THE RADIANT EDUCATION POINT
(MRITUNJAY MISHRA)
H.N. 1256, 33-FEET ROAD, S.G.M. NAGAR
FARIDABAD
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LIGHT: REFLECTION AND REFRACTION

Introduction

•Light is a form of energy due to which we are able to see the objects
•The objects which emits light for example objects like sun, lamp, candle emits light of their own and thus they are known as ***luminous objects***
•There are objects like table , chair etc. which are not luminous objects and still we are able to see them and this happens because they reflects lights which falls on them from a luminous object like sun, lamp etc. and when this reflected light reaches our eyes we are able to see such **non luminous objects**.
•Light rays basically consist of electromagnetic waves which do not require any material medium (like solid, liquid or gas) for their propagation.
•When light falls on the surface of an object it can either be

1. **Absorbed**:- If an object absorbs all the light falling on it , then it will appear perfectly black for example a blackboard
2. **Transmitted**: - An object is said to transmit light if it allows light to pass through itself and such objects are transparent.
3. **Reflected**:- If an object sends back light rays falling on its surface then it is said to have reflected the light

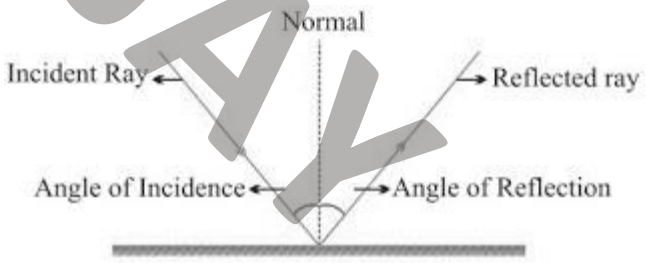
• **Speed of light in vacuum 3×10^8m/s**

Reflection

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

Laws of Reflection

(i) Angle of incidence is equal to the angle of reflection.
(ii) The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.



Virtual and Real image

Image is a point where at least two light rays actually meet or appear to meet.

Real Image	Virtual Image
Formed when light rays actually meet.	Formed when light rays appear to meet.
Can be obtained on screen.	Can't be obtained on screen.
Inverted	Erect
Example: image formed on cinema screen or formed by concave mirror.	Example: image formed by plane mirror or convex mirror.

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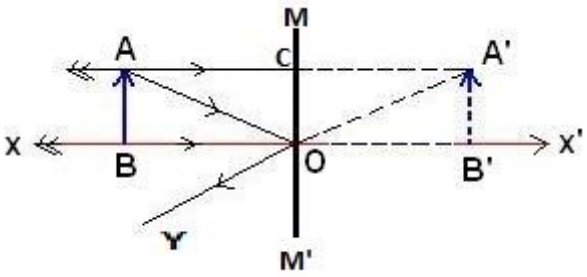
Image Formed by Plane Mirror

Characteristics of Image formed by Plane Mirror

(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 in reverse direction so that it can be read correctly in rear view mirror of vehicles going in front of it.

Spherical Mirrors

- The reflecting surface of a spherical mirror may be curved inwards or outwards.
- Spherical mirrors are of two types
  1. **Concave mirror**: - In a concave mirror reflection of light takes place at the concave surface or bent-in surface as shown below in the figure.
  2. **Convex mirror**:- In a convex mirror reflection of light takes place at the convex surface or bent out surface as shown below in the figure

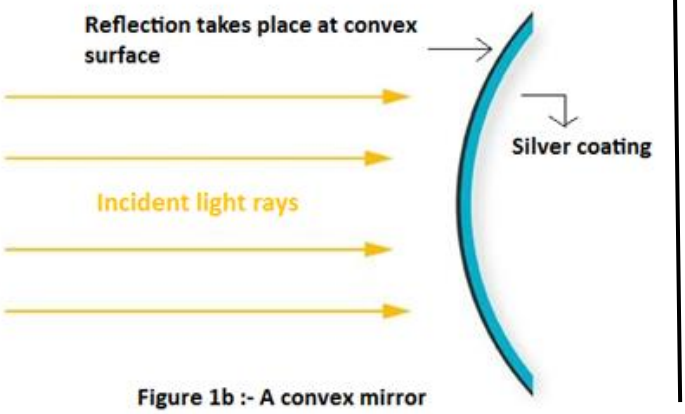


Figure 1b :- A convex mirror

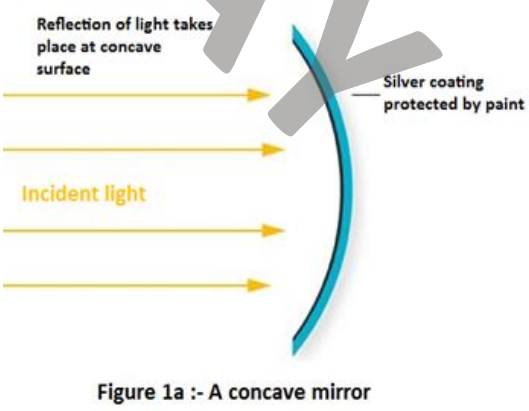


Figure 1a :- A concave mirror

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Commonly used terms about Spherical mirrors :-

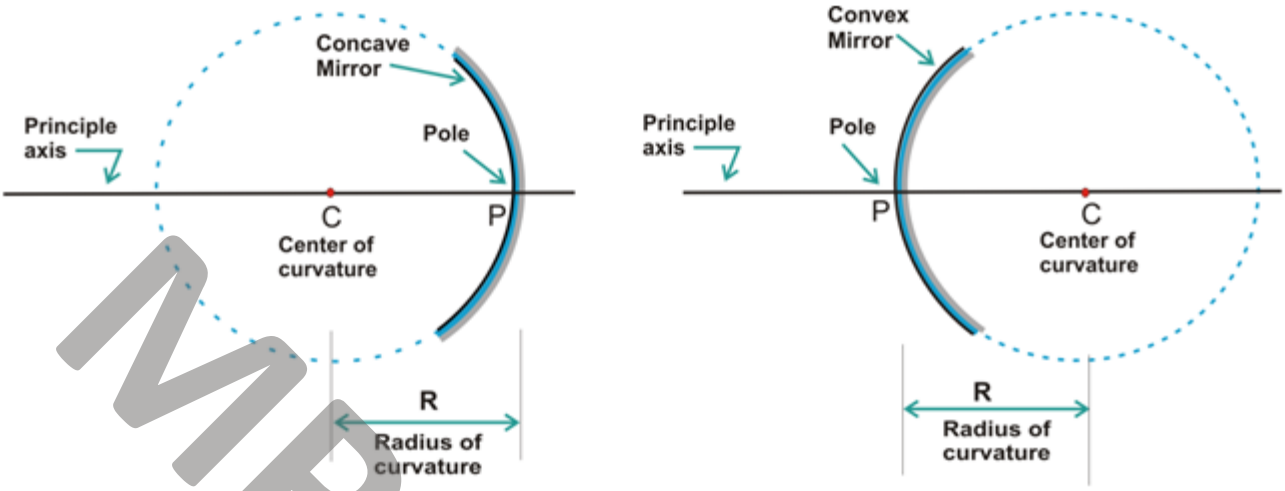


Figure 2. Concave and convex mirrors shown as part of complete hollow sphere

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.

Radius of curvature: - The distance between the pole and the centre of curvature.

Pole: - The centre of a spherical mirror is called its pole and is represented by letter P as can be seen in figure 2.

Principle axis: - Straight line passing through the pole and the centre of curvature

Aperture of the mirror: - Portion of the mirror from which reflection of light actually takes place is called the aperture of the mirror. Aperture of the mirror actually represents the size of the mirror.

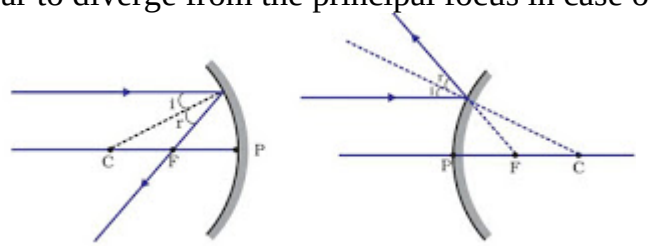
Focus (F): The point on principal axis where all the parallel light rays actually meet or appear to meet after reflection.

Focal length (f): The distance between the pole and the focus.

→ Relationship between focal length and radius of curvature: f = R/2

Rules for making ray diagrams by spherical mirror

(i) A ray parallel to the principal axis, after reflection, will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror.



(ii) A ray passing through the principal focus of a concave mirror or a ray which is directed towards the principal focus of a convex mirror, after reflection, will emerge parallel to the principal axis.

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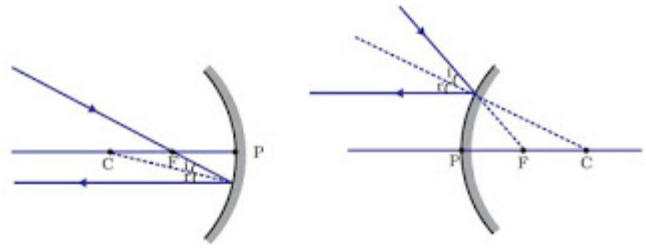
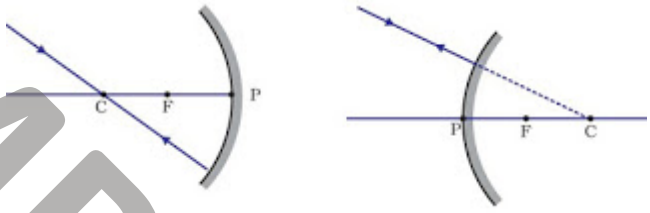
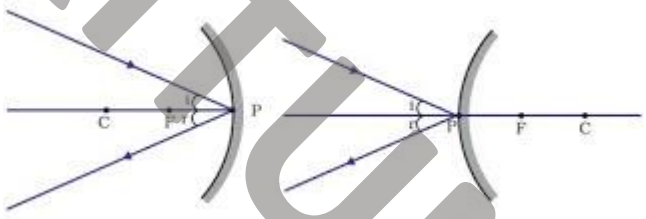


(iii) A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path.



(iv) A ray incident obliquely to the principal axis, towards a point P (pole of the mirror), on the concave mirror or a convex mirror, 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.



Ray diagrams for images formed by concave mirror

S.No.	Position of object	Position of image	Nature of image	Uses
1.	Between the pole and the principal focus	Behind the mirror	Virtual, erect and magnified	Shaving mirror, dentist mirror
2.	At the principal focus	At infinity	Extremely magnified	In torches, head lights
3.	Between focus and the centre of curvature	Beyond centre of curvature	Real, inverted and bigger than object.	In flood lights
4.	At the centre of curvatrue	At the centre of curvature	Real, inverted and equal to the size of the object	Reflecting mirror for projector lamps
5.	Beyond the centre of curvature	Between the principal focus and centre of curvature	Real, inverted and diminished	
6.	At infinity	At the principal focus or in the focal plane	Real, inverted and extremely diminished in size	To collect heat radiations in solar devices

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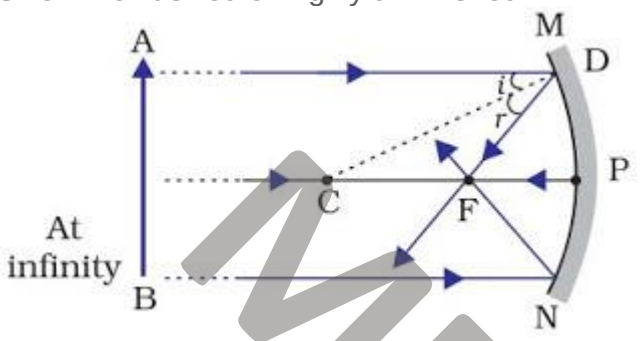
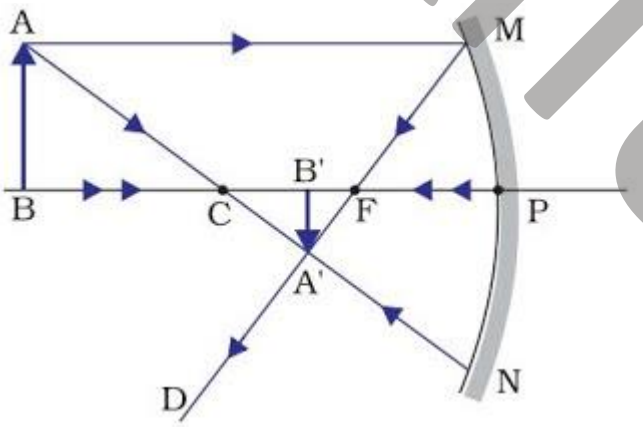
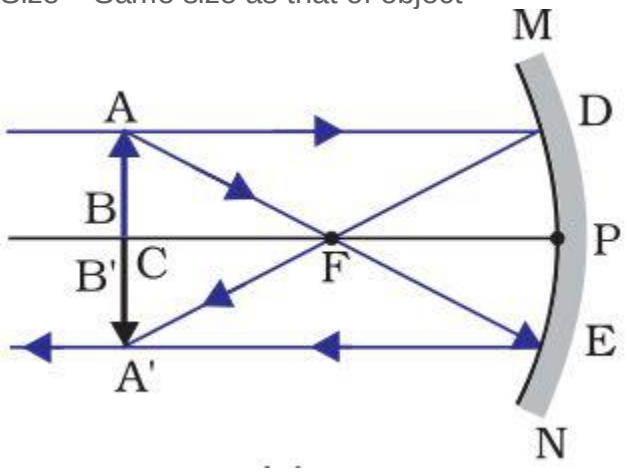
(i) When object is at infinity
Image Position − At 'F'
Nature of image – Real, inverted
Size – Point sized or highly diminished



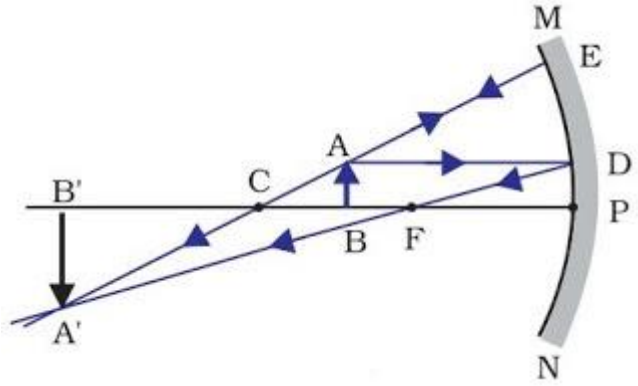
(ii) When object is beyond 'C'
Image Position – Between 'F' and 'C'
Nature of image – Real, inverted
Size – Diminished



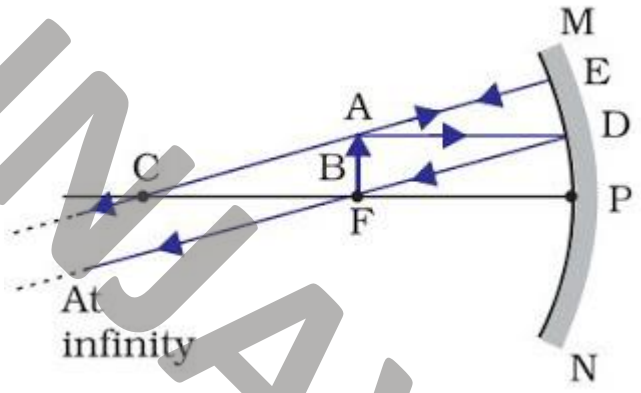
(iii) When object is at 'C'
Image Position – At 'C'
Nature of image – Real, inverted
Size – Same size as that of object



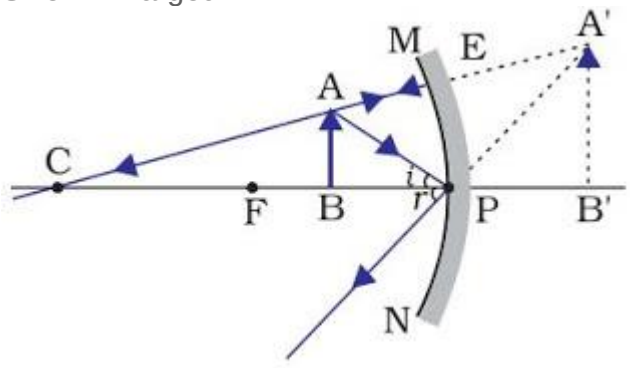
(iv) When object is placed between 'F' and 'C'
Image Position – Beyond 'C'
Nature of image– Real, inverted
Size – Enlarged



(v) When object is placed at 'F'
Image Position – At Infinity
Nature of image – Real, inverted
Size – Highly enlarged



(vi) When object is between 'P' and 'F'
Image Position – Behind the mirror
Nature of image – Virtual, erect
Size – Enlarged



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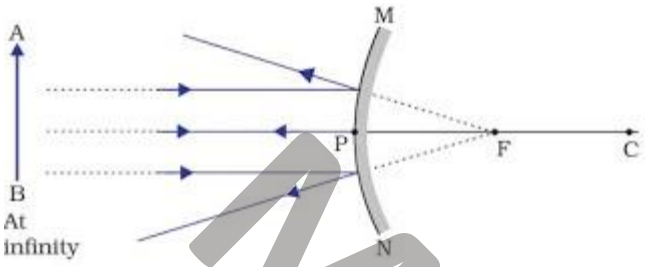
Ray diagrams for images formed by convex mirror

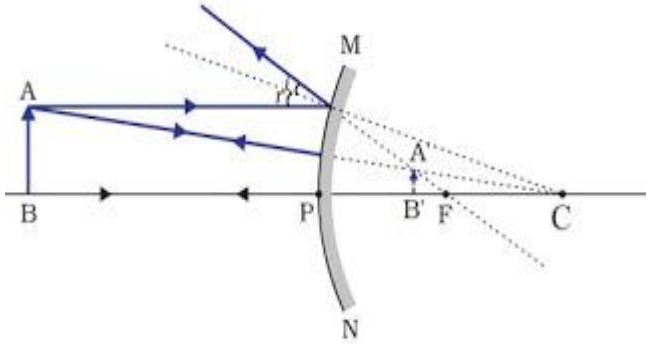
(i) When object is placed at infinity

Image Position − At 'F'
Nature of image – Virtual, erect
Size – Point sized



(ii) When object is placed between pole and infinity

Image Position – Between 'P' and 'F'
Nature of image– Virtual, erect
Size – Diminished



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

S.No.	Position of object	Position of image	Nature of image	Uses
1.	At infinity	Appears at the principal focus	Virtual, erect and extremely diminished	Used as a rear view mirror
2.	Between infinity and the pole	Appears between the principal focus and the pole	Virtual, erect and diminished	Used as a rear view mirror

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.

Uses of Convex Mirror

(i) Convex mirrors are used as rear view mirrors in vehicles because
→ they always give an erect though diminished image.
→ 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.

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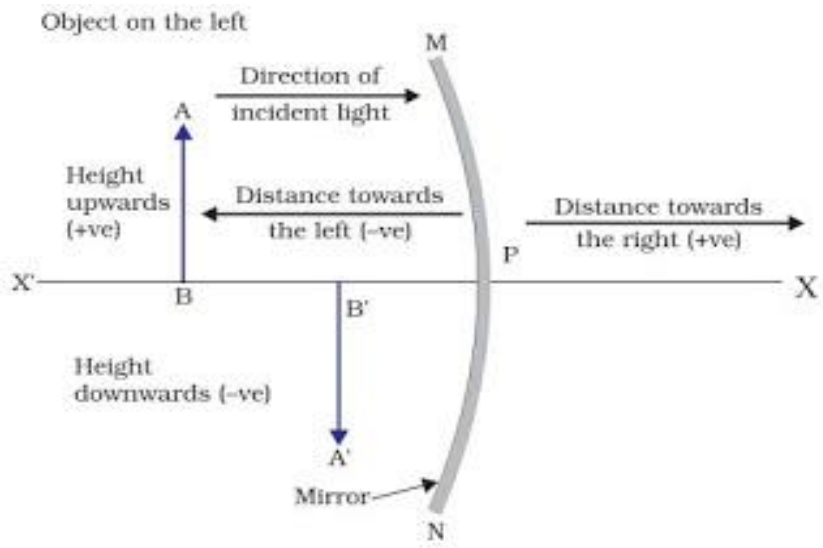
Sign Convention for Reflection by Spherical Mirror

(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 along + X-axis are taken as positive and those measured 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
- Focal length of convex mirror = Positive

Mirror formula and magnification

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

$$1/v + 1/u = 1/f$$

where, v = Image distance
u = Object distance
f = Focal length

Magnification

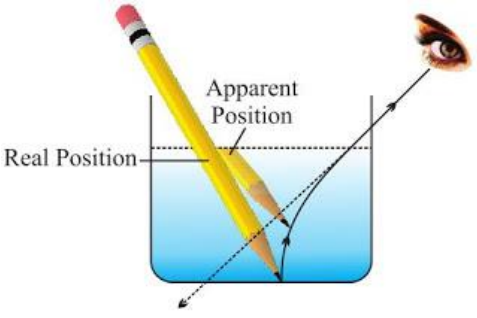
It is the ratio of the height of image to the height of object.
m = Height of image/Height of object

$$m = h_i/h_o$$

$$\text{Also, } m = -v/u$$

Refraction of light

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



- If the velocity of light in medium is more, then medium is called optical rarer. Example, air or vacuum is more optical rarer.
- If the velocity of light in medium is less, then medium is called optical denser. Example, glass is more denser than air.

***Refractive Index*:** It represents the amount or extent of bending of light when it passes from one medium to another.

There are two types of refractive index

- **Relative refractive index and**
- **Absolute refractive index.**

Refractive index of medium with respect to other medium is called **Relative 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. 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}.

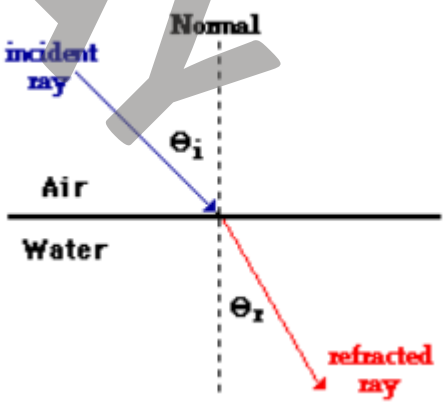
$$n_{21} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \frac{v_1}{v_2}$$

Refractive index of medium with respect to air or vacuum is called **Absolute Refractive Index.** 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.

$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

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.

Incident ray: It is incoming ray on the refracting surface.
Refracted ray: It is an outgoing ray from the refracting surface.
An angle of incidence (i): It is the angle between incident rays and perpendicular line (normal) at the point of incidence.
An angle of refraction (r): It is the angle between refracted rays and perpendicular line (normal) at the point of incidence.



Law of Refraction: According to this law

- "The incident ray, refracted ray and normal at the point of incidence all lie in the same plane."
- **Snell's law**: The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant= constant (μ)

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

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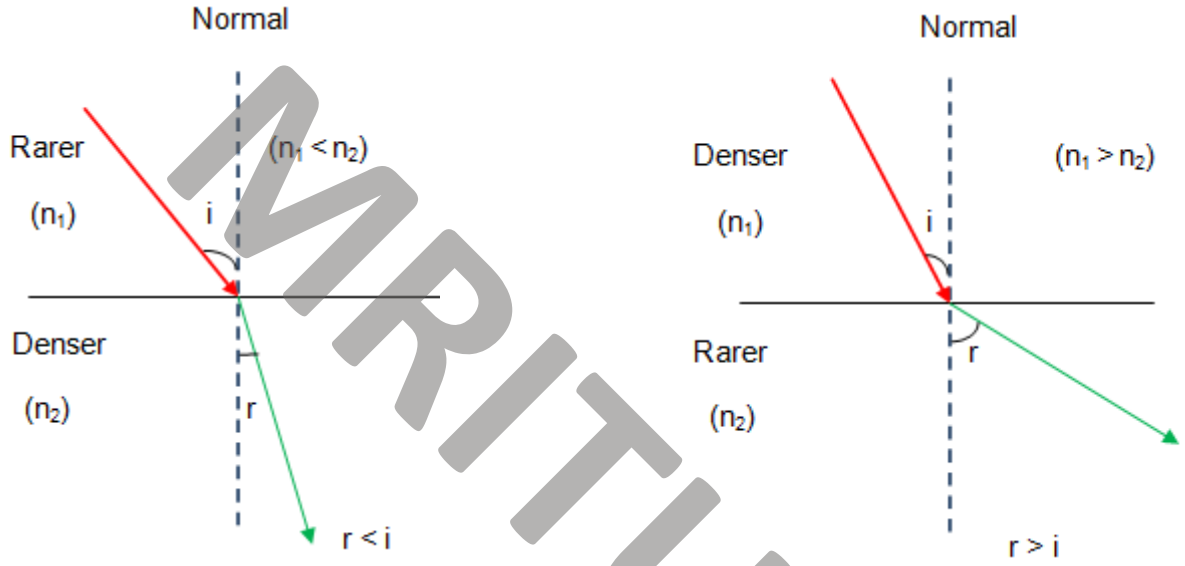
• **Optically denser medium:** Out of two given media, the medium with higher value of refractive index.
• **Optically rarer medium:** Out of two given media, the medium with lower value to refractive index.
→ When light enters obliquely from a rarer to a denser medium, it bends towards the normal.

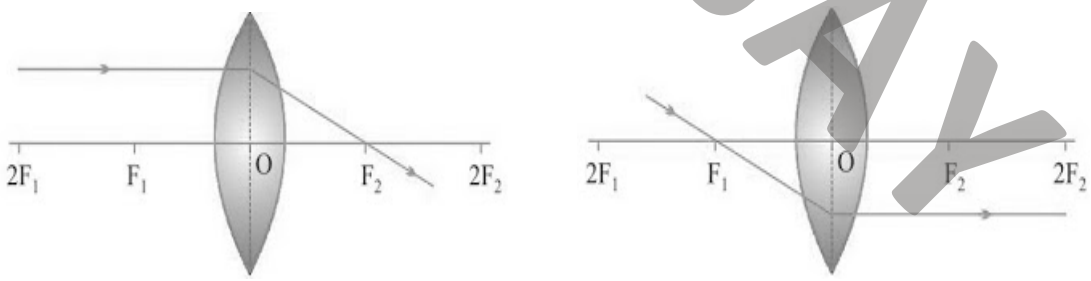


→ When light enters obliquely from denser to a rarer medium, it bends away from the normal.

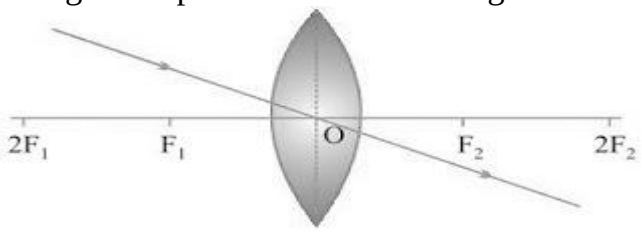
• ***Spherical lens:*** A transparent medium bound by two surfaces, of which one or both surfaces are curved.

Rules for image formation by 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.



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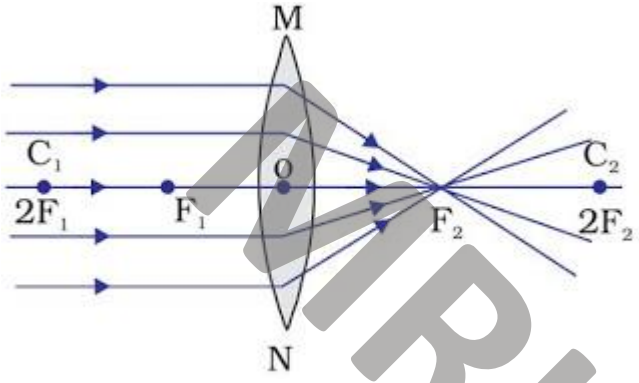
Ray Diagrams of Image formed by Convex Lens

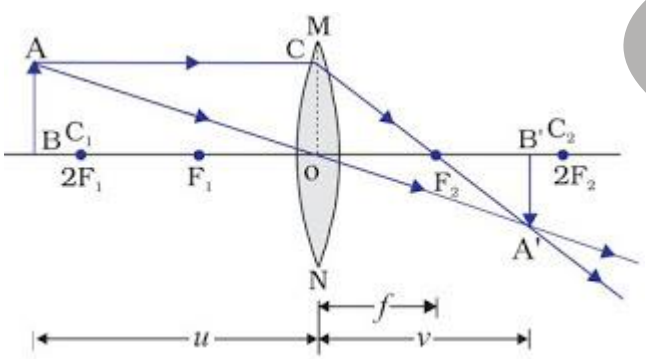
(i) When object is at infinity

Image Position − At 'F 2 '
Nature of image – Real, inverted
Size – Point sized or highly diminished



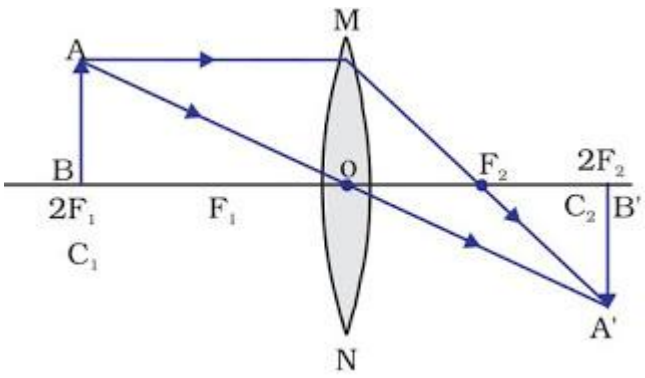
(ii) When object is beyond '2F1'

Image Position – Between 'F2' and '2F2'
Nature of image– Real, inverted
Size – Diminished



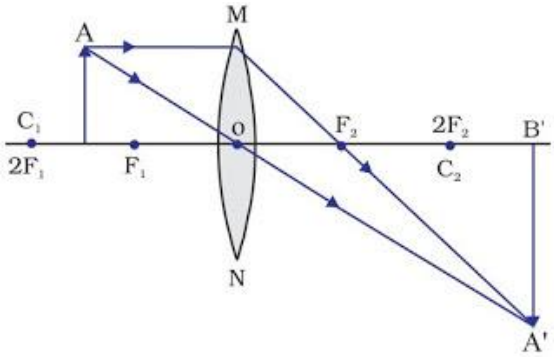
(iii) When object is at '2F1 '

Image Position – At '2F2 '
Nature of image – Real, inverted
Size – Same size



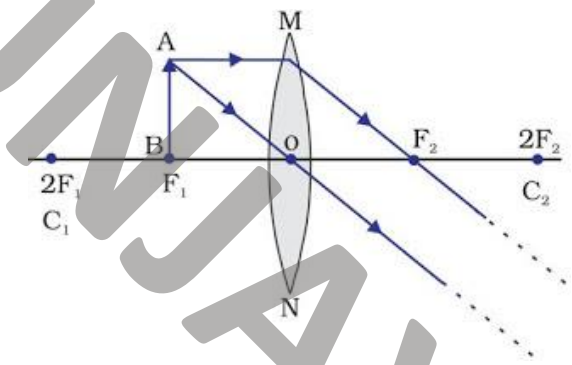
(iv) When object is between 'F1' and '2F1'

Image Position – Beyond '2F2'
Nature of image – Real, inverted
Size – Enlarged



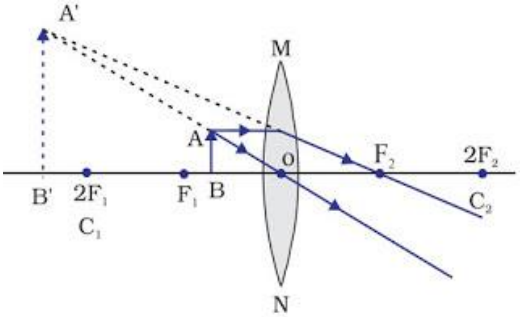
(v) When object is at 'F1'

Image Position – At Infinity
Nature of image – Real, inverted
Size – Highly enlarged



(vi) When object is between 'F1' and optical centre

Image Position – On the same side of the lens as object
Nature of image – Virtual and erect
Size – Enlarged



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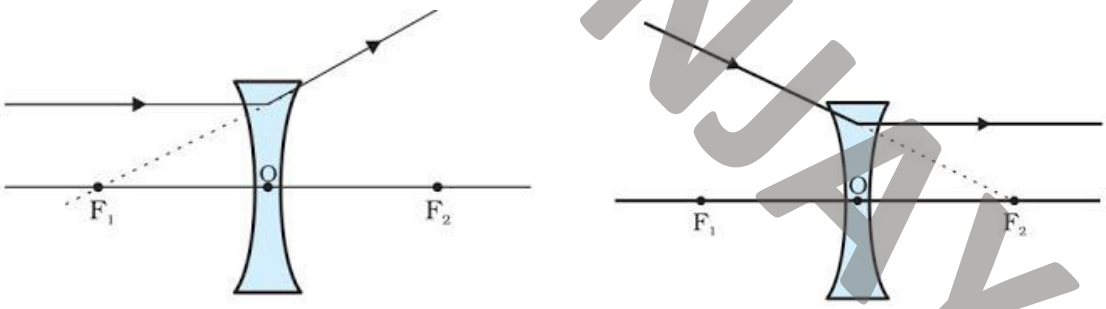
S.No.	Position of object	Position of image	Nature of image	Uses
1.	At infinity	At the principal focus or in the focal plane	Real, inverted and extremely diminished in size	Telescopes
2.	Beyond 2F	Between F and 2F	Real, inverted and diminished	In a camera, In eye while reading
3.	At 2F	At 2F	Real, inverted and equal to the size of the object	Photocopier
4.	Between F and 2F	Beyond 2F	Real, inverted and bigger than object	Projector, microscope objective
5.	At the principal focus	At infinity	Real, inverted and extremely magnified	Spotlights
6.	Between the optical centre and the principal focus	On the same side as that of object	Virtual, erect and magnified	Magnifying glass, eye lenses spectacles for short sightedness

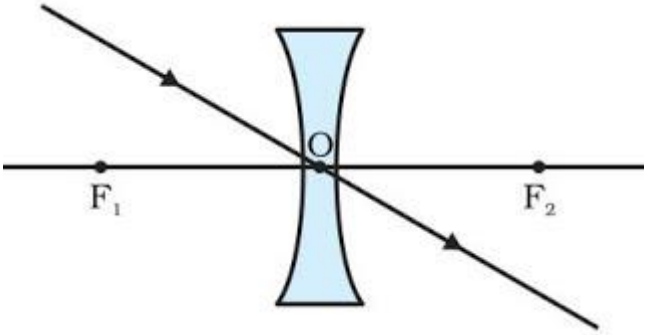
Rules for Image Formation by Concave Lens

(i) A ray of light parallel to the principal axis appear to diverge from the principal focus located on the same side of the lens.



(ii) A ray of light appearing to meet at the principal focus of a concave lens will emerge parallel to principal axis.

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



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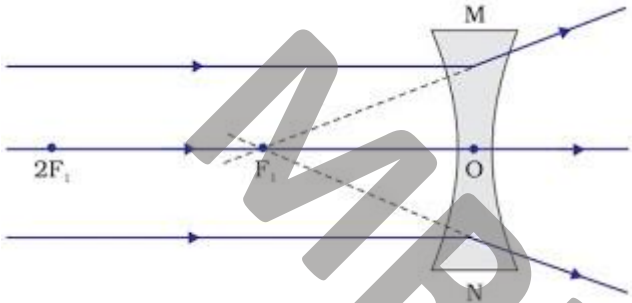
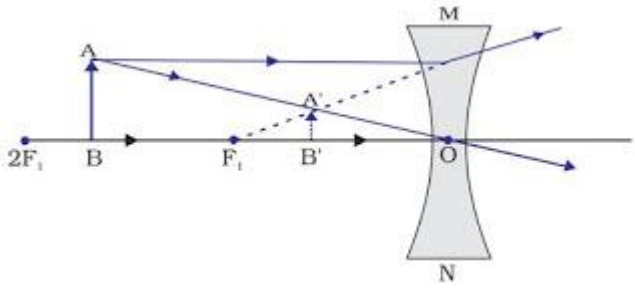
Ray Diagrams of Images Formed by a Concave Lens

(i) When object is placed at infinity
Image Position – At 'F1'
Nature of image – Virtual, erect
Size – Point sized or highly diminished



(ii) When object is placed between infinity and optical centre
Image Position – Between 'F' and 'O'
Nature of image – Virtual, erect
Size – Diminished



S.No.	Position of object	Position of image	Nature of image	Uses
1.	At infinity	Appears at the principal focus on the same side as that of the object	Virtual, erect and extremely diminished	Spectacles for short sightedness
2.	Between infinity and the lens	Appears between the principal focus and the lens	Virtual, erect and diminished	Spectacles for short sightedness

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

$1/v - 1/u = 1/f$

Magnification

$m = h_i/h_o = v/u$

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.
Power (P) = $1/v - 1/u = 1/f$
→ 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
→ Power ∝ 1/(focal length or thickness)
→ Power of a lens combination (P) = $P_1 + P_2 + P_3$ .....