# 7 REFLECTION OF LIGHT

**Syllabus :**

*(i) Reflection of light; images formed by a pair of parallel and perpendicular plane mirrors.*

**Scope –** Laws of reflection; experimental verification; characteristics of images formed in a pair of mirrors (a) parallel and (b) perpendicular to each other; uses of plane mirrors.

*(ii) Spherical mirrors; characteristics of image formed by these mirrors (only simple direct ray diagrams are required).*

**Scope –** Brief introduction to spherical mirrors-concave and convex mirrors, centre and radius of curvature, pole and principal axis, focus and focal length, location of images from ray diagram for various positions of a small linear object on the principal axis of concave and convex mirrors; characteristics of images, $f = R/2$ (without proof); sign convention and direct numerical problems using the mirror formulae are included (Derivation of formula not required). Uses of spherical mirrors. *Scale drawing or graphical representation of ray diagram not required.*

## (A) LAWS OF REFLECTION & FORMATION OF IMAGE BY A PLANE MIRROR

### 7.1 REFLECTION OF LIGHT

When a beam of light strikes a surface, a part of it returns into the same medium. The part of light which is returned into the same medium is called the *reflected light*. Thus

***The return of light into the same medium after striking a surface is called reflection.***

The remaining part of light is either absorbed if the surface on which the light strikes is opaque or it is partly transmitted and partly absorbed if the surface is transparent.

It is the reflection of light which enables us to see the different objects around us. An object is seen when light from it enters our eyes. The luminous bodies which emit light by themselves are directly seen, but the non-luminous objects are seen only when they reflect the light incident on them and the reflected light reaches our eyes.

Different surfaces reflect light to different extent. A highly polished and silvered surface, such as a *plane mirror*, reflects almost the entire light falling on it.*

A plane mirror is made from a few mm thick glass plate. One surface of glass plate is polished to a high degree of smoothness. This forms the front surface of mirror and the other (or back) surface is silvered (*i.e.*, silver, mercury or some suitable material is deposited over it). The silvered surface is further coated with some opaque material so as to protect the silvering on it. The two surfaces of plane mirror are shown in Fig. 7.1. Light enters from the side of polished surface and is strongly reflected from the silvered surface. The coating serves as an opaque surface and it does not reflect the light.

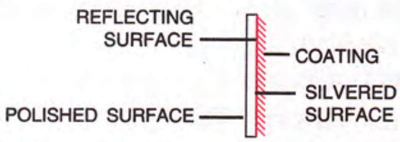


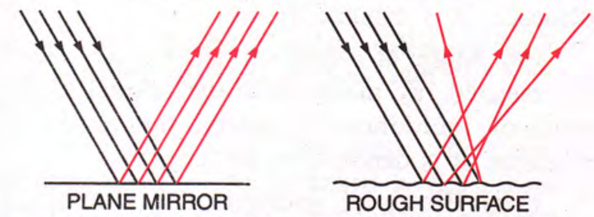

*Fig. 7.1 Representation of a plane mirror*

**Kinds of reflection :** There are the following *two* kinds of reflection:

(i) Regular reflection, and

(ii) Irregular reflection.

**(i) Regular reflection :** *Regular reflection occurs when a beam of light falls on a smooth and polished surface,* such as a plane mirror. In




**(a) REGULAR REFLECTION** **(b) IRREGULAR REFLECTION**

*Fig. 7.2 Regular and irregular reflection*

* A plane mirror does not reflect cent percent light falling on it.

Fig. 7.2(a), a parallel beam of light is incident on a plane mirror. The reflected beam is also parallel and it is in a fixed direction. It can be seen only from a particular direction.

**(ii) Irregular reflection :** *Irregular reflection occurs when a beam of light falls on a rough surface* such as the wall of a room, the page of a book or any other object. Although the wall of a room or the page of a book appears to be smooth, but actually it is quite uneven having many small projections over it. In Fig. 7.2(b) *light rays fall at different points on a rough surface and each ray gets reflected from it obeying the laws of reflection of light. Due to uneven surface, at different points, light rays get reflected in different directions and give rise to the diffused or irregular reflection.* As a result, the reflected light spreads over a wide area and it does not follow a particular direction. Thus the reflected light can be seen from anywhere.

It is the diffused light obtained by reflection from various uneven surfaces which enables us to see the objects around us.

## 7.2 SOME TERMS RELATED WITH REFLECTION

**(i) Incident ray :** The light ray striking a reflecting surface is called the incident ray.

**(ii) Point of incidence :** The point at which the incident ray strikes the reflecting surface, is called the point of incidence.

**(iii) Reflected ray :** The light ray obtained after reflection from the surface, in the same medium in which the incident ray is travelling, is called the reflected ray.

**(iv) Normal :** The perpendicular drawn to the surface at the point of incidence, is called the normal.

**(v) Angle of incidence :** The angle which the incident ray makes with the normal at the point of incidence, is called the angle of incidence. It is denoted by the letter $i$.

**(vi) Angle of reflection :** The angle which the reflected ray makes with the normal at the point of incidence, is called the angle of reflection. It is denoted by the letter $r$.

**(vii) Plane of incidence :** The plane containing the incident ray and the normal, is called the plane of incidence.

**(viii) Plane of reflection :** The plane containing the reflected ray and the normal, is called the plane of reflection.

In Fig. 7.3, $MM_1$ is a plane reflecting surface (say, a plane mirror) kept perpendicular to the plane of paper. A light ray is incident in the direction $AO$ at the point $O$ on mirror. It is reflected along the direction $OB$. Thus, $AO$ is the *incident ray*, $O$ is the point of incidence and $OB$ is the *reflected ray*.

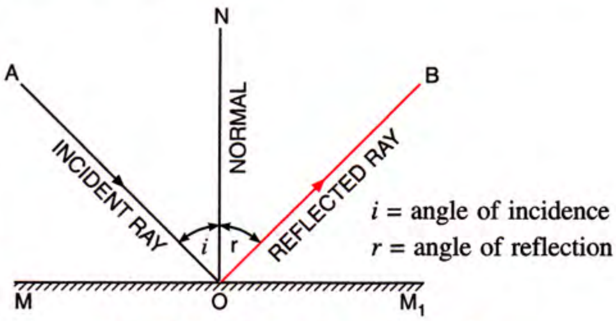



*Fig. 7.3 Reflection at a plane surface*

Let $ON$ be the *normal* (or perpendicular) drawn to the surface $MM_1$ at the point $O$. The angle $i$ (= $\angle AON$), which the incident ray makes with the normal, is the *angle of incidence* and the angle $r$ (= $\angle BON$), which the reflected ray makes with the normal, is the *angle of reflection*. The plane of paper is the *plane of incidence*.

## 7.3 LAWS OF REFLECTION

A light ray obeys the following *two* laws for reflection from a surface, which are called the *laws of reflection*.

(1) *The angle of incidence i is equal to the angle of reflection r (i.e., $\angle i = \angle r$).*

In Fig. 7.3, $\angle AON = \angle BON$ ...(7.1)

(2) *The incident ray, the reflected ray and the normal at the point of incidence, lie in the same plane.*

In Fig. 7.3, *AO, ON* and *OB* are in one plane (*i.e.*, the plane of paper).

***Reflection of a ray of light normally incident on a plane mirror***

For a ray incident normally on a plane mirror, the angle of incidence $i = 0°$, therefore the angle of reflection $r = 0°$. Thus, a ray of light $AO$ incident normally on a mirror is reflected along the same path $OA$ *i.e.*, it retraces its path as shown in Fig. 7.4.

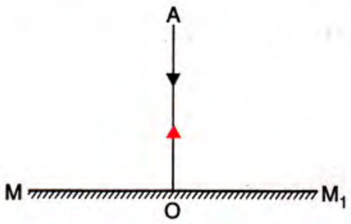



*Fig. 7.4 Reflection of a ray of light normally incident on a plane mirror*

## 7.4 EXPERIMENTAL VERIFICATION OF THE LAWS OF REFLECTION

**Experiment :** Fix a sheet of white paper on a drawing board and draw a line $MM_1$ as shown in Fig. 7.5. On this line, take a point $O$ nearly at the middle of it and draw a line $OA$ such that $\angle MOA$ is less than 90° (say, $\angle MOA = 60°$). Then draw a normal $ON$ on line $MM_1$ at the point $O$, and place a small plane mirror vertical by means of a stand with its silvered surface on the line $MM_1$.

Now fix two pins $P$ and $Q$ at some distance ($\approx$ 5 cm) apart vertically on line $OA$, on the board. Keeping eye on other side of normal (*but on the same side of mirror*), see clearly the images $P'$ and $Q'$ of the pins $P$ and $Q$. Now fix a pin $R$ such that it is in line with the images $P'$ and $Q'$ as observed in the mirror. Now fix one more pin $S$ such that the pin $S$ is in line with the pin $R$ as well as the images $P'$ and $Q'$ of pins $P$ and $Q$.

Draw small circles on paper around the position of pins as shown in Fig. 7.5. Remove the pins and draw a line $OB$ joining the point $O$ to the pin points $S$ and $R$.

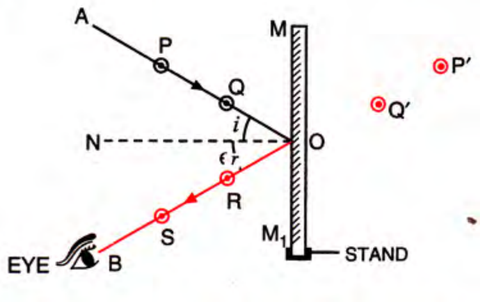



*Fig. 7.5 Verification of laws of reflection*

In Fig. 7.5, *AO is the incident ray, OB is the reflected ray, $\angle AON = i$ is the angle of incidence* and *$\angle BON = r$ is the angle of reflection*. The angles $AON$ and $BON$ are measured and recorded in the observation table.

The experiment is repeated for the $\angle MOA$ equal to 50°, 40° and 30°.

### Observations

| S. No. | Angle of incidence $i = \angle AON$ (in degree) | Angle of reflection $r = \angle BON$ (in degree) |
|---|---|---|
| 1. | 30 | 30 |
| 2. | 40 | 40 |
| 3. | 50 | 50 |
| 4. | 60 | 60 |

From the above observation table, we find that in each case, angle of incidence is equal to the angle of reflection. *This verifies the first law of reflection.*

The experiment is being performed on a flat drawing board, with mirror normal to the plane of board on which white sheet of paper is being fixed. Since the lower tips of all the four pins lie on the same plane (*i.e.*, the plane of paper), therefore the incident ray, the reflected ray and the normal at the point of incidence, all lie in one plane. *This verifies the second law of reflection.*

## 7.5 FORMATION OF IMAGE BY REFLECTION

From each point of an illuminated object, rays of light travel in all directions. To find the position of image of an object formed by a mirror after reflection, we need to consider at least *two* rays of light incident on the mirror from a point of object. Each incident ray gets reflected obeying the laws of reflection. The point where the two reflected rays actually meet or they appear to meet (when produced backwards), gives the position of image of that point of object. Thus we can obtain the positions of image of different points of the object. By joining these points, complete image of the object can be obtained.

**Types of image :** The image can be of *two* types : (a) real image, and (b) virtual image.

**(a) Real image :** The image which can be obtained on a screen, is called a *real image*. It is formed when light rays after reflection *actually intersect*. It is *inverted*. *For example*, for a distant object, the image formed by a concave mirror is real.

**(b) Virtual image :** The image which cannot be obtained on a screen, is called a *virtual image*. It is formed when light rays after reflection *do not* actually intersect, but they appear to diverge from the image*. Geometrically, they intersect when they are produced backwards. It is *erect*. *For example*, the image of an object formed by a plane mirror or by a convex mirror is virtual.

**Distinction between a real and virtual image**

| Real image | Virtual image |
|---|---|
| 1. A real image is formed due to actual intersection of the reflected rays. | 1. A virtual image is formed when the reflected rays meet if they are produced backwards |
| 2. A real image can be obtained on a screen. | 2. A virtual image can not be obtained on a screen. |
| 3. A real image is inverted with respect to the object *Example* : The image of a distant object formed by a concave mirror | 3. A virtual image is erect with respect to the object. *Example* : The image of an object formed by a plane mirror or by a convex mirror. |

## 7.6 IMAGE OF A POINT OBJECT FORMED BY A PLANE MIRROR

In Fig. 7.6, let $MM_1$ be a plane mirror in front of which a point object $O$ is placed. From the object $O$, rays of light travel in all directions. To show the formation of image by the plane mirror, we consider *two* rays from the object $O$ which fall on mirror $MM_1$. Let $OA$ and $OB$ be two rays incident from the object $O$ which get reflected from the mirror $MM_1$ in directions $AC$ and $BD$ respectively such that $\angle CAN_1 = \angle OAN_1$ and $\angle DBN_2 = \angle OBN_2$. Here $AN_1$ and $BN_2$ are the normals at the points $A$ and $B$.

When seen from a position between $C$ and $D$, the rays between $C$ and $D$ appear to come from some point $I$ behind the mirror. The point $I$ is the image of the object $O$. To locate the position of $I$, reflected rays $AC$ and $BD$ are produced backwards and the point where they meet, gives the position of image $I$. The image is *virtual* because the reflected rays $AC$ and $BD$ do not actually meet at $I$, but to our eye they appear to come from the point $I$.

## 7.7 IMAGE OF AN EXTENDED OBJECT FORMED BY A PLANE MIRROR

In Fig. 7.7, let $MM_1$ be a plane mirror in front of which an extended object $AB$ is placed. From all points of the object, light rays travel in all directions. We consider only *two* rays incident on the plane mirror from the end points $A$ and $B$ of the object. Let $AP$ and $AQ$ be the *two* rays incident on the mirror from the point $A$ of the object which get reflected from the mirror as $PP'$ and $QQ'$ respectively. These reflected rays when produced backwards, meet at a point $A'$. Thus $A'$ is the virtual image of point $A$. Similarly, from the point $B$ of object, $BR$ and $BS$ be the *two* incident rays on the mirror which are reflected as $RR'$ and $SS'$ respectively. The reflected rays $RR'$ and $SS'$ meet at a point $B'$ when produced backwards. Thus, $B'$ is the virtual image of point $B$. Similarly, for all other points of the object $AB$, virtual images are formed between $A'$ and $B'$. Thus $A'B'$ is the virtual image

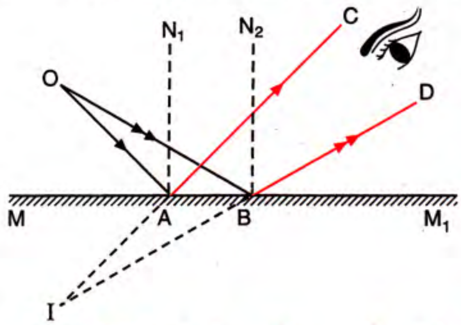



*Fig. 7.6 Formation of image of a point object by a plane mirror*

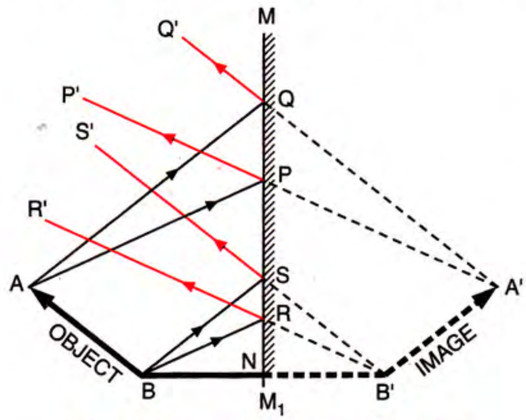



*Fig. 7.7 Image of an extended object formed by a plane mirror*

* When these diverged rays enter our eye, they converge to form an image on our retina and the image is seen by us.

of the object $AB$. *It is erect and of size equal to that of the object. The normal distance of each point of image behind the mirror is same as the normal distance of the corresponding object point in front of the mirror (i.e., $BN = B'N$).*

## 7.8 POSITION OF IMAGE

*The image I is as far behind the mirror as the object O is in front of it i.e., the perpendicular distance of image from the mirror is equal to the perpendicular distance of object from the mirror.*

**Proof :** Fig. 7.8 shows the formation of image of a point object $O$ by a plane mirror $MM_1$. A ray $OF$ incident normally on the mirror gets reflected by the mirror along the same path (*i.e.,* along $FO$), since $\angle i = 0°$, therefore $\angle r = 0°$. The other incident ray $OA$ gets reflected along $AC$, such that $\angle OAN = \angle NAC$ where $AN$ is the normal drawn at the point $A$ on mirror $MM_1$. The reflected rays $FO$ and $AC$ meet at a point $I$ when they are produced backwards. The point $I$ is the virtual image of the point object $O$. We are to prove that $IF = OF$.

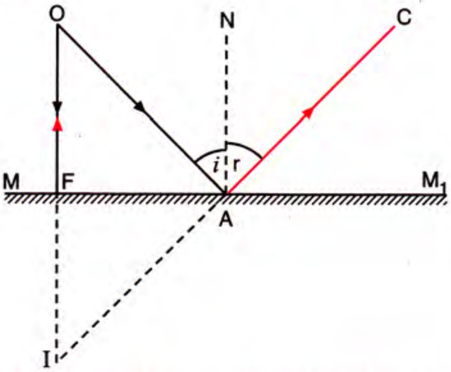



*Fig. 7.8 Formation of image of a point object due to reflection at a plane mirror*

For the incident ray $OA$ reflected as $AC$,

$\angle OAN$ = angle of incidence $i$

$\angle CAN$ = angle of reflection $r$

By the law of reflection,

angle of incidence = angle of reflection

or $\angle OAN = \angle CAN$ ...(7.2)

But $\angle OAN = \angle AOF$ (Alternate angles)

and $\angle CAN = \angle AIF$ (Corresponding angles)

$\therefore$ $\angle AOF = \angle AIF$ ...(7.3)

Now consider the triangles $AOF$ and $AIF$

$\angle AOF = \angle AIF$

$\angle AFO = \angle AFI$ (= 90°)

and $FA$ is the common side.

Therefore, the triangles $AOF$ and $AIF$ are congruent.

Hence, $OF = IF$ .... (7.4)

Since $OF$ is the normal drawn from the object $O$ on the mirror, so the normal distance of the object from the mirror is equal to the normal distance of image from the mirror. Thus,

*The image is situated on the normal drawn from the object on the mirror and it is as far behind the mirror as the object is in front of it.*

## 7.9 LATERAL INVERSION

In our daily experience while looking in a mirror, we notice that a ring on the finger of our left hand appears to be in the finger of the *right hand of our image* as shown in Fig. 7.9. Similarly, the pocket on the left appears to be on the right in the image. This interchange of the left and right sides is called the *lateral inversion.* Thus,

***The interchange of the left and right sides in the image of an object in a plane mirror is called lateral inversion.***


*Fig. 7.9 Image of a ring on the finger of left hand in a plane mirror*

Fig. 7.10 shows the image formation of a letter P in a plane mirror. The letter **P** appears in a plane mirror as **ꟼ**. Similarly, the letter **F** will appear as **ꟻ**.

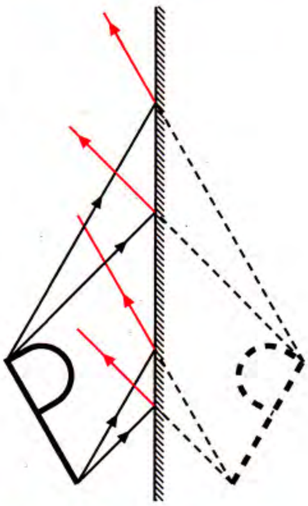


*Fig. 7.10 Lateral inversion*

**Note : (1)** The lateral inversion produced by a plane mirror is similar to the inversion that occurs on a blotting paper used to dry ink while writing.

The individual letter obtained on the blotting paper cannot be read directly, but it can be read by seeing its image in a plane mirror.

**(2)** The lateral inversion of letters such as A, H, I, M, O, T, U, V, W, X and Y is not noticeable since their image remains unchanged (because each of these letters has a symmetry about a vertical line passing through the mid point of the letter).

**(3)** It is because of the lateral inversion that it becomes difficult to read the text of a page from its image formed by a plane mirror. But one can easily read the text written in '*laterally inverted letters*' formed by seeing its image in a plane mirror. It is why the letters on the front of an ambulance are written laterally inverted like ƎƆИA⅃UᗺMA, so that the driver of the vehicle moving ahead of the ambulance reads the word laterally inverted as AMBULANCE, in his rear view mirror, and gives side to pass the ambulance first.

**(4)** The image formed by a spherical mirror is also laterally inverted.

## 7.10 CHARACTERISTICS OF THE IMAGE FORMED BY A PLANE MIRROR

The image formed by a plane mirror has the following characteristics :

*(i) upright (or erect),* *(ii) virtual,*
*(iii) of same size as the object,* and
*(iv) laterally inverted.*

The location of the image is given by the fact that, *the image is situated at the same perpendicular distance behind the mirror as the object is in front of it.*

**Note :** If the object is shifted by a distance $d$ towards the mirror, the image will also shift by the same distance $d$ towards the mirror *i.e.,* the separation between the object and image will decrease by $2d$. Similarly, if an object moves with a speed $v$ towards (or away) from a mirror, the *image to him* will appear to move with a speed $2v$ towards (or away from) him.

*Example* : A boy standing at a distance 5 m away from a plane mirror at $A$, finds his image at a distance 10 m from him at $A'$. Now if he moves to the position $B$ by a distance 2 m still farther away from the mirror, his distance from the mirror will become 7 m and then to him, his image $B'$ will appear to be at a distance 14 m from him as shown in Fig. 7.11.

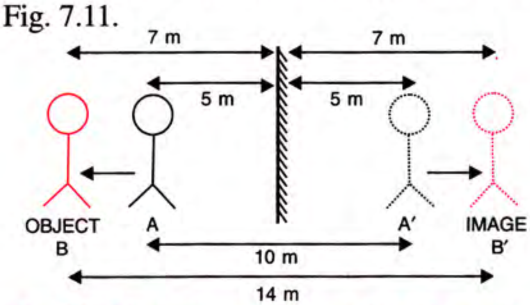



*Fig. 7.11 Displacement of image in a plane mirror when the object moves*

## EXAMPLES

**1. In a dark room, a parallel beam of light falls on a plane mirror and another parallel beam of light falls on a white wall. The light reflected by the mirror can be seen only in a certain direction, but the reflected light from the wall can be seen from anywhere. Give reason.**

The plane mirror has a plane smooth reflecting surface, so regular reflection takes place and the reflected light goes in a fixed direction. Therefore, the reflected light can be seen only in a certain direction.

On the other hand, the wall is a rough surface so irregular reflection takes place, and reflected light gets diffused in all directions. Therefore, the reflected light from the wall can be seen from anywhere.

**2. Complete the diagram in Fig. 7.12 to form the image $A'B'$ of the object $AB$ by the plane mirror $MM_1$. State in words how have you completed the diagram. Measure the perpendicular distance of the points $A$ and $B$ of the object from the mirror and also the perpendicular distance of the points $A'$ and $B'$ of the image from the mirror and state how are they related.**

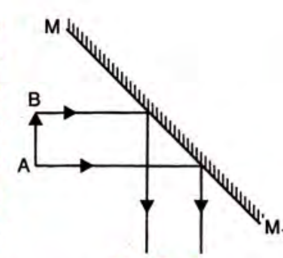



*Fig. 7.12*

The completed diagram is shown in Fig. 7.13.

To complete the diagram, rays $AP$ and $BQ$ are made incident normally on the mirror $MM_1$ from the points $A$ and $B$ of the object, which retraces their path after reflection. The other rays $AP'$ and $BQ'$ get reflected from the plane mirror obeying the laws of reflection Each of the reflected ray is produced backwards to get the image $A'B'$.

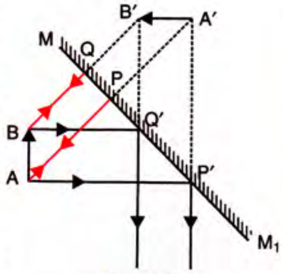


*Fig. 7.13*

Perpendicular distance $AP$ of $A$ from the mirror = **1·5 cm** = Perpendicular distance $A'P$ of $A'$ from the mirror.

Perpendicular distance $BQ$ of $B$ from the mirror = **1·1 cm** = Perpendicular distance $B'Q$ of $B'$ from the mirror.

**3. An object is at a distance 25 cm in front of a plane mirror. The mirror is shifted 5 cm away from the object. Find : (i) the new distance between the object and its image, and (ii) the distance between the two positions of the image.**

Fig. 7.14 shows the images $B$ and $B'$ the object $A$, by the mirror in its initial and new postions.

Initially, the distance of the object $A$ in front of plane mirror $M$ is $AM$ = 25 cm, therefore the image

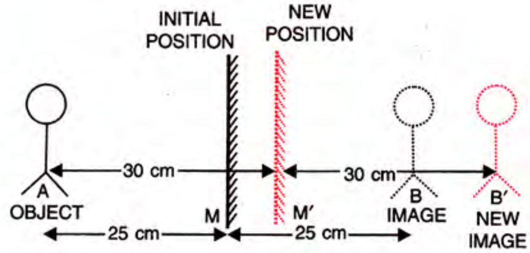


*Fig. 7.14*

$B$ is at a distance $MB$ = 25 cm from the mirror $M$ behind it. Distance between the object $A$ and its image $B$ = 25 cm + 25 cm = 50 cm.

On shifting the mirror by 5 cm away from the object, the new distance of object $A$ from the mirror $M'$ becomes $AM' = 25 + 5 = 30$ cm. The new image $B'$ is now at a distance $M'B'$ = 30 cm behind the mirror $M'$. Hence

(i) The new distance $AB'$ between the object $A$ and the image $B'$ = 30 cm + 30 cm = **60 cm**.

(ii) Taking the position of the object $A$ as reference point, the distance between the two positions of the image, $BB'$ = new distance of image from the object, $AB'$ – initial distance of image from the object, $AB$ = 60 – 50 = **10 cm**.

## EXERCISE 7(A)

1. What do you mean by reflection of light ?
2. State which surface of a plane mirror reflects most of the light incident on it : the front smooth surface or the back silvered surface.

   **Ans.** Back silvered surface.
3. Explain the following terms :
   (a) plane mirror, (b) incident ray,
   (c) reflected ray, (d) angle of incidence, and
   (e) angle of reflection.
   Draw diagram/diagrams to show them.
4. With the help of diagrams, explain the difference between the regular and irregular reflection.
5. Differentiate between the reflection of light from a plane mirror and that from a plane sheet of paper.
6. State the *two* laws of reflection of light.
7. State the laws of reflection and describe an experiment to verify them.
8. A light ray is incident normally on a plane mirror.
   (a) What is its angle of incidence ?
   (b) What is the direction of reflected ray ? Show it on a diagram.

   **Ans.** (a) 0°, (b) same as incident ray
9. Draw a diagram to show the reflection of a ray of light by a plane mirror. In the diagram, label the incident ray, the reflected ray, the normal, the angle of incidence and the angle of reflection.
10. Fig. 7.15 shows an incident ray $AO$ and the normal $ON$ on a plane mirror. The angle which the incident ray $AO$ makes with the mirror is 30°. (a) Find the angle of incidence. (b) Draw the reflected ray and then find the angle between the incident and reflected rays.

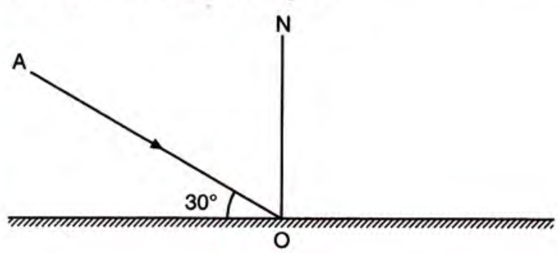


*Fig. 7.15*

**Ans.** (a) 60°, (b)120°

11. The diagram in Fig. 7.16 shows a point object $P$ in front of a plane mirror $MM_1$.

(a) Complete the diagram by taking *two* rays from the point $P$ to show the formation of its image.

(b) In the diagram, mark the position of eye to see the image.

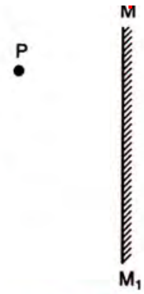



*Fig. 7.16*

(c) Is the image formed real or virtual ? Explain why ?

**Ans.** (c) Virtual because the reflected rays meet only when they are produced backwards

12. The diagram below in Fig. 7.17 shows an object $XY$ in front of a plane mirror $MM_1$. Draw on the diagram, path of *two* rays from each point $X$ and $Y$ of the object to show the formation of its image.

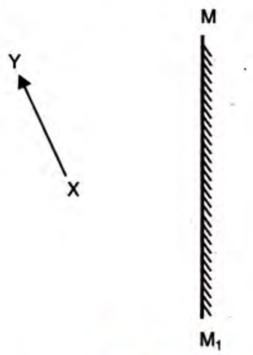



*Fig. 7.17*

13. (a) Write *three* characteristics of the image formed by a plane mirror ?

(b) How is the position of image related to the position of the object ?

14. Differentiate between a real and a virtual image.

15. What is meant by lateral inversion of an image in a plane mirror ? Explain it with the help of a ray diagram.

16. The letters on the front of an ambulance are written laterally inverted like ƎƆИA⅃UBMA.Give reason.

17. Why is it difficult to read the image of the text of a page formed due to reflection by a plane mirror ? **Ans.** Due to lateral inversion.

**Multiple choice type :**

1. According to the law of reflection :
   (a) $i/r$ = constant
   (b) $\sin i/\sin r$ = constant
   (c) $i + r$ = constant
   (d) $i = r$

   **Ans.** (d) $i = r$

2. The image formed by a plane mirror is :
   (a) erect and diminished
   (b) erect and enlarged
   (c) inverted and of same size
   (d) erect and of same size.

   **Ans.** (d) erect and of same size

3. The image formed by a plane mirror is :
   (a) real
   (b) virtual
   (c) virtual with lateral inversion
   (d) real with lateral inversion.

   **Ans.** (c) virtual with lateral inversion

**Numericals :**

1. A ray is incident on a plane mirror. Its reflected ray is perpendicular to the incident ray. Find the angle of incidence. **Ans.** 45°

2. A man standing in front of a plane mirror finds his image at a distance 6 metre from himself. What is the distance of man from the mirror ? **Ans.** 3 m

3. An insect is sitting in front of a plane mirror at a distance 1 m from it.
   (a) Where is the image of the insect formed ?
   (b) What is the distance between the insect and its image ?

   **Ans.** (a) 1 m behind the mirror (b) 2 m

4. An object is kept at 60 cm in front of a plane mirror. If the mirror is now moved 25 cm away from the object, how does the image shift from its previous position ?

   **Ans.** 50 cm away.

5. An optician while testing the eyes of a patient keeps a chart of letters 3 m behind the patient and asks him to see the letters on the image of chart formed in a plane mirror kept at distance 2 m in front of him. At what distance is the chart seen by the patient ? **Ans.** 7 m.

## 7.11 IMAGES FORMED IN TWO INCLINED MIRRORS

For an object kept in between the two inclined plane mirrors, we get many images of the object. This is because the light rays after reflection from one mirror fall on the other mirror. In other words, the image formed by one mirror acts as an object for the other mirror. This continues till no more reflection can occur on any mirror.

*The object and the images formed by the two inclined mirrors lie on the circumference of a circle whose centre lies at the point of intersection of the two mirrors and radius is equal to the distance of object from the point of intersection.*

The number of images formed depends on the angle $\theta°$ between the two mirrors. Following two cases are possible :

**Case (1) :** If angle $\theta°$ between the mirrors is such that $n = \frac{360°}{\theta°}$ is odd,

(i) the number of images is $n$, when the object is placed *asymmetrically* between the mirrors.

(ii) the number of images is $n - 1$, when the object is placed *symmetrically* (*i.e.*, on the bisector of the angle) between the mirrors.

*Example :* If $\theta$ is 72°, then $n = \frac{360°}{72°} = 5$. So images formed will be $n = 5$ for the object placed asymmetrically between the mirrors and images formed will be $(n - 1) = 4$, if the object is placed symmetrically (on the bisector) between the mirrors because two images now overlap.

**Case (2) :** If $n = \frac{360°}{\theta°}$ is even, the number of images is always $n - 1$ for all positions of object in between the mirrors.

*Example :* If the angle between two mirrors is 60°, $n = \frac{360°}{60°} = 6$, the number of images is $(n - 1) = 5$, *i.e.* five images will be formed for all positions of the object in between the mirrors..

We shall now consider image formation in *two* special cases :

(a) When the two mirrors are parallel to each other.

(b) When the two mirrors are perpendicular to each other.

## 7.12 IMAGES FORMED IN A PAIR OF MIRRORS PLACED PARALLEL TO EACH OTHER

When two mirrors are kept parallel to each other, *i.e.*, ($\theta = 0°$), then $n = \frac{360°}{\theta°} = \frac{360°}{0°} = \infty$ (infinite), so the number of images of an object kept in between the two parallel mirrors will be infinite. Thus

*For two mirrors kept parallel to each other, an infinite number of images are formed for an object kept in between them.*

In Fig. 7.18, $AM$ and $BM_1$ are the two plane mirrors placed parallel to each other. An object $P$ is placed in between them. The image of $P$ formed by reflection from mirror $AM$ is $I_1$ and by reflection from mirror $BM_1$ is $I'$. The ray diagram for the formation of image $I'$ is not shown in Fig. 7.18. Now $I_1$ acts as a virtual object for mirror $BM_1$ and the image $I_2$ is formed. Similarly, $I'$ acts as the virtual object for mirror $AM$ and the image $I''$ is formed. In this manner, many images are formed. But the brightness of the remote images keeps on decreasing because at each reflection, some light is absorbed, thus not more than few images are seen. Fig. 7.18 shows the ray diagram for the formation of one set of images only (*i.e.*, $I_1$, $I_2$,

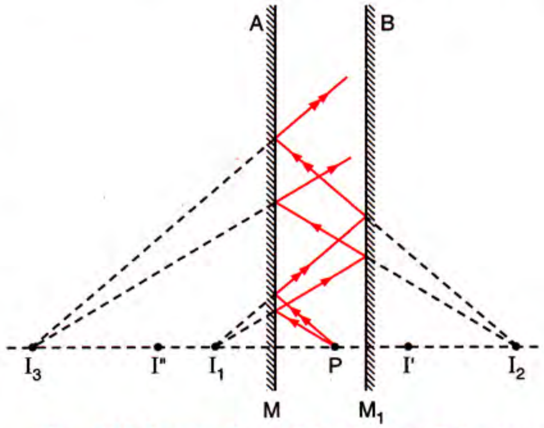


*Fig. 7.18 Images formed in two parallel mirrors*

$I_3$,...). The formation of other set of images (*i.e.*, $I'$, $I''$, ....) can similarly be obtained. All images lie on the perpendicular drawn from the base of object on the mirrors.

**Use :** In a showroom and in a barber's shop, mirrors are arranged in this manner.

**Note :** *A thick plane mirror also forms a multiple number of images* due to multiple reflections within the glass from front surface and back reflecting surface. Out of these, the second image formed due to reflection from the back reflecting surface is brightest.

## 7.13 IMAGES FORMED BY TWO MIRRORS PLACED PERPENDICULAR TO EACH OTHER

When two mirrors are kept perpendicular to each other, *i.e.*, $\theta = 90°$, then

$$n = \frac{360°}{\theta°} = \frac{360°}{90°} = 4$$

$\therefore$ for an object placed in between the two perpendicular mirrors, the number of images formed will be $n - 1 = 3$. Thus

*For two mirrors kept perpendicular to each other, three images are formed for an object kept in between them.*

In Fig. 7.19, $AO$ and $OB$ are the two plane mirrors kept mutually perpendicular to each other. Let $P$ be an object in between the two mirrors. The image of object $P$ formed by reflection from the mirror $OB$ is $P_2$ and by reflection from the mirror $OA$ is $P_1$. Fig. 7.19 shows ray diagram for the formation of image $P_2$ only. Now the image $P_2$ acts as the virtual object for the mirror $OA$ since rays after reflection from mirror $OB$ fall on

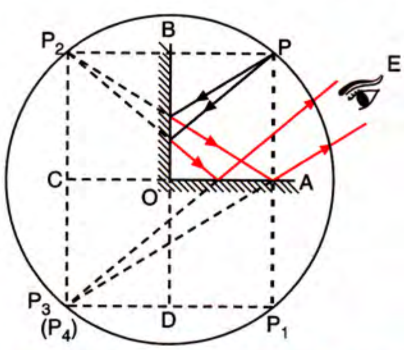



*Fig. 7.19 Images formed in two perpendicular mirrors*

the mirror $OA$. For this, the image formed by mirror $OA$ is $P_3$. Similarly, $P_1$ acts as the virtual object for the mirror $OB$ since the rays after reflection from the mirror $OA$ fall on mirror $OB$ (they are not shown in figure). For this, the image formed by mirror $OB$ is $P_4$ which is at the same point as $P_3$ (*i.e.*, the image $P_4$ of $P_1$ in mirror $OB$ overlaps with the image $P_3$ of $P_2$ in mirror $OA$). *As such, three images of object are formed in this case.* In Fig. 7.19, ray diagram for the formation of images $P_2$ and $P_3$ is shown. Similarly, we can draw the ray diagram for the formation of images $P_1$ and $P_4$. Geometrically it can be seen that the images $P_1$, $P_2$, $P_3$ and the object $P$, all lie on a circle whose centre is at $O$ (the point of intersection of the two mirrors $OA$ and $OB$) and radius is $OP$.

## 7.14 USES OF PLANE MIRROR

The plane mirrors find wide applications in our daily life. Some of the applications of a plane mirror are given below.

**(1)** The most common and wide use is as a looking glass.

**(2)** In the optician's room to increase the effective length of the room. It is done by keeping a plane mirror on the front wall and the sign board on the opposite wall, just behind the patient. For the patient, the sign board is at nearly double the length of the room.

**(3)** In the barber's shop for seeing the hairs at the back of head. Here two mirrors facing each other are fixed on the opposite walls at the front and back of the viewer.

**(4)** In a periscope, two parallel plane mirrors each inclined at 45° with the vertical walls are placed facing each other.

**(5)** In a kaleidoscope, three plane mirrors inclined with each other at 60° are used. If small coloured bangle pieces are kept between the mirrors, beautiful hexagonal patterns are seen on rotating the tube.

**(6)** In solar heating devices such as solar cooker, solar water heater, etc., a plane mirror is used to reflect the incident light rays from sun on the substance to be heated.

## EXERCISE 7(B)

1. Two plane mirrors are placed making an angle θ in between them. Write an expression for the number of images formed if an object is placed in between the mirrors. State the condition, if any.
**Ans.** $n$ if $n = \frac{360°}{θ°}$ is odd and object is asymmetrically placed, $n - 1$ if $n$ is even or odd if object is placed symmetrically.
2. Two plane mirrors are placed making an angle θ° in between them. For an object placed in between the mirrors, if angle is gradually increased from 0° to 180°, how will the number of images change: increase, decrease or remain unchanged ? **Ans.** Decrease
3. How many images are formed for a point object kept in between the two plane mirrors at right angles to each other ? Show them by drawing a ray diagram. **Ans.** 3
4. Two plane mirrors are arranged parallel and facing each other at some separation. How many images are formed for a point object kept in between them ? Show the formation of images with the help of a ray diagram. **Ans.** Infinite
5. State *two* uses of a plane mirror.

**Multiple choice type :**

1. Two plane mirrors are placed making an angle 60° in between them. For an object placed in between the mirrors, the number of images formed will be :
   (a) 3 (b) 6
   (c) 5 (d) infinite. **Ans.** (c) 5
2. In the barber's shop, two plane mirrors are placed :
   (a) perpendicular to earth other
   (b) parallel to each other
   (c) at an angle 60° between them
   (d) at angle 45° between them.
   **Ans.** (b) parallel to each other

**Numericals :**

1. State the number of images of an object placed between the two plane mirrors, formed in each case when the mirrors are inclined to each other at (a) 90º, and (b) 60º. **Ans.** (a) 3, (b) 5
2. An object is placed (i) asymmetrically (ii) symmetrically, between two plane mirrors inclined at an angle of 50º. Find the number of images formed. **Ans.** (i) 7, (ii) 6

## (C) SPHERICAL MIRRORS, IMAGE FORMATION AND THEIR USES

### 7.15 SPHERICAL MIRRORS

*A spherical mirror is made by silvering a part of a hollow glass sphere.* Thus

***A reflecting surface which is a part of a sphere is called a spherical mirror.***

**Types of spherical mirrors :** Depending on whether the inner or outer surface of the sphere is silvered, spherical mirrors are of *two* types:

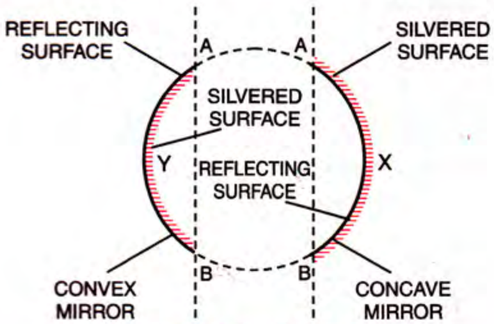


*Fig. 7.20 Spherical mirrors*

(i) the *concave mirror,* and (ii) the *convex mirror.* In Fig. 7.20, the right part *X* of a hollow sphere is silvered and coated on its outer surface, and it forms the *concave mirror*, while the left part *Y* of the sphere is silvered and coated on its inner surface, and it forms the *convex mirror*.

**(i) *Concave mirror***

A concave mirror is made by silvering the outer (or bulging) surface of the piece of a hollow sphere such that the reflection takes place

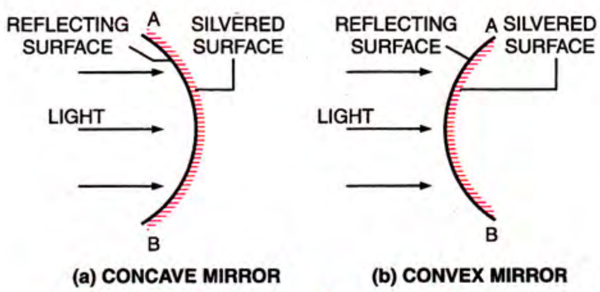


*Fig. 7.21 Concave and convex mirrors*

from the hollow (or concave) surface as shown in Fig. 7.21 (a).

**(ii) *Convex mirror***

A convex mirror is made by silvering the inner surface of the piece of a hollow sphere such that the reflection takes place from the outer (or bulging) surface as shown in Fig. 7.21 (b).

## 7.16 BRIEF INTRODUCTION OF TERMS RELATED TO A SPHERICAL MIRROR

**(1) *Centre of curvature***

*The centre of curvature of a mirror is the centre of the sphere of which the mirror is a part.*

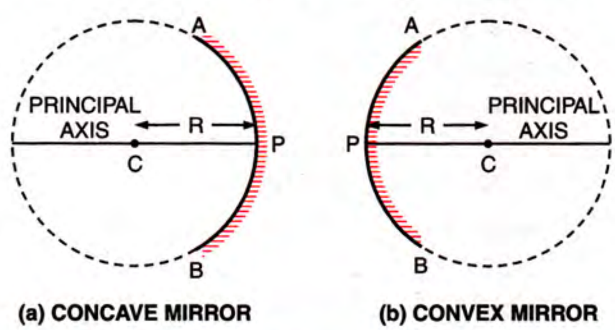
In Fig. 7.22, it is represented by the symbol *C*.

The normal at any point of the mirror passes through the centre of curvature *C*. In other words, *a line joining any point on the surface of mirror to the centre of curvature C will be normal to the surface of mirror at that point.*

**(2) *Radius of curvature***

*The radius of sphere of which the spherical mirror is a part, is called the radius of curvature of the mirror.*

Thus, it is the distance of centre of curvature *C* from any point on the surface of mirror. In Fig. 7.22, distance *PC* is the radius of curvature. It is represented by the symbol *R*.




**(a) CONCAVE MIRROR** **(b) CONVEX MIRROR**

*Fig. 7.22 Centre of curvature, radius of curvature, pole, aperture and principal axis*

**(3) *Pole***

*The geometric centre of the spherical surface of mirror is called the pole of mirror.*

It is the central point of the surface of the mirror. It is represented by the letter *P* as shown in Fig. 7.22.

**(4) *Aperture***

*The plane surface area of the mirror through which the light rays enter and fall on the mirror is called its aperture.*

Thus for the mirror shown in Fig. 7.22, *AB* is the diameter of aperture.

**(5) *Principal axis***

*It is the straight line joining the pole of the mirror to its centre of curvature.*

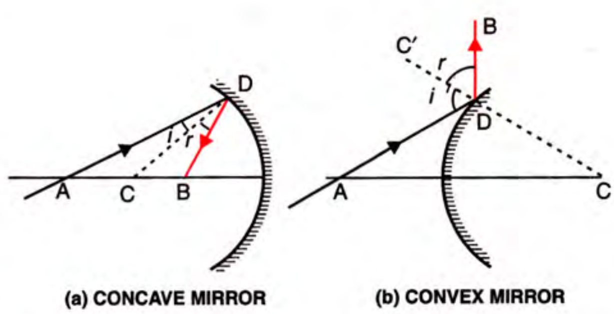
In Fig. 7.22, the line *PC* represents the principal axis. It can extend on either side.

## 7.17 REFLECTION OF LIGHT RAY FROM A SPHERICAL MIRROR

From a spherical mirror, reflection of light follows the same laws of reflection as for the plane surface (*i.e. angle of incidence i = angle of reflection r* and the incident ray, reflected ray and the normal lie in same plane).

**Note :** In a spherical mirror, to obtain the direction of reflected ray for a given incident ray, first draw a normal at the point of incidence. For this, draw a line joining the point of incidence to the centre of curvature *C**. Then draw a line on the other side of the normal, making an angle (*i.e.,* the angle of reflection) equal to the angle of incidence. This line represents the reflected ray.

*Example :* In Fig. 7.23, we are to find the direction of reflected ray for an incident ray *AD* on a concave mirror and convex mirror for which *C* is the position of centre of curvature.




**(a) CONCAVE MIRROR** **(b) CONVEX MIRROR**

*Fig. 7.23 Reflection of a ray of light from a spherical mirror*

* The line joining the point of incidence to the centre of curvature is normal to the tangent drawn on the spherical surface at the point of incidence, so it becomes normal at the point of incidence.

For this, the point of incidence $D$ is joined to the centre of curvature $C$ to get the normal $DC$ on the mirror at the point of incidence $D$. Then the reflected ray $DB$ is drawn such that $\angle BDC = \angle ADC$ in concave mirror and $\angle BDC' = \angle ADC'$ in convex mirror.

## 7.18 FOCUS AND FOCAL LENGTH

**For concave mirror :** In Fig. 7.24, the rays of light are incident parallel to its principal axis on a concave mirror. Each ray gets reflected from the mirror obeying the law of reflection (*i.e.*, angle of incidence $i$ = angle of reflection $r$) for which the dotted line joining the point of incidence to the centre of curvature $C$ acts as normal at the point of incidence. We note that in Fig. 7.24, concave mirror converges the rays on reflection and the rays after reflection pass through a point $F$ on the principal axis. This point is called the *focus* of concave mirror. Thus a concave mirror has a *real focus* because the reflected rays actually meet at this point. The focus is represented by the symbol $F$. Thus

*The focus of a concave mirror is a point on the principal axis through which the light rays incident parallel to the principal axis, pass after reflection from the mirror.*

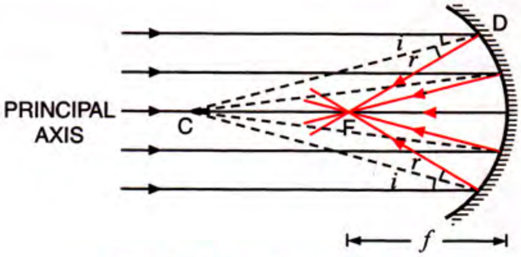



*Fig. 7.24 Focus and focal length of a concave mirror*

The distance of focus $F$ from the pole $P$ of the mirror is called its focal length. *i.e.*, focal length $f = PF$.

**For convex mirror :** In Fig. 7.25, the rays of light are incident parallel to the principal axis on a convex mirror. Each ray after reflection appears to diverge and the reflected rays do not meet at any point, but they appear to come from a point $F$ on the principal axis, behind the mirror. This point is called the *focus* of the convex mirror. This point is obtained geometrically, when the reflected rays are produced backwards. Thus a convex mirror has a *virtual focus*. Thus,

*The focus of a convex mirror is a point on the principal axis from which, the light rays incident parallel to the principal axis, appear to come, after reflection from the mirror.*

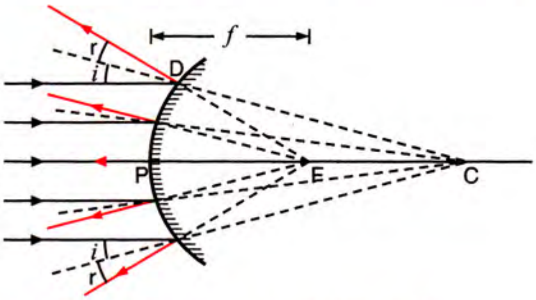
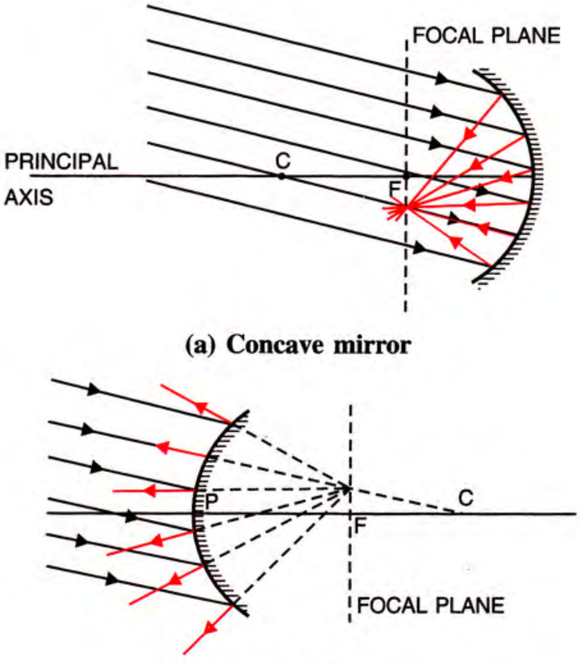



*Fig. 7.25 Focus and focal length of a convex mirror*

The distance of the focus $F$ from pole $P$ of the mirror is called its focal length *i.e.*, focal length $f = PF$.

**Focal plane :** A plane passing through the focus and normal to the principal axis of the mirror, is called focal plane. A *parallel beam of light inclined* to the principal axis get focused at a point in this plane [Fig. 7.26(a) and Fig. 7.26(b)]. It is the point where the ray passing through the centre of curvature meets the focal plane.




**(a) Concave mirror**

**(b) Convex mirror**

*Fig. 7.26 (b) Focal plane*

## 7.19 CONVENIENT RAYS FOR THE CONSTRUCTION OF IMAGE BY RAY DIAGRAM

Although from each point of an object, infinite number of rays travel in all directions, but to find the position and nature of image formed due to reflection from a spherical mirror *by drawing,* we need to consider at least *two* rays incident on the mirror from the same point of the object. 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*

A line joining the centre of curvature to any point on the surface of mirror is normal to the mirror at that point, therefore a ray *AD* passing through the centre of curvature *C* (or appearing to pass through the centre of curvature *C*) is incident normally on the spherical mirror. Since its angle of incidence is zero, therefore the angle of reflection will also be zero and the ray *AD* gets reflected along its own path *DA* as shown in Fig. 7.27. Thus

*A ray passing through (or directed towards) the centre of curvature of a spherical mirror, is reflected back along its own path.*

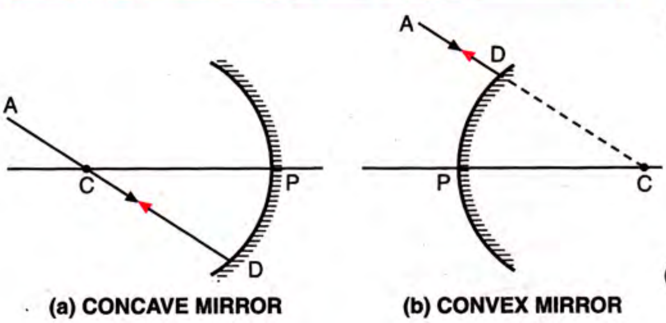



*Fig. 7.27 A ray passing through the centre of curvature is reflected back along its own path*

### (2) *A ray parallel to the principal axis*

A ray of light *AD* incident parallel to the principal axis, after reflection passes either through the focus *F* (*in a concave mirror*) or will appear to come from the focus *F* (*in a convex mirror*) along *DB* as shown in Fig. 7.28 . Thus

*A ray incident parallel to the principal axis, after reflection from a spherical mirror either passes or appears to be coming from focus.*

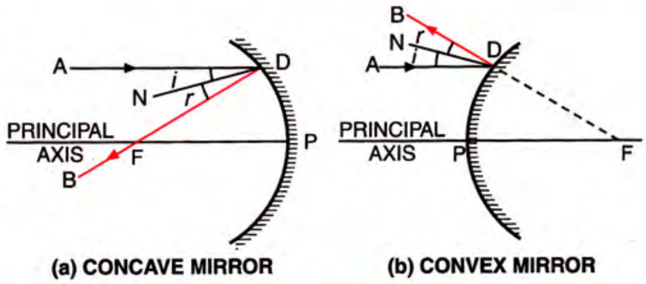



*Fig. 7.28 A ray parallel to the principal axis either passes or appears to pass through focus after reflection*

### (3) *A ray passing through the focus*

A ray of light *AD* incident on the mirror passing through the focus *F* (*in a concave mirror*) or converging at the focus *F* (*in a convex mirror*) after reflection becomes parallel to the principal axis as *DB* (Fig. 7.29). Thus

*A ray either incident from the focus (or converging at the focus), after reflection from a spherical mirror becomes parallel to the principal axis.*

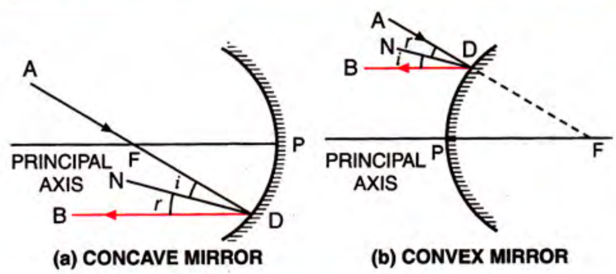



*Fig. 7.29 A ray passing through the focus gets reflected parallel to the principal axis*

### (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 $\angle APC$ is equal to the angle of reflection $\angle BPC$ in a concave mirror (or $\angle APC' = \angle BPC'$ in a convex mirror) as shown in Fig. 7.30. In this case, principal axis itself is the normal at the pole. Thus

*For a ray incident at the pole of a spherical mirror, the reflected ray is at an angle of reflection equal to the angle of incidence with principal axis as normal.*

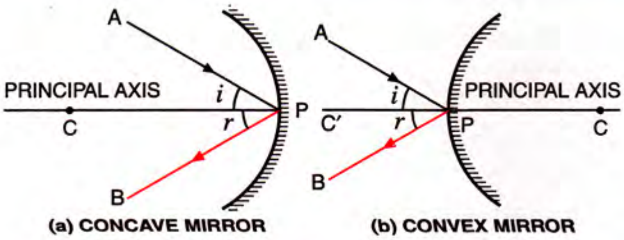



*Fig. 7.30 Reflection of a ray incident at the pole*

## 7.20 RAY DIAGRAMS FOR FORMATION OF IMAGES IN A CONCAVE MIRROR

We shall now find the position, size and nature of image by drawing the ray diagram for *a small linear object* placed on the principal axis of a concave mirror at different positions.

**Case (i) : *When the object is at infinity***

When the object (e.g. sun) is at infinity, the rays of light reaching the concave mirror even from the different points of the object subtend nearly the same angle at each point of the mirror, so they can be treated to be parallel to each other. In Fig. 7.31, let two rays $AD$ and $BE$ from the same point of object are incident on the concave mirror, parallel to its principal axis $CP$. They after reflection from the concave mirror pass through its focus $F$ as $DF$ and $EF$ respectively. The two reflected rays $DF$ and $EF$ meet at the focus $F$. Hence a *real* and *point* image is formed at the focus. Thus

*When the object is at infinity, the image is at the focus F. It is (i) Real, (ii) Inverted and (iii) Diminished to a point.*

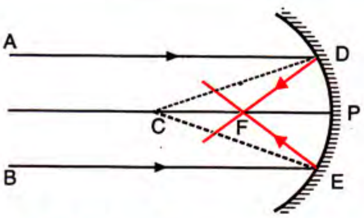



*Fig. 7.31 When the object is at infinity*

**Case (ii) : *When the object is at a far distance***

Consider two rays $AP$ and $BD$ from the *same point* of an object (*e.g.* a tree) incident on a concave mirror, parallel to each other as shown in Fig 7.32. The incident ray $AP$ striking at the pole $P$ is reflected along $PA_1$, such that $\angle APC = \angle A_1PC$ (*i.e.*, $\angle i = \angle r$ ). Similarly the other ray $BD$ is reflected along $DA_1$ such that $\angle BDC = \angle A_1DC$ (*since DC is normal at the point D*). The reflected rays $PA_1$ and $DA_1$ intersect at a point $A_1$ which is the image of the point of the object. The point $A_1$ lies on the focal plane of the mirror. Similarly, the rays from other points of the object also converges in the focal plane thus forming the image along $A_1F$. Hence $A_1F$ is an *inverted, real and highly diminished image formed in the focal plane of the concave mirror.* Thus

*When object is at a far distance, image is in the focal plane of the mirror. It is (i) Real, (ii) Inverted, and (iii) Highly diminished.*

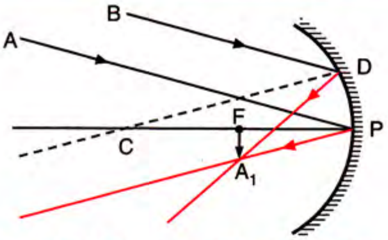



*Fig. 7.32 When the object is at far distance*

**Case (iii) : *When object is beyond the centre of curvature***

In Fig. 7.33, $AB$ is an object placed beyond the centre of curvature $C$. Consider two light rays from a point $A$ of the object. A ray $AD$ incident parallel to the principal axis, after reflection from the concave mirror passes through its focus $F$ along $DA_1$. Another ray $AE$ passing through the centre of curvature $C$ is incident normally on the mirror, so it gets reflected back as $EA$. The two reflected rays $DA_1$ and $EA$ intersect at a point $A_1$ to form the image. Similarly, the image is formed at points between $A_1$ and $B_1$ for other points of the object between $A$ and $B$. So image $A_1B_1$ is obtained between the focus $F$ and the centre of curvature $C$. The image is *real, inverted* and *diminished.* Thus

*When object is beyond the centre of curvature C, the image is between the focus F and the centre of curvature C. It is* (i) *Real,* (ii) *Inverted, and* (iii) *Diminished.*

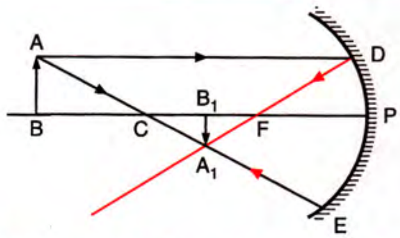



*Fig. 7.33 When the object is beyond centre of curvature C*

**Case (iv) : *When object is at the centre of curvature C***

In Fig. 7.34, $AB$ is an object placed at the centre of curvature $C$. An incident ray of light $AD$ being parallel to the principal axis, passes through its focus $F$ along $DA_1$ after reflection. The other ray $AE$, being incident on the concave mirror through focus $F$, becomes parallel to the principal axis as $EA_1$, after reflection. The two reflected rays $DA_1$ and $EA_1$ meet at a point $A_1$ to form the image. Similarly, the image is formed for other points of the object and $B_1A_1$ is the image of the object $AB$ formed at the centre of curvature $C$ itself. It is *real, inverted and of same size as the object.* Thus

*When the object is at the centre of curvature C, the image is also at the centre of curvature C. It is* (i) *Real,* (ii) *Inverted, and* (iii) *Size same as that of the object.*

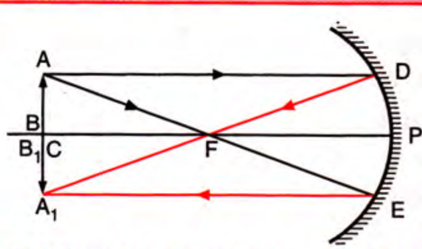



*Fig. 7.34 When the object is at centre of curvature C*

**Case (v) : *When object is between the centre of curvature C and focus F***

In Fig. 7.35, $AB$ is an object placed between $C$ and $F$. An incident ray of light $AD$ from the point $A$ of the object is parallel to the principal axis, so it passes through its focus $F$ after reflection along $DA_1$. Another ray $AE$, being incident on the concave mirror through focus $F$, becomes parallel to the principal axis as $EA_1$, after reflection. The two reflected rays $DA_1$ and $EA_1$ intersect at a point $A_1$ to form the image of point $A$ of the object. Similarly, the image is formed on $A_1B_1$ for the other points on the object $AB$, thus the image $A_1B_1$ is formed beyond the centre of curvature $C$ which is *real, inverted* and *magnified.* Thus,

*When the object is between the centre of curvature C and the focus F, the image is beyond the centre of curvature C. It is* (i) *Real,* (ii) *Inverted, and* (iii) *Magnified.*

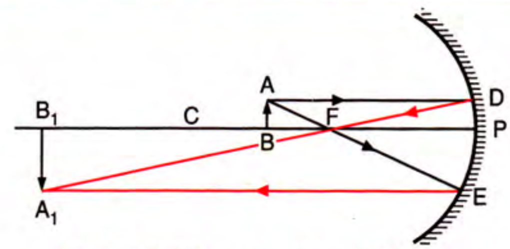



*Fig. 7.35 When the object is between centre of curvature C and focus F*

**Case (vi) : *When object is at the focus F***

In Fig. 7.36, $AB$ is an object placed at the focus $F$. A ray of light $AD$ is incident on the mirror parallel to the principal axis and so it gets reflected along $DF$, passing through its focus $F$. The other ray $AE$ moving in direction $CA$, appears to be coming from the centre of curvature $C$, so it gets reflected back along $EA$. The two reflected rays $DF$ and $EA$ are parallel to each other which are assumed to meet at infinity, so image is *formed at infinity*. In this case image is *real, inverted and highly magnified.* Thus

*When the object is at the focus F, the image is at infinity. It is* (i) *Real,* (ii) *Inverted, and* (iii) *Highly magnified.*

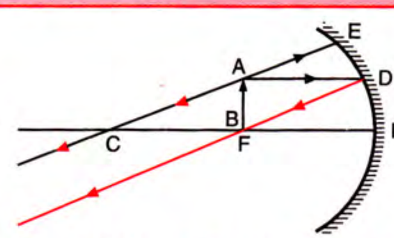



*Fig. 7.36 When the object is at focus F*

**Case (vii) : *When the object is between the focus F and the pole P***

In Fig. 7.37, $AB$ is an object placed between pole $P$, and focus $F$. A light ray $AD$ incident parallel to the principal axis, gets reflected along $DF$ passing through its focus $F$ and the incident ray $AE$ coming from the centre of curvature $C$ gets reflected back along $EA$. The two reflected rays $DF$ and $EA$ do not intersect each other, but they appear to diverge from a point $A_1$ (*when produced backwards*). For an eye between $C$ and $F$, the reflected rays appear to come from $A_1$ which is the virtual image of $A$. Similarly, image is formed for other points on the object and an image $A_1B_1$ is formed behind the mirror which is *virtual, upright* and *magnified.* Thus

*When the object is between the focus F and pole P, the image is behind the mirror. It is* (i) *Virtual,* (ii) *Upright, and* (iii) *Magnified.*

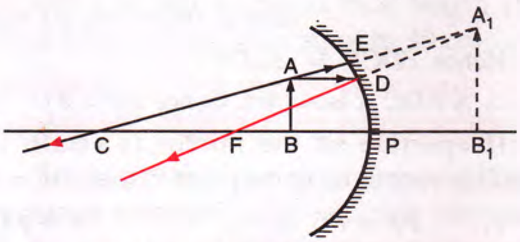



*Fig. 7.37 When the object is between focus F and pole P*

**Note :** In this case, as the object $AB$ moves towards its pole $P$, image $A_1B_1$ formed behind the mirror, also shifts towards the pole $P$ and its size keeps on decreasing, but it remains bigger than the object $AB$. Finally when the object $AB$ comes very close to the pole $P$ of the mirror, the virtual image will be at the pole and it is of size same as of object.

**Inference :** *In case of a concave mirror, the image formed can be real as well as virtual; it can be diminished, of the same size as well as magnified. The nature and size of the image depends on the position of object. For the object situated beyond focus, the image is always real and inverted, whereas for the object situated between the focus and pole, the image is upright and virtual.* The image is diminished when the object is beyond centre of curvature, but it becomes magnified as the object comes within the centre of curvature. The image is of size of the object when the object is at the centre of curvature.

The table below gives the position, size and nature of the image formed by a concave mirror corresponding to the different positions of the object.

**Position, size and nature of the image formed by a concave mirror for different positions of the object.**

| No. | Position of the object | Position of the image | Size of the image | Nature of the image |
|---|---|---|---|---|
| 1 | At *infinity* | At the *focus* | *Diminished* to a point | *Real & inverted* |
| 2 | At very far distance | In focal plane | Highly *diminished* | *Real & inverted* |
| 3 | Beyond the *centre of curvature* | Between the *centre of curvature and focus* | *Diminished* | *Real & inverted* |
| 4 | At *the centre of curvature* | *At centre of curvature* | *Same size* | *Real & inverted* |
| 5 | Between the *centre of curvature and focus* | Beyond the *centre of curvature* | *Magnified* | *Real & inverted* |
| 6 | At *focus* | At *infinity* | *Highly magnified* | *Real & inverted* |
| 7. | Between the *focus and pole* | Behind the mirror | *Magnified* | *Virtual and upright* |

## 7.21 RAY DIAGRAM FOR FORMATION OF IMAGE IN A CONVEX MIRROR

In Fig. 7.38, $AB$ is a linear object placed in front of a convex mirror. Consider two rays starting from a point $A$ of the object. A ray of light $AD$, incident parallel to the principal axis is reflected along $DM$ such that it appears to diverge from its focus $F$. The other ray $AE$ travelling towards the centre of curvature $C$, falls normally on the mirror, so it is reflected back as $EA$ along the same path. The *two* reflected rays $DM$ and $EA$ meet at a point $A_1$ when they are produced backwards. In other words, the reflected rays appear to come from a point $A_1$

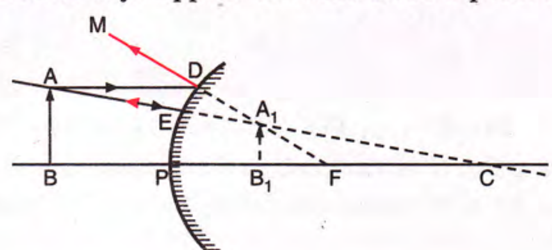



*Fig. 7.38 Image formation in convex mirror*

which is the virtual image of $A$. Similarly, for the rays incident from the other points of the object, a virtual image is formed along $A_1B_1$ which is *situated between the pole and focus*. The image is *virtual, upright and diminished.* Thus

> *When the object is in front of a convex mirror, the image is between the pole P and focus F on the other side of the mirror. It is* (i) *Virtual,* (ii) *Upright, and* (iii) *Diminished.*

**Note :** When the object, in front of a convex mirror, is at a distance equal to the focal length of mirror, the image is exactly at the midpoint between its pole and focus.

**Inference :** *In a convex mirror, the image formed is always virtual, upright, and diminished, It is always situated between its pole and focus, irrespective of the distance of object in front of the mirror.* As the object comes closer to the mirror from a far distance, its image shifts from focus towards the pole and increases in size.

The table below gives the position, size and nature of image formed by a convex mirror for the different positions of the object.

**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* |

## 7.22 RELATIONSHIP BETWEEN THE FOCAL LENGTH AND RADIUS OF CURVATURE

> *The focal length of a spherical mirror is equal to half of its radius of curvature. i.e.*
>
> $$f = \frac{1}{2}R \qquad ....(7.5)$$

**Proof* :** In Fig. 7.39 and Fig. 7.40, $P$ is the pole, $C$ is the centre of curvature and $F$ is the focus of the mirror. The distance $PF$ is equal to the focal length $f$ the distance $PC$ is equal to the radius of curvature $R$ of the mirror.

* Not included in the syllabus

**For concave mirror –**

In Fig. 7.39, a ray light $BD$, parallel to the principal axis $PC$, is incident on the concave mirror $PD$. After reflection, it goes along $DR$ passing through its focus $F$.

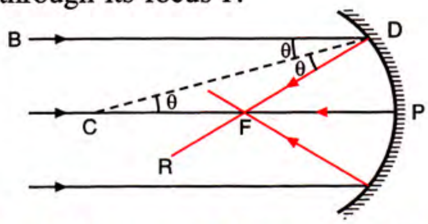



*Fig. 7.39 Relationship between f and R for a concave mirror*

Then $\angle BDC = \angle DCF$ (alternate angles)

and $\angle BDC = \angle CDF$

(law of reflection, $\angle i = \angle r$)

Hence $\angle DCF = \angle CDF$

$\therefore \Delta FDC$ is isosceles. Hence $DF = FC$

If aperture of the mirror is small, the point $D$ is very close to the point $P$, then $DF = PF$

$\therefore \quad PF = FC$ or $PF + PF = PF + FC$

or $\quad 2PF = PC$

or $\quad PF = \frac{1}{2} PC$ or $f = \frac{1}{2} R$

**For convex mirror –**

In Fig. 7.40, a ray of light $BD$ incident on the convex mirror, parallel to the principal axis $PC$, after reflection appears to come from its focus $F$. At the point of incidence $D$, the normal on mirror is $DC$.

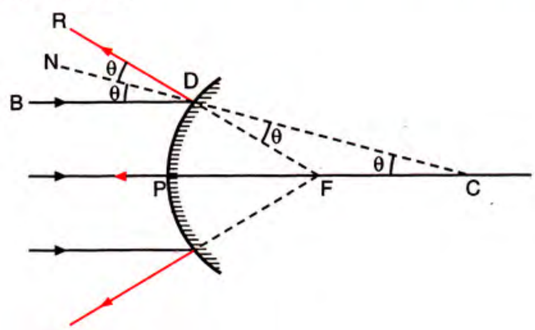



*Fig. 7.40 Relationship between f and R for a convex mirror*

Then $\angle BDN = \angle FCD$ (corresponding angles)

$\angle BDN = \angle NDR$ (law of reflection, $\angle i = \angle r$)

and $\angle NDR = \angle CDF$ (vertically opposite angles)

Hence $\angle FCD = \angle CDF$

$\therefore$ $\Delta$ $FDC$ is isosceles. Hence, $DF = FC$

If the aperture of the mirror is small, the point $D$ is very close to the point $P$. Then $DF = PF$.

$\therefore \quad PF = FC \text{ or } PF + PF = PF + FC$

or $\quad 2PF = PC$

or $\quad PF = \frac{1}{2} PC$ or $f = \frac{1}{2}R$

Thus, *for a spherical mirror (both concave and convex), focal length is half of its radius of curvature.*

***Examples :*** **(1)** A concave mirror of radius of curvature 20 cm has its focal length equal to 10 cm.

**(2)** A convex mirror of focal length 15 cm has its radius of curvature equal to 30 cm.

## 7.23 SIGN CONVENTION FOR THE MEASUREMENT OF DISTANCES

To specify the position of object and image, we need a reference point and sign convention. We follow the *cartesian* sign convention, according to which the rules are :

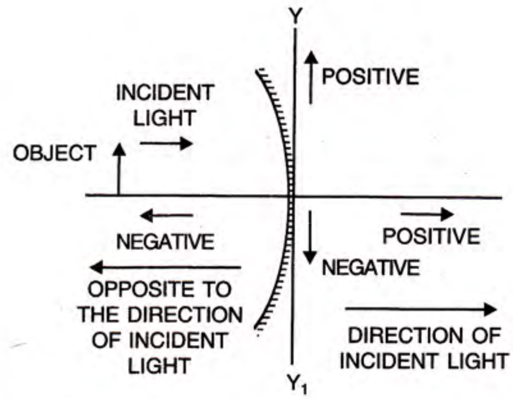
**(i)** *All distances are measured from the pole of the mirror taken as origin.* The rays are made incident from the left.

**(ii)** *The distances measured along the principal axis in the direction of incident light, are positive while those opposite to the incident light, are negative.*

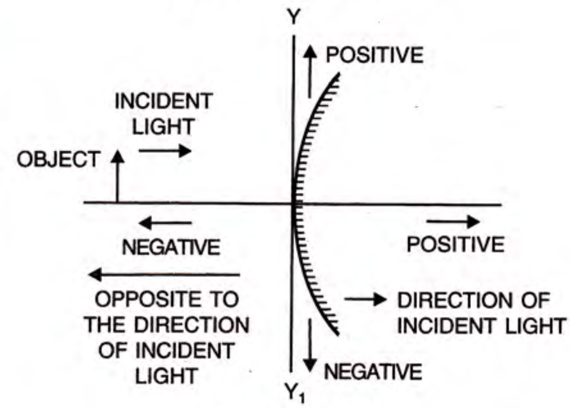
**(iii)** *The distances above the principal axis are taken positive and those below the principal axis are taken negative.*

This convention gives the focal length of a *concave mirror* to be *negative* (since in Fig. 7.24. $PF$ is the distance measure opposite to the incident rays), and that of *convex mirror* to be *positive* (since in Fig. 7.25, $PF$ is the distance measured in the direction of incident rays). For convenience, the object is placed to the left of the mirror so that the graphical convention of sign comes into operation.

Fig. 7.41 shows the sign convention in concave and convex mirror.




**(a) CONCAVE MIRROR**




**(b) CONVEX MIRROR**

*Fig. 7.41 Sign convention*

## 7.24 FORMULAE FOR THE SPHERICAL MIRROR

**(1)** The expression relating the distance of object $u$, distance of image $v$ and focal length $f$ for a spherical mirror, is called the formula for spherical mirror. It is gives as :

$$\boxed{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}} \qquad \text{....(7.6)}$$

In the above relation, the values of known quantities out of $u$, $v$ and $f$ are substituted with their proper sign. For a concave mirror, the values of $u$ and $f$ are always negative, while the value of $v$ is negative for a real image and positive for a virtual image. For a convex mirror, the value of $u$ is always negative and the values of $v$ and $f$ are always positive.

**(2)** If the length of the object and image are measured perpendicular to the principal axis, *the ratio of length of the image to the length of the object, is called linear magnification.* If length of the image is $I$ and that of the oject is $O$, then

$$\text{Magnification } m = \frac{\text{Length of the image } (I)}{\text{Length of the object } (O)} = \frac{\text{Distance of image } (v)}{\text{Distance of object } (u)}$$

or
$$\boxed{m = \frac{I}{O} = -\frac{v}{u}} \qquad ....(7.7)$$

For the real image, $u$ and $v$ both are negative, so linear magnification $m$ is negative. For virtual image, $u$ is negative and $v$ is positive, so linear magnification $m$ is positive. A real image is always inverted, while a virtual image is always errect.

## 7.25 USES OF SPHERICAL MIRRORS

### *Uses of a concave mirror*

**(1) As a shaving mirror :** When a concave mirror is held near the face (such that face is between the pole and focus of mirror), it gives an upright and magnified image as shown in Fig. 7.37 and hence even the tiny hairs on the face can easily be seen. For this, a concave mirror of *large focal length* (so that the face always lies between its focus and the pole) and *large aperature* (so as to view the entire face) is used.

**(2) As a reflector :** *In torch, search light, and head light of automobiles, cars or cycles* etc., a concave polished metallic surface is used as a reflector to obtain a parallel beam of light. For this, the source of light (*i.e.*, bulb) is placed at the focus of concave reflector. The rays of light from the bulb fall on the concave reflector which after reflection form a parallel beam (Fig. 7.42).

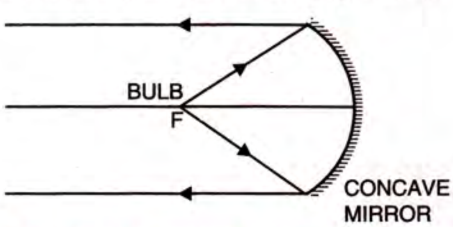


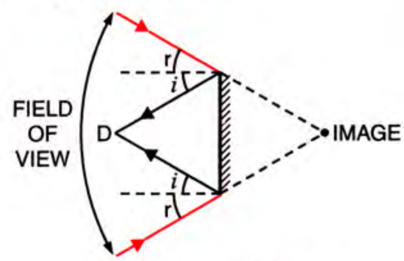

*Fig. 7.42 Use of a concave mirror as a reflector*

**(3) As a dentist's head mirror :** If a parallel beam of light is incident on a concave mirror, it focuses the beam to a point [Fig. 7.26(a)]. This fact enables us to use it as a doctor's head mirror to concentrate a light beam on a small area of the body part (such as teeth, nose, throat, ear, etc.) to be examined. For this, a parallel beam of light is made to fall on a concave mirror attached to the band tied at the fore-head of doctor examining the body part.

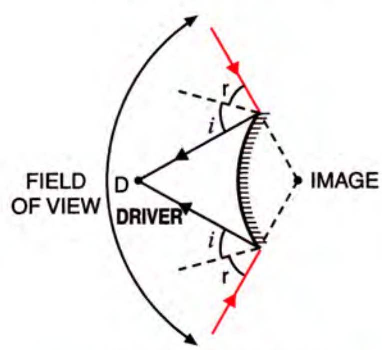
### *Uses of a convex mirror*

**(1) As a reflector in street lamps :** A convex polished metallic surface is used in street lamp as a reflector so as to diverge light over a larger area.

**(2) As a rear view mirror :** A convex mirror diverges the incident light beam and always forms a virtual, small and erect image between its pole and focus. This fact enables the driver to use it as a rear view mirror in vehicles to see all the traffic approaching from behind. Although a plane mirror can also be used for the purpose, but a convex mirror provides a much *wider field of view* as compared to a plane mirror of the *same size*. The ray diagrams in Fig. 7.43 show how a convex mirror provides a wider field of view than a plane mirror of the same aperture. Here $D$ is the position of the driver of the vehicle.




**(a) PLANE MIRROR**




**(b) CONVEX MIRROR**

*Fig. 7.43 Use of a convex mirror as a rear view mirror*

## 7.26 DISTINCTION BETWEEN A PLANE MIRROR, CONCAVE MIRROR AND CONVEX MIRROR (WITHOUT TOUCHING)

To distinguish between a plane mirror, concave mirror and convex mirror, the given mirror is held near the face and image is seen.

There can be the following *three* cases :

**Case (i) :** If image is *upright, of same size* and it does not change in size by moving the mirror towards or away from the face, the mirror is *plane.*

**Case (ii) :** If image is *upright, magnified,* and increases in size on small movement of the mirror away, the mirror is *concave.*

**Case (iii) :** If image is *upright, diminished* and decreases in size on small movement of the mirror away, the mirror is *convex.*

## 7.27 DIFFERENCE BETWEEN A CONCAVE AND CONVEX MIRROR

**Difference between a concave and convex mirror**

| *Concave mirror* | *Convex mirror* |
|---|---|
| 1. It is made by silvering the outer surface of a part of the hollow sphere, so reflection takes place from the inner surface. | 1. It is made by silvering the inner surface of a part of the hollow sphere, so reflection takes place from the bulging surface. |
| 2. The light rays incident on it converge after reflection. | 2. The light rays incident on it diverge after reflection. |
| 3. The image formed by it is real as well as virtual. For all positions of the object at or beyond the focus, the image is real, while for positions of the object between the focus and pole, the image is virtual. | 3. The image formed by it is always virtual for all positions of the object in front of it. |
| 4. For object away from the centre of curvature, the image is diminished, for object at centre of curvature, image is of same size and for object within the centre of curvature, image is magnified. | 4. The image is always diminished for all positions of the object in front of it. |

**EXAMPLES**

**1. Complete the ray diagram shown in Fig. 7.44 to show the formation of image for parallel rays incident on a concave mirror. State position, nature and size of the image formed.**

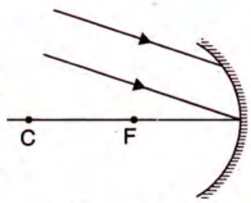



*Fig. 7.44*

The completed ray diagram is shown in Fig. 7.45. The image is formed at the focus *F*. It is **real, inverted** and **diminished**.

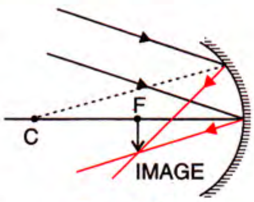



*Fig. 7.45*

**2. Complete the ray diagram shown in Fig. 7.46 to show the formation of image for parallel rays incident on a convex mirror. State position, nature and size of the image formed.**

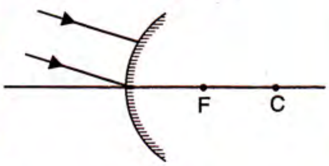



*Fig. 7.46*

The completed ray diagram is shown in Fig. 7.47. The image is formed at the focus *F* (behind the mirror). It is **virtual, erect** and **diminished**.

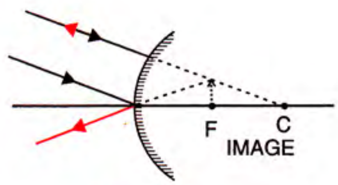



*Fig. 7.47*

**3. In case of a convex mirror, if object is moved away from the mirror, how do the position, size and nature of image change ?**

As the object is moved away from a convex mirror, the distance of virtual image from the mirror (formed behind it between pole and focus) increases *i.e.*, the image shifts from the pole towards the focus and the size of the image gradually decreases. When the object is at infinity (very far), the image is at its focus. The image is always erect and virtual.

**4. An object is brought from a far distance towards a concave mirror. How do the nature, position and size of image change ?**

When object is very far from the concave mirror, its image is at the focus and it is real, diminished, and inverted. As the object is brought towards the mirror, the image shifts away from the mirror and its size increases, but it remains smaller than the object. When the object is at centre of curvature of the mirror, the image is also at the centre of curvature and it is of size equal to the size of the object. By further bringing the object towards the mirror, the image gets magnified and it moves away from the centre of curvature. When object is at focus of mirror, the image is at infinity. The image remains real and inverted. If the object is further moved towards the mirror, the image now becomes virtual, erect and magnified and it is formed behind the mirror.

**5. You are given a concave mirror of focal length 10 cm, a point source of light and a screen placed at distance 30 cm in front of mirror. How can you obtain a bright patch of light on screen, of size equal to that of the aperture of mirror ? Draw diagram to explain your answer.**

By placing the point source of light at the focus of the concave mirror, it is possible to obtain a bright patch on the screen, of size equal to that of the aperture of the mirror. The completed ray diagram is shown in Fig. 7.48.

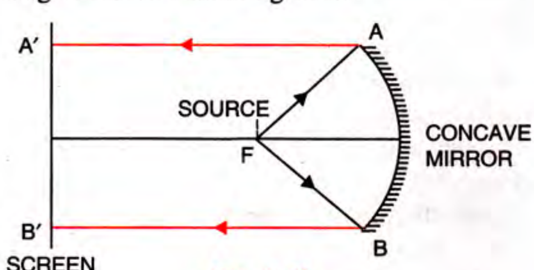



*Fig. 7.48*

**6. What is the focal length of a concave mirror of radius of curvature 16·0 cm ?**

Given, radius of curvature = 16·0 cm

$$\text{Focal length} = \frac{1}{2} \times \text{Radius of curvature}$$
$$= \frac{1}{2} \times 16{\cdot}0 \text{ cm} = \mathbf{8{\cdot}0\ cm}$$

**7. A concave mirror is a part of hollow sphere of radius 40 cm. What will be the focal length of concave mirror ?**

Given : radius of curvature $R$ = 40 cm

$$\therefore \quad \text{Focal length } f = \frac{\text{Radius of curvature } R}{2}$$
$$= \frac{40}{2} = \mathbf{20\ cm}$$

**8. The focal length of a convex mirror is 10 cm. Find the radius of curvature of mirror.**

Given : Focal length $f$ = 10 cm

$\therefore$ Radius of curvature $R = 2 \times$ focal length $f$

$$= 2 \times 10 = \mathbf{20\ cm}$$

**9. For an object placed at a distance 20 cm from a concave mirror, the image is formed at the same position. What is the focal length of the mirror ?**

For an object placed at the centre of curvature of a concave mirror, the image is formed at the centre of curvature itself. Thus radius of curvature $R$ = 20 cm

$$\text{Focal length } f = \frac{\text{Radius of curvature } R}{2}$$
$$= \frac{20\text{ cm}}{2} = \mathbf{10\ cm}$$

**10. The image of an object placed at a distance of 30 cm on the principal axis of a concave mirror from its pole, is formed on the object itself. Find (a) the focal length and (b) linear magnification of mirror.**

Since the image of an object placed at the centre of curvature of a concave mirror is formed at the centre of curvature, hence according to the question, radius of curvature of mirror $R$ = 30 cm.

(a) $$\text{Focal length } f = \frac{1}{2} \times \text{Radius of curvature}$$
$$= \frac{1}{2} \times 30 \text{ cm} = \mathbf{15\ cm}$$

(b) Now $u$ = 30 cm (negative),
$v$ = 30 cm (negative)

$\therefore$ Linear magnification

$$m = -\frac{v}{u} = -\left(\frac{-30}{-30}\right) = \mathbf{-1}$$

**11. An object is placed at a distance of 48 cm in front of a concave mirror of focal length 24 cm.**

**(a) Find the position of image.**

**(b) What will be the nature of image ?**

Given : $f$ = 24 cm (negative),
$u$ = 48 cm (negative)

(a) From relation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$,

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{(-24)} - \frac{1}{(-48)}$$

or $$\frac{1}{v} = \frac{-2+1}{48} = \frac{-1}{48} \quad \text{or} \quad v = \mathbf{-48\ cm}$$

**Alternative :** The object is at the centre of curvature of concave mirror, so image will form on itself *i.e.*, at distance 48 cm in front of mirror.

(b) The image is at a distance **48 cm in front** of mirror. The image is **inverted**, **real** and **of same size** as object.

**12. An object is placed at a distance of 15 cm in front of a convex mirror of radius of curvature 10 cm. (a) Where will the image form ? (b) Find the magnification $m$. (c) What will be the nature of image real or virtual ?**

Given : $R = 10$ cm, $f = \frac{R}{2} = 5$ cm (positive),

$u = 15$ cm (negative), $v = ?$

(a) From relation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$,

$$\frac{1}{v} + \frac{1}{(-15)} = \frac{1}{5}$$

or $$\frac{1}{v} = \frac{1}{5} + \frac{1}{15} = \frac{4}{15}$$

or $$v = \frac{15}{4} = \mathbf{3{\cdot}75\ cm}$$

Thus the image will form at a distance **3·75 cm behind** the mirror.

(b) Magnification $m = -\frac{v}{u} = -\frac{3{\cdot}75}{(-15)} = \mathbf{\frac{1}{4}}$

Thus the size of image is **one-fourth** the size of the object.

(c) The image will be **virtual** and **erect**.

**13. When an object is placed at a distance of 40 cm from a concave mirror, the size of image is one fourth that of the object. (a) Calculate the distance of image from the mirror. (b) What will be the focal length of the mirror ?**

Given : $u = 40$ cm (negative),

$m = \frac{1}{4}$ (negative for the real image)

(a) From $m = -\frac{v}{u}$, $-\frac{1}{4} = -\frac{v}{(-40)}$ or $v = \mathbf{-10\ cm}$

Thus the image is formed at a distance **10 cm in front** of the mirror.

(b)Now from relation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$,

$$\frac{1}{f} = \frac{1}{(-40)} + \frac{1}{(-10)}$$

$$= \frac{-5}{40}$$

or $$f = \frac{-40}{5} = \mathbf{-8\ cm}$$

*i.e.*, the focal length of concave mirror is **8 cm**.

**14. At what distance in front of a concave mirror of focal length 10 cm, an object be placed so that its real image of size five times that of the object is obtained ?**

Given : $f = 10$ cm (negative),

$m = 5$ (negative for the real image)

But $m = -\frac{v}{u}$ $\therefore$ $-5 = -\frac{v}{u}$ or $v = 5u$

Now from relation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$,

$$\frac{1}{u} + \frac{1}{5u} = \frac{1}{-10}$$

or $$\frac{6}{5u} = \frac{-1}{10}$$

or $$u = \mathbf{-12\ cm}$$

Thus the object should be placed at a distance **12 cm in front** of the mirror.

**15. At what distance in front of a concave mirror of focal length 10 cm, an object be placed so that its virtual image of size five times that of the object is obtained?**

Given : $f = 10$ cm (negative),

$m = 5$ (positive for the virtual image)

But $m = -\frac{v}{u}$ $\therefore$ $5 = -\frac{v}{u}$ or $v = -5u$

Now from relation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$,

$$\frac{1}{u} + \frac{1}{(-5u)} = \frac{1}{-10}$$

or $$\frac{4}{5u} = \frac{-1}{10}$$

or $$u = \mathbf{-8\ cm}$$

Thus the object should be placed at a distance **8 cm in front** of the mirror.

**16. A convex mirror forms the image of an object placed at a distance 40 cm in front of mirror, at distance 10 cm. Find the focal length of mirror.**

Given : $u = 40$ cm (negative),

$v = 10$ (positive), $f = ?$

since the image formed by a convex mirror is always virtual, erect and on other side of mirror.

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

$$\frac{1}{(-40)} + \frac{1}{10} = \frac{1}{f}$$

or $$\frac{1}{f} = \frac{-1+4}{40}$$

or $$\frac{1}{f} = \frac{3}{40}$$

or $$f = \frac{40}{3} = \mathbf{13{\cdot}33\ cm}$$

**17. The focal length of a convex mirror is 40 cm. A point source of light is kept at distance 40 cm from the mirror. Find the distance of image from the mirror.**

Given : $f = 40$ cm (positive),

$u = 40$ (negative)

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

$$\frac{1}{(-40)} + \frac{1}{v} = \frac{1}{40}$$

or $\frac{1}{v} = \frac{1}{40} + \frac{1}{40} = \frac{1}{20}$

or $v =$ **20 cm**

*i.e.*, the image is formed at distance **20 cm behind** the mirror.

**18. A convex mirror forms an erect image of an object of size one-third the size of object. If radius of curvature of convex mirror is 36 cm, find the position of object.**

Given : $m = \frac{1}{3}$ (positive) for the erect (or virtual) image, $R = 36$ cm (positive).

$\therefore$ From relation $f = \frac{R}{2} = 18$ cm (positive).

From relation $m = -\frac{v}{u}$,

$$\frac{1}{3} = -\frac{v}{u} \quad \therefore v = -\frac{1}{3}u$$

From mirror's formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$,

$$\frac{1}{u} + \frac{1}{(-u/3)} = \frac{1}{18}$$

or $\frac{-2}{u} = \frac{1}{18}$ or $u =$ **– 36 cm**

Thus the object is at a distance **36 cm in front** of the mirror.

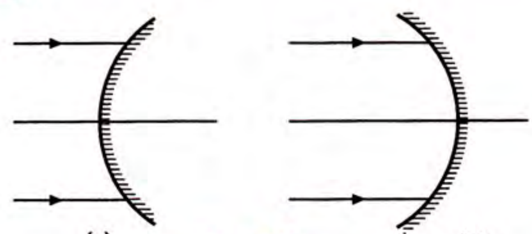
## EXERCISE 7(C)

1. What is a spherical mirror ?
2. Name the *two* kinds of spherical mirrors and distinguish between them.
3. Define the terms pole, principal axis and centre of curvature with reference to a spherical mirror.
4. Draw suitable diagrams to illustrate the action of (i) concave mirror, and (ii) convex mirror, on a beam of light incident parallel to the principal axis.
5. Name the spherical mirror which (i) diverges (ii) converges the beam of light incident on it. Justify your answer by drawing a ray diagram in each case.
6. Define the terms focus and focal length of a concave mirror. Draw diagram to illustrate your answer.
7. Explain the meaning of the terms focus and focal length in case of a convex mirror, with the help of a suitable ray diagram.
8. State the direction of incident ray which after reflection from a spherical mirror retraces its path. Give a reason to your answer.

   **Ans.** Incident ray is directed towards the centre of curvature

   **Reason :** The ray is normal to the spherical mirror, so $\angle i = 0$, $\therefore \angle r = 0$.
9. (i) Name the mirrors shown in Fig. 7.49 (a) and (b).

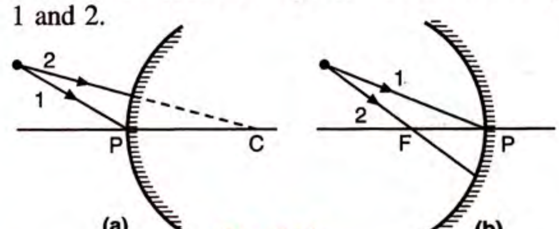
   (ii) In each case (a) and (b), draw the reflected rays for the given incident rays and mark focus by the symbol *F*.



(a) *Fig. 7.49* (b)

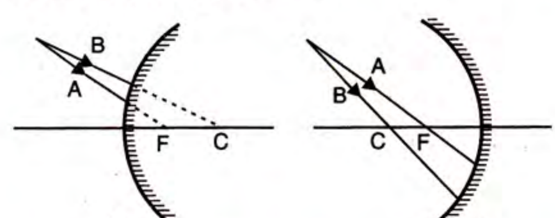
**Ans.** (i) (a) convex mirror (b) concave mirror

10. Complete the following diagrams in Fig. 7.50 by drawing the reflected rays for the incident rays 1 and 2.




(a) *Fig. 7.50* (b)

11. Complete the following diagrams shown in Fig. 7.51 by drawing the reflected ray for each of the incident ray *A* and *B*.




(a) (b)

*Fig. 7.51*

12. State the *two* convenient rays that are chosen to construct the image by a spherical mirror for a given object ? Explain your answer with the help of suitable ray diagrams.

13. Fig. 7.52 shows a concave mirror with its pole at $P$, focus $F$ and centre of curvature $C$. Draw ray diagram to show the formation of image of an object $OA$.

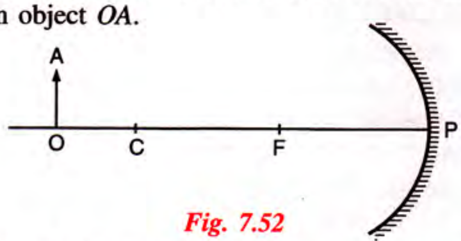



*Fig. 7.52*

14. Fig. 7.53 shows a concave mirror with its pole at $P$, focus $F$ and centre of curvature $C$. Draw ray diagram to show the formation of image of an object $OA$.

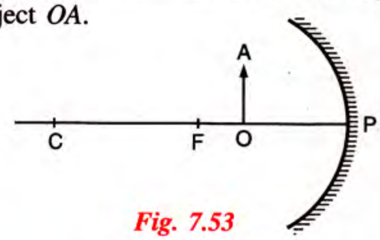



*Fig. 7.53*

15. The diagram below in Fig. 7.54 shows a convex mirror. $C$ is its centre of curvature and $F$ is its focus. (i) Draw *two* rays from $A$ and hence locate the position of image of object $OA$. Label the image $IB$. (ii) State *three* characteristics of the image.

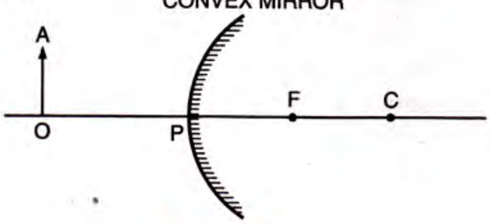



*Fig. 7.54*

**Ans.** (ii) Erect, virtual and diminished

16. Draw a ray diagram to show the formation of image by a concave mirror for an object placed between its pole and focus. State *three* characteristics of the image.

17. Draw a ray diagram to show the formation of image by a concave mirror for the object beyond its centre of curvature. State *three* characteristics of the image.

18. Draw a ray diagram to show the formation of image of an object kept in front of a convex mirror. State *three* characteristics of the image.

19. Name the mirror which always produces an erect and virtual image. How is the size of image related to the size of object ?

**Ans.** Convex mirror, image is shorter than the object

20. (a) For what position of object, the image formed by a concave mirror is magnified and erect ?
(b) State whether the image in part (a) is real or virtual ?
**Ans.** (a) Between pole and focus, (b) virtual

21. (a) State the position of object for which the image formed by a concave mirror is of same size.
(b) Write *two* more characteristics of the image.

**Ans.** (a) At centre of curvature. (b) Real and inverted

22. (a) What is a real image ?
(b) What type of mirror can be used to obtain a real image of an object ?
(c) Does the mirror mentioned in part (b) form real image for all locations of the object ?
**Ans.** (a) A real image is one which can be obtained on a screen, (b) Concave, (c) No

23. Discuss the position and nature of image formed by a concave mirror when an object is moved from infinity towards the pole of mirror.

24. Discuss the position and nature of image formed by a convex mirror when an object is moved from infinity towards the pole of mirror.

25. Name the kind of mirror used to obtain :
(a) a real and enlarged image,
(b) a virtual and enlarged image,
(c) a virtual and diminished image,
(d) a real and diminished image.
**Ans.**(a) concave, (b) concave, (c) convex, (d) concave

26. How is the focal length of a spherical mirror related to its radius of curvature ? **Ans.** $f = \frac{1}{2}R$

27. Write the spherical mirror's formula and explain the meaning of each symbol used in it.
**Ans.** $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

28. What is meant by magnification ? Write its expression. What is its sign for the (a) real (b) virtual, image ?

29. At what maximum distance the image in a convex mirror can be obtained ? What will be the location of object then ? **Ans.** focal length, infinity

30. At what maximum distance from a concave mirror, the image can be obtained ? What will be the location of object for it ? **Ans.** infinity, focus.

31. How will you distinguish between a plane mirror, a concave mirror and a convex mirror, without touching them ?
32. State *two* uses of a concave mirror.
33. State the kind of mirror used
    (a) by a dentist, (b) as a search-light reflector.
    **Ans.** (a) concave, (b) concave
34. (a) When a concave mirror is used as a shaving mirror, where is the person's face in relation to the focus of mirror ?
    (b) State *three* characteristics of the image seen in part (a).
    **Ans.** (a) Between pole and focus. (b) Erect, virtual and magnified
35. Which mirror will you prefer to use as a rear view mirror in a car : plane mirror or convex mirror ? Give *one* reason.
36. Why does a driver use a convex mirror instead of a plane mirror as a rear view mirror ? Illustrate your answer with the help of a ray diagram.

**Multiple choice type :**

1. For an incident ray directed towards centre of curvature of a spherical mirror, the reflected ray :
   (a) retraces its path
   (b) passes through the focus
   (c) passes through the pole
   (d) becomes parallel to the principal axis.
   **Ans.** (a) retraces its path
2. The image formed by a convex mirror is :
   (a) erect and diminished
   (b) erect and enlarged
   (c) inverted and diminished
   (d) inverted and enlarged.
   **Ans.** (a) erect and diminished
3. A real and enlarged image can be obtained by using a :
   (a) convex mirror (b) plane mirror
   (c) concave mirror
   (d) either convex or plane mirror.
   **Ans.** (c) concave mirror

**Numericals :**

1. The radius of curvature of a convex mirror is 40 cm. Find its focal length. **Ans.** 20 cm.
2. The focal length of a concave mirror is 10 cm. Find its radius of curvature. **Ans.** 20 cm.
3. An object of height 2 cm is placed at a distance 20 cm in front of a concave mirror of focal length 12 cm. Find the position, size and nature of the image.
   **Ans.** 30 cm in front of mirror, 3 cm high, real, inverted and magnified
4. An object is placed at 4 cm distance in front of a concave mirror of radius of curvature 24 cm. Find the position of image. Is the image magnified ? **Ans.** 6 cm behind the mirror, Yes
5. At what distance from a concave mirror of focal length 25 cm should an object be placed so that the size of image is equal to the size of the object. **Ans.** 50 cm
6. An object 5 cm high is placed at a distance 60 cm in front of a concave mirror of focal length 10 cm. Find (i) the position and (ii) size, of the image.
   **Ans.** (i) 12 cm in front of the mirror, (ii) 1 cm
7. A point light source is kept in front of a convex mirror at a distance of 40 cm. The focal length of the mirror is 40 cm. Find the position of image.
   **Ans.** Behind the mirror at a distance 20 cm
8. When an object of height 1 cm is kept at a distance 4 cm from a concave mirror, its erect image of height 1·5 cm is formed at a distance 6 cm behind the mirror. Find the focal length of mirror.
   **Ans.** 12 cm
9. An object of length 4 cm is placed in front of a concave mirror at distance 30 cm. The focal length of mirror is 15 cm. (a) Where will the image form ? (b) What will be the length of image ?
   **Ans.** (a) 30 cm in front of mirror, (b) 4 cm.
10. A concave mirror forms a real image of an object placed in front of it at a distance 30 cm, of size three times the size of object. Find (a) the focal length of mirror (b) position of image.
    **Ans.** (a) 22·5 cm, (b) 90 cm in front of mirror.
11. A concave mirror forms a virtual image of size twice that of the object placed at a distance 5 cm from it. Find : (a) the focal length of the mirrror (b) position of image.
    **Ans.** (a) 10 cm, (b) 10 cm behind the mirror.
12. The image formed by a convex mirror is of size one-third the size of object. How are $u$ and $v$ related ? **Ans.** $v = -\frac{1}{3}u$ or $u = -3v$
13. The erect image formed by a concave mirror is of size double the size of object. How are $u$ and $v$ related ? **Ans.** $v = 2u$
14. The magnification for a mirror is –3. How are $u$ and $v$ related ? **Ans.** $v = -3u$