Light – Reflection

LIGHT

Light is a form of energy, which induces the sensation of vision in our eyes and makes us able to see various things present in our surrounding. The light ray may be objects self-light or reflected light.

Luminous objects are objects which emit light of their own. E.g., sun, bulb, tubelight, glow worms

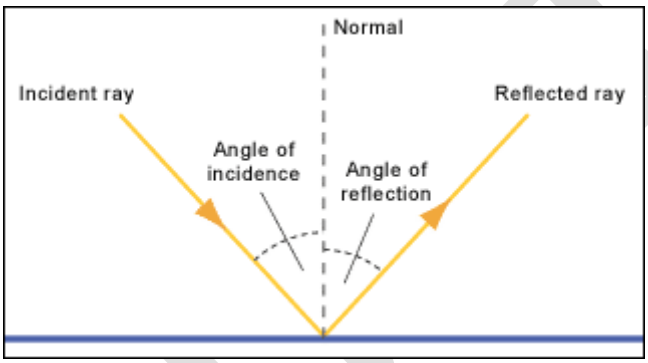
Non-luminous objects are objects which reflect light from other sources. They do not emit light of their own. E.g., Moon, tree, table, painting.

Light

1. It is form of energy
2. It travels in straight line.
3. Light can form shadows.

REFLECTION OF LIGHT

The bouncing back of rays of light from a polished and shiny surface is called reflection or reflection of light. It is similar to bouncing back of a football after colliding with a wall or any hard surface.

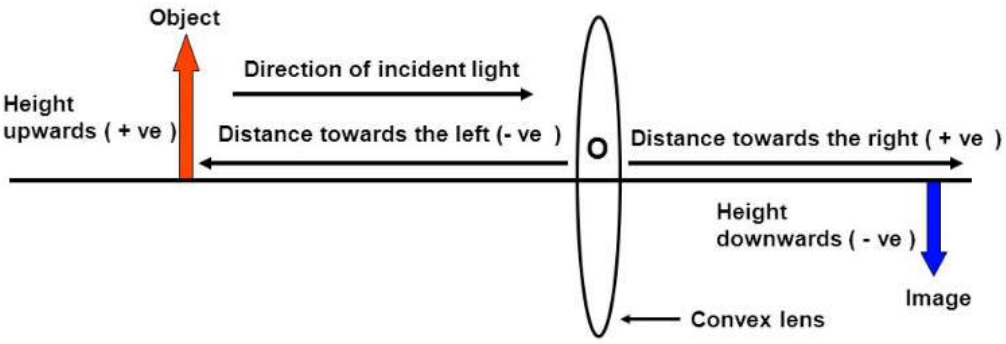


A highly polished surface, such as a mirror, reflects most of the light falling on it. Similarly, Shiny/smooth surfaces reflects more light whereas dull/rough surfaces reflects less light

A plane mirror is a flat mirror that is usually made of glass with a very thin layer of silver on the back. The reflection occurs at the silver and this is protected by a layer of paint.

Sign Convention for spherical lenses

- The sign convention for spherical lenses is the same as in spherical mirrors except that the distances are measured from the optical centre (O)
- The focal length of a convex lens is the positive (+ve) and the focal length of a concave lens is negative (-ve)



Light hitting a plane mirror is reflected back and if you look into such a mirror you will see an image of yourself.

Some mirrors have the silvering at the back like the ones used by us (normal use)

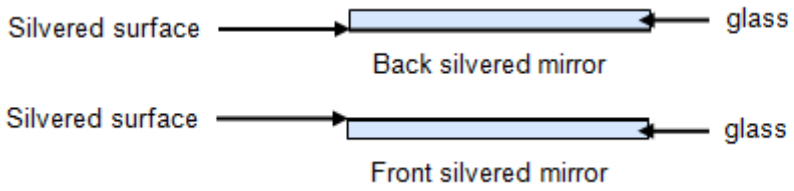


Figure 1

The way the light reflects is shown in the following diagram. (It is usual to show the shiny surface by a line and the back of the mirror by a shaded section).

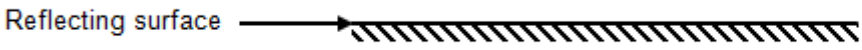


Figure 2

General terms related to plane mirrors:

Incident ray– An incident ray is a ray of light that strikes a surface.

Reflected ray– A ray that represents the light reflected by the surface..

Point of incidence– The point of incidence is the point where the ray of incidence strikes the mirror.

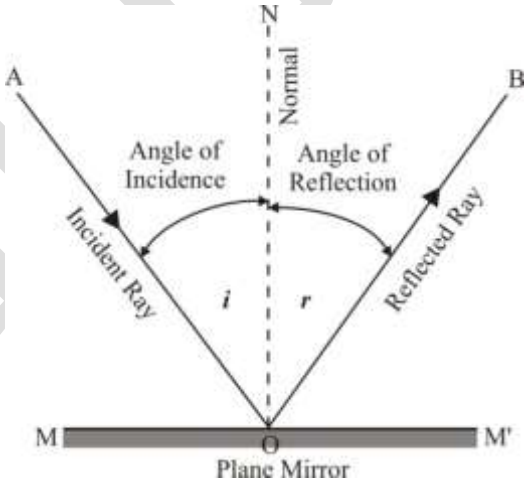
Normal– Normal is a line perpendicular to mirror drawn at point of incidence. The normal is a line perpendicular to the surface at the point where the incident ray reflects. The angles of the incident and reflected rays are always measured from the **normal**.

Angle of incidence– Angle between incident ray and normal. Denoted using 'i'.

Angle of reflection– Angle between reflected ray and normal .Denoted using 'r'

Laws of Reflection of light:

The two laws of reflection are:



i) The angle of incidence is equal to the angle of reflection,

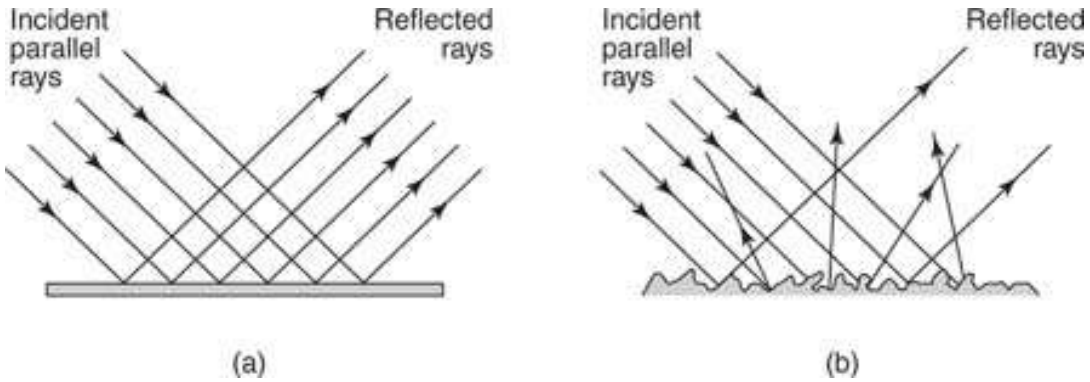
ii) The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.
These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.

Types of reflection

Light undergoes either diffuse or regular reflection.

Regular and diffused reflection:

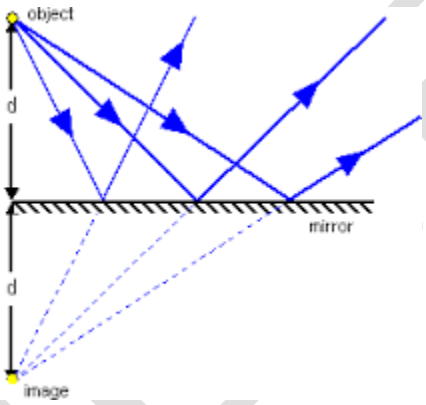
Regular reflection: When the reflection surface is smooth and well-polished, the parallel rays falling on it are reflected parallel to another one, the reflected light goes in one particular direction and are also parallel to each other. This is regular reflection. E.g., plane mirror, reflection from still water etc



Diffused reflection: When the reflecting surface is rough, the parallel rays falling on it are reflected in different direction. Such a reflection is known as diffuse reflection or irregular reflection. For example, reflection of light from the wall of a room or tree etc

Formation of image by plane mirror:

The light rays from the object spread out, hit the mirror and then reflect – they seem to have come from a point behind the mirror. This is the image of the object. Image is denoted as 'I'



Light rays from an object hit the mirror after reflection they appear to meet at (I). Image is seen at I

i) Image is formed behind the mirror

ii) Distance of object from mirror = Distance of image from the mirror. In other words, distance of object and image is the same from the mirror.(Shown as distance 'd' in fig shown above)

Image of extended object:

An extended object AB is placed in front of a plane mirror MM_1. From the points A and B of the object, rays of light travel in all directions. Two rays(AP and AQ) starting from A, incident on the mirror gets reflected as PP' and QQ' respectively from the mirror.

These reflected rays when produced backwards meet at the point A'. In other words, for an observer these reflected rays appear to come at A' . Thus A' is the virtual image of the point A.

In the same way, two rays(BR and BS) starting from B, incident on the mirror gets reflected as RR' and SS' respectively from the mirror.

Thus, B 'is the virtual image of the point B. Thus A'B' is the virtual image of the object AB. It is erect and of size equal to that of the object. It is formed far behind the plane mirror as the object is in front of it. i.e., the distance of object and image is the same from the mirror

Lateral inversion:

"Lateral inversion" means the apparent reversal of the mirror image's left and right when compared with the object. In other words, when an object is placed in front of the plane mirror, sides are reversed. Right becomes left and left becomes right. This reversal is only in the direction perpendicular to the surface of the mirror.

For example, the word AMBULANCE is painted left-right inverted on the ambulance so that when the driver of a vehicle in front looks into his rear-view mirror, he can make out the word AMBULANCE quickly and give way.

Object: Something from which light rays start is called object. The light rays may be the self or reflected rays of object(i.e., they can either be luminous or non-luminous)

Image: Image is the point where light rays meet or appear to meet.

Image can be of two types:

1. Real image – A **real image** occurs where rays converge, i.e., light rays actually meet at image. They can be projected on screen

2. Virtual image – virtual image occurs where rays only appear to converge,.i.e., light rays appear to meet at image. They cannot be projected on screen

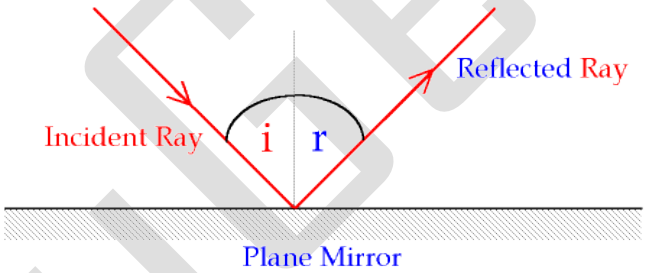
Property of image formed by plane mirror:

i) Image is virtual and cannot be projected on screen
ii) Image is erect
iii) Image is of the same size as the object
iv) Laterally inverted
v) Distance of image and object from the plane mirror is same

Uses of plane mirror

1. To see ourselves
2. To make some instruments like periscope
3. In shops for decoration

For light rays striking a plane mirror, the angle of reflection equals the angle of incidence.



Spherical mirrors:

The curved surface of a shining spoon could be considered as a curved mirror. The most commonly used type of curved mirror is the spherical mirror. The reflecting surface of such mirrors can be considered to form a part of the surface of a sphere. Such mirrors, whose reflecting surfaces are spherical, are called **spherical mirrors**.

Types of Spherical Mirror:

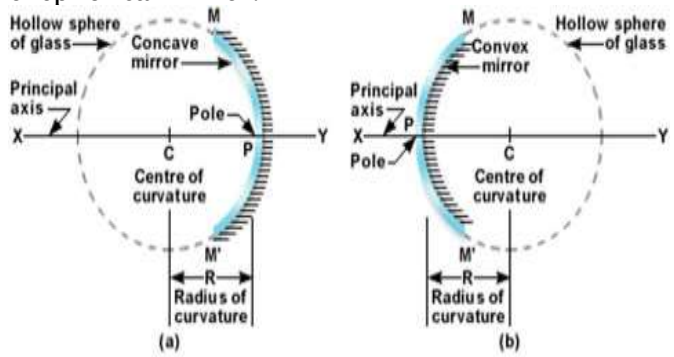
The reflecting surface of a spherical mirror may be curved inwards or outwards.

i) A spherical mirror whose outer surface is polished and inner side is the reflecting surface is called **concave mirror**. A concave mirror is also known as **converging mirror** as it converges the incident rays after reflection.

ii) A spherical mirror, spherical mirror whose inner is polished and outer side is the reflecting surface is called **convex mirror**. A convex mirror is also known as **diverging mirror** as it diverges the incident rays after reflection.

Laws of reflection are applicable to all types of mirrors.

Important terms in the case of spherical mirror:



i) Pole: The centre of reflecting surface of a spherical mirror is known as Pole. Pole lies on the surface of spherical mirror. Pole is generally represented by 'P'. The middle point of the mirror is called pole of the mirror.

ii) Centre of Curvature: The reflecting surface of a spherical mirror forms a part of a sphere. This sphere has a centre. This point is called the centre of curvature of the spherical mirror. It is represented by the letter C.
In the case of concave mirror centre of curvature lies in front of the reflecting surface. On the other hand, centre of curvature lies behind the reflecting surface in the case of convex mirror.

iii) Radius of Curvature: The radius of sphere of which the reflecting surface of a spherical mirror is a part is called the Radius of Curvature of the spherical mirror. The radius of curvature of a spherical mirror is denoted by letter 'R'.
Similar to centre of curvature, radius of curvature lies in front of concave mirror and lies behind the convex mirror and is not a part of the mirror as it lies outside the mirror.

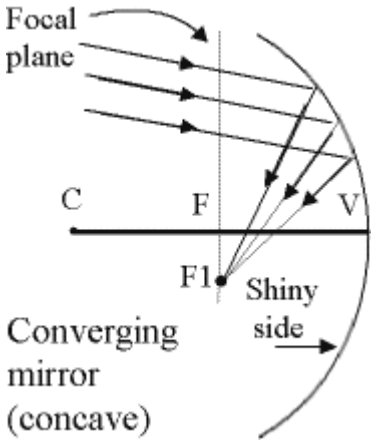
iv) Aperture: The diameter of reflecting surface of a spherical mirror is called aperture(shown as MM'.i.e., vertical line joining M and M')

v)Principal Axis: Imaginary line passing through the centre of curvature and pole of a spherical mirror is called the Principal Axis.

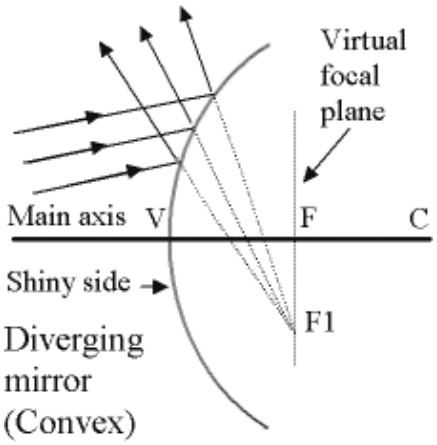
vi)Focus or Principal Focus: Point on principal axis at which parallel rays coming from infinity converge after reflection is called the Focus or Principal Focus of the spherical mirror. Focus is represented by letter 'F'.

Focal plane – The plane through the focus perpendicular to the axis of a mirror or lens. In other words, the vertical plane in which the focal point lies is the **focal plane**

If parallel rays traveling toward a converging mirror are not parallel to the main axis, they still come to a point after reflection, but not at the main focal point F. We can visualize a plane that passes through F and is perpendicular to the main axis, as shown. It is called the "focal plane." Parallel rays that are not parallel to the main axis gather at a point (such as F1)on the focal plane.



In the case of a diverging (convex) mirror, rays reflect in a manner that they appear to have come from a point on the virtual focal plane



A **concave mirror can** be used to focus light of the sun to **burn a hole in paper.** The light from the Sun is converged at a point, as a sharp, bright spot by the mirror. This spot of light is the image of the Sun on the sheet of paper. This point is the focus of the concave mirror. The heat produced due to the concentration of sunlight ignites the paper. The distance of this image from the position of the mirror gives the approximate value of focal length of the mirror

Rays parallel to principal axis meet at focus on reflection from concave mirror. In the case of a concave mirror, parallel rays coming from infinity converge after reflection in front of the mirror. Thus, the focus lies in front of a concave mirror.

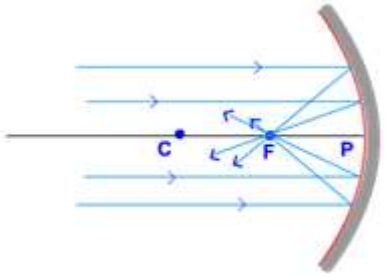


Fig: Converging Mirror(concave)

Rays parallel to principal axis meet at focus on extending on reflection from convex mirror.
In the case of a convex mirror, parallel rays coming from infinity appear to be diverging from behind the mirror. Thus, the focus lies behind the convex mirror.

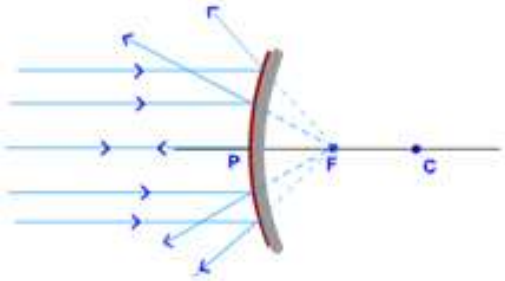


Fig: Diverging Mirror(convex)

vii)Focal length: The distance from pole to focus is called focal length. Focal length is denoted by letter 'f'. Focal length is equal to half of the radius of curvature.

$$Or, f = \frac{R}{2} \qquad Or, R = 2f$$

Image Formation by Spherical Mirrors

Representation of Images Formed by Spherical Mirrors Using Ray Diagrams

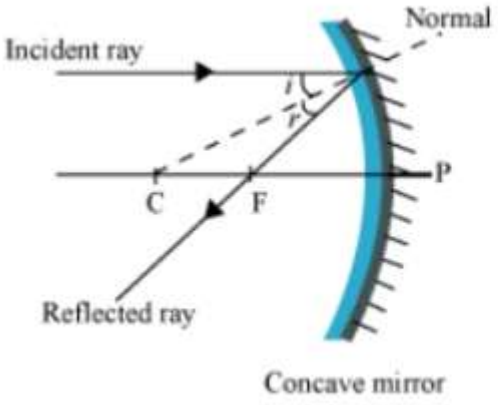
The different ways in which a ray of light is reflected from a spherical mirror are:

Case I:

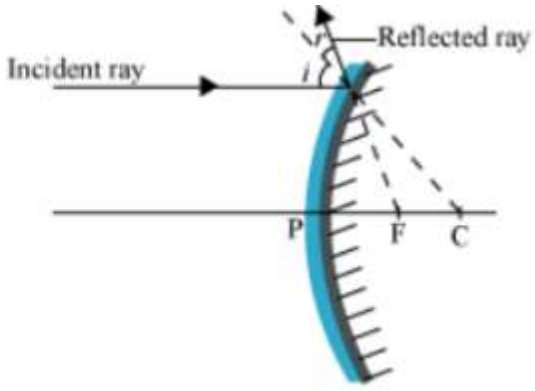
Reflection of Rays parallel to Principal Axis:

In the case of concave mirror: A ray parallel to principal axis passes through the principal focus after reflection from a concave mirror.

Similarly, all parallel rays to the principal axis pass through the principal focus after reflection from a concave mirror. Since, a concave mirror converge the parallel rays after reflection, thus a concave mirror is also known as converging mirror.



Concave mirror



Convex mirror

In the case of convex mirror: A ray parallel to principal axis appears to diverge from the principal focus after reflecting from the surface of a convex mirror.

Similarly, all rays parallel to the principal axis of a convex mirror appear to diverge or coming from principal focus after reflection from a convex mirror. Since, a convex mirror diverges the parallel rays after reflection, thus it is also known as diverging mirror.

Case 2

Reflection of ray passing through the Principal Focus:

In the case of concave mirror: Ray passing through the principal focus goes parallel to principal axis after reflection in the case of concave mirror.

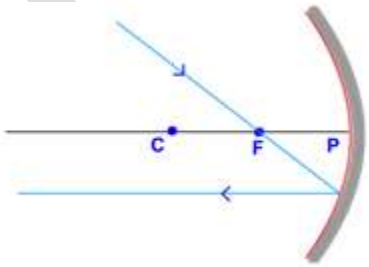


Fig: Ray passing through principal focus

In the case of convex mirror: A ray directed towards principal focus goes parallel to principal axis after reflecting from the surface of a convex mirror.

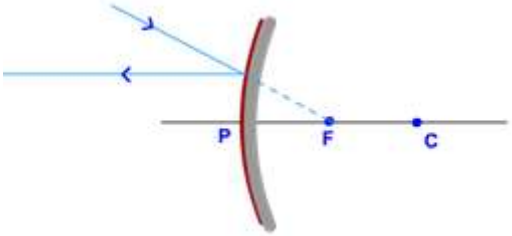
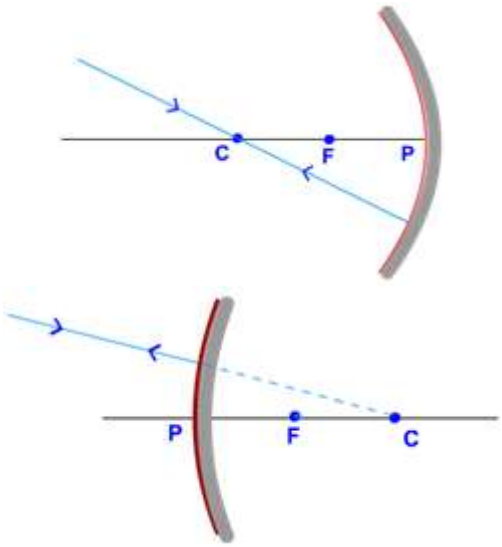


Fig: Ray through principal focus

Case 3:

Ray passing through the Centre of curvature:

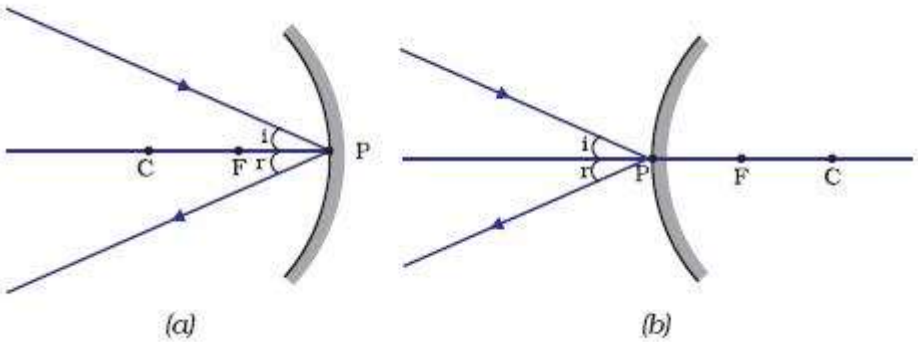
A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path. The light rays come back along the same path because the incident rays fall on the mirror along the normal to the reflecting surface



Case 4

Ray incident obliquely to the principal axis: Ray obliquely to the principal axis goes obliquely after reflecting from the pole of the both concave and convex mirror and at the same angle.

1. *A ray incident obliquely to the principal axis*, towards a point P (pole of the mirror), on the concave mirror [Fig. (a)] or a convex mirror [Fig. (b)], is reflected obliquely. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis.

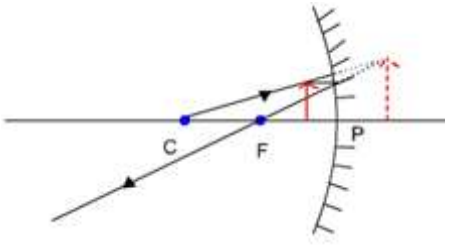


In all the above cases, the laws of reflection are followed. At the point of incidence, the incident ray is reflected in such a way that the angle of reflection equals the angle of incidence.

Ray diagrams for the formation of image by a concave mirror for various positions of the object are-

i) Object between Principal Focus (F) and Pole (P):

When the object is placed between principal focus and pole of a concave mirror, an enlarged, virtual and erect image is formed behind the mirror.

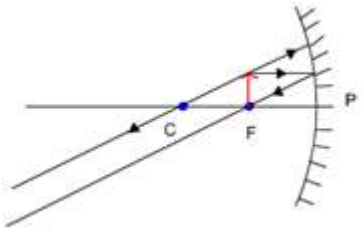


Properties of image:

- Enlarged
- Virtual and erect

ii) Object at Principal Focus (F):

When the object is placed at principal focus (F) of a concave mirror, a highly enlarged image is formed at infinity.

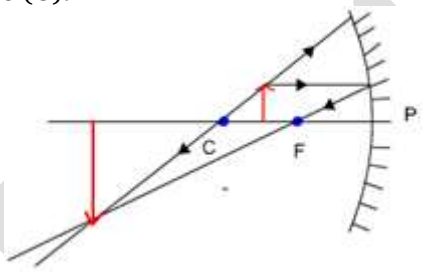


Properties of image:

- Highly enlarged
- Real and inverted

iii) Object between Centre of curvature (C) and Principal Focus (F):

When the object is placed between centre of curvature and principal focus of concave mirror, a real image is formed beyond the centre of curvature (C).

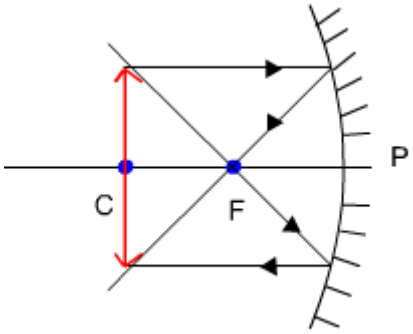


Properties of image:

- Larger than object
- Real and inverted

iv) Object at Centre of Curvature (C):

When the object is placed at centre of curvature (C) of a concave mirror, a real and inverted image is formed at the same position.

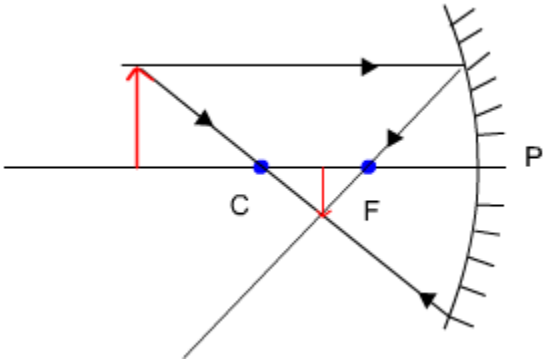


Properties of image:

- Same size as object
- Real and inverted

v) Object between infinity and centre of curvature:

When object is placed between infinity and centre of curvature of a concave mirror the image is formed between centre of curvature (C) and focus (F).

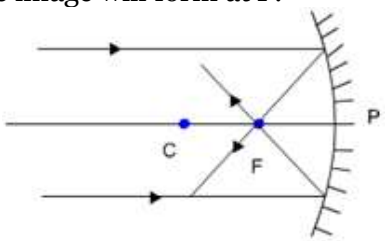


Properties of image:

- Diminished compared to object
- Real and inverted

vi) Object at infinity:

Since parallel rays coming from the object converge at principal focus, F of a concave mirror after reflection. Hence, when the object is at infinity the image will form at F.



Properties of image:

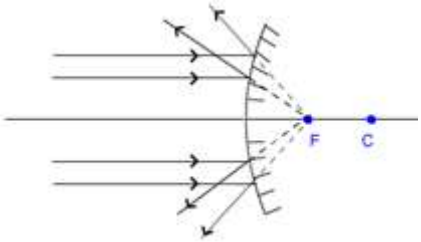
- Point sized
- Highly diminished
- Real and inverted

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished, point sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

The ray diagrams the image formation by a convex mirror for different positions of the object

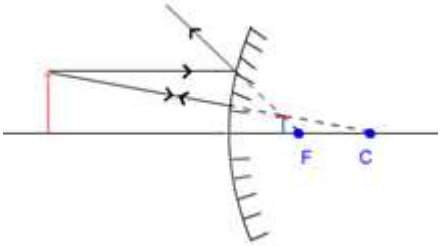
There are only two possibilities of position of object in the case of a convex mirror, i.e. object at infinity and object between infinity and pole of a convex mirror.

i) Object at infinity: When the object is at the infinity, a point sized image is formed at principal focus behind the convex mirror.



Properties of image: Image is highly diminished, virtual and erect.

ii) Object between infinity and pole: When the object is between infinity and pole of a convex mirror, a diminished, virtual and erect image is formed between pole and focus behind the mirror.



Properties of image: Image is diminished, virtual and erect.

Position and Nature of Image in Convex Mirror			
Position of object	Position of image	Size of image	Nature of image
At infinity	At F, behind mirror	Highly diminished	Virtual and Erect
Between infinity and pole	Between F and P, behind mirror	Diminished	Virtual and Erect

Distinguishing between the 3 types of mirrors
When we stand in front of the mirror, then the image

1. Plane mirror- Will be of the same size as object
2. Concave mirror- Larger than the object
3. Convex mirror- Will be smaller than the object

Uses of concave mirror:

- Concave mirrors are commonly used in torches, search-lights and vehicles headlights to get powerful parallel beams of light.
- As shaving mirror to produce larger image of face to facilitate better viewing during shaving.
- Concave mirror is used by dentists to see larger image of teeth of the patient. When a tooth is placed between focus and pole, the concave mirror produces a magnified image of the tooth.
- As reflector in solar furnace. By using concave mirror in solar furnace the concentrated rays of sunlight is obtained at focus which produces enormous amount of heat because of concentration.
- In doctor's head mirror to see details of various body parts like nose, ears etc.
- In dish TV antennas to focus signals

Uses of convex mirrors

- Convex mirror is used in rear view mirror of vehicles so that the driver can see the traffic coming from behind. The field of view is widest in case of a convex mirror, which enables it to show a wider area from behind.
- Convex mirror is used on hairpin bends on the road so that the driver can see the traffic approaching from another side of the bend.
- In big shops for security

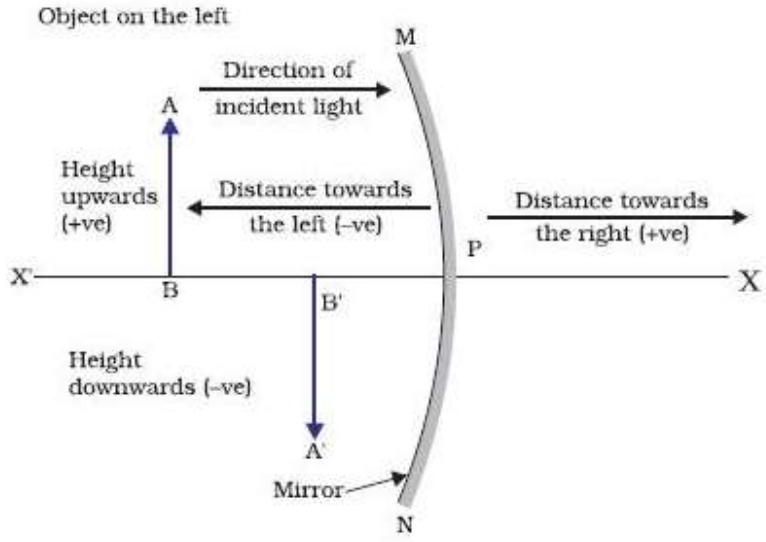
Mirror Formula and Magnification

A formula which provides a relation between image distance (v), object distance (u), and focal length (f) of a spherical mirror is known as Mirror formula.
Mirror formula:
Where v = distance of image from the mirror
u = distance of object from the mirror
f= focal length of the mirror.

Sign Convention for Reflection by Spherical Mirrors

Reflection of light by spherical mirrors follow a set of sign conventions called the New Cartesian Sign Convention. In this convention, the pole (P) of the mirror is taken as the origin. The principal axis of the mirror is taken as the X-axis (X'X) of the coordinate system.
The conventions for spherical mirrors are as follows-

- The object is always placed to the left of the mirror. This implies that the light from the object falls on the mirror from the left hand side.
- All distances parallel to the principal axis are measured from the pole of the mirror.
- All the distances measured to the right of the origin (along + x-axis) are taken as positive while those measured to the left of the origin (along – x-axis) are taken as negative.
- Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.
- Distances measured perpendicular to and below the principal axis (along –y-axis) are taken as negative



Magnification

Magnification is the ratio of the height of the image to the height of the object. It is usually represented by the letter 'm'.

$$Magnification(m) = \frac{Height\ of\ image\ (h')}{Height\ of\ object\ (h)}$$

$$Or, \quad m = \frac{h'}{h}$$

Relation among magnification, distance of object and distance of image:

$$Magnification\ (m) = \frac{Distance\ of\ image}{Distance\ of\ object} = -\frac{v}{u}$$

$$Thus, m = \frac{h'}{h} = -\frac{v}{u}$$

Where, m = magnification, h' = height of image, h = height of object, v = image distance and u = object distance.

Magnification produced by a spherical mirror gives the relative extent to which the image of an object is magnified with respect to the object size. The height of the object is taken to be positive as the object is usually placed above the principal axis. The height of the image should be taken as positive for virtual images and as negative for real images.

A negative sign in the value of the magnification indicates that the image is real. A positive sign in the value of the magnification indicates that the image is virtual.