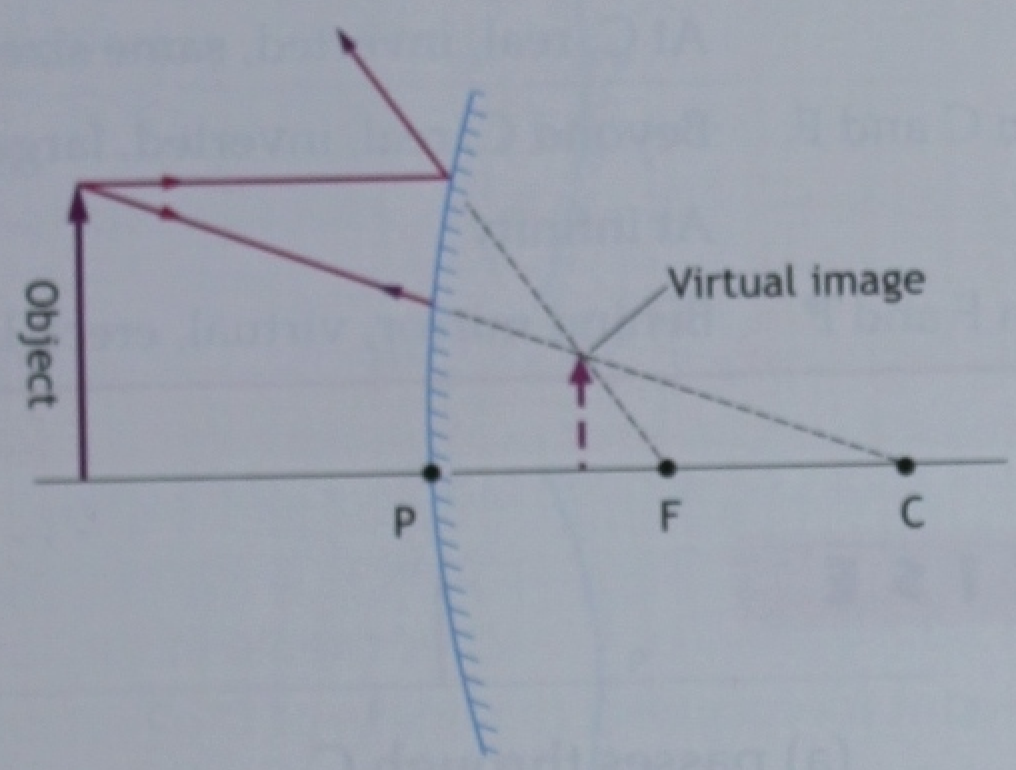
Fig. 6.19 Concave mirrors are used as 'shaving mirrors' or 'compact mirrors' because they produce a magnified image when held close to the face.

If you look carefully at the ray diagrams for the formation of images by a concave mirror, you may notice something helpful. The general rules for the formation of images are:

- When two rays start from a point O, move along different paths, and meet (intersect) again at a point I, a real image of O forms at I.
- If one or both the rays have to be produced backwards to make them intersect at I, a virtual image of O forms at I. If you turn back to Figure 6.6, you will see that this is true of images formed by plane mirrors.

Images Formed by a Convex Mirror

The image formed by a convex mirror is always virtual, erect and smaller than the object. Convex mirrors are used as rear-view mirrors in vehicles. They are more helpful than plane mirrors in this case because they form smaller images, and hence, give a wider view.



(a)

(b)

Fig. 6.20 (a) Convex mirrors produce images that are erect and smaller than the object. (b) Hence, they are used as rear-view mirrors.

POINTS TO REMEMBER

- When light travelling in a medium strikes a surface and moves back into that medium, it is said to be reflected.
- Regular reflection occurs at smooth surfaces, creating clear images. Diffuse reflection occurs at rough surfaces, as they have small irregularities.
- An image that can be formed on a screen is a real image. An image that cannot be formed on a screen is a virtual image.
- A ray of light travelling towards a mirror is called the incident ray. A ray of light travelling away from a mirror after reflection is called the reflected ray. A line drawn perpendicular to the reflecting surface at the point of incidence is called the normal to the surface.
- The angle between the incident ray and the normal is the angle of incidence. The angle between the reflected ray and the normal is the angle of reflection.
- An image formed by a plane mirror is virtual, erect, laterally inverted and of the same size as the object. It forms as far behind the mirror as the object is in front of it.
- The incident ray, the normal to the reflecting surface, and the reflected ray lie in the same plane.

- The angle of incidence is equal to the angle of reflection.
- In a convex mirror, the reflecting surface bulges outwards. In a concave mirror, the hollow part is made reflecting.
- The centre of the imaginary sphere of which a spherical mirror is a part is called the centre of curvature (C). The radius of the sphere is called the radius of curvature (R). The centre of the mirror is called its pole (P). A diameter of the imaginary sphere passing through the pole is the principal axis of the mirror. The point lying midway between P and C is the focus (F). The distance PF = focal length $(f) = R/2$.
- When two rays start from a point O, move along different paths, and meet (intersect) again at some point I, an image of O is formed at I.
- The nature of the image formed by a concave mirror depends on the distance of the object from the mirror.
- The image formed by a convex mirror is always virtual, erect and smaller than the object.

Images formed by a concave mirror

Object	Image
At infinity	At F, real, inverted, point-sized
Beyond C	Between C and F, real, inverted, smaller
At C	At C, real, inverted, same size
Between C and F	Beyond C, real, inverted, larger
At F	At infinity
Between F and P	Behind mirror, virtual, erect, larger

EXERCISE

Short-Answer Questions

1. Distinguish between regular and diffuse reflection.
2. Differentiate between real and virtual images.
3. What are the characteristics of an image formed by a plane mirror?
4. What does the hatching in a drawing of a mirror represent?
5. What is meant by lateral inversion?

Long-Answer Questions

1. State and explain the laws of reflection.
2. What are convex and concave mirrors? Explain with the help of a diagram what you understand by the focus, pole and centre of curvature of such mirrors.
3. With the help of a neat sketch, show how an image is formed by a plane mirror. Hence, prove that the object and its image are equidistant from the mirror.
4. Distinguish between the nature of the images formed by plane mirrors and convex mirrors. Mention one use of convex mirrors.

Objective Questions

Choose the correct option.

1. When a ray of light parallel to the principal axis is incident on a concave mirror, the reflected ray
   (a) passes through C
   (b) passes through F
   (c) passes midway between P and F
   (d) retraces its path
2. The image formed by a concave mirror is larger in size than the object. Which of the statements cannot be correct?
   (a) The object lies between the focus and the pole of the mirror.
   (b) The object lies between the focus and the centre of curvature of the mirror.
   (c) The object and the image lie on the same side of the principal axis.
   (d) The object is beyond the centre of curvature of the mirror.
3. The image formed by a convex mirror is
   (a) inverted (b) magnified
   (c) virtual (d) real
4. Which of the following is not correct with respect to all spherical mirrors?
   (a) The pole lies on the principal axis.
   (b) The focal length is half of the radius of curvature.
   (c) Both real and virtual images can be formed by them.

(d) Light rays moving towards or passing through the centre of curvature retrace their path after reflection.

5. When a ray of light moves towards the focus of a convex mirror, the reflected ray

(a) passes through C

(b) is parallel to the principal axis

(c) passes through F

(d) retraces the path of the incident ray

Write true or false.

1. We see things around us due to the reflection of light.

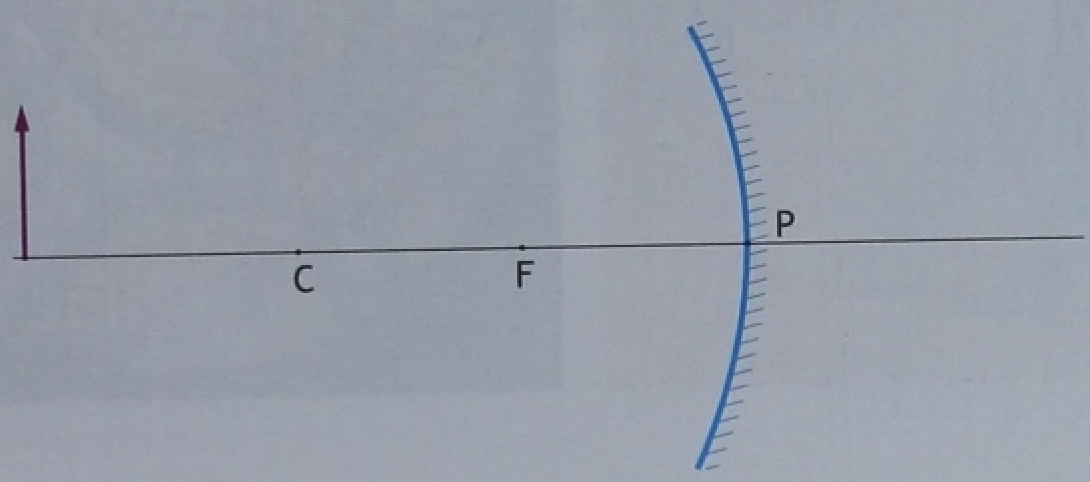
2. Cameras form virtual images.

3. The first law of reflection states that the angle of incidence is equal to the angle of reflection.

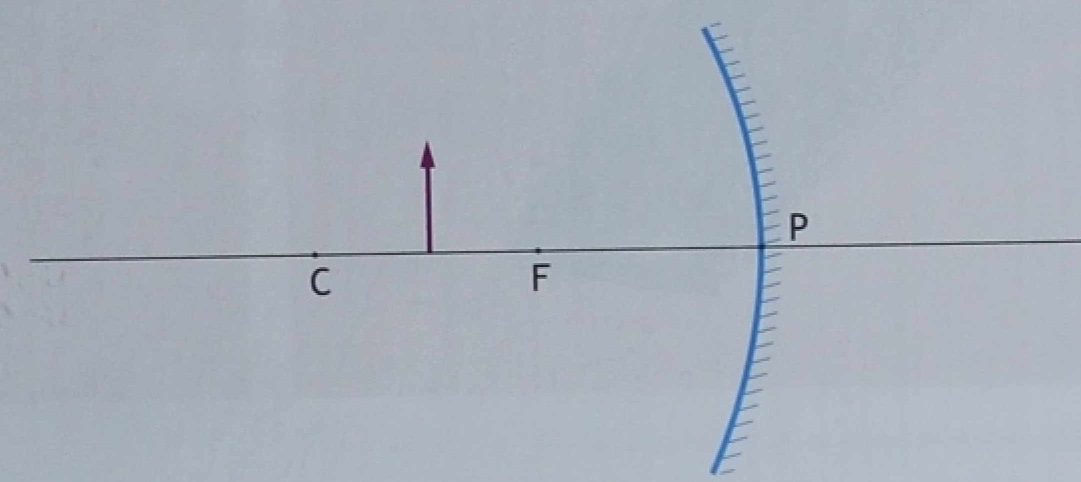
4. Concave mirrors are used in vehicles as rear-view mirrors.

5. A plane mirror can be used to form magnified images.

Locate the images by completing the ray diagrams.



(a)



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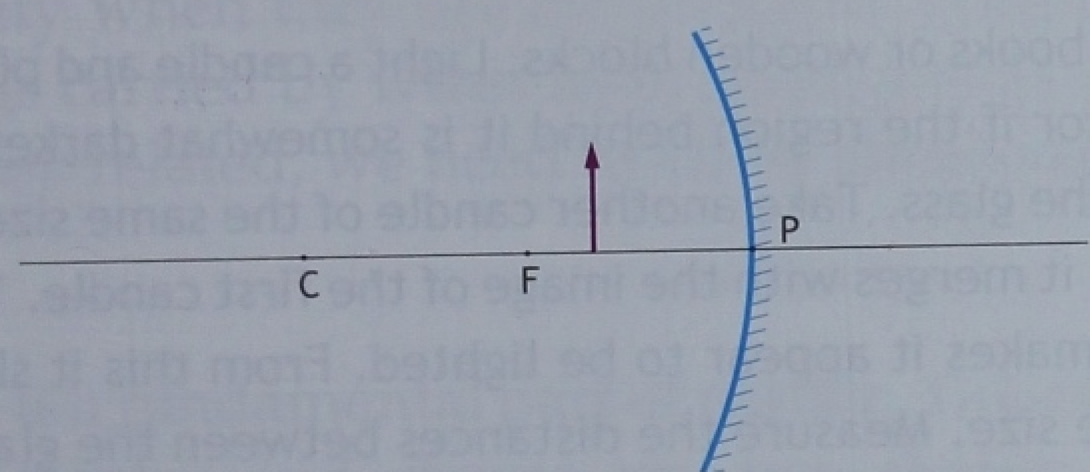

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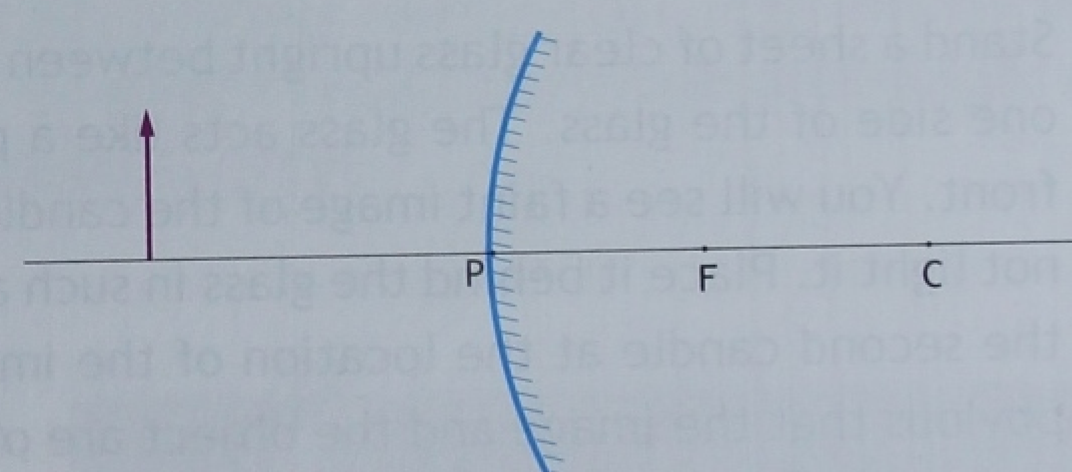

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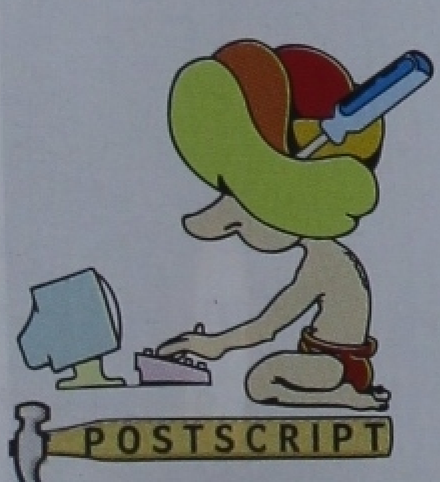
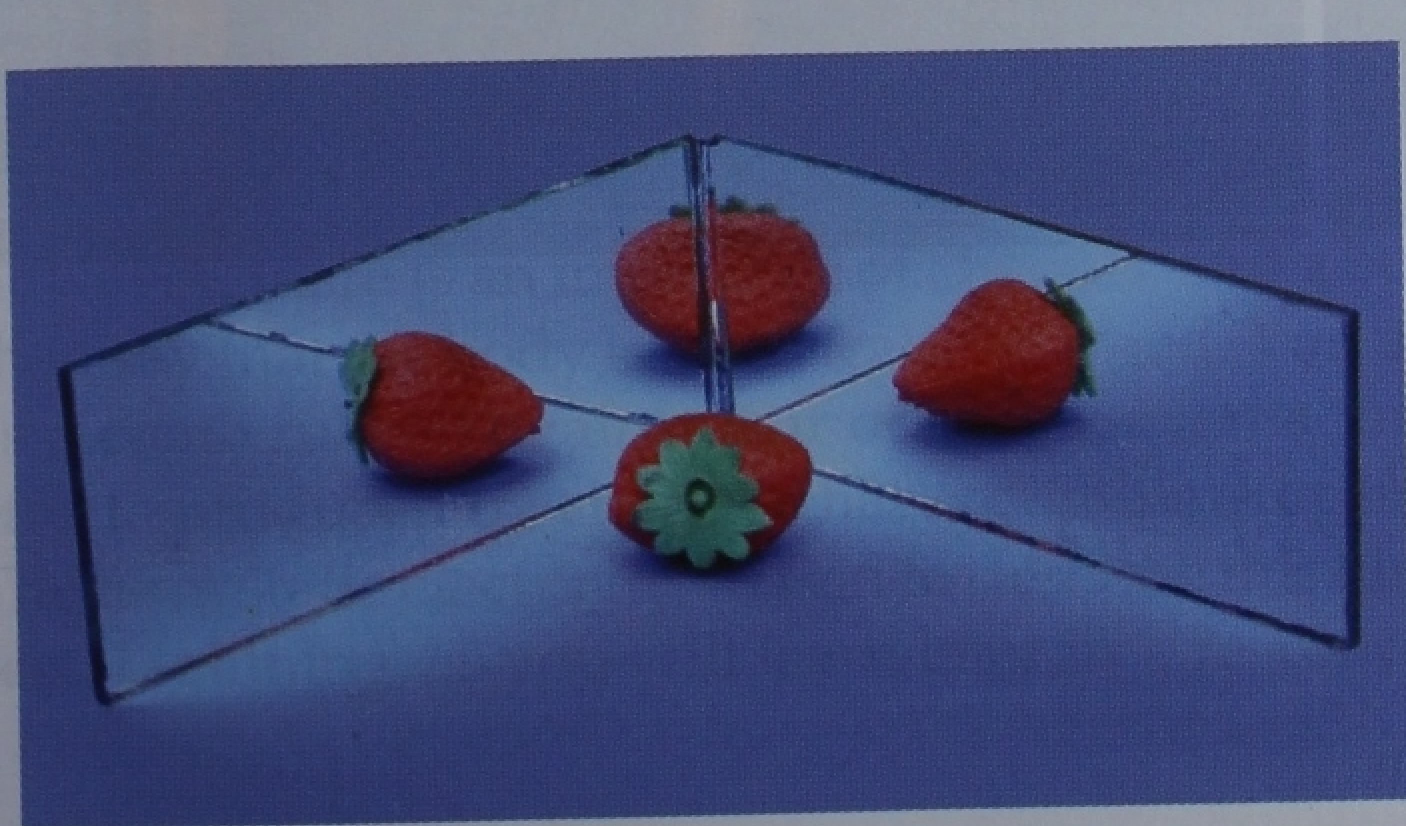
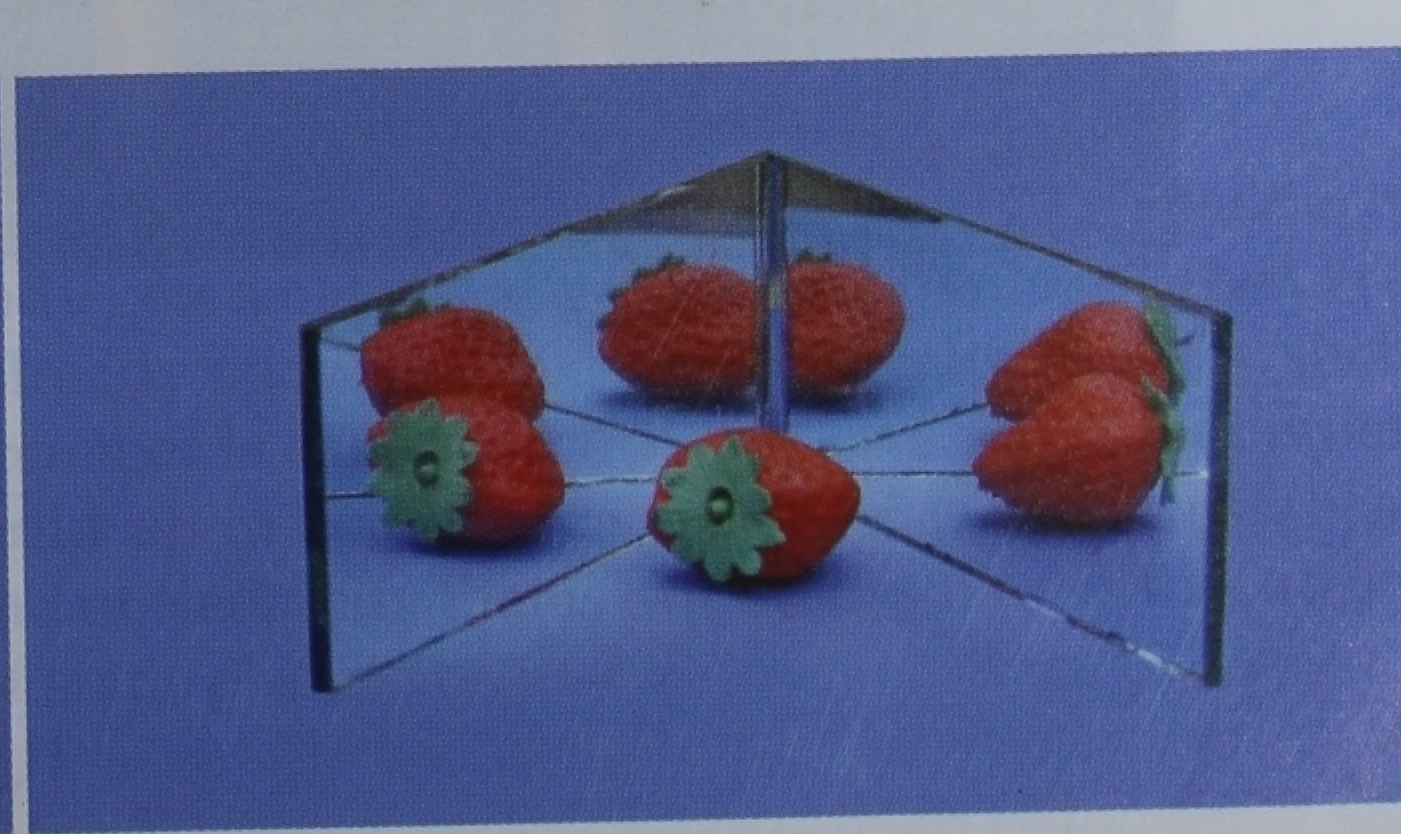


Multiple Reflections

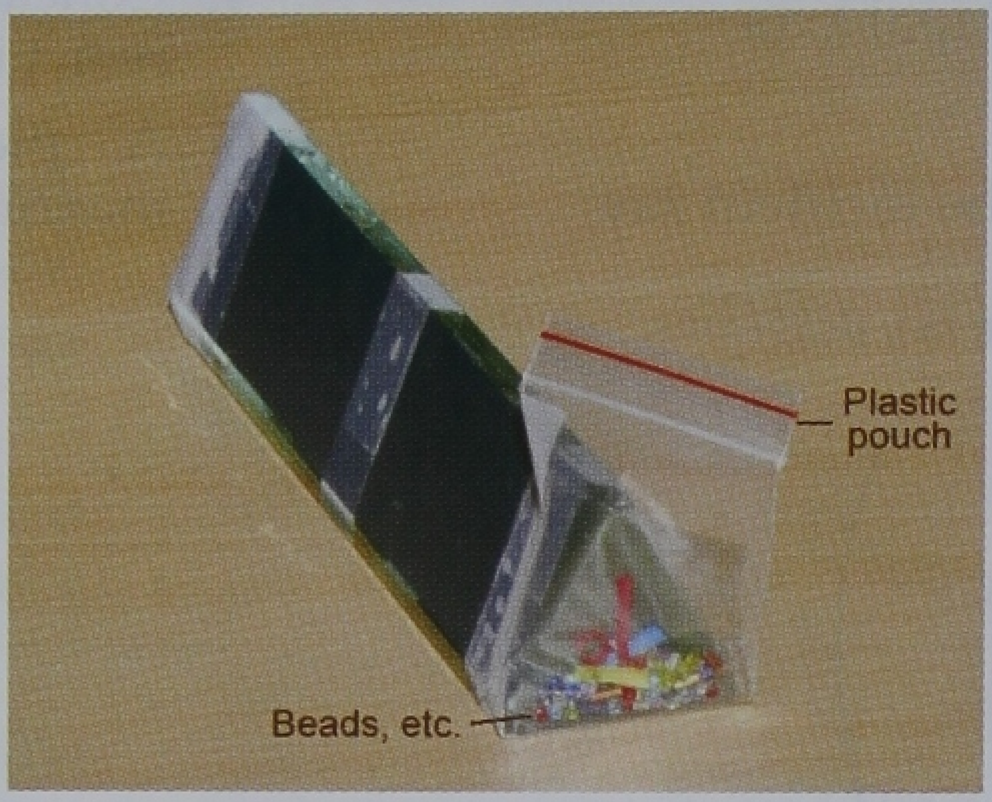
If you stand two mirrors at right angles to each other and place an object between them, you will see three images. Each mirror forms an image of the object. A third image forms behind the line where the mirrors meet. This image is formed by rays that are reflected twice (once in each mirror).

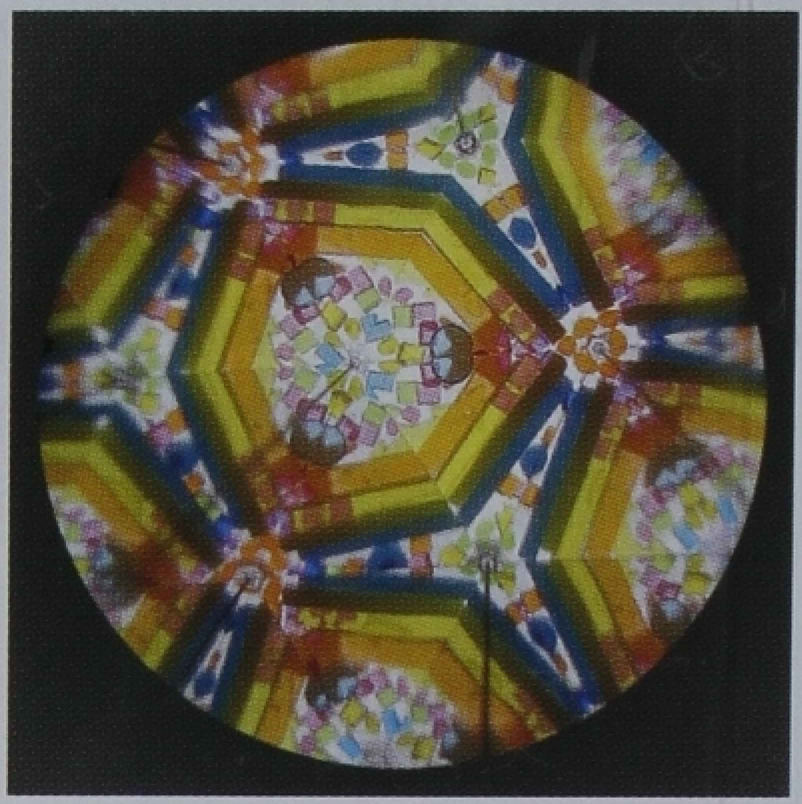
If you decrease the angle between the two mirrors, the number of images will increase. And if you place the mirrors parallel to each other, the number of images will become infinite.





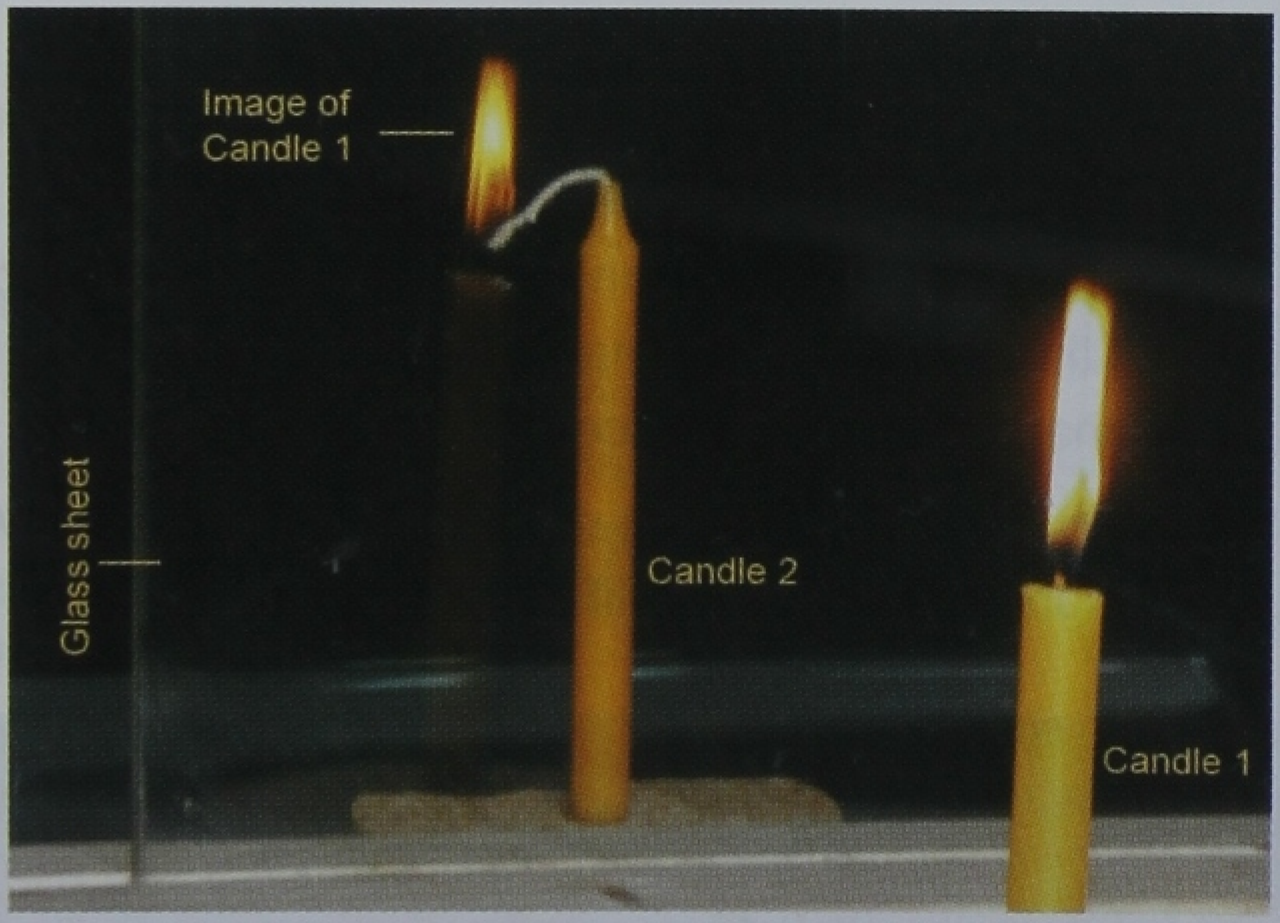
ACTIVITY You can use multiple reflections to make a kaleidoscope. Tape three strips of mirror of equal size, with their reflecting surfaces facing each other, to form a triangular tube. Then tape two sides of a small polythene pouch to two sides of the tube. Put pieces of coloured bangles, beads, and so on, into the pouch. Tape the open end of the pouch to the third side of the tube. Cover the other end of the tube with stiff paper and make a hole in it. Look through the hole and rotate the kaleidoscope. You will see beautiful patterns like the one shown here.





ACTIVITY The image formed by a plane mirror is as far behind the mirror as the object is in front of it.

Stand a sheet of clear glass upright between two thick books or wooden blocks. Light a candle and place it on one side of the glass. The glass acts like a plane mirror if the region behind it is somewhat darker than in front. You will see a faint image of the candle behind the glass. Take another candle of the same size, but do not light it. Place it behind the glass in such a way that it merges with the image of the first candle. This puts the second candle at the location of the image, and makes it appear to be lighted. From this it should be obvious that the image and the object are of the same size. Measure the distances between the glass sheet and the candles. Repeat the experiment a number of times. You will find that the two candles are always equidistant from the sheet of glass.



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