6

Reflection of Light — Plane Mirrors

SYLLABUS

1. Images formed by a plane mirror – their properties : same size as object, as far behind the mirror as the object is in front, lateral inversion.
   - Exploring the properties of images formed in a plane mirror using a mirror strip, a ruler and a small doll or paper-cut-out or other suitable object (E).
2. (a) The Laws of Reflection – definitions of incident and reflected rays, normal at the point of incidence, incident and reflected angles.
   (b) Regular and diffuse reflection.
3. Drawing a ray diagram for an image formed by a plane mirror.
   (a) Understanding the difference between real and virtual images.
   (b) The image formed by a plane mirror is also a virtual image.

We all have seen mirrors. We use them in our homes, shops, cars, *etc*. When you get ready to go to your school or a party, you stand in front of a mirror to see yourself. You can also see your image on the surface of a pond, in a water tank, polished steel utensils, *etc*.

When we hold a mirror in sunlight, we see a bright patch of light on the wall opposite to the mirror. This is due to the reflection of light (sunlight) by the mirror.

The reflection of light can thus be defined as **the bouncing of light after striking a surface**.

Let us see what happens when light falls on an object.

1. The object may allow the light to pass through it.
2. The object may completely absorb the light and stop it from passing through it.
3. It may scatter the light.
4. It may reflect the light incident on it.

Whether the light falling on a surface will completely reflect or not depends on the material and nature of the surface on which it falls.

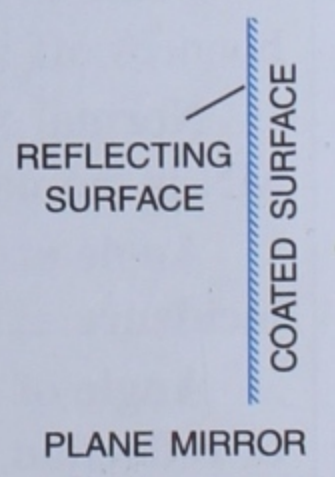
A translucent surface allows some light to pass through it, absorbs some light and reflects the rest.

A smooth and polished surface like that of stainless steel or a mirror reflects almost all the light and absorbs almost a negligible amount of light.

A *transparent* object reflects a very little amount of light and allows most of the light to pass through it.

MIRRORS

A straight (without any curve), highly polished, smooth and reflecting surface is known as a **plane mirror**. To make a mirror, a thin and uniform glass



is taken. One surface of the mirror is made opaque by silvering it. Over the silvered surface, another thin coating of red lead oxide is given which protects the silvering of the mirror. Mirrors in general are of two types :

(i) Plane mirrors (ii) Spherical mirrors.

The best mirror or an ideal mirror should have the following features :

1. It should not absorb any light.
2. There should be no refraction.
3. It should reflect all the colours and give maximum reflection.

This is achieved by —

1. A smooth surface for a neat and clean image. That is why a thin uniform glass sheet is used in a mirror.
2. A shiny surface for reducing refraction. That is why silvering is used in a mirror.
3. A red paint for protecting the silver coat.

Smooth Surfaces Cause Regular Reflection

Take a small plane mirror, a highly polished brass plate and a book.

Let the rays of the sun fall on a mirror. Now turn the mirror through various angles, such that the light of the sun striking the mirror falls on the wall. You will find that as the angle of mirror is changed, the position of light on the wall also changes. Thus, we observe that the plane mirror reflects light. When we repeat the process with the brass plate, it also shows the same observation but the patch is found to be less bright. If the process is repeated by holding the book in sunlight, we see that no light patch is formed on the wall. This is due to the reason that (i) the book is an opaque object and (ii) that the surface of the book

Terms Related to Reflection

Consider Fig. 6.1 in which a light ray is shown to fall on a mirror so that it may reflect.

Reflecting surface : The light rays striking a surface get reflected. This surface is called the **reflecting surface.** In Fig. 6.1, AB is the reflecting surface.

Incident ray : The ray of light falling on the surface AB is called the incident ray. Here, PN is the incident ray.

Reflected ray : The incident ray bouncing back to the same medium after striking the reflecting surface is called the reflected ray. NQ is the reflected ray.

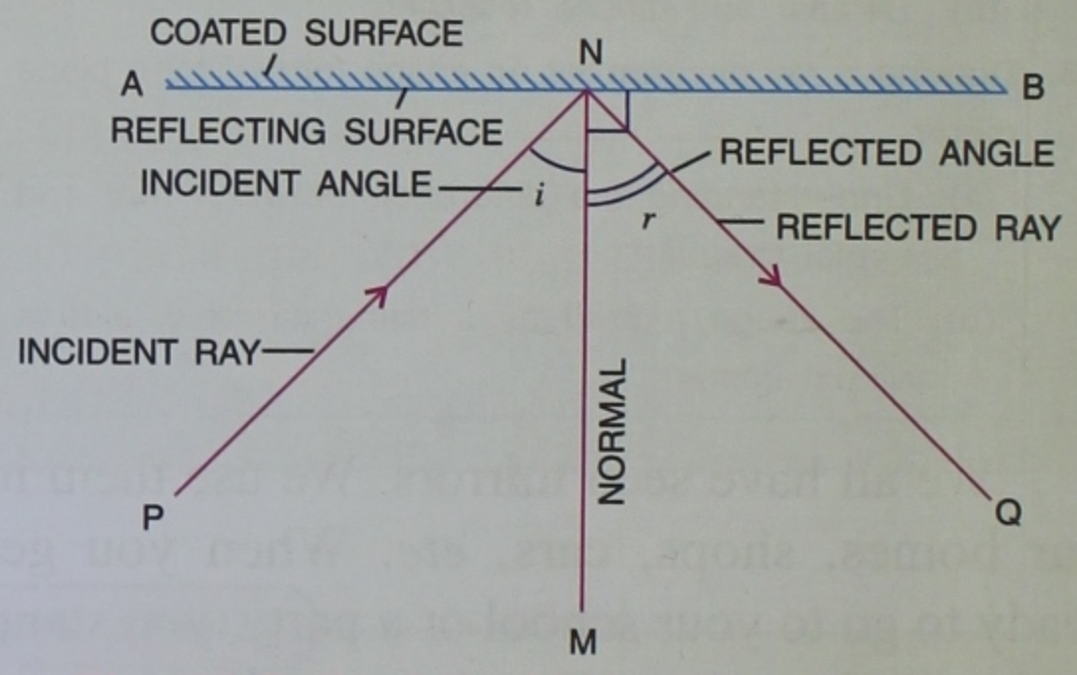


Fig. 6.1 Reflection of light on a plane mirror

Point of incidence : The point on the mirror surface, where incident ray strikes or the reflected ray bounces off is called the point of incidence. Here, N is the point of incidence.

Normal : It is the line drawn perpendicular to the reflecting surface at the point of incidence. Here, MN is the **normal**.

Angle of incidence : The angle formed between the incident ray and the normal is called the **angle of incidence**. ∠PNM is the angle of incidence which is denoted by the letter *i*.

Angle of reflection : The angle formed between the normal and the reflected ray is called the **angle of reflection**. ∠MNQ is the angle of reflection which is denoted by the letter *r*.

is rough, so light rays bouncing from it move in various directions and no light patch is formed.

TYPES OF REFLECTION

There are *two* types of surfaces (i) regular and (ii) irregular or diffused surface. Similarly, depending upon the surface, we have two types of reflection (i) regular reflection and (ii) irregular or diffused reflection. Let us study them in detail.

Regular Reflection

When we stand in front of a plane mirror, we see our bright image in it.

If the parallel incident rays are reflected in such a way that all the reflected rays are also parallel to each other, then it is known as *regular reflection*. Regular reflection occurs only if the rays are falling on a highly smooth and polished plane surface like a *plane mirror*. Plane mirror, surface of water at rest, highly polished plane metal sheet, etc., cause regular reflection.

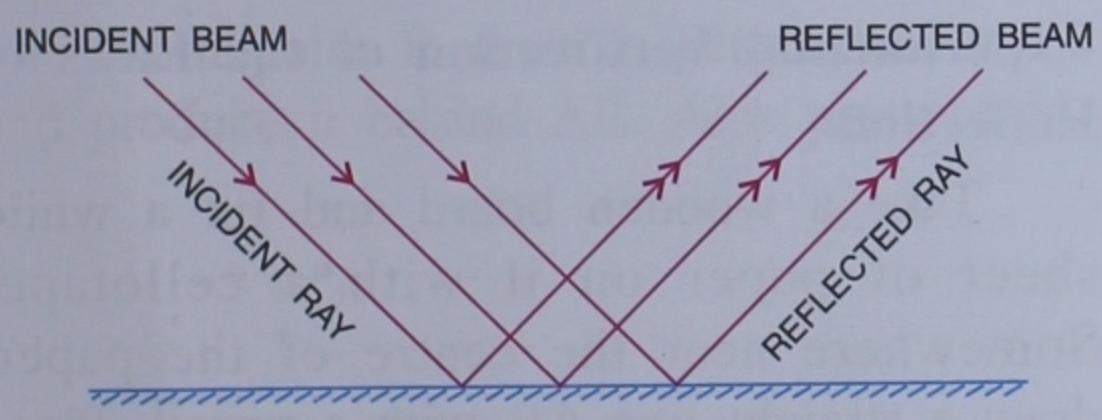


Fig. 6.2 Regular reflection

Irregular Reflection

Irregular reflection occurs when a beam of light falls on a rough surface such as walls of a room, screen of cinema hall, etc. When the surface of a plane mirror is rough, the beam of parallel rays, falling on the mirror surface, does not remain parallel to each other after reflection. Fig. 6.3 shows the irregular reflection from a rough surface.

For example, when we light a bulb or a tube light in a room all the objects kept in the room are visible in that room. The simple reason for this is that, different objects and walls of the room reflect the light rays coming from the bulb/tube light irregularly in all directions.

The diffused rays, after irregular reflection from a rough surface scatter in different directions. This is called an *irregular reflection* or *diffused reflection*.

Thus, if parallel incident rays fall on an irregular surface, then the reflected rays spread in all the directions. Such a reflection is known as an *irregular reflection*. This type of reflection enables us to see the objects around us. Concrete floor, stones, book, walls, cardboards etc. cause irregular reflection.

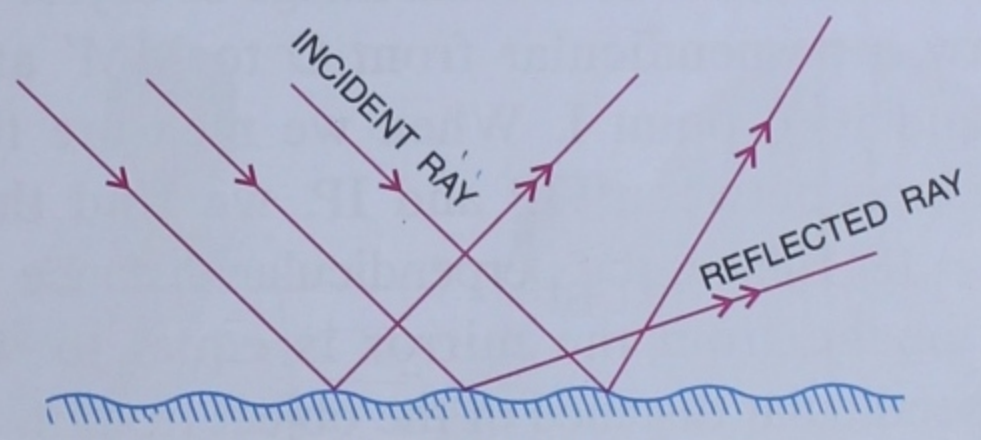


Fig. 6.3 Irregular reflection

Whether the reflection is regular or irregular, in both the cases the laws of reflection are always obeyed.

Formation of Image by a Plane Mirror

Let us see how a plane mirror MM′ forms the image of a point object. In Fig. 6.4, O is the point object placed in front of a plane mirror MM′. From the object O, rays of light travel in all directions. Two rays OA and OB are shown which are reflected as AC and BD respectively from the mirror.

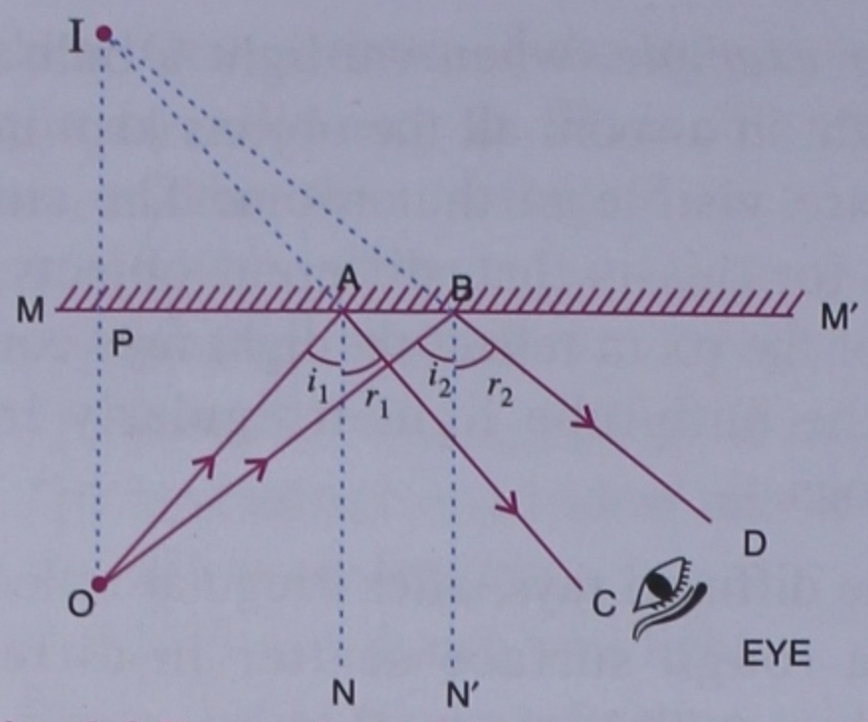


Fig. 6.4 Formation of image of a point object by a plane mirror

The diagram shows that at both the reflections, the angle of incidence and the angle of reflection are equal.

i.e. $\angle i_1 = \angle r_1$ and $\angle i_2 = \angle r_2$

To find out the position of the image, the reflected rays AC and BD are produced backwards. They meet at point I behind the mirror. Thus, I is the virtual image of object O. Draw a perpendicular from O to MM′ and extend it to point I. When we measure the distance between OP and IP, we find that OP = IP. Hence, the perpendicular distance of the image from the mirror is equal to the perpendicular distance of the object from it.

Reflection of light from a reflecting surface takes place according to definite laws. These are known as **laws of reflection**.

Do You Know ?

You can see your friend behind the mirror

Position a mirror at certain distance from yourself and your friend. Adjust the mirror so that you can see the image of your friend in the mirror. Your friend will appear to be standing behind the mirror.

How does it happen? The light from your friend's body falls on the mirror. After suffering reflection, the rays of light enter your eyes. These rays appear to come from a point behind the mirror. That is why you see the image of your friend behind the mirror.

LAWS OF REFLECTION

Reflection is governed by the following *two* laws :

1. The incident ray, the normal at the point of incidence on the reflecting surface and the reflected ray essentially lie in the same plane.

   In Fig. 6.1, PN is the incident ray, NQ is the reflected ray and MN is the normal and N is the point of incidence.

2. When a ray of light falls on a reflecting surface its angle of incidence is always equal to its angle of reflection.

   $\angle i = \angle r$

   In Fig. 6.1, $\angle PNM = \angle QNM$

   In Fig. 6.4, $\angle OAN = \angle CAN$

   and, $\angle OBN' = DBN'$

Experimental Verification of the Laws of Reflection

Take a wooden board and fix a white sheet of paper on it with a cellotape. Somewhere near the centre of the paper, draw a straight line AB with a pencil. Place the long face of the plane mirror along the line AB and hold it in vertical position with plasticene. Fix two common pins P and Q in front of the mirror in an upright position. The distance between the pins should be 4 to 5 cm. Looking from the side B of the plane mirror, as shown in Fig. 6.5, fix two more pins R and S, such that these pins and images of pins P and Q are in the same straight line. Now remove the mirror.

Remove the pins P, Q, R and S one by one and draw small circles around the pinholes. Join PQ and RS and produce them to meet the mirror line AB at O as shown in Fig. 6.6. O is the point of incidence. At O, draw ON perpendicular to mirror surface. Measure the angle of incidence ∠PON and angle of reflection ∠SON. It is found that both the angles are equal.

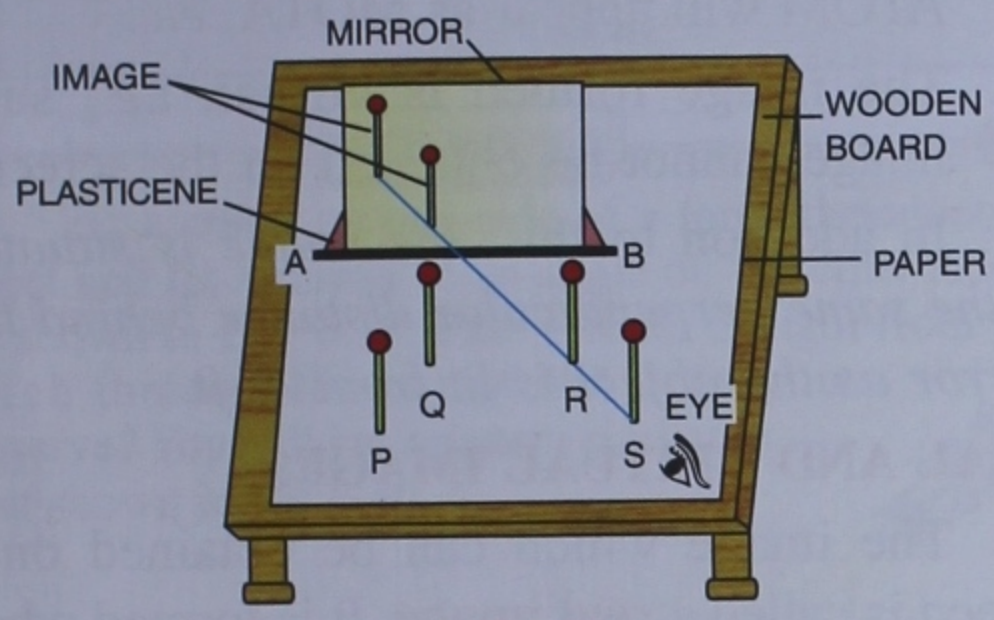


Fig. 6.5

Further, since the incident ray PO, the reflected ray OS and the normal ON lie in the plane of the paper, all the three are also in the same plane.

From point P, draw a perpendicular PL and produce it behind AB. Also produce SO behind AB. The lines produced meet at the point P_1. Thus, P_1 gives the position of image of the pin P (Fig. 6.6).

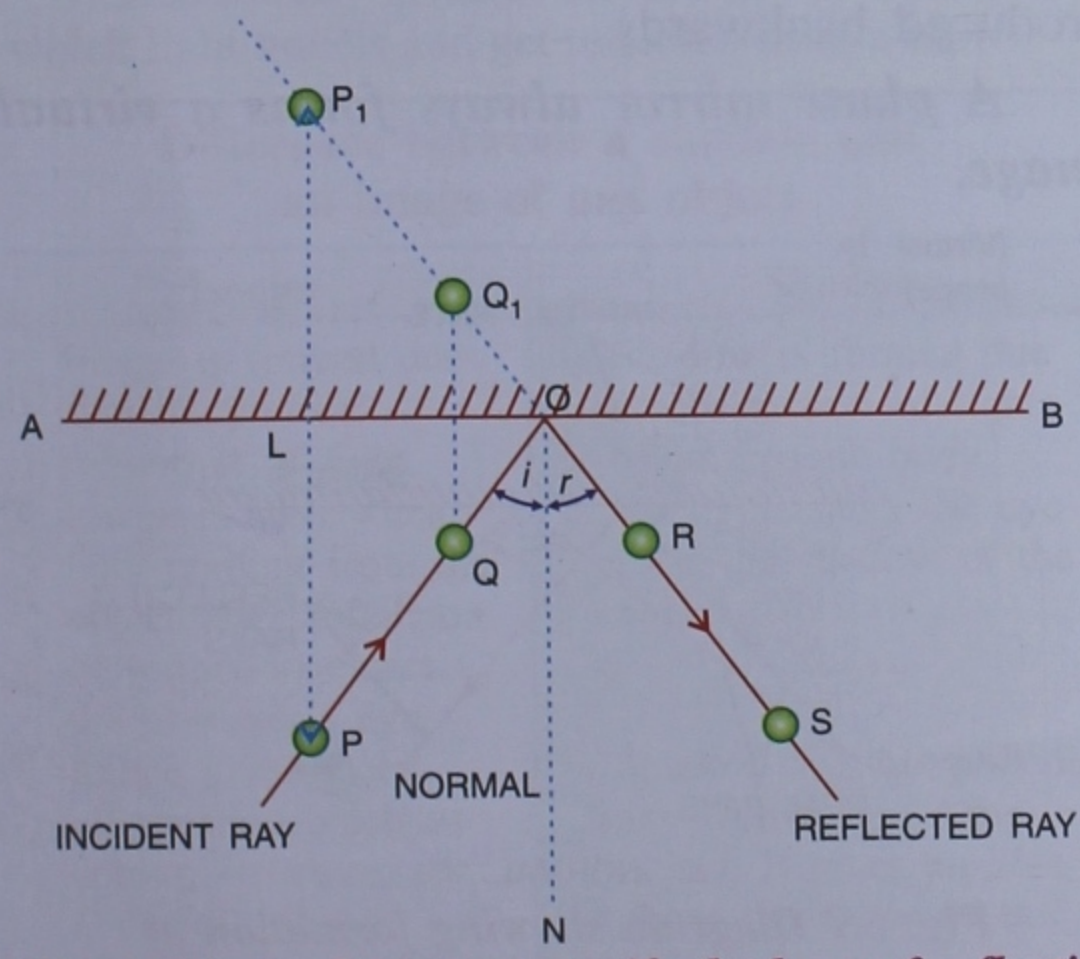


Fig. 6.6 A ray diagram to verify the laws of reflection

Now measure the distance PL and P_1L. It is found that PL = P_1L. This proves that images in a plane mirror are formed as far behind as the objects are in front of it.

LATERAL INVERSION

Take a book in your right hand and stand in front of a plane mirror. What do you observe ? It will appear as if the book is in your left hand. The images formed in a plane mirror are always laterally inverted.

The phenomenon due to which the left side of an object appears to be the right side in its image in a reflecting medium (a mirror) and vice-versa is called *lateral inversion.*

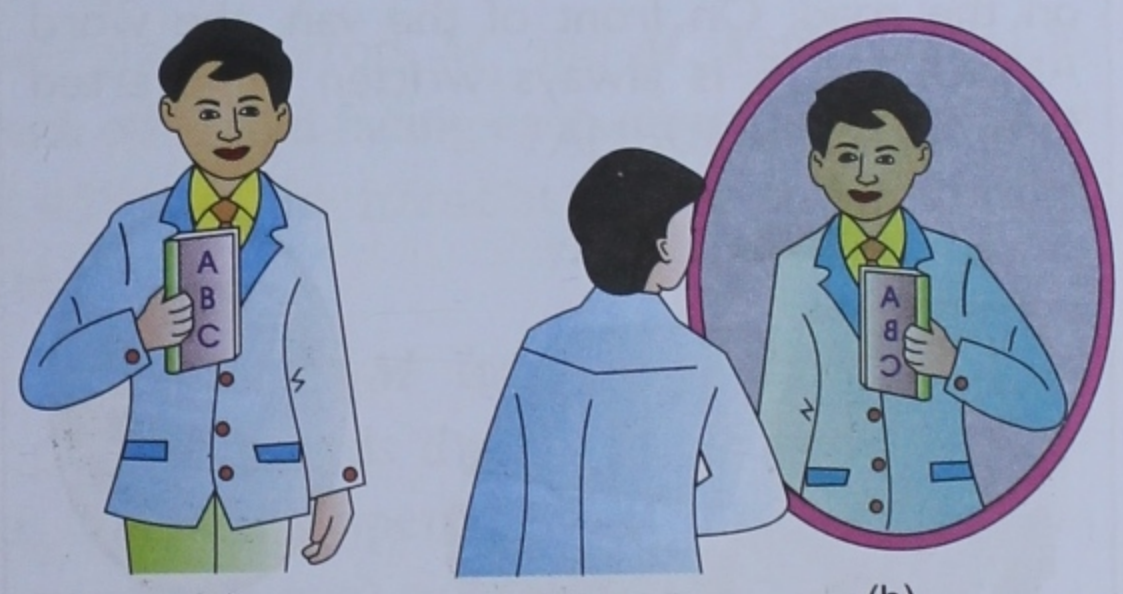


Fig. 6.7

ACTIVITY 1

To observe that an image formed on a plane mirror interchanges sides.

- Stand in front of a looking glass (plane mirror) and observe your image. Also observe the distance between you and your image from the mirror.
- Now raise your left hand and note which hand does your image raise.
- Touch your right ear with your left hand and observe your image. Do you find that in the image, the right hand touches the left ear?

- Write a name for example AMIT on a piece of paper and hold it in front of a plane mirror. Are you able to read it. Now interchange the sides and see what happens?

AMIT | TIMA

TIMA | AMIT

Image formed on a plane mirror interchanges sides, *i.e.* on a plane mirror, left appears right and right appears left.

This interchange of sides between the object and its image is called **lateral inversion**.

Also the image is as far behind the plane mirror as the object is in front of it.

Do You Know ?

A practical application of lateral inversion

You might have seen an ambulance van on the road. On front of the van, the word AMBULANCE is always written in inverted form as ƎCNAJUBMA .

Fig. 6.8 Phenomenon of lateral inversion

Do you know the reason ?

The reason is that when a person is driving a vehicle ahead of the van, on seeing through his rear view mirror, the driver will see the laterally inverted image of the words. Thus, he can see the right image of the words and act accordingly.

CHARACTERISTICS OF IMAGE FORMED BY A PLANE MIRROR

1. The image is of the same size as that of the object.
2. The image formed is erect.
3. The image formed is laterally inverted *i.e.* the right side of the object appears as the left side in the image. *For example*, letter 'B' will appear as 'ꟴ'. The word ATOM will appear as MOTA, *etc.*
4. The image formed is virtual, *i.e.*, such image cannot be obtained on the screen.

In addition to this, *the image is situated at the same perpendicular distance behind the mirror as the object is in front of it.*

REAL AND VIRTUAL IMAGES

The image which can be obtained on a screen is called a **real image**. It is formed when the light rays after reflection actually intersect.

The image which cannot be obtained on a screen is called a **virtual image**. It is formed when the light rays after reflection do not actually intersect, but they appear to diverge from a point inside the mirror. Geometrically, they intersect when they are produced backwards.

A plane mirror always forms a virtual image.

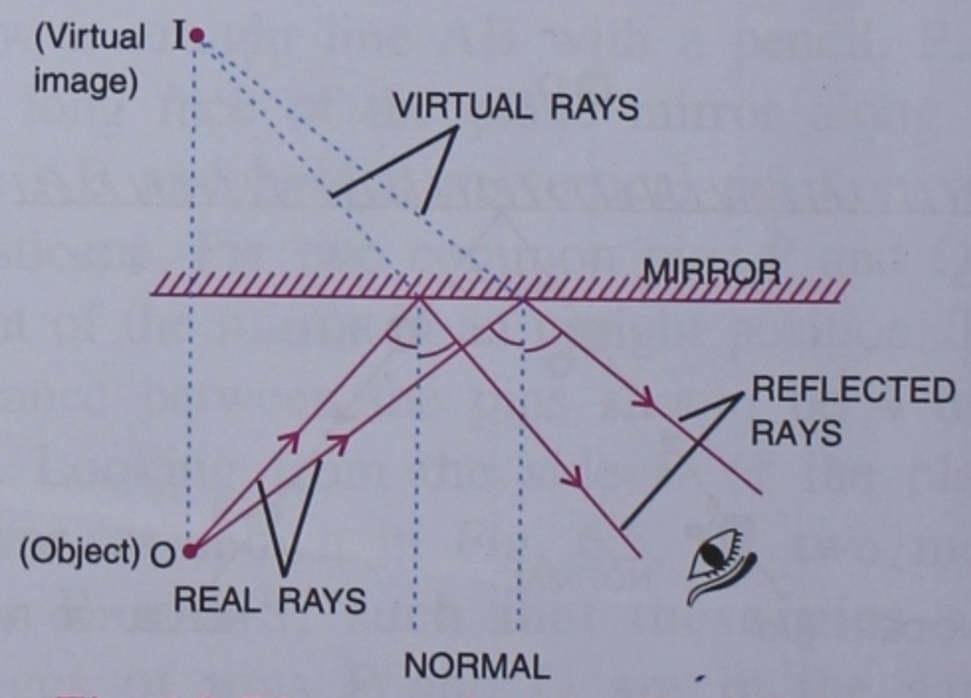


Fig. 6.9 Diagram showing formation of virtual image at the back of the mirror

Table showing differences between real and virtual images

Real image	Virtual image
1. It can be obtained on a screen.	1. It cannot be obtained on a screen.
2. The rays of light after reflection meet at a point.	2. The rays of light after reflection appear to diverge from a point.
3. It is always inverted.	3. It is always erect.
4. It is formed in front of the mirror.	4. It is always formed on the back side of the mirror

ACTIVITY 2

Fix a comb on one side of a large thermocol sheet and fix a mirror at an angle on the other side as shown in Fig. 6.10. Pass a beam of light from a torch through the comb. What do you observe? You will get a pattern similar to that shown in Fig 6.10.

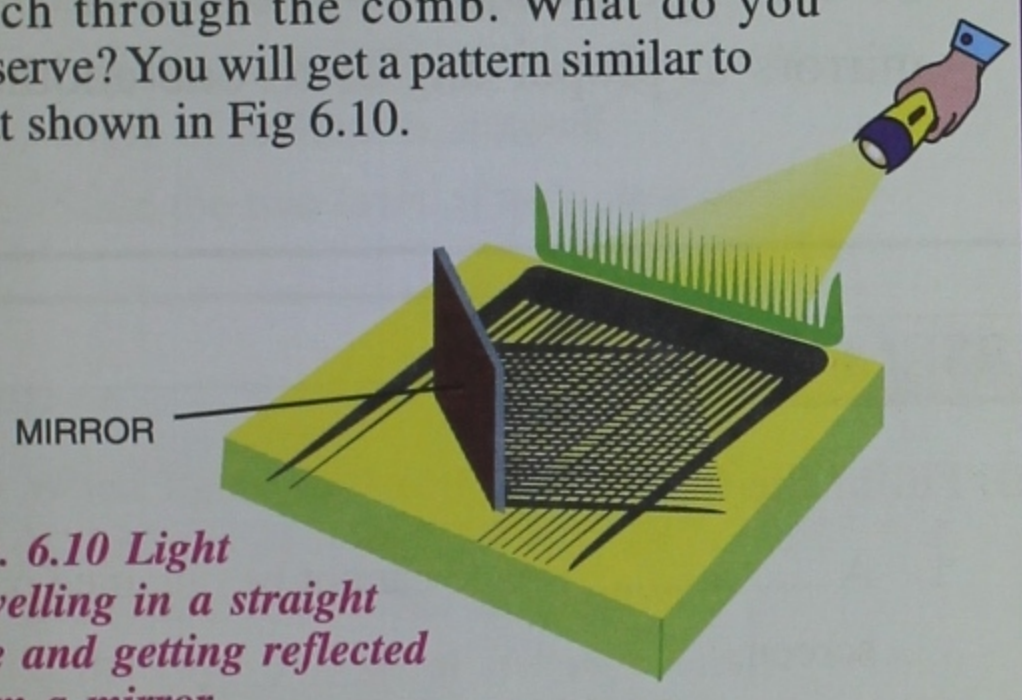


Fig. 6.10 Light travelling in a straight line and getting reflected from a mirror

This activity gives us an idea of the manner in which light travels and get reflected from a mirror.

Difference between a shadow and an image of any object

Image	Shadow
1. Image is formed due to reflection or refraction of light.	1. Shadow is formed due to obstruction of light by an apaque body.
2. Image is seen when light coming from the object after reflection or refraction enters the observer's eye.	2. No light enters the eye from the shadow of the object.
3. Image gives more information, such as colour, structure, *etc.*, about the object.	3. Shadow does not provide any details about the object. It gives an idea about the shape of the object.

Simple periscope

It is an apparatus used for looking over the heads of crowd by raising it above the obstacle, or for observing enemy movements from trenches without being seen. It is also used in submarines for observing the movements of ships.

Periscopes are also used in nuclear reactors and laboratories where scientists use them to observe everything keeping quite safe distance from every danger.

It is based on the principle of reflection at *two* parallel plane mirrors.

It consists of a long cylindrical hollow tube bent at right angles near the ends. The opening X at the top is directed towards the object, keeping the tube vertical. The object is viewed through the opening Y at the bottom. There are two plane mirrors M_1 and M_2 kept parallel to each other and facing each other. They are fixed at 45° with the frame at the top and bottom of the tube.

The mirror M_1 faces the opening X at the top (*i.e.*, towards the object) while the mirror M_2 faces the opening Y at the bottom (*i.e.*, towards the eye) as shown in Fig. 6.11.

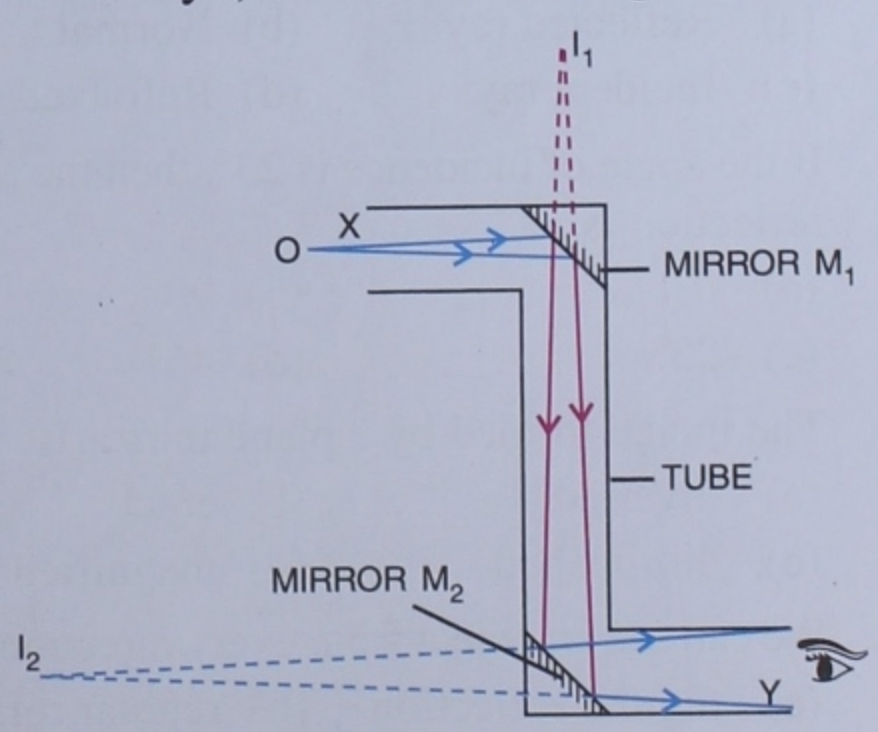


Fig. 6.11 Periscope

Rays of light entering the tube from the object O strike the mirror M_1 at an angle of incidence nearly equal to 45°. These rays are reflected along the axis of the tube striking the mirror M_2 at an angle of incidence nearly equal to 45°. The rays are finally reflected by the mirror M_2 reaching the eye at Y. Thus, the objects which could not be seen due to obstruction, can now be easily seen. The object O forms an image I_1 in the mirror M_1 and this virtual image I_1 forms an image I_2 in the mirror M_2, which is seen by the eye.

ACTIVITY 3

1. Ask your teacher to help you to make periscope.
2. Ask your teacher what is a kaleidoscope. How it can be made ?

Uses of plane mirror

1. As a dressing mirror.
2. In the opticians room to double the effective length of room by keeping a mirror in opposite wall of the room.
3. In barbar's shop for seeing the rear view at the back, two mirror are fixed on the opposite walls facing each other.
4. In periscope, kaleidoscope and solar cooker plane mirrors are used as reflector.
5. They are used for getting multiple images of the same object by keeping plane mirrors at proper angles to one another.

TEST YOURSELF

A. Tick the correct answer :

1. The property due to which a light ray striking a surface is thrown back into the same medium is called
   (a) Refraction (b) Reflex action
   (c) Reflection (d) Regression
2. A ray of light after reflection from a mirror is known as
   (a) Reflected ray (b) Normal
   (c) Incident ray (d) Refracted ray
3. If the angle of incidence is 23°, then the angle of reflection is
   (a) 0° (b) 90°
   (c) 23° (d) 46°
4. The image formed by a plane mirror is
   (a) inverted (b) erect
   (c) diminished (d) magnified
5. We can see an object from every direction due to
   (a) regular reflection (b) regular refraction
   (c) irregular reflection (d) None of these

B. Fill in the blanks :

1. A ..... image cannot be obtained on the screen.
2. A ..... image can be focussed on the screen.
3. An ..... reflection helps us to see an object.
4. The image formed by a plane mirror is ..... inverted.
5. One surface of mirror is made opaque by ..... it, followed by a thin coating of lead oxide paint.
6. The angle formed between the incident ray and the normal is called .....
7. A plane mirror ..... all the light that falls on it.

C. Write true or false :

1. The image formed by a plane mirror is upright.
2. The image of the right hand in a plane mirror looks like a left hand.
3. The image formed by a plane mirror is diminished.
4. Due to irregular reflections, we are able to see objects clearly.
5. The sun and stars are artificial sources of light.
6. The image formed by a plane mirror is real.

D. Answer the following :

1. What do you mean by the term reflection of light ?
2. Explain the following terms :

   Incident ray, reflected ray, angle of incidence, angle of reflection, normal.
3. State the two laws of reflection of light.
4. How is plane mirror made ?
5. How does a plane mirror form the image of an object ?
6. State three characteristics of the image formed by a plane mirror.
7. Draw a labelled diagram to show the formation of an image of a point object placed in front of a plane mirror.
8. Differentiate between :
   (a) Real image and virtual image
   (b) Image and shadow
9. What is lateral inversion? Explain with the help of an example.
10. Write the uses of plane mirrors.
11. Why the word AMBULANCE is written laterally inverted on ambulance vehicle?
12. Find out the letters of English alphabet in which the image formed in a plane mirror appears exactly like the letter itself.

RECAPITULATION

- When light bounces from a smooth polished surface, it is known as reflection.
- If the rays of a parallel beam after reflection remain parallel to each other, then the reflection is known as regular reflection. Regular reflection occurs from polished and smooth plane surfaces.
- If the rays of a parallel beam after reflection does not remain parallel to each other, then the reflection is known as irregular reflection. Irregular reflection occurs from rough and un-even surfaces.
- According to the first law of reflection, the incident ray, the normal at the point of incidence on the reflecting surface and the reflected ray essentially lie in the same plane.
- According to the second law of reflection, the angle of incidence is always equal to the angle of reflection.

KALEIDOSCOPE

A kaleidoscope is an optical device that is cylindrical in shape. Both its ends are closed but one of them has an eye-hole used for looking through into the device.

The device works on the principle of multiple images created by mirrors inclined to each other.

Three or more mirrors run through the entire cylindrical tube. Also there are two plates one of smooth glass while the other of ground glass. The smooth plate is close to the eye-hole. Several pieces of colored beads of glass are placed between the two plates. The images of these beads are formed in the mirrors. When we turn the device, the patterns of these head images change.

This device was developed by Sir David Brawster in 1917 for the designers to guide them for creating new patterns of rugs, wall-paper and fabrics.