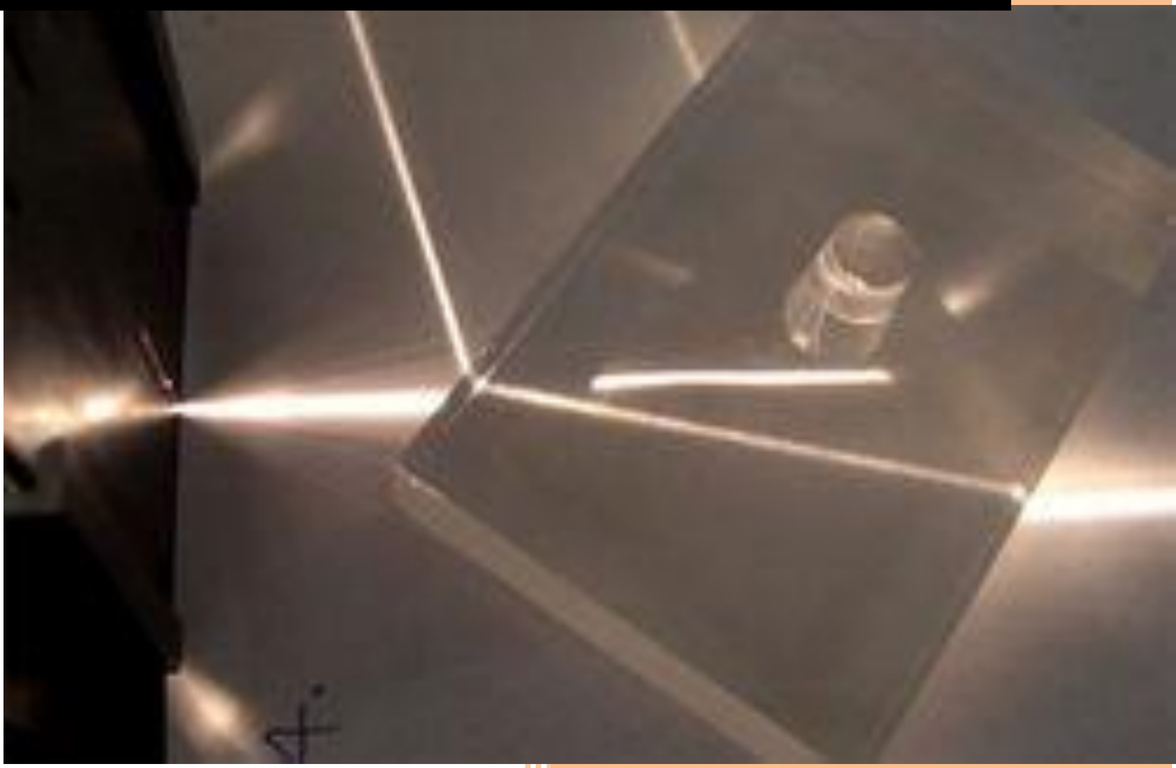
EKAdemy

Class-10

Chapter 9

Light: Reflection and Refraction



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Chapter 9: Light Reflection and Refraction

Introduction

- *Light is a form of energy.*
- *Light enables us to see objects from which it comes or from which it is reflected.*
- *objects like sun, bulb, fire etc. which emit their own light are called luminous object.*
- *Objects which do not emit their own light are called non-luminous object.*
- *Light travels in straight line.*
- *Light has wave as well as particle nature.*
- *It does not need a material medium to travel that is light wave can travel in vacuum also.*
- *The speed of light is 3,00,000 kilometres per second.*
- *The speed of light is different in different transparent media.*

Reflection of light

- The the phenomenon of bouncing back of light in the same medium after striking the surface is called reflection of light.

Laws of Reflection

- There are two laws of reflection:
  - The angle of incidence is equal to angle of reflection.

- The incident ray, the reflected ray and the normal all lie in the same plane at the point of incidence.

- Laws of reflection of light are applicable to all kinds of mirrors i.e., plane mirrors as well as spherical mirrors (like concave mirrors and convex mirror).
- Image is an optical appearance produced when light rays coming from an object are reflected from a mirror or refracted through a lens.

Properties of image formed by Plane Mirror

- A plane mirror forms a virtual image.
- It is erect.
- Size of the image is equal to the size of the object.
- The image formed in a plane mirror is laterally inverted with respect to the object.
- When we see in a plane mirror, we notice our left appears right and right appears left. This is due to the **lateral inversion** phenomenon.

Spherical Mirrors

- Mirrors made up of glass cut from a sphere are spherical mirrors.
- Spherical mirrors are the most common type of curved mirrors.
- Mirrors in which reflecting surface are spherical in shape, is known as spherical mirrors.
- Reflecting surface of a mirror can be curved inwards or curved outwards.

- The mirrors in which reflecting surface is curved inward is known as **concave mirror** and the one which curved outwards is known as **convex mirror**.

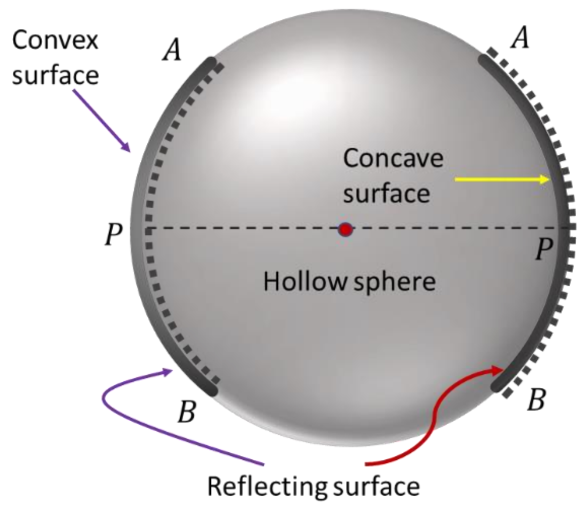


Fig.1. Spherical mirrors

Some Important Terms

- **Pole:** The centre of the reflecting surface in a spherical mirror is a pole. It is represented by P.
- **Centre of curvature:** Reflecting surface in a spherical mirror has a centre, this is known as centre of curvature. Centre of curvature in convex mirror lies behind the mirror whereas in concave mirror, it lies in front of the mirror.
- **Radius of curvature:** The radius of the reflecting surface of the spherical mirror is known as radius of curvature. It is represented by R.

- **Principal axis:** Straight line passing through the pole and centre of curvature in a spherical mirror is known as principal axis.
- **Principal focus:** The reflected rays appear to come from a point on the principal axis, this is known as principal focus.
- **Focal length:** The distance between the pole and the principal focus in a spherical mirror is known as focal length and it is represented by f.
- **Aperture:** The diameter of the reflecting surface is defined as aperture.

Note: If aperture of mirror is small then the radius of curvature is twice the focal length (R=2f).

$$R = 2f$$

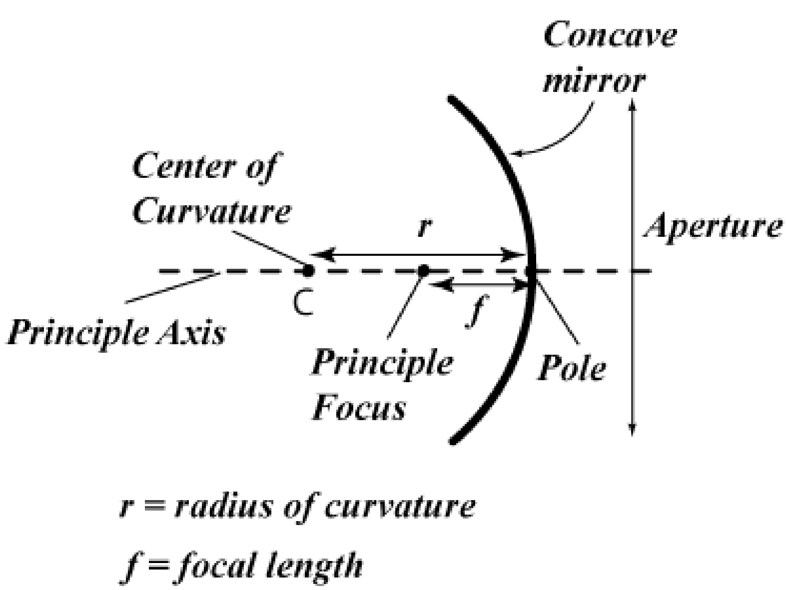
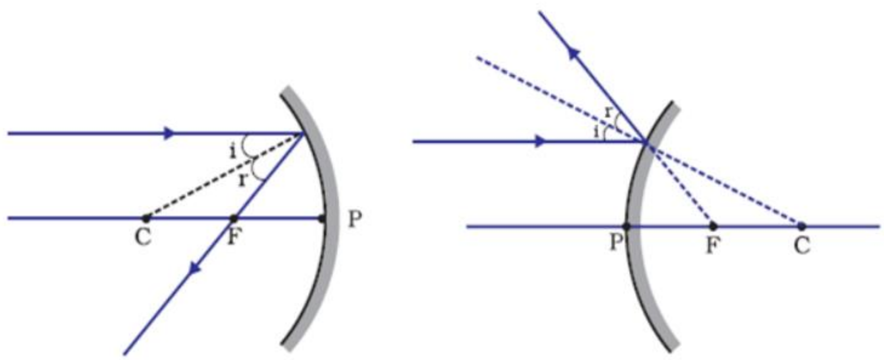


Fig.2. Image showing pole, principal axis, centre of curvature, aperture, and principal focus in concave mirror.

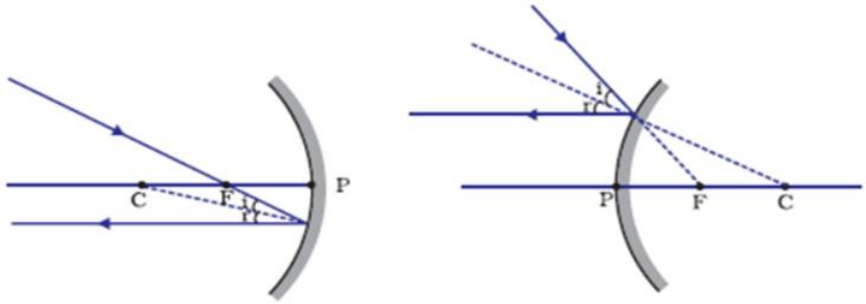
Representations of the images formed by Spherical Mirrors using Ray Diagrams

- We draw a ray diagram to locate the image of an object formed.
- The intersection points of at least two reflected rays will give the position of image of the point object.
- The two rays that can be used to draw the ray diagram are: -
  - A ray parallel to the principal axis passes through the focus after reflection in case of concave mirror or appears to diverge from focus in case of convex mirror.



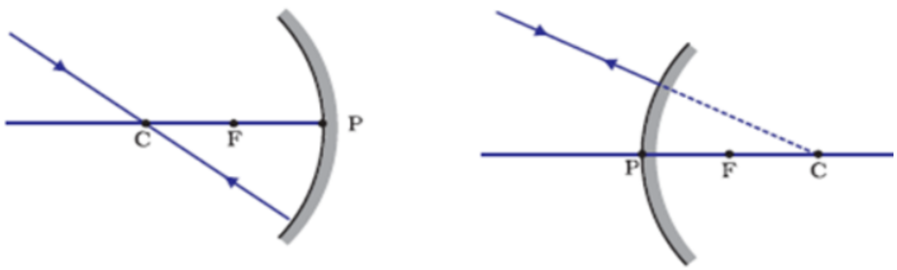
(a) concave mirror (b) convex mirror

  - A ray passing through the focus of the concave mirror or directed towards the focus in case of convex mirror, should appear parallel to the principal axis after reflection.



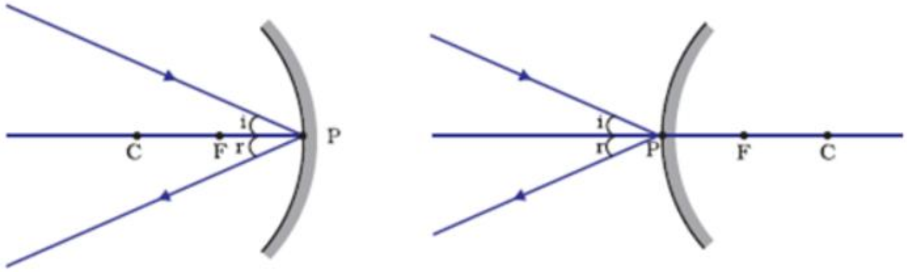
(a) concave mirror (b) convex mirror

- A ray which is passing through the centre of curvature in a concave mirror or directed on centre of curvature in case of convex mirror, should reflect along the same path.



(a) concave mirror (b) convex mirror

- A ray when incident obliquely to principal axis on a concave or convex mirror is also reflected obliquely. In this case, the angle of incidence will be equal to the angle of reflection.



(a) concave mirror (b) convex mirror

Image formation by Concave Mirror

- The position, nature, and the size of the image formed by a concave mirror is dependent on the position of the object in relation to P, C and F.
- Image formed can be real or virtual.
- The image can also be magnified, diminished or even of the same size.
- See table 1, on the next page, to get a better idea about images formed by concave mirror.

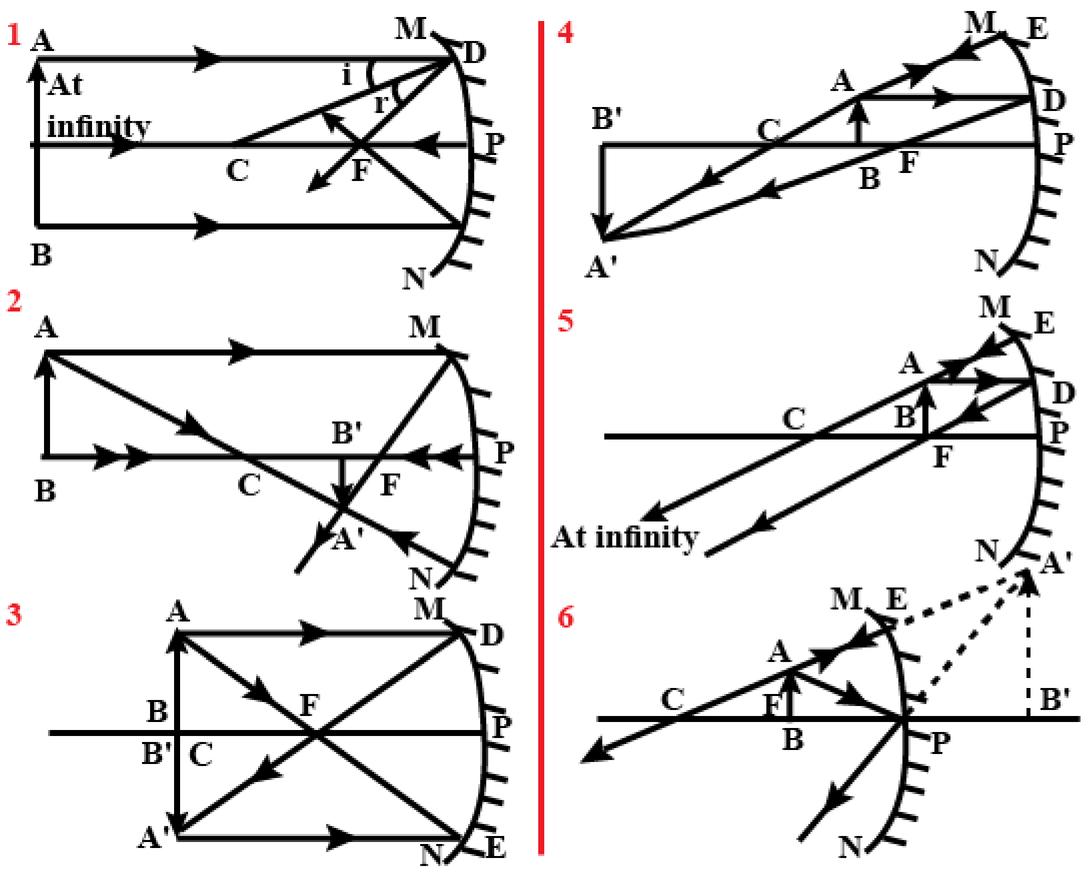


Fig. 3. Ray diagram for the image formation by concave mirror

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

Table.1. Nature, relative size and position of the image formed by concave mirror.

Uses of Concave Mirror

- Used in search lights, torches, head lights of vehicles.
- Used in shaving mirrors.
- Used by dentists to see larger image of the teeth.
- Large concave mirrors are used in solar furnaces.

Image formation by Convex Mirror

- Two positions of the object are considered while understanding the image formed by convex mirror.
- Either the object should be at infinity or at finite distance from the mirror.
- Formation of the image by the convex mirror are as follows-

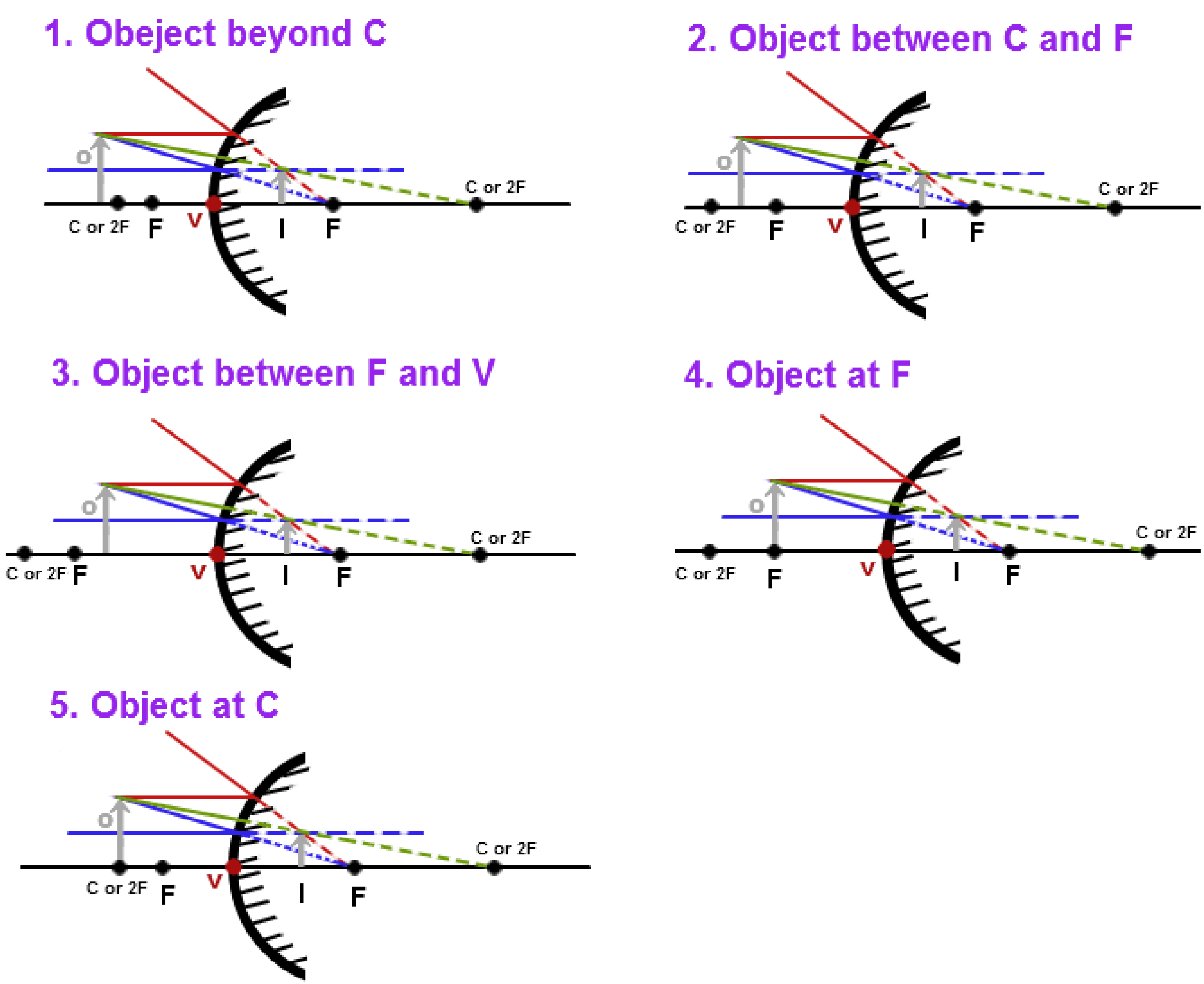


Fig. 5. Ray diagram for the image formation by convex mirror

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished	Virtual and erect
Between infinity and the pole P	Between P and F, behind the mirror	Diminished	Virtual and erect

Table.2. Nature, relative size, and position of the image formed by convex mirror.

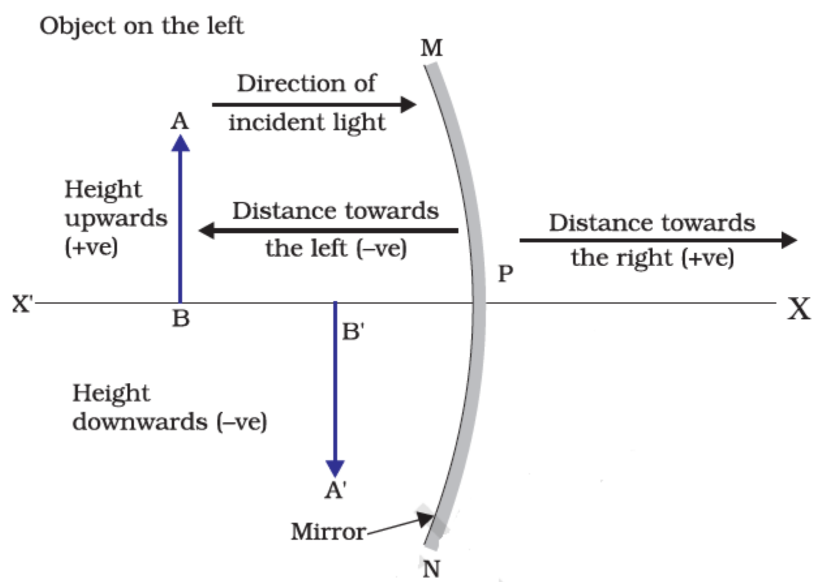
Uses of Convex Mirror

- They are used as rear-view mirrors, to see the traffic behind. They are preferred as they give an erect but diminished image.
- Used in super stores due to their wide view coverage.
- Used at blind turns to have better view to incoming traffic.

Sign conventions for reflection by spherical mirrors

- The new cartesian sign convention is used to give sign convention used for spherical mirrors.
- The conventions are as follows-
    - The object is always placed to the left of the mirror.
    - The pole of the mirror is considered as the origin.

- 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) will be taken as positive.
- Distances measured perpendicular to and below the principal axis (along –y-axis) will be taken as negative.



Mirror formula and Magnification

- The distance of the object from its pole is known as object distance (u), whereas distance of image from the pole of the mirror is known as image distance (v).
- The mirror formula is given by-

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

- It is applicable for spherical mirrors in all positions of the object.
- Numerical values of u, v and f should be used with proper sign.

Magnification/ Linear Magnification

- It is defined as the relative extent to which an image is magnified in comparison to the object size.
- It is given by ratio of height of image to the height of object.

$$m = \frac{h_i}{h_o} = -\frac{v}{u}$$

- Where m is the magnification, h_o is the height of the object and h_i is the height of the image.
- h_o is always positive as an object is always placed above the principal axis.
- h_i is negative for real images and positive for virtual images (reason?).
- A negative sign in the value of magnification indicates that the nature of the image is real.
- A positive sign in the value of the magnification indicates the virtual nature of the image.

Refraction of light

- Bending of the light rays as it passes from one transparent medium to another transparent medium is known as refraction of light.

- Refraction of light happens because the speed of light changes when it travels from one transparent medium to another transparent medium.
- Speed of light is maximum in vacuum and is close to $3 \times 10^8\ m/s$.
- To make things simple we will consider the speed of light in air equivalent to speed of light in vacuum.
- When light travels from air/vacuum to glass its speed decreases and light bends towards normal.
  - Here glass with respect to air is known as optically denser medium or simply denser medium.
- When light travels from glass to air/vacuum, its speed increases i.e., light regains it speed in air/vacuum and it bends away from the normal.
  - Here air with respect to glass is known as rarer medium.
- This change in the speed of light or bending of light is not a random phenomenon and it follows certain laws.
- Refraction takes place at the boundary surface or interface of the two transparent mediums.

Laws of Refraction

- There are two laws of refraction of light:
  - The incident ray, the refracted ray and the normal all lie in the same plane at the point of incidence.
  - The ratio of sine of angle of incidence to the sine of angle of refraction is constant. This law is also known as Snell's law of refraction.

$$\frac{\sin i}{\sin r} = constant$$

Refractive Index

- When light passes from one medium to another medium, it changes its direction.
- The extent to which the direction changes is expressed in terms of refractive index of that medium.
- The value of refractive index is dependent on the speed of light in two media. v_1 is the speed of light in medium 1 and v_2 is the speed of light in medium 2. The refractive index of medium 2 with respect to medium 1 is represented as n_{21}.

$$n_{21} = \frac{speed\ of\ light\ in\ medium\ 1}{speed\ of\ light\ in\ medium\ 2} = \frac{v_1}{v_2}$$

- If medium 1 is vacuum or air, then the refractive index of medium 2 with respect to vacuum is known as absolute refractive index of the medium.

$$n_m = \frac{speed\ of\ light\ in\ air}{speed\ of\ light\ in\ medium} = \frac{c}{v}$$

Where c is the speed of light in air, v is the speed of light in other medium and n_m is the refractive index of the medium.

Refraction by Spherical Lenses

- Lenses are defined as transparent materials which are bounded by two surfaces, out of which one or both can be spherical.
- When the two spherical surfaces bulge outwards, it is known as convex lens.
    - They converge the light rays.
    - Also known as converging lens.
- When the two spherical surfaces bulge inwards, they are known as concave lens.
    - They are known as diverging lenses.
    - They diverge the light rays.
- The centre of these spherical surfaces is known as the **centre of curvature**, represented by C.
- Any imaginary straight line passing through the centre of curvature of a lens is known as **principal axis**.
- The centre point is known as the **optical centre**.
- The effective diameter of the spherical lens is known as **aperture**.

Image formation by lenses

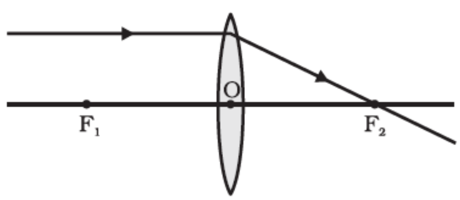
- Nature, relative size, and position of the image formed by convex lens are given below in the form of table-

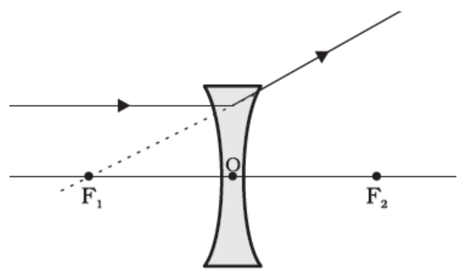
Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_2	Highly diminished	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Image formation by Lens using Ray Diagrams

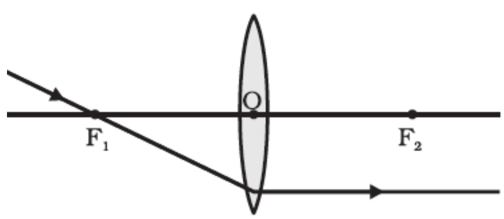
Rules for drawing the ray diagrams are as follows:

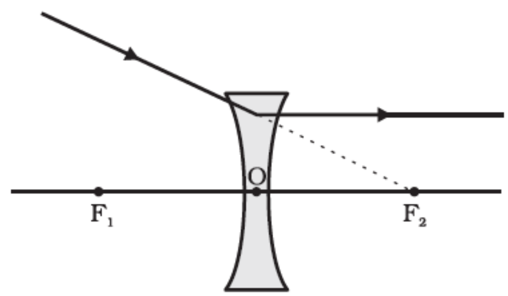
- A ray of light which is parallel to the principal axis will pass through the principal focus after refraction from the convex lens.
    - And appear to diverge from the principle focus in case of concave lens.





- A ray of light passing through principal focus, will emerge parallel to principal axis after refraction from the convex lens. Or a ray incident on principal focus of concave lens will emerge parallel to principal axis.





- A light ray passing through the optical centre will emerge without any deviation both in convex and concave lens.

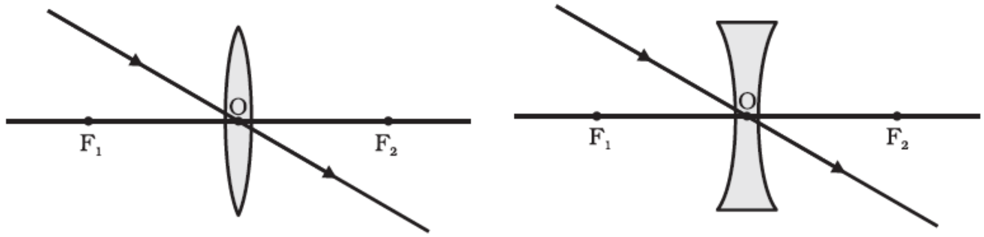


Image formed by the Convex Lens

- The behavior of convex lens is same as that of concave mirror in terms of image formation.

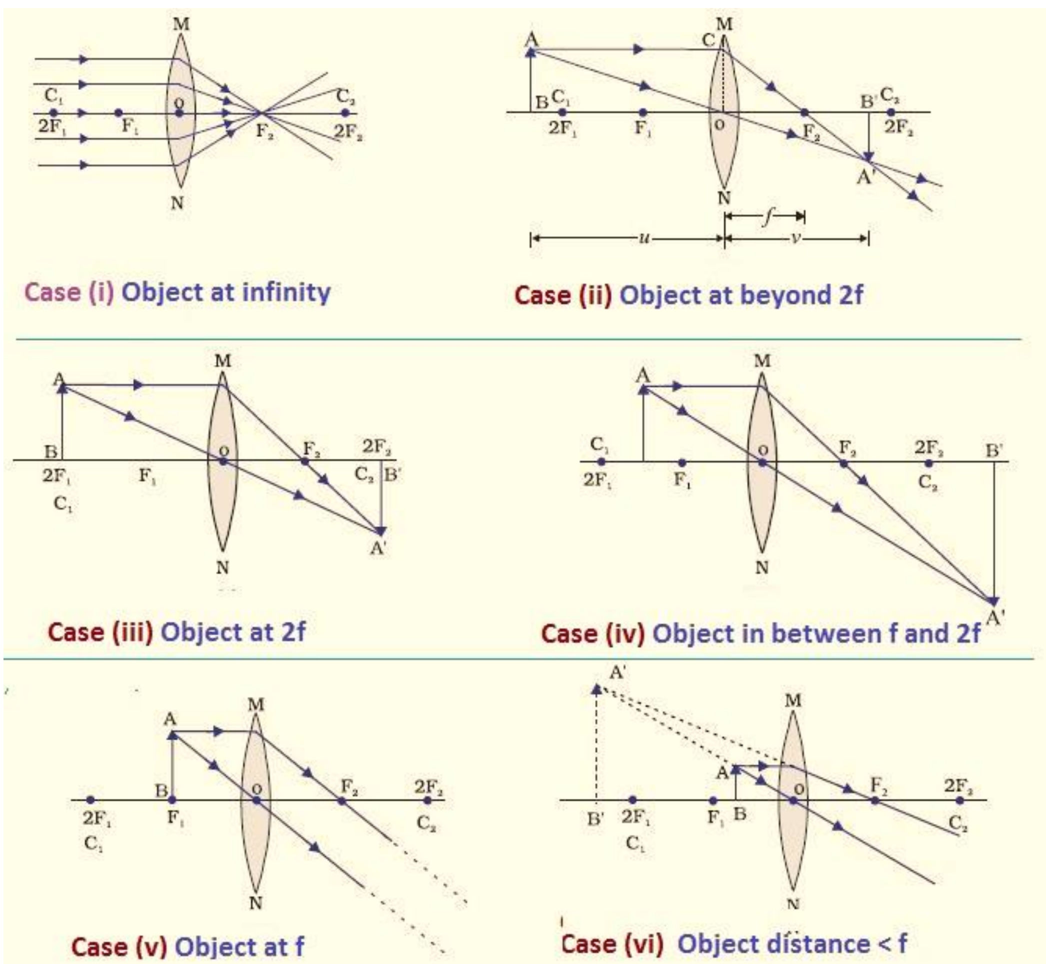
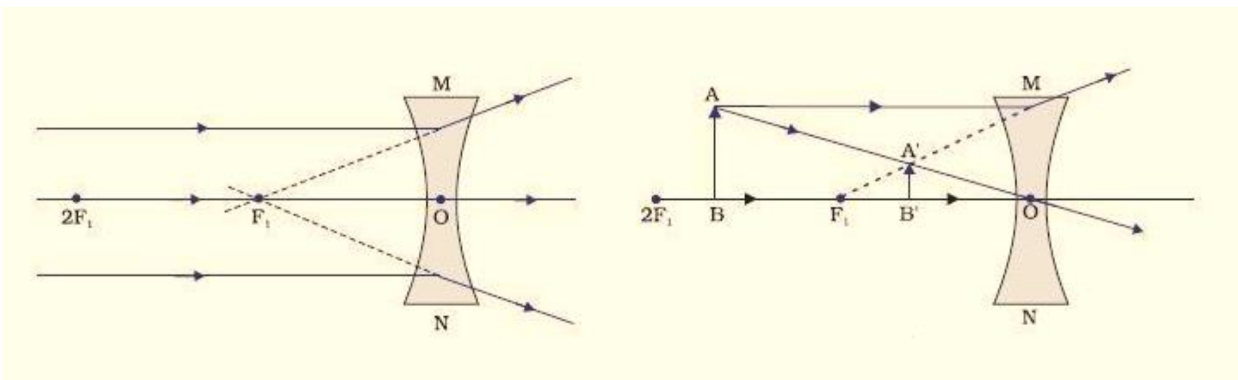


Image formed by the Concave Lens

- Concave lens behaves exactly like convex mirror.
- Only two types of images are formed by concave lens:
    - When an object is at infinity, the image is formed at the focus, highly diminished (point size), virtual and erect, and at the same side of the object.
    - When an object is between infinity and lens, the image is on the same side of the object, diminished, virtual and erect.



Sign convention for Spherical Lenses

- Sign conventions for spherical lens are like spherical mirrors.
- The focal length of a convex lens is taken as **positive** and that of concave lens is **negative**.

Lens formula and magnification

- The lens formula is given as:

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

- Where, u is object distance, v is image distance and f is focal length.
- The ratio of the height of an image to the height of an object is defined as **magnification**.
- Magnification is represented by m, h_0 is the height of the object and h_i is the height of the image.

$$m = \frac{h_i}{h_o} = \frac{v}{u}$$

Power of a Lens

- The extent of convergence or divergence of light rays is expressed in terms of power.
- The reciprocal of focal length is known as its power. It is represented by letter P. The power is given by:

$$P = \frac{1}{f}$$

$$Here, f\ is\ expressed\ in\ meters\ (m)$$

- The SI unit of power is dioptre. It is represented by D.
- 1 dioptre is the power of a lens having focal length of 1m.
- The power of concave lens is negative, and power of convex lens is positive.

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