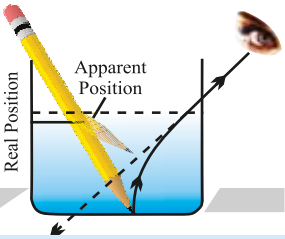


Chapter - 9

Light
Reflection and Refraction

- Light is the form of energy that enables us to see.

Properties of Light

- Electromagnetic wave, it does not require any medium to travel.
- Light tends to travel in straight line.
- Light has dual nature *i.e.,* wave as well as particle.
- Light casts shadow.
- Speed of light is maximum in vaccum. Its value is 3×10^8 ms^{-1}.
- When light falls on a surface, following may happen :
  - (a) Reflection
  - (b) Refraction
  - (c) Absorption

REFLECTION

Bouncing back of light when it strikes on a polished surface like mirror.

Laws of Reflection :

(1) Angle of incidence is equal to the angle of reflection.

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

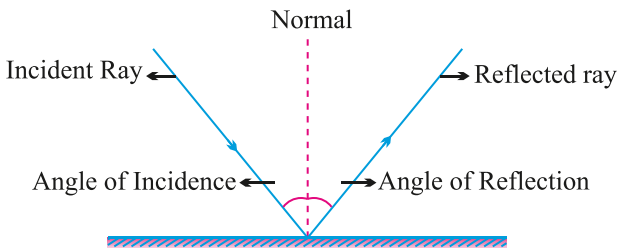
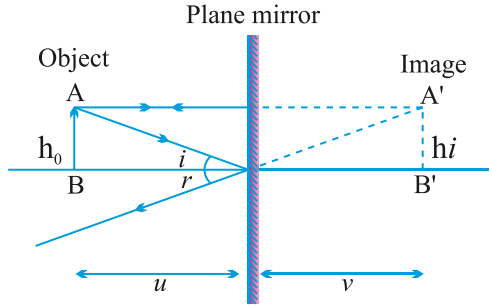


Image : It is a point where atleast two light rays actually meet or appear to meet.

Real Image	Virtual Image
• Formed when light rays actually meet. • Can be obtained on screen. • Inverted • *E.g.,* image formed on cinema screen.	• Formed when light rays appear to meet. • Can't be obtained on screen. • Erect • *E.g.,* image formed by plane mirror or convex mirror.

Image Formed by Plane Mirror



Characteristics of Image

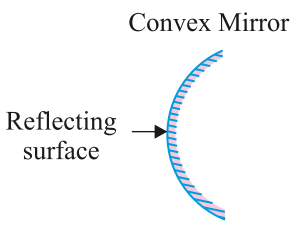
(i) Virtual and erect.
(ii) Size of image is equal to the size of object.
(iii) Image is formed as far behind the mirror as the object is in front of it.
(iv) Laterally inverted.

Lateral Inversion : The right side of the object appears left side of the image and vice-versa.

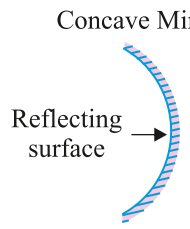
Application of lateral inversion : The word AMBULANCE is written as ƎƆИAJUƃMA so that it can be read correctly in rear view mirror of vehicles going in front of it.

Spherical Mirrors : Mirrors whose reflecting surface is curved.

Convex Mirror

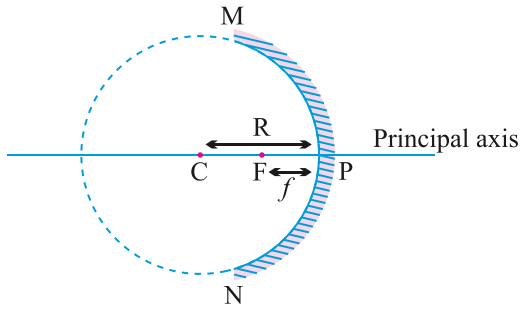


Concave Mirror



- Reflecting surface is curved outwards.
- Diverging mirror

- Reflecting surface is curved inwards.
- Converging mirror



- **Principal axis :** The line joining the pole and center of curvature.
- **Pole (P) :** The centre of the spherical mirror.
- **Aperture (MN) :** It is the effective diameter of the spherical mirror.
- **Center of Curvature (C) :** The centre of the hollow glass sphere of which the mirror was a part.
- **Radius of Curvature (R) :** The distance between the pole and the centre of curvature (PC).
- **Focus (F) :** The point on principal axis where all the parallel light rays actually meet or appear to meet after reflection.
- **Focal length (*f*) :** The distance between the pole and the focus (PF).

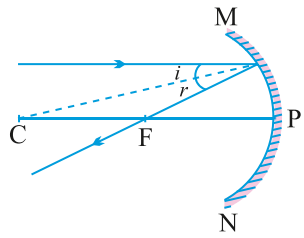
Relationship between focal length and radius of curva ture :

$$f = \frac{R}{2}$$

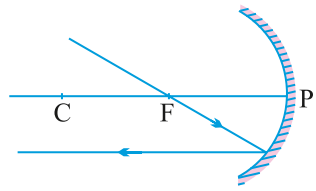
Important Variables → u,v, R, f, h_0, h_i, m

Rules for making ray diagrams for concave mirror

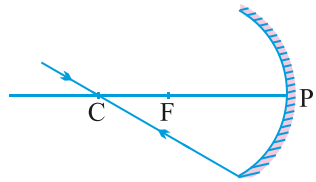
(i) A ray parallel to the principal axis will pass through the principal focus, after reflection.



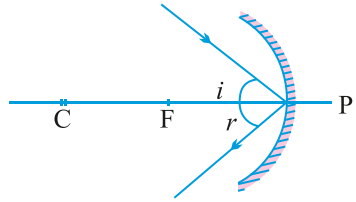
(ii) A ray passing through the principal focus of concave mirror will emerge parallel to principal axis after reflection.



(iii) A ray of light passing through the centre of curvature of a concave mirror is reflected back along the same path as it is a normally incident ray.

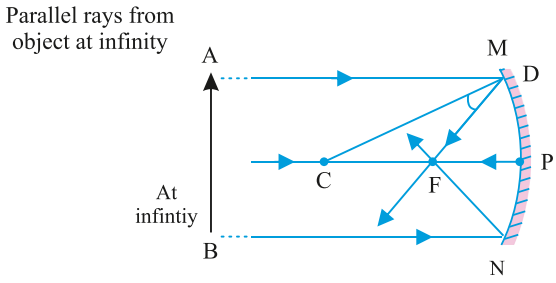


(iv) A ray incident obliquely to the principal axis of a concave mirror is reflected obliquely making equal angle.



Ray diagrams for images formed by concave mirror

(i) When object is at infinity :



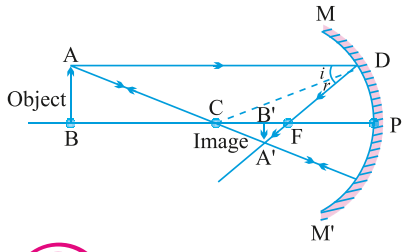
Image

Position – At 'F'

Nature – Real, inverted

Size – Point sized or highly diminished

(ii) When object is beyond 'C'



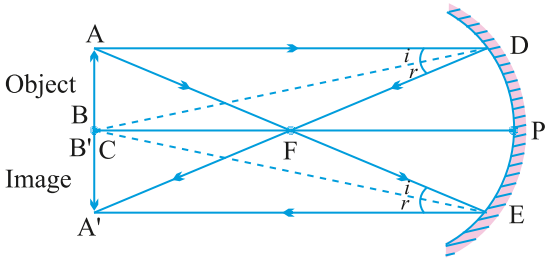
Image

Position – Between 'F' and 'C'

Nature – Real, inverted

Size – Diminished

(iii) When object is at 'C'



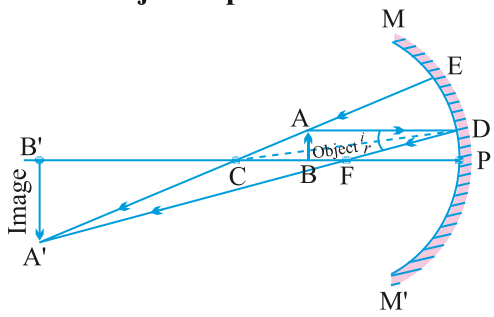
Image

Position – At 'C'

Nature – Real, inverted

Size – Same size as that of object

(iv) When object is placed between 'F' and 'C'



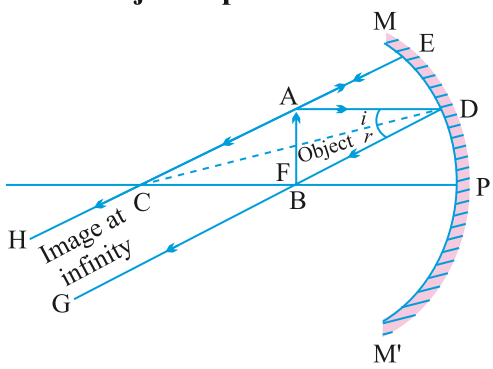
Image

Position – Beyond 'C'

Nature – Real, inverted

Size – Enlarged

(v) When object is placed at 'F'



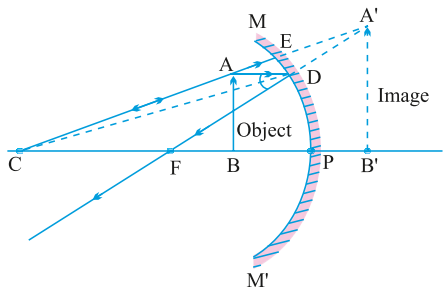
Image

Position – At Infinity

Nature – Real, inverted

Size – Highly enlarged

(vi) When object is between 'P' and 'F'



Image

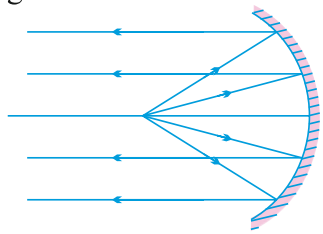
Position – Behind the mirror

Nature – Virtual, erect

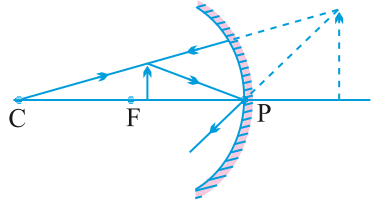
Size – Enlarged

Uses of Concave Mirror

(i) Used in torches, search lights and vehicles headlights to get powerful parallel beam of light.



(ii) Concave mirrors are used by dentists to see large image of teeth of patients. (Teeth have to be placed between pole and focus).

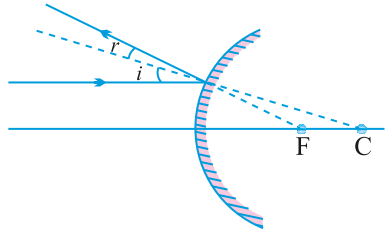


(iii) Concave mirror is used as shaving mirror to see a larger image of the face.

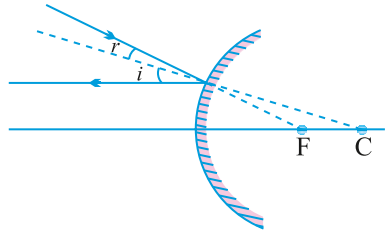
(iv) Large concave mirrors are used to concentrate sunlight to produce heat in solar furnace.

Rule for image formation by Convex Mirror

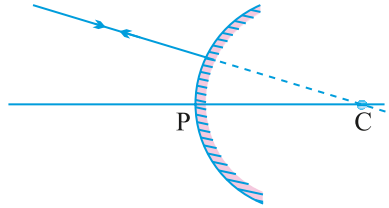
(i) A ray of light parallel to the principal axis of a convex mirror appear to diverge from the principal focus.



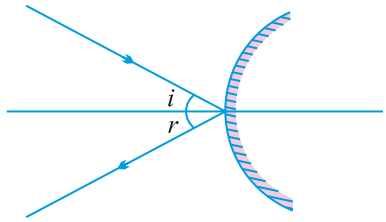
(ii) A ray which is directed towards the focus of the convex mirror will emerge parallel to the principal axis after reflection.



(iii) A ray directed towards the center of curvature of a convex mirror is reflected back along the same.

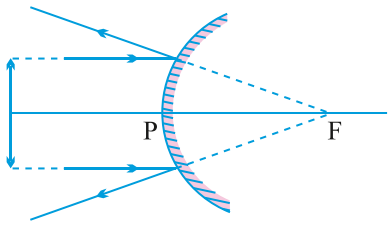


(iv) A ray incident obliquely to the principal axis is reflected obliquely.



Ray diagrams of images formed by convex mirror

(i) When object is placed at infinity : **Image**

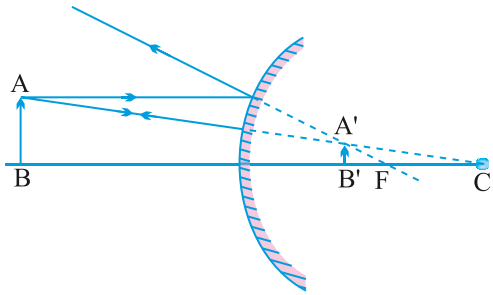


Position – At 'F'

Nature –Virtual, erect

Size –Point sized

(ii) When object is placed between pole and infinity: **Image**



Position – Between 'P' and 'F'

Nature –Virtual, erect

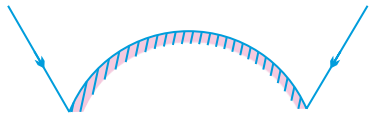
Size – Diminished

- A full length image of a tall building/tree can be seen in a small convex mirror.

Uses of Convex Mirror

(i) Convex mirrors are used as rear view mirrors in vehicles because

(a) they always give an erect though diminished image.
(b) they have a wider field of view as they are curved outwards.



(ii) Convex mirrors are used at blind turns and on points of merging traffic to facilitate vision of both side traffic.
(iii) Used in shops as security mirror.

Sign Convention for Reflection by Spherical Mirror
Or
New Cartesian Sign Convention

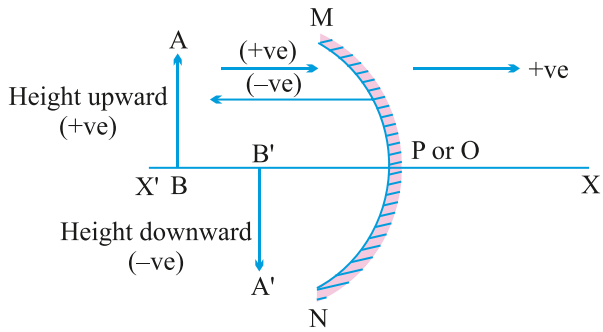
(i) The object is placed to the left of the mirror.

(ii) All distances parallel to the principal axis are measured from the pole of the mirror.

(iii) All distances measured in the direction of incident ray (along + X-axis) are taken as positive and those measured against the direction of incident ray (along – X-axis) are taken as negative.

(iv) Distance measured perpendicular to and above the principal axis are taken as positive.

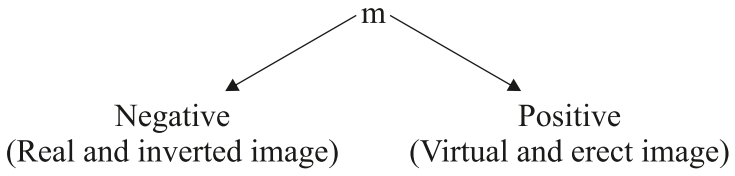
(v) Distances measured perpendicular to and below the principal axis are taken as negative.



- Object distance = '*u*' is always negative.
- Focal length of concave mirror = Negative (f = -ve)
- Focal length of convex mirror = Positive (f = +ve)

Case Wise Summary

	Concave Mirror						Convex Mirror	
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(i)	(ii)
u	-	-	-	-	-	-	-	-
v	-	-	-	-	-	+	+	+
R	-	-	-	-	-	-	+	+
f	-	-	-	-	-	-	+	+
h_o	+	+	+	+	+	+	+	+
h*i*	-	-	-	-	-	+	+	+
m	-	-	-	-	-	+	+	+



Mirror Formula :

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

where, v = Image distance

u = Object distance

f = Focal length

Magnification of Spherical Mirrors (m)

It is the ratio of the height of image to the height of object.

$$m=\frac{\text{Height of image}}{\text{Height of object}}$$

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

Also, $$m = \frac{image\ distance}{object\ distance}$$

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

If $h_i = h_o$ then $m = 1$, *i.e.,* image is equal to object.

If $h_i > h_i$ then $m > 1$ *i.e.,* image is enlarged.

If $h_i < h_o$ then $m < 1$ *i.e.,* image is diminished.

- Magnification of plane mirror is always + 1.
  '+' sign indicates virtual image.
  '1' indicates that image is equal to object's size.
- If '*m*' is '+ve' and less than 1, it is a convex mirror.
- If '*m*' is '+ve' and more than 1, it is a concave mirror.
- If '*m*' is ' - ve', it is a concave mirror.

Check Your Knowledge

1. Magnification of plane mirror is + 1. What does it indicate ?
2. A real image, 1/5 th size of object is formed at a distance of 18 cm from a mirror. What is the nature of the mirror ? Calculate its focal length.
3. Name the type of mirror used in the following and reason for using it :
   (a) Solar furnace
   (b) Rear view mirror in a vehicle
4. What should be the position of the object, when a concave mirror is used :
   (a) as a shaving mirror ?
   (b) in torches as reflecting mirror ?
5. (a) Define principal focus of a spherical mirror.
   (b) For what position of the object does a concave mirror form a real, inverted and diminished image of the object ? Draw the ray diagram.
   (c) An object 4 cm high is placed at a distance of 6 cm in front of a concave mirror of focal length 12 cm. Find the position of the image.
6. For what position of an object, a concave mirror forms a real image equal to size of object ?
7. Identify the nature of mirror and mention two characteristics of image formed when magnification $m = + 6$.
8. Suggest a method to find approximate focal length of a concave mirror.

9. Draw ray diagram when :

   (a) object is placed between pole and focus of a concave mirror.

   (b) object is placed at infinity from a convex mirror.

10. Name the type of spherical mirror which

   (a) has positive focal length.

   (b) always forms a virtual image.

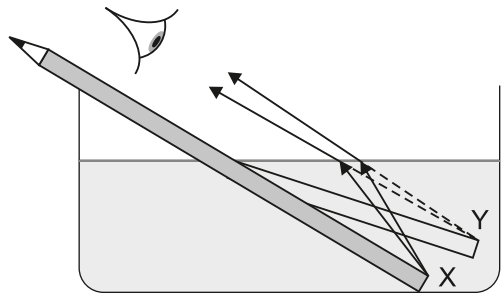
REFRACTION

Bending of light when it enters obliquely from one transparent medium to another.

- Speed of light is maximum in vaccum. It is 3×10^8 m/s.
- **Cause of refraction :** Change in speed of light.
- **Some examples of refraction :**

   (i) The bottom of swimming pool appears higher.

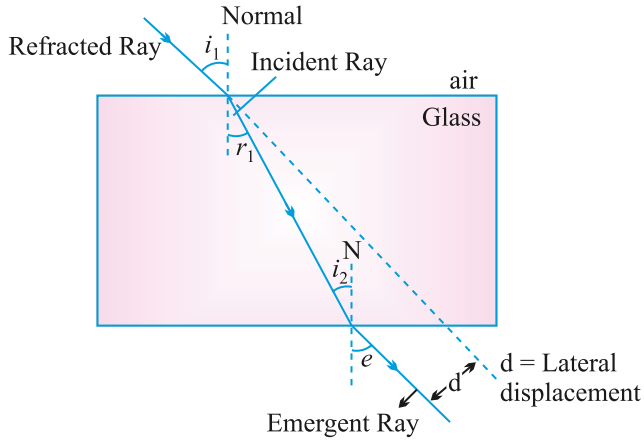
   (ii) A pencil partially immersed in water appears to be bent at the interface of water and air.



   (iii) Lemons placed in a glass tumbler appear bigger.

   (iv) Letters of a book appear to be raised when seen through a glass slab.

Refraction through glass slab



- The extent of bending of ray of light at the opposite parallel faces of rectangular glass slab is equal and opposite, so the ray emerges parallel to incident ray. The perpendicular distance between incident and emergent rays is called lateral displacement.

- Lateral displacement depends on :
  (a) Refractive index of glass slab
  (b) Thickness of the glass slab
  (c) Wavelength of light rays
  (d) Angle of incidence

Laws of Refraction

(i) The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

(ii) **Snell's law :** The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for a light of given colour and for a given pair of media.

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

Refractive index (n) : The ratio of speed of light in a given pair of media

$$n = \frac{\text{Velocity of light in medium 1}}{\text{Velocity of light in medium 2}}$$

n_{21} means refractive index of second medium with respect to first medium, and

$$n_{21} = \frac{V_1}{V_2}$$

n_{12} means refractive index of first medium with respect to second medium.

$$n_{12} = \frac{V_2}{V_1}$$

- **Absolute Refractive Index :** Refractive index of a medium with respect to vaccum or air.

$$n = \frac{c}{v} \quad (c = 3 \times 10^8 \text{ ms}^{-1})$$

- Refractive index of one medium is reciprocal of other's refractive index in a given pair.

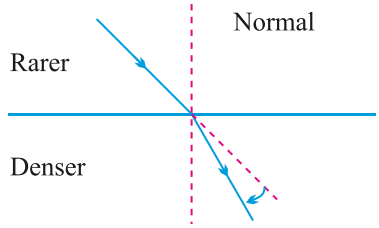
$$n_{12} = \frac{1}{n_{21}}$$

If refractive index of medium 1 w.r.t. air is given as ${}_1n^{air}$, and
If refractive index of medium 2 w.r.t. air is given as ${}_2n^{air}$

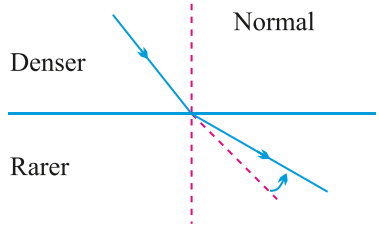
Then, refractive index of medium 1 w.r.t. medium 2 = $\frac{{}_1n^{air}}{{}_2n^{air}}$

- Refractive index of diamond is the highest till date. It is 2.42. It means speed of light is $\frac{1}{2.42}$ times in diamond of that in vaccum.
- **Optically denser medium :** Out of two given media, the medium with higher value of refractive index.

- **Optically rarer medium :** Out of two given media, the medium with lower value of refractive index.
- When light enters obliquely from a rarer to a denser medium, it bends towards the normal.



- When light enters obliquely from denser to a rarer medium, it bends away from the normal.

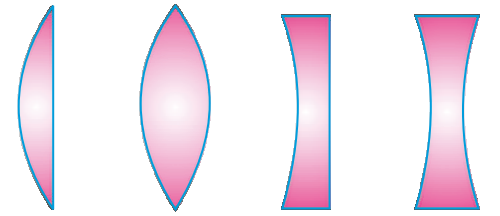


- Refractive index of a medium does not depend on physical density.

Spherical lens : A transparent medium bound by two surfaces, of which one or both surfaces are curved.

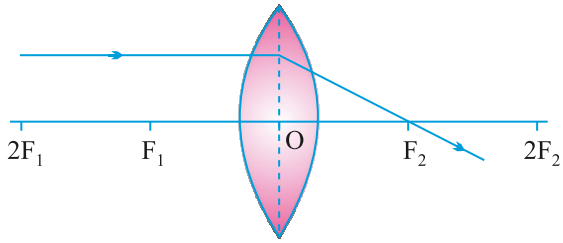
Spherical lens

Convex lens	Concave lens
• Thin from corners • Thick at center • Converging	• Thick from corners • Thin at centre • Diverging

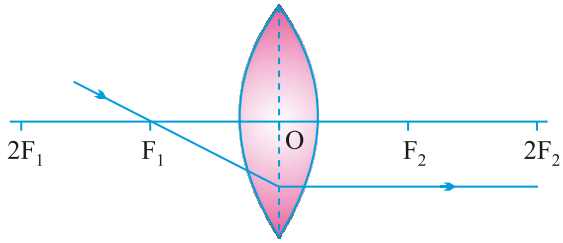


Rules for making ray diagrams for convex lens

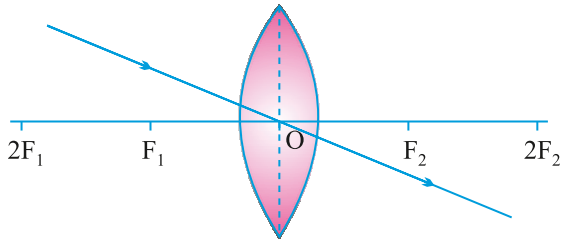
(i) A ray of light parallel to principal axis of a convex lens always pass through the focus on the other side of the lens.



(ii) A ray of light passing through the principal focus will emerge parallel to principal axis after refraction.

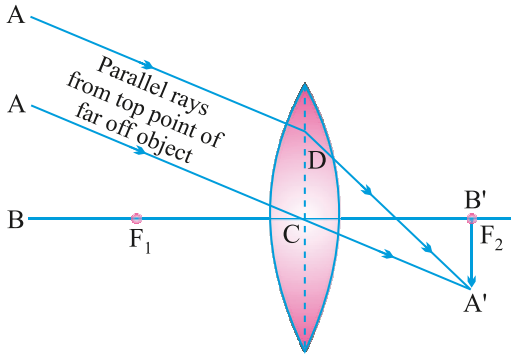


(iii) A ray of light passing through the optical center will emerge without any deviation.



Ray Diagrams of Images formed by Convex Lens

(i) When object is at infinity :



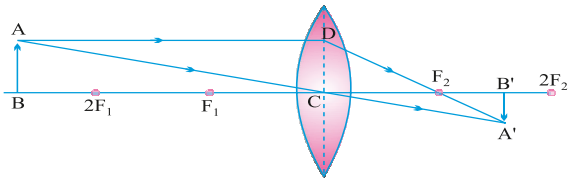
Image

Position – At 'F_2'

Nature – Real, inverted

Size – Point sized or highly diminished

(ii) When object is beyond '$2F_1$'



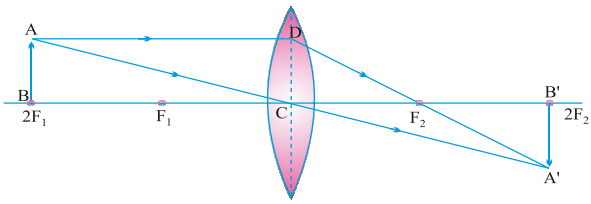
Image

Position – Between 'F_2' and '$2F_2$'

Nature – Real, inverted

Size – Diminished

(iii) When object is at '$2F_1$'



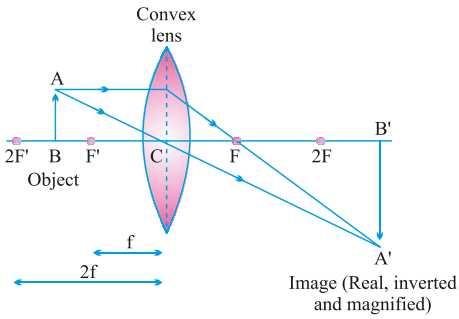
Image

Position – At '$2F_2$'

Nature – Real, inverted

Size – Same size

(iv) When object is between 'F_1' and '$2F_1$'



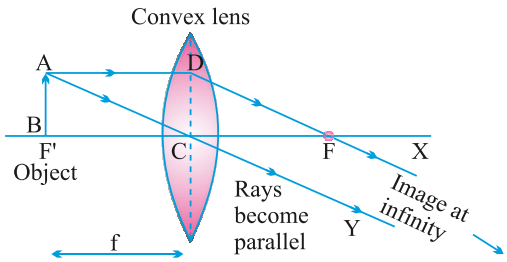
Image

Position – Beyond '$2F_2$'

Nature – Real, inverted

Size – Enlarged

(v) When object is at 'F_1'



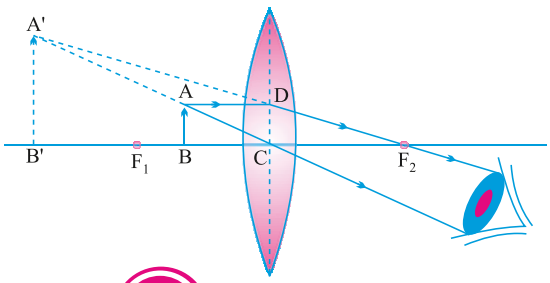
Image

Position – At Infinity

Nature – Real, inverted

Size – Highly enlarged

(vi) When object is between 'F_1' and optical centre



Image

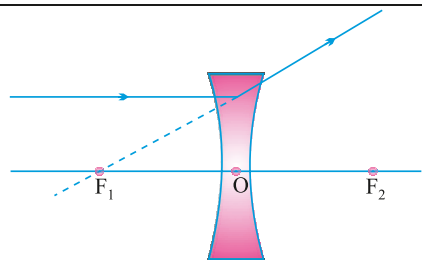
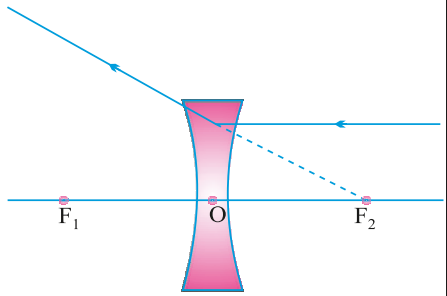
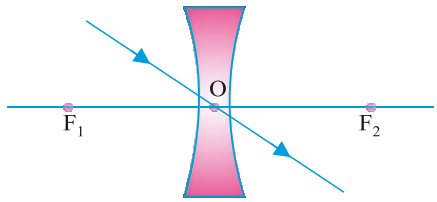
Position – On the same side of the lens as object

Nature – Virtual and erect

Size – Enlarged

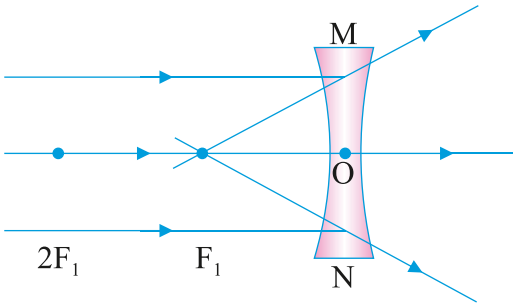
On the basis of this position, this lens is also known as magnifying lens.

Rules for Image Formation by Concave Lens

S.No.	Light ray from object is	Ray diagram	How it appears after refraction
1.	Parallel to the principal axis		After refraction from a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens
2.	Passing through a principal focus		After refraction from a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens
3.	Passing through the optical center of a lens		After refraction from a concave lens will emerge without any deviation

Ray Diagrams of Images Formed by a Concave Lens

(i) When object is placed at infinity :



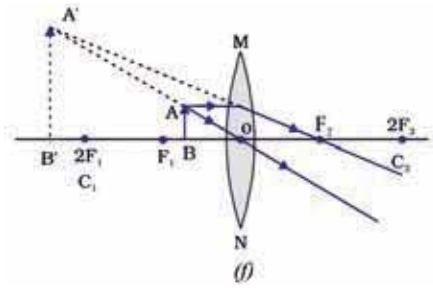
Image

Position – At 'F_1'

Nature – Virtual, erect

Size – Point sized or highly diminished

(ii) When object is placed between infinity and optical centre



(f)

Position – Between 'F' and 'O'

Nature – Virtual, erect

Size – Diminished

Sign convention for spherical lenses

- Sign conventions are similar to the one used for spherical mirrors, except that measurements are taken from optical center of the lens.
- Focal length of convex lens = Positive
  Focal length of concave lens = Negative

Lens Formula :

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

Magnification :

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

$\therefore$ h_i = height of image

h_o = height of object

Also,

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

Case Wise Summary

	Convex Lens						Concave Lens	
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(i)	(ii)
u	-	-	-	-	-	-	-	-
v	+	+	+	+	+	-	-	-
f	+	+	+	+	+	+	-	-
h_o	+	+	+	+	+	+	+	+
h*i*	-	-	-	-	-	+	+	+
m	-	-	-	-	-	+	+	+

Power of a lens :

It is defined as the reciprocal of focal length in meter.

The degree of convergence or divergence of light rays is expressed in terms of power.

$$\text{Power} = \frac{1}{\text{focal length (in meter)}} \quad P = \frac{1}{f}$$

- SI unit of Power = dioptre = D

  1 D = 1 m^{-1}

  1 dioptre is the power of lens whose focal length is one meter.

  - Power of convex lens = Positive
  - Power of concave lens = Negative
  - $\text{Power} \propto \frac{1}{\text{focal length}}$
  - Power of a lens combination

    $P = P_1 + P_2 + P_3 .....$

1 MARKER OBJECTIVE QUESTIONS

I. MULTIPLE CHOICE QUESTIONS

1. Focal length of plane mirror is

   a) Infinity b) Zero

   c) Negative d) None of these

2. Image formed by plane mirror is

   a) Real and erect b) Real and inverted

   c) Virtual and erect d) Virtual and inverted

3. A concave mirror gives real, inverted and same size image if the object is placed

   a) At F b) At infinity

   c) At C d) Beyond C

4. Power of the lens is-4D, its focal length is

   a) 4m b) -40m

   c) -0.25m d) 25 m