11. Reflection of Light

➢ **Mirrors and types of mirrors** ➢ **Spherical mirrors and images formed by them** ➢ **Magnification due to spherical mirrors**

Can you recall?

1. What is light?
2. What is meant by reflection of light? Which are the different types of reflection?

Light is an agent which gives us information about what is happening in our surroundings. We can enjoy various wonders of nature like the sunrise, sunset and rainbow only because there is light. It is only because of light that we can see the lush green vegetation, colourful flowers, deep blue skies in the day, stars shining in the dark night sky in the beautiful world around us. We can see the man-made objects in our surroundings as well. Light is actually electromagnetic radiation which causes the sensation of vision.

Light reflects differently from the various surfaces around us. We have already learnt that the reflection from smooth, flat surfaces is regular reflection while rough surfaces reflect light irregularly.

Mirror and types of mirrors

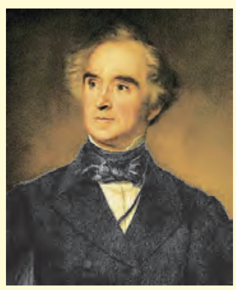
Can you tell? What is a mirror?

We need polished surfaces for reflecting light. This is because polished surfaces absorb less light and so maximum light gets reflected.

In scientific language, a surface which reflects light and creates clear images is called a mirror. A mirror is a reflecting surface.

We use various types of mirrors in our daily life. Mirrors are of two types: plane mirrors and spherical mirrors.

An introduction to scientists



The German scientist Justus von Liebig coated the plane surface of a piece of ordinary glass with silver metal and made the first mirror. Such a mirror is called a silvered glass mirror.

Plane mirror – Plane mirrors are used in various activities in our day to day life. A mirror is made by coating the back surface of a flat and smooth glass piece with a thin, reflecting film of aluminium or silver. To protect this reflecting film and to make that side opaque, another coat of a substance like lead oxide is given over it.

10.1 Plane mirror

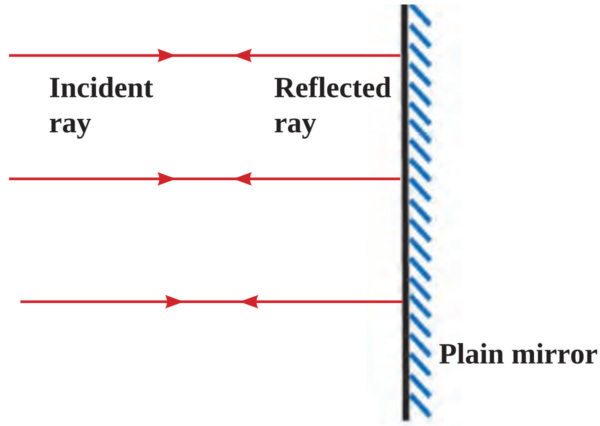
Can you recall? What are the laws of reflection of light?

We see a clear image of ourselves when we stand in front of a mirror in our house. To understand how an image is formed in a mirror let us first consider an image formed by a point source. Light rays travel in all directions from such a source. Several of these rays fall on the mirror, get reflected and reach our eyes. Due to reflection, they appear to be coming from a point behind the mirror. That point is the image of the point source.

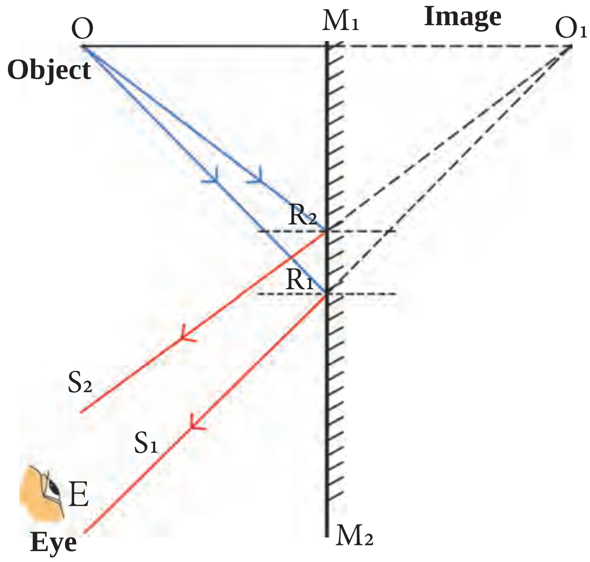
As figure 11.2 A shows, light rays falling perpendicularly on the mirror are reflected back in the perpendicular direction.

Figure 11.2 B shows a point source O in front of the plane mirror M_1M_2. Incident rays OR_1 and OR_2 get reflected according to the laws of reflection along paths R_1S_1 and R_2S_2 respectively. When these reflected rays are extended behind the mirror, they meet at O_1. When seen from E, the rays appear to be coming from O_1. Other rays starting from O also get reflected and appear to be coming from O_1. Thus, point O_1 is the image of point O. **The reflected rays do not actually meet. Hence, such an image is called a virtual image. The perpendicular distance of the image from the mirror is equal to the perpendicular distance of the source from the mirror.**

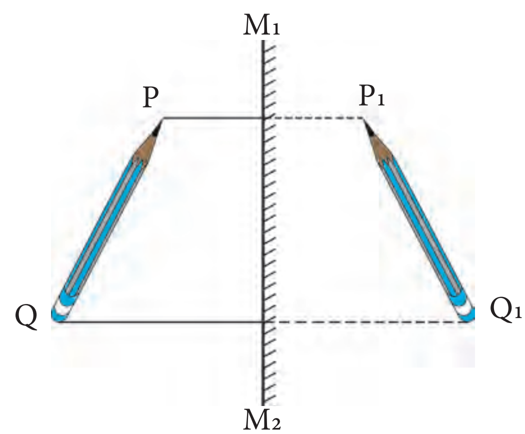
If we use an extended source instead of a point source, an image is formed of every point of the source, thereby forming an extended image of the whole source. As shown in figure 11.2 C, an extended source PQ is kept in front of the mirror M_1M_2. The images of P and Q are formed at P_1 and Q_1 respectively. Similarly, images of all points between P and Q are formed between P_1 and Q_1 resulting in the image P_1Q_1 of the entire extended source.
The image formed by a plane mirror is of the same size as the source.



A. Rays falling on a mirror normal to its surface



B. Image of a point source formed by a mirror



C. Image of an extended source formed by a mirror

11.2 Formation of images by a mirror

Can you tell?

1. If we hold a page of a book in front of a mirror, we see laterally inverted letters in the mirror. Why does it happen?
2. Which letters of the English alphabet form images that look the same as the original letters?

The image of a word appears laterally inverted in the mirror. The image of every point on the word is formed behind the mirror at the same distance from the mirror as the point itself. This is called lateral inversion.

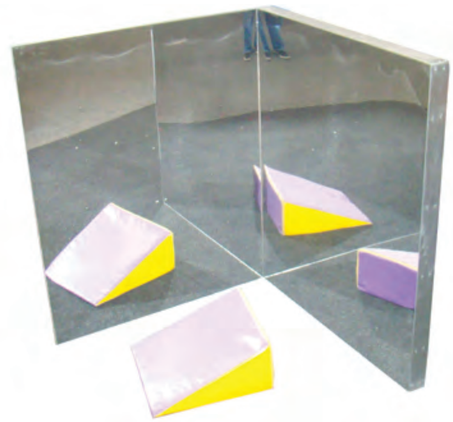
Use your brain power !

When a person stands in front a plane mirror, how is the image formed? What is the nature of the image?

Try this

Place two plane mirrors at an angle of 90^0 to each other. Place a small object between them. Images will be formed in both mirrors. How many images do you see?

Now change the angle between the mirrors as given in the following table and count the number of images each time. How is this number related to the measure of the angle? Discuss this relationship.



11.3 Mirrors at right angles to each other

Angle	Number of images
120°	
90°	
60°	
45°	
30°	

$$n = \frac{360^0}{A} - 1$$

n = number of images, A = angle between the mirrors

1. Check if the number of images that you obtained for different values of angles is consistent with the above formula.
2. If we keep the mirrors parallel to each other, how many images will we see?

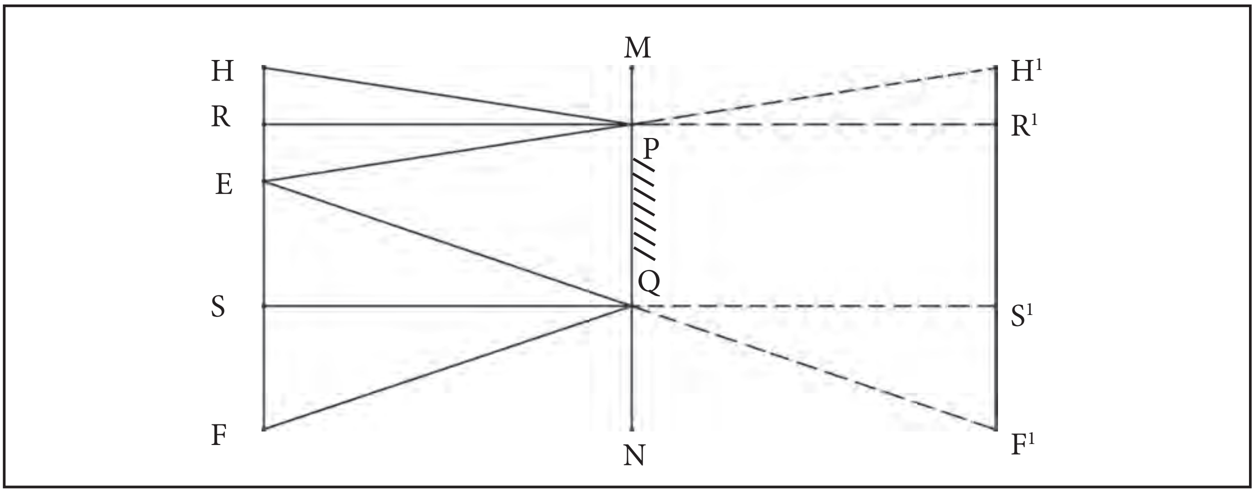
Statement: **In order to see the full image of a person standing in front of a mirror, the minimum height of the mirror must be half the height of the person.**

Proof : In figure 11.4, the point at the top of the head, the eyes and a point at the feet of a person are indicated by H, E and F respectively. R and S are midpoints of HE and EF respectively. The mirror PQ is at a height of NQ from the ground and is perpendicular to it. PQ is the minimum height of the mirror in order to obtain the full image of the person. For this, RP and SQ must be perpendicular to the mirror. Find out why, by studying the figure 11.4.

Minimum height of the mirror

PQ = RS

$$= RE + ES = \frac{HE}{2} + \frac{EF}{2} = \frac{HF}{2} = \text{Half of the person's height}$$



11.4 A plane mirror and the full image of a person

Spherical mirrors

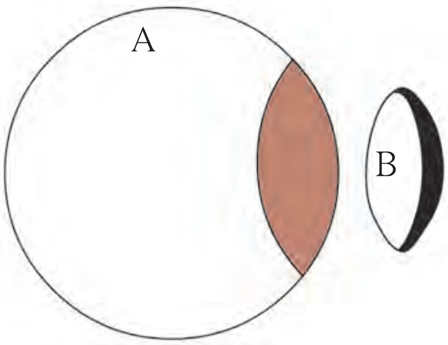
Observe and discuss.

11.5 Laughing Chamber

You must have seen the mirrors displayed in the Laughing Chamber in a fair. Your face appears distorted in these mirrors. Why does this happen? These mirrors are different from the mirrors we have at home. They are curved. The images formed by curved mirrors are different from those formed by plane mirrors. Because of this we do not see the familiar images in these mirrors.

The rear view mirrors in cars, which enable drivers to see the vehicles coming from behind, are curved mirrors.

Try this



11. 6 Creation of spherical mirrors

If we cut a rubber ball into two parts as shown in figure 11.6, we can see that each of the two parts has two types of surfaces.

Generally, spherical mirrors are parts of a hollow glass sphere like the part B in the figure. The inner or outer surface of this part is coated with a shiny substance to produce a spherical mirror. Reflection of light takes place either from its outer or inner surface. Thus, there are two types of spherical mirrors as described below.

A. Concave mirror

If the inner surface of the spherical mirror is the reflecting surface, then it is called a concave mirror.

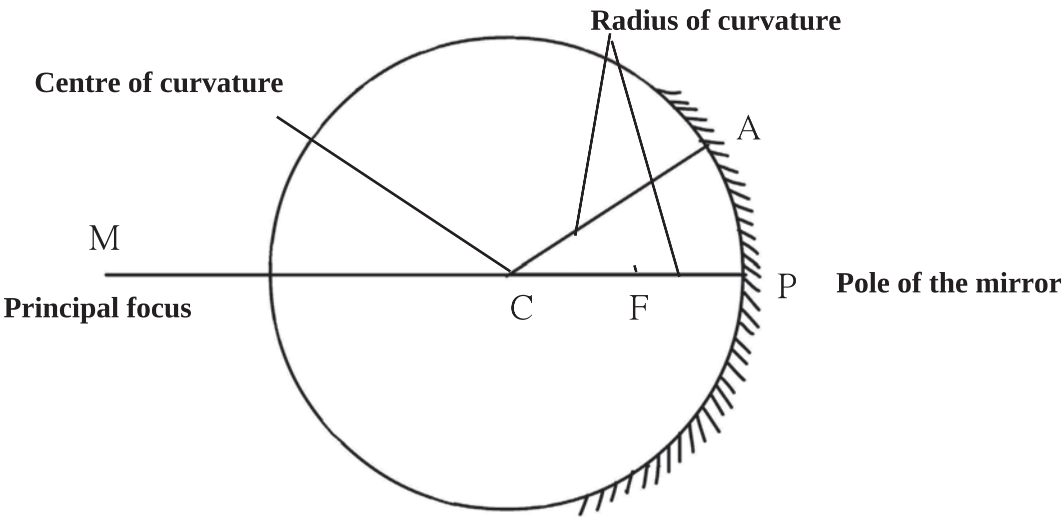
B. Convex mirror

If the outer surface of the spherical mirror is the reflecting surface then it is called a convex mirror.

Terms related to spherical mirrors

Pole : The centre of the mirror surface is called its pole. P is the pole of the mirror in figure 11.7.

Centre of curvature : The centre of the sphere of which the mirror is a part, is called the centre of curvature of the mirror. C is the centre of curvature of the mirror in the figure.



11.7 Terms related to spherical mirrors

Radius of curvature : The radius of the sphere of which the mirror is a part, is called the radius of curvature of the mirror. The length CP or CA in the figure is the radius of curvature of the mirror.

Principal axis : The straight line passing through the pole and centre of curvature of the mirror is called its principal axis. PM is the principal axis of the mirror in the figure.

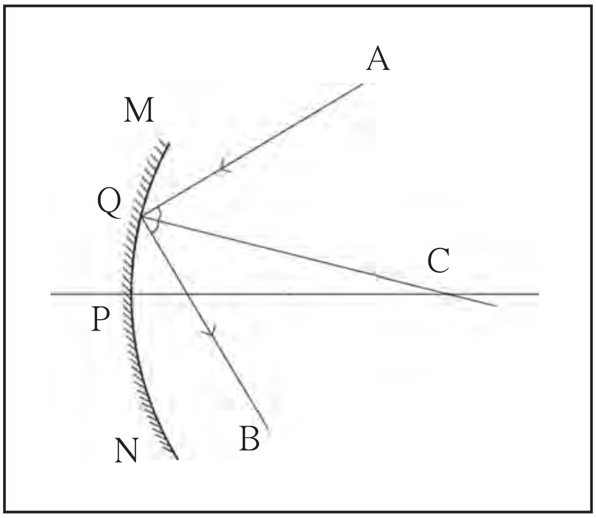
Principal focus : Incident rays which are parallel to the principal axis of a concave mirror, after reflection from the mirror, meet at a particular point in front of the mirror on the principal axis. This point (F) is called the principal focus of the concave mirror. In the case of a convex mirror, incident rays parallel to the principal axis, after reflection, appear to come from a particular point behind the mirror lying along the principal axis. This point is called the principal focus of the convex mirror.

Focal length : The distance (f) between the pole and the principal focus of the mirror is called the focal length. This distance is half of the radius of curvature of the mirror.

Use your brain power ! What is the difference between the principal focus of the concave and convex mirrors?

Drawing the reflected rays

Try this



11.8 **Drawing the reflected rays.**

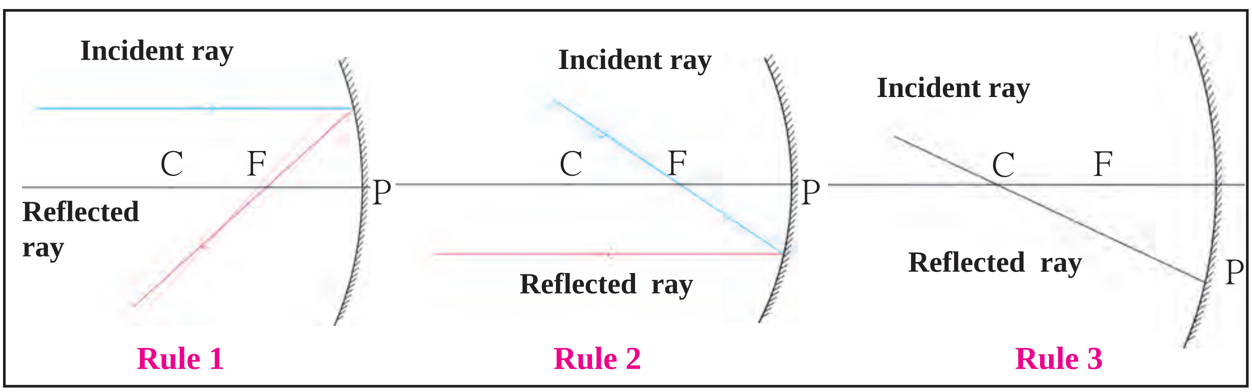
How do we determine the direction that an incident ray will take after reflection from a spherical mirror? In figure 11.8, MN is a spherical mirror and ray AQ is incident on it. CQ is a radius and therefore is perpendicular to the mirror at Q. Thus, angle AQC is the angle of incidence. According to the laws of reflection, angle of incidence and angle of reflection are of the same measure. Thus, while drawing the reflected ray QB, angle CQB must be equal to the angle AQC.

We can study the images produced by spherical mirrors by drawing ray diagrams. A ray diagram is the depiction of the path taken by light rays. To draw a ray diagram, we use the following rules, which are based on the laws of reflection of light. (See figure 11.9).

Rule 1 : If an incident ray is parallel to the principal axis then the reflected ray passes through the principal focus.

Rule 2 : If an incident ray passes through the principal focus of the mirror, the reflected ray is parallel to the principal axis.

Rule 3 : If an incident ray passes through the centre of curvature of the mirror, the reflected ray traces the same path back.



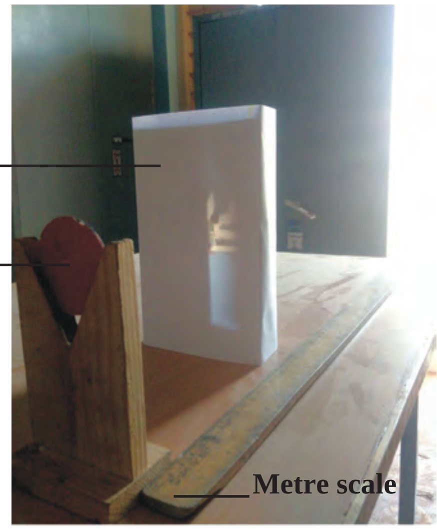
11.9 Rules for drawing ray diagrams

Images formed by a concave mirror

Try this

Material : Candle or glass lamp, two cardboard boxes, large cardboard sheet, white paper, concave mirror, metre ruler, wooden block.

Action : Take the cardboard box, large enough to hold the candle or lamp. Cut off one side and place the candle inside. Cut out an arrow shaped slit from one side, so that we get an arrow shaped light source. Make a screen of size 20 cm x30 cm by sticking a white paper on the cardboard sheet and set it up vertically with the help of the wooden block. Fix the mirror vertically on the other cardboard box by making a slit on its top surface.



11.10 Images formed by a plane mirror

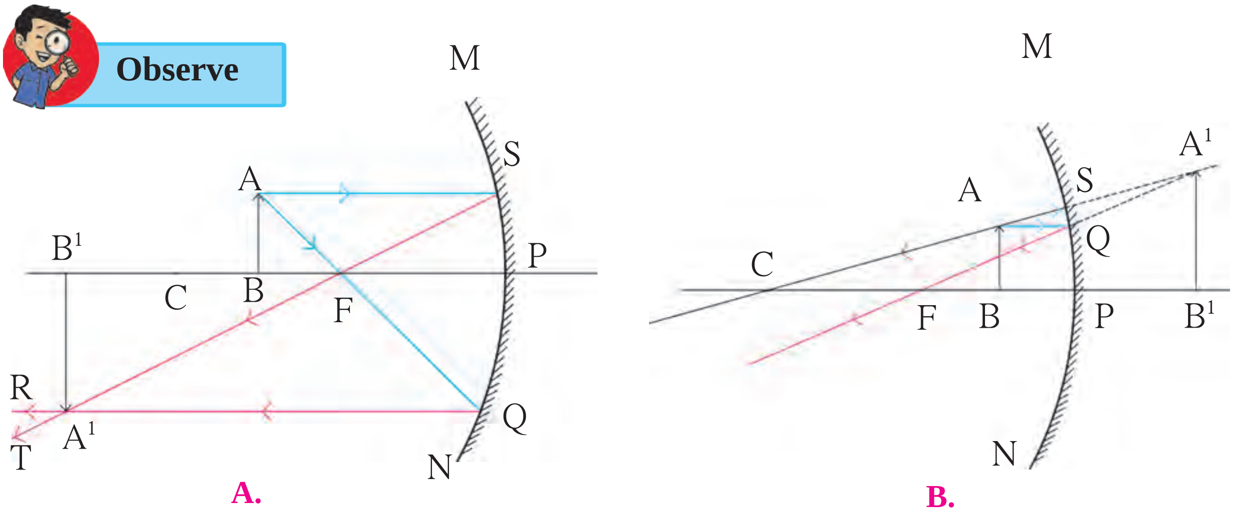
Place the screen near a window and place the mirror in front of it such that the image of the sun or some far away object forms clearly on the screen. Measure the distance between the screen and the mirror in this situation. This is the focal length of the mirror.

Set up the experiment as shown in figure 11.10, in a dark room. Place the mirror near the 0 mark on the metre scale. Place the screen in front of it and place the light source in between the two so that the distance between the mirror and the source is a little more than the focal length of the mirror.

Obtain a clear image of the source on the screen by moving the screen along the metre scale and perpendicular to it. The image will be inverted and larger than the source. As the image is obtained on the screen, it is a real image.

Now move the source away from the mirror so that the distance between the two is greater than twice the focal length of the mirror. Get a clear image on the screen by moving it towards the mirror. The image is inverted, smaller than the object and real.

Observe



11.11 Images obtained in a concave mirror

As shown in figure 11.11 A, an object AB is placed between the focus and the centre of curvature of the concave mirror MN. The incident ray AQ, starting from A, and going through the focus F, becomes parallel to the principal axis after reflection and returns along QR. The incident ray AS, parallel to the axis, after reflection passes through the focus and returns along the path ST. It cuts the reflected ray QR at point A^1. Thus, the image of A is formed at A^1. The point B is situated on the principal axis and so its image will also be on the axis and will be directly above A^1. Thus the image of B is at B^1. The images of points between A^1 and B^1 will be formed between points A^1 and B^1. Thus, the image of object AB is A^1B^1.

From this we see that when the object is placed between the focus and the centre of curvature of the mirror, the image is formed beyond the centre of curvature. This image is larger than the object and is inverted. As the reflected rays actually cross each other, the image is a real image and can be obtained on a screen.

In figure 11.11 B, an object AB is placed between the pole and focus of the mirror. The incident ray AQ is parallel to the principal axis and the incident ray AS is in the direction joining A with the centre of curvature. The figure shows how these rays get reflected and form the image A^1B^1 of the object. This image is behind the mirror, erect and larger than the object. As the reflected rays do not actually meet but appear to come together behind the mirror, the image is a virtual image.

The position and type of the image produced by a concave mirror when an object is placed at different distances from it are given in the following table.

Images formed by concave mirrors

No.	Position of the object	Position of the image	Nature of image	Size of the image
1	Between pole and focus	Behind the mirror	Erect, virtual	Magnified
2	At the focus	At infinity	Inverted, real	Very large
3	Between focus and centre of curvature	Beyond the centre of curvature	Inverted, real	Magnified
4	At the centre of curvature	At the centre of curvature	Inverted, real	Same as the object
5	Beyond the centre of curvature	Between the centre of curvature and focus	Inverted, real	Diminished
6	At a very large (infinite) distance	At focus	Inverted, real	Point image

Website for more information www.physicsclassroom.com

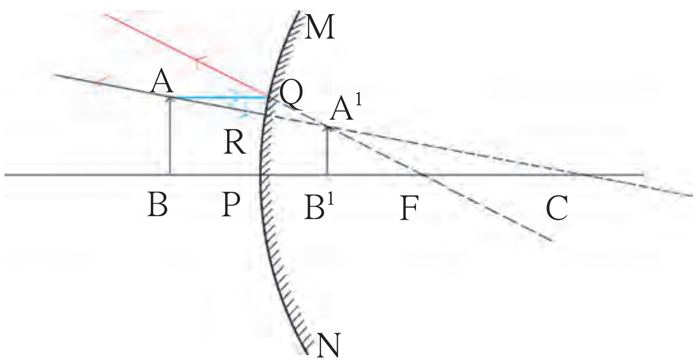
Try this

Draw ray diagrams and determine the position and type of images formed by a concave mirror when the object is placed at (1) Focus (2) Centre of curvature (3) Beyond the centre of curvature and (4) At an infinite distance. Tally your answers with the information given in the table.

Image formed by a convex mirror

Figure 11.12 shows an object AB kept in front of a convex mirror MN. Incident rays AQ, starting from A and travelling parallel to the axis and AR going towards the centre of curvature are shown. How these get reflected and form the image A^1B^1 can be understood from the figure. It is clear that the image is smaller than the object, behind the mirror and erect. As the reflected rays do not actually cross one another, the image is a virtual image.

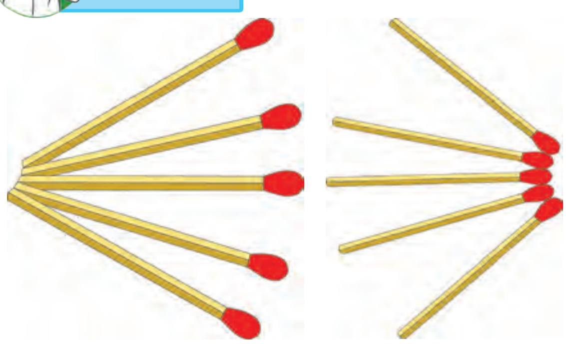
The nature of the image formed by a convex mirror does not depend on the distance of the object from the mirror. These images are always virtual, smaller than the object and situated behind the mirror.



11.12 Image formed in a convex mirror

Divergence and convergence of light

Try this



11.13 Divergence and convergence

A. Take 5 sticks from a matchbox. Arrange them so that their heads come together at a point. In this arrangement, the heads of the matchsticks are said to have converged.

B. Now arrange the sticks so that their uncoated ends are together at a point. The heads are spread apart. In this arrangement, the heads are diverging from the point.

A concave mirror is also called a focusing mirror. This is because, as shown in figure 11.14 A, parallel rays get focused after reflection in this mirror. The size of the image produced by these mirrors can be larger or smaller than the object, depending upon the distance of the object from the mirror.

A convex mirror is also called a dispersing mirror. This is because, as shown in figure 11.14 B, parallel incident rays get dispersed after reflection in this mirror. The size of the images produced by these mirrors is always smaller than the size of the objects.

How will you find out if a mirror is concave or convex?

The special mirror which is used for shaving is a concave mirror. When held close to the face, it gives vertical and larger image of the face. If the same mirror is taken farther away from the face, the image gets smaller and smaller.

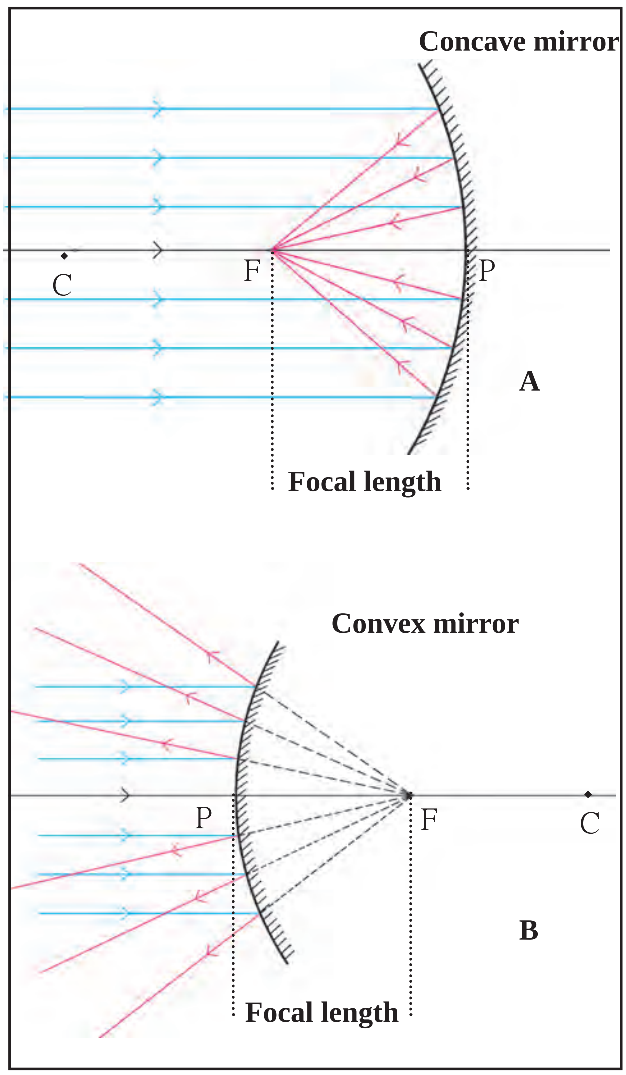
The mirrors used in cars and motorcycles are convex mirrors. In these mirrors the image of a face is erect and smaller and it remains erect but becomes smaller and smaller when the mirror is taken away from the face. As a result we can see the images of the surroundings also in the mirror. Thus, we can determine the nature of the mirror by studying the images produced by them.

When the light rays coming from an object enter our eyes, we can see the object because, while passing through the lenses in our eyes, the rays converge, and the image of the object forms on the retina of our eye. This image, formed by the light rays actually converging at a point, is a real image. A real image can be obtained on a screen.

The image produced by a plane mirror is a virtual image. This image is produced at a point from which the reflected light rays appear to diverge (figure 11.2 B). This image cannot be obtained on a screen as the rays do not actually meet there.

When light rays collect at a point after reflection from a spherical mirror, they are said to converge there. When we want to bring light rays together at a point, a converging light beam is used. Doctors use such a beam to converge light on a tooth, ear, nose, etc. Equipment using solar energy also use converging light.

When light rays starting from a point spread out after reflection by a spherical mirror, light is said to have diverged. When we want light rays to spread out from a source, a divergent beam is used, as for example, in street lamps.



11.14 Concave and convex mirror

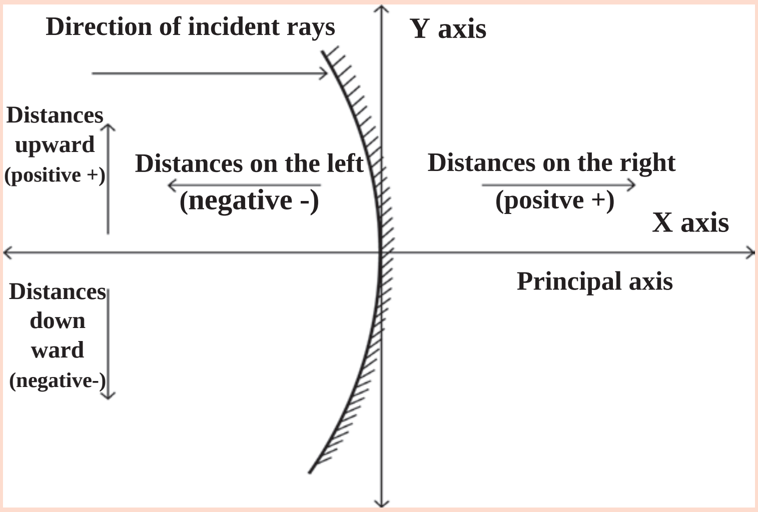
Uses of concave mirrors

1. Barber shop, dental hospital – If the object is placed between the pole and focus of the mirror, an erect, virtual and magnified image is obtained
2. Torch and head lamps of vehicles- The source of light is kept at the focus of the mirror. Thus, a parallel beam of light is obtained.
3. Flood lights- The source of light is placed a little beyond the centre of curvature of the mirror. This gives a bright beam of light.
4. Various equipment using solar energy - Sun rays reflected by a concave mirror come together in the focal plane.

Uses of convex mirrors

1. Mirrors on the sides of cars are convex mirrors
2. Big convex mirrors are fitted at gate and in square.

According to the Cartesian sign convention, the pole of the mirror is taken as the origin. The principal axis is taken as the X- axis of the frame of reference. The sign conventions are as follows.



11.15 Cartesian sign conventions

1. The object is always kept on the left of the mirror. All distances parallel to the principal axis are measured from the pole of the mirror.
2. All distances measured towards the right of the pole are taken to be positive, while those measured towards the left are taken to be negative.
3. Distances measured vertically upwards from the principal axis are taken to be positive.
4. Distances measured vertically downwards from the principal axis are taken to be negative.
5. The focal length of a concave mirror is negative while that of a convex mirror is positive.

Mirror formula

We get the correct values of distances by using the Cartesian sign convention. The object distance (u) is the distance of the object from the pole, while the image distance (v) is the distance of the image from the pole. The relationship between the object distance, image distance and the focal length (f) is called the mirror formula.

Mirror formula

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

This formula is valid for all spherical mirrors, for all positions of objects, under all circumstances.

Magnification due to spherical mirrors

The magnification due to a spherical mirror is given by the ratio of the height of the image (h_2) to the height of the object (h_1). This tells us how large the image is as compared to the object.

Magnifiction M $= \dfrac{\text{Height of the image}}{\text{Height of the object}} = \dfrac{h_2}{h_1}$. From this it can be shown that $M = -\dfrac{v}{u}$

As the object is always kept above the principal axis, its height is always taken to be positive. For virtual images, the height is positive while for real images, it is negative. As the object is kept on the left of the mirror, its distance (u) is always negative.

Try this

Determine the sign of magnification in each of the 6 cases in the table on page 122 using both formulae and verify that they are the same.

Solved examples

Example : Rajashree wants to get an inverted image of height 5 cm of an object kept at a distance of 30 cm from a concave mirror. The focal length of the mirror is 10 cm. At what distance from the mirror should she place the screen ? What will be the type of the image, and what is the height of the object?

Given :

Focal length = f = - 10 cm, object distance = u = - 30 cm ,
height of the image = h_2 = -5 cm
Image distance = v = ?, height of object = h_1 = ?

775XTD

According to the mirror formula

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

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

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

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

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

$$\frac{1}{v} = \frac{1}{-15} \text{ cm}$$

$$v = -15$$

Rajashree has to place the screen 15 cm to the left of the mirror.

Magnification

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

$$h_1 = -\frac{uh_2}{v}$$

$$h_1 = -\frac{(-30)(-5)}{-15}$$

$$h_1 = (-2)(-5)$$

$$h_1 = 10 \text{ cm}$$

The height of the object is 10 cm. Thus, the image will be real and diminshed.

Always remember

The image in front of the mirror which can be obtained on a screen is called a real image. For any position of the object, a convex mirror always produces an erect diminished image (which is smaller than the object) and is situated behind the mirror. The image which is behind the mirror and thus cannot be obtained on a screen is called a virtual image. The magnification of such an image is less than 1.

Exercises

1. Answer the following questions.

a. Explain the difference between a plane mirror, a concave mirror and a convex mirror with respect to the type and size of the images produced.

b. Describe the positions of the source of light with respect to a concave mirror in 1.Torch light
2. Projector lamp 3. Floodlight

c. Why are concave mirrors used in solar devices?

d. Why are the mirrors fitted on the outside of cars convex?

e. Why does obtaining the image of the sun on a paper with the help of a concave mirror burn the paper?

f. If a spherical mirror breaks, what type of mirrors are the individual pieces?

2. What sign conventions are used for reflection from a spherical mirror?

3. Draw ray diagrams for the cases of images obtained in concave mirrors as described in the table on page 122.

4. Which type of mirrors are used in the following?

Periscope, floodlights, shaving mirror, kaleidoscope, street lights, head lamps of a car.

5. Solve the following examples

a. An object of height 7 cm is kept at a distance of 25 cm in front of a concave mirror. The focal length of the mirror is 15 cm. At what distance from the mirror should a screen be kept so as to get a clear image? What will be the size and nature of the image? **(Answer: 37.5 cm and 10.5 cm. Image is real)**

b. A convex mirror has a focal length of 18 cm. The image of an object kept in front of the mirror is half the height of the object. What is the distance of the object from the mirror?

(Answer: 18 cm)

c. A 10 cm long stick is kept in front of a concave mirror having focal length of 10 cm in such a way that the end of the stick closest to the pole is at a distance of 20 cm. What will be the length of the image?

(Answer: 10 cm)

6. Three mirrors are created from a single sphere. Which of the following - pole, centre of curvature, radius of curvature, principal axis - will be common to them and which will not be common?

Project :

Make a kaleidoscope and make a presentation in the class about how it works.

◈◈◈