Unit 3 Natural Phenomena

Chapter 9:

Light- Reflection And Refraction

➡ Light

Light is a type of electromagnetic radiation that allows the human eye to see or makes object visible. It is also defined as visible radiation to the human eye. Photons, which are tiny packets of energy are found in light.

➡ Reflection of Light

The bouncing back of light in the same medium is called reflection of light

LAWS OF REFLECTION

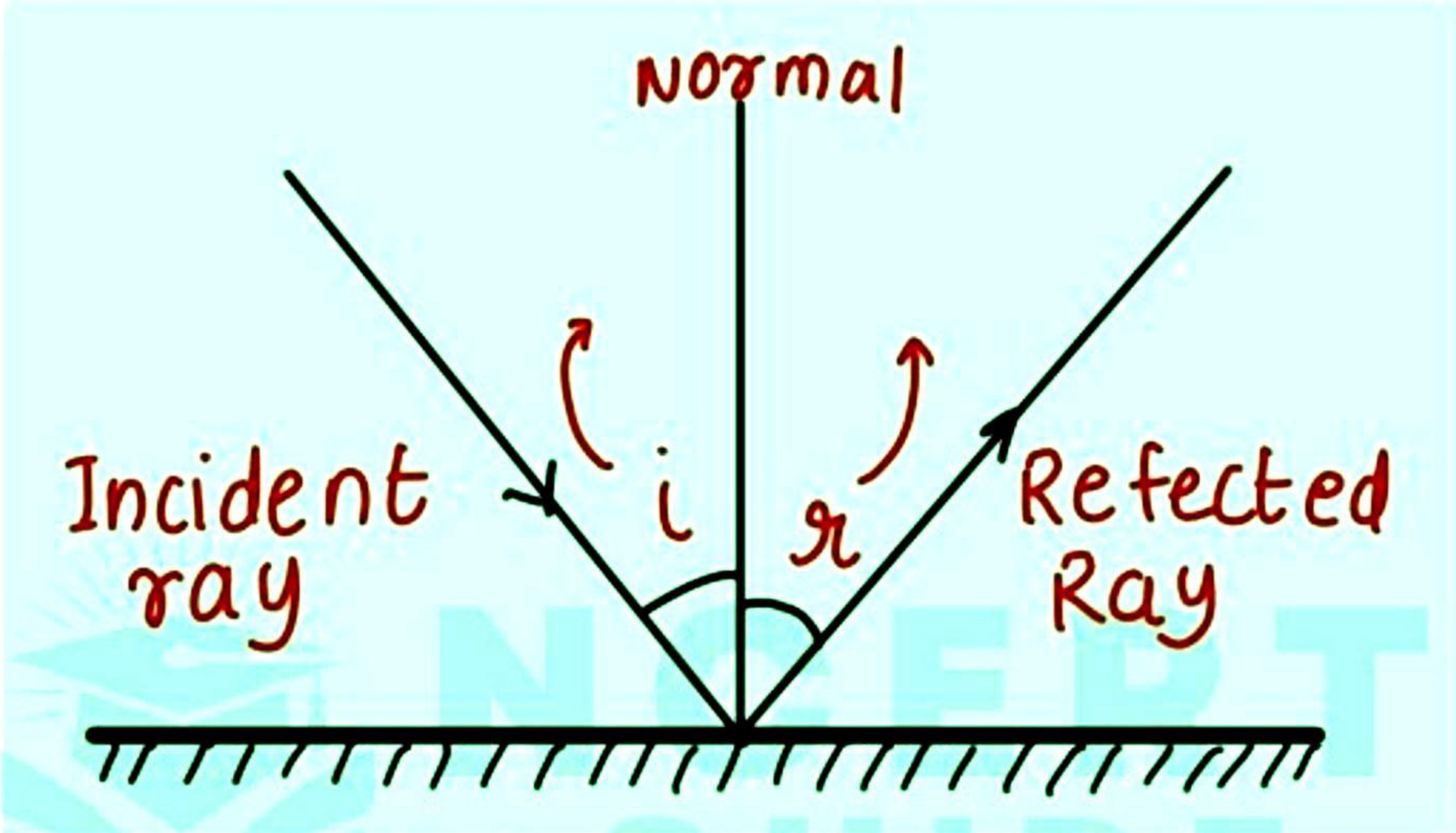
- The First Law of Reflection - All the incident ray, the reflected ray and the normal to the surface at the point of incidence lie on the same plane.
- The Second Law of Reflection - The angle of incidence equals the angle of Reflection. In other words, the angle between the incident ray and the normal is equal to the angle between the reflected ray and the normal.

➡ Terms Related to Reflection

- Incident Ray - The light ray striking a reflecting surface is called the incident ray.

- **Point of Incident** - The point at which the incident ray strikes the reflecting surface is called the point of Incident.

- **Reflected Ray** - The light Ray obtained after reflection from the surface in the same medium in which the incident ray is travelling is called Reflected Ray.



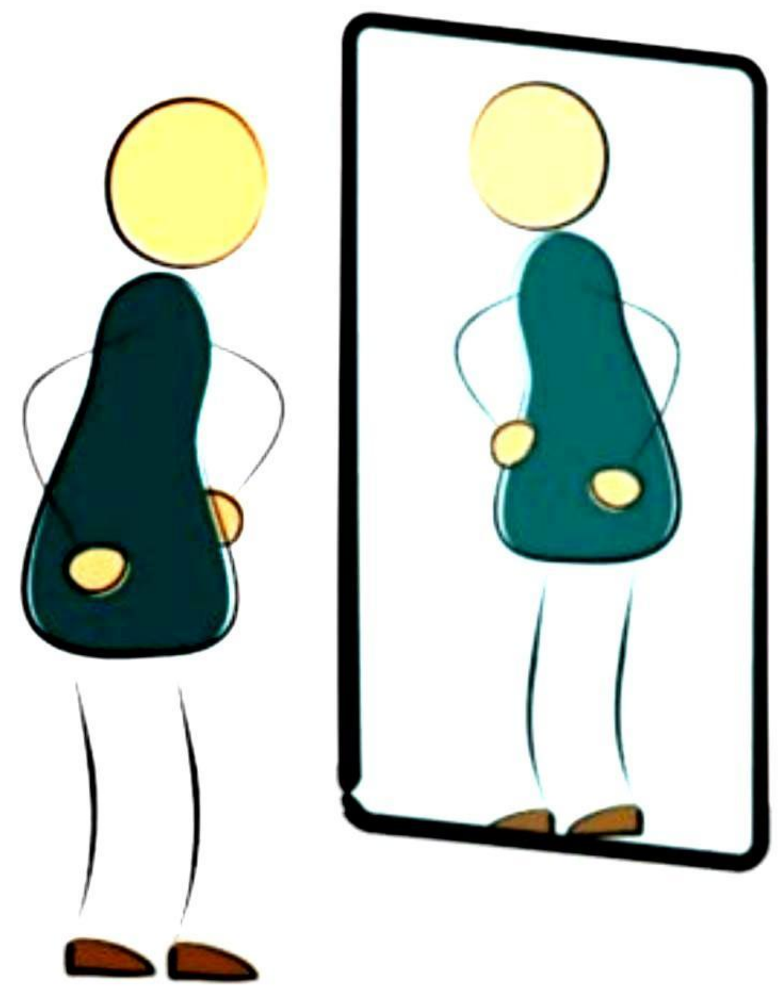
Reflecting of light

- **Normal** - The perpendicular drawn to the surface at the point of incident is called the normal.

- **Angel of Incidence** - The angle which the incident ray makes with the normal at the point of incidence is called angle of Incidence.

- **Angel of reflection** - The angle which the reflected ray makes with the normal at the point of incidence is called the angle of reflection.

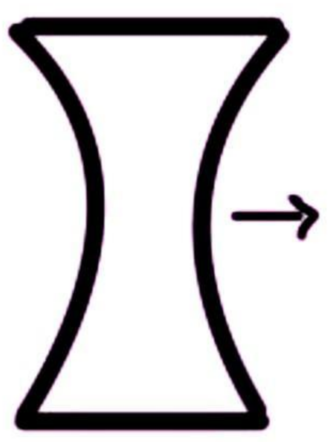
➡ Properties of Image Formed by a plane Mirror



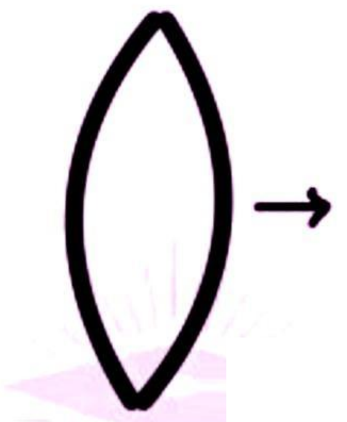
- A plane mirror forms an image that is virtual and erect.
- The image appears laterally inverted.
- The distance of the image from the mirror is the same as the distance of the object from the mirror, but behind the mirror.
- The Size of the image is equal to the size of the object (magnification factor, m, equals 1)

➡ Spherical Mirrors

Mirrors with spherical reflecting surfaces are part of hollow glass spheres. A concave mirror has a curved reflecting surface on its inner side, while a convex mirror has a reflective surface that bulges outward, away from the light source.



A concave mirror, characterized by its inwardly curved reflecting surface, is known as a concave mirror



Conversely, a convex mirror, distinguished by its outwardly curved reflecting surface is referred to as a convex mirror.

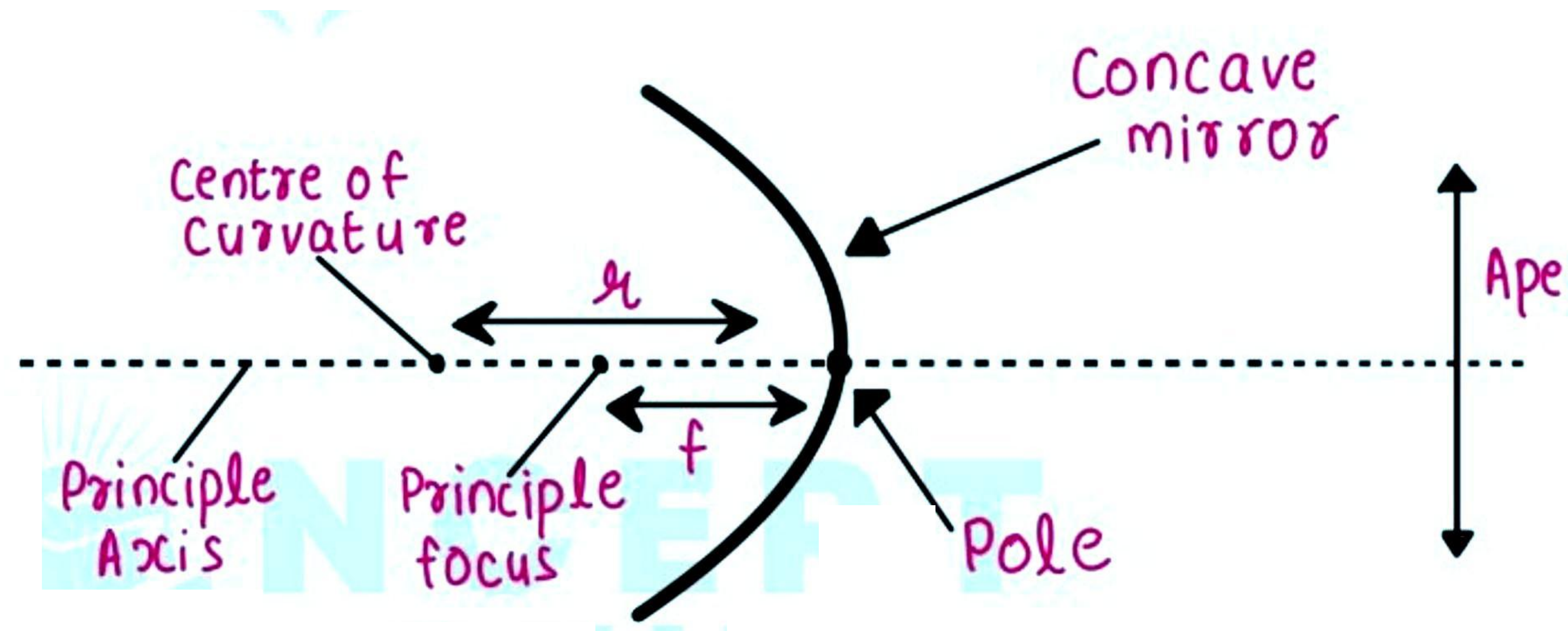
➡ Some Important terms of spherical mirror.

- Pole - Denoted by 'P', the pole of spherical mirror is the centre of its reflecting surface, coinciding with the mirror's surface itself.

- Centre of Curvature - The Centre of the sphere from which the reflecting surface of a spherical mirror is derived is called the centre of curvature. For concave mirrors, it lies in front, while for convex mirror, it lies behind the mirror.

- The Radius of Curvature - Represented by 'R', it is the radius of the sphere from which the reflecting surface of a spherical mirror is derived.

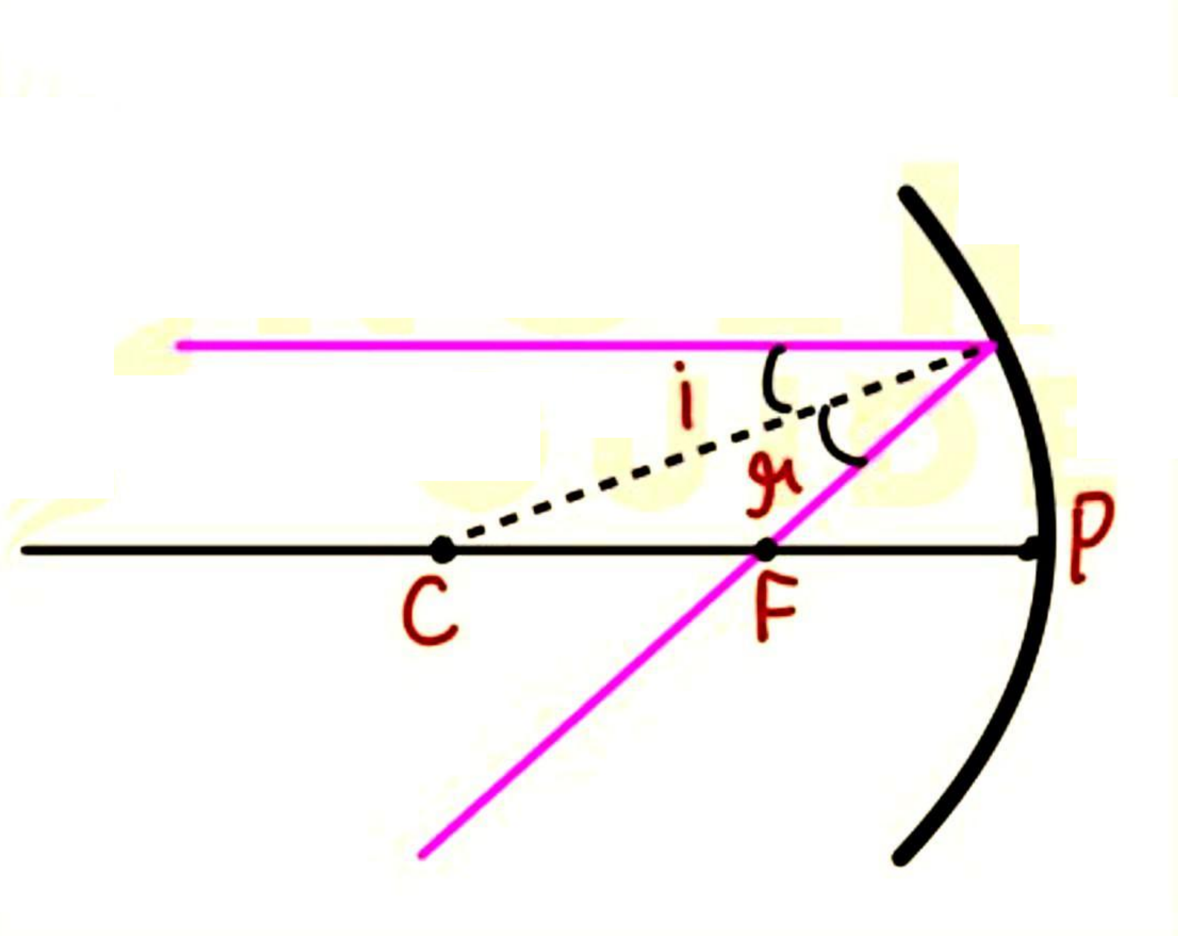
- Principal axis - The principal axis of a spherical mirror is a straight line passing through the mirror's pole and its centre of curvature. It is perpedicular to the mirror's surface and its pole

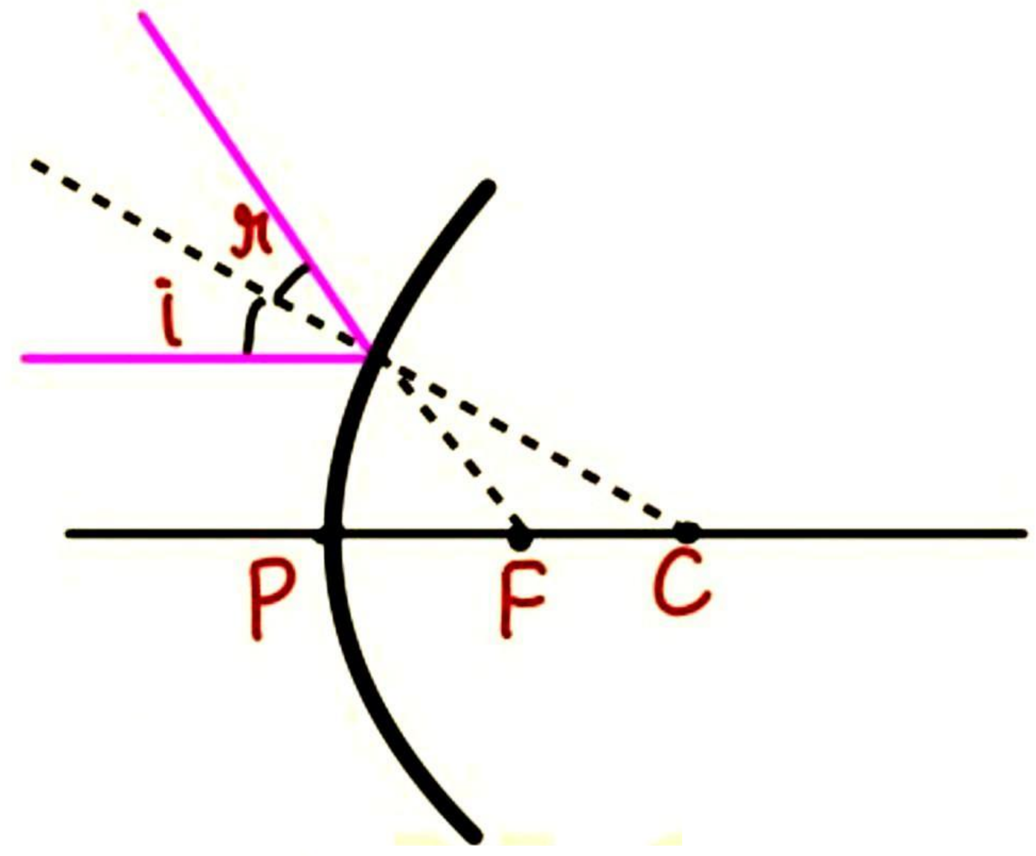


- Principal focus - Denoted by 'F', for a concave mirror, parallel rays converge at the principal focus, while for a convex mirror, they appear to diverge from it. The distance between the mirror's pole and the principal focus is the focal length

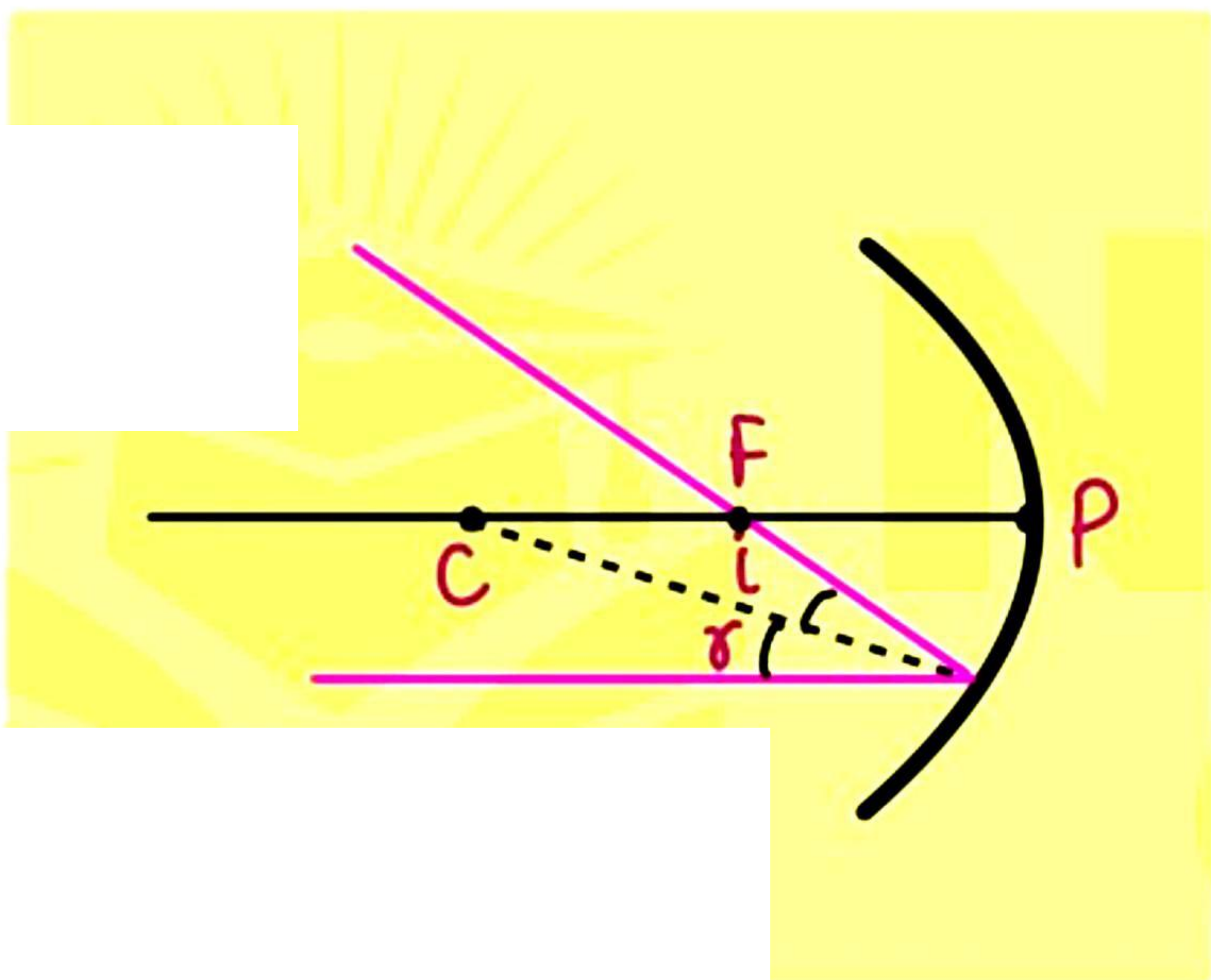
- Apperture - The diameter of the reflecting surface in a spherical mirror is referred to as the aperture. when the aperture is significantly smaller than the radius of curvature, an approximation of $R = 2f$ can be used.

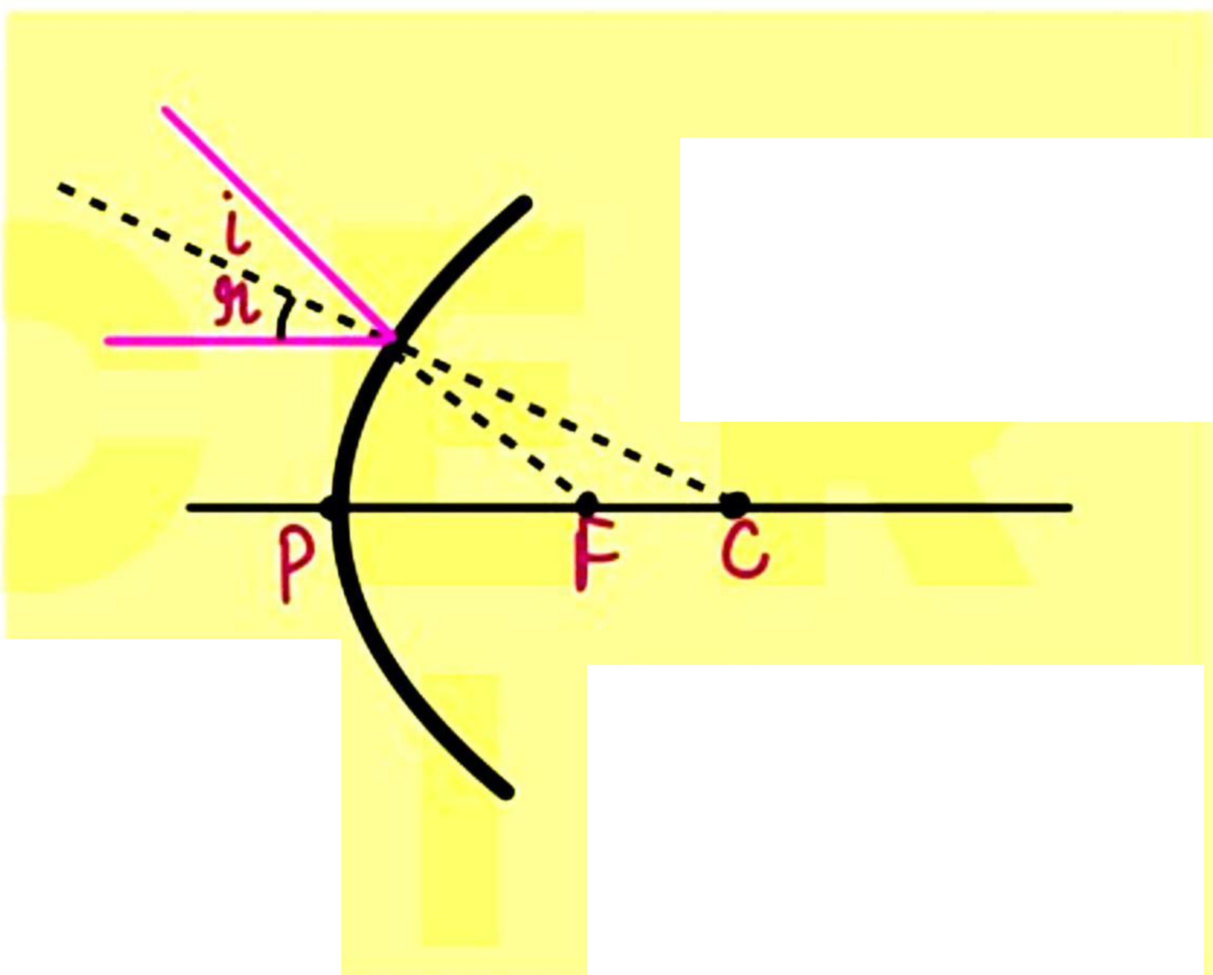
➡ Representation of Image by spherical mirror using ray diagram



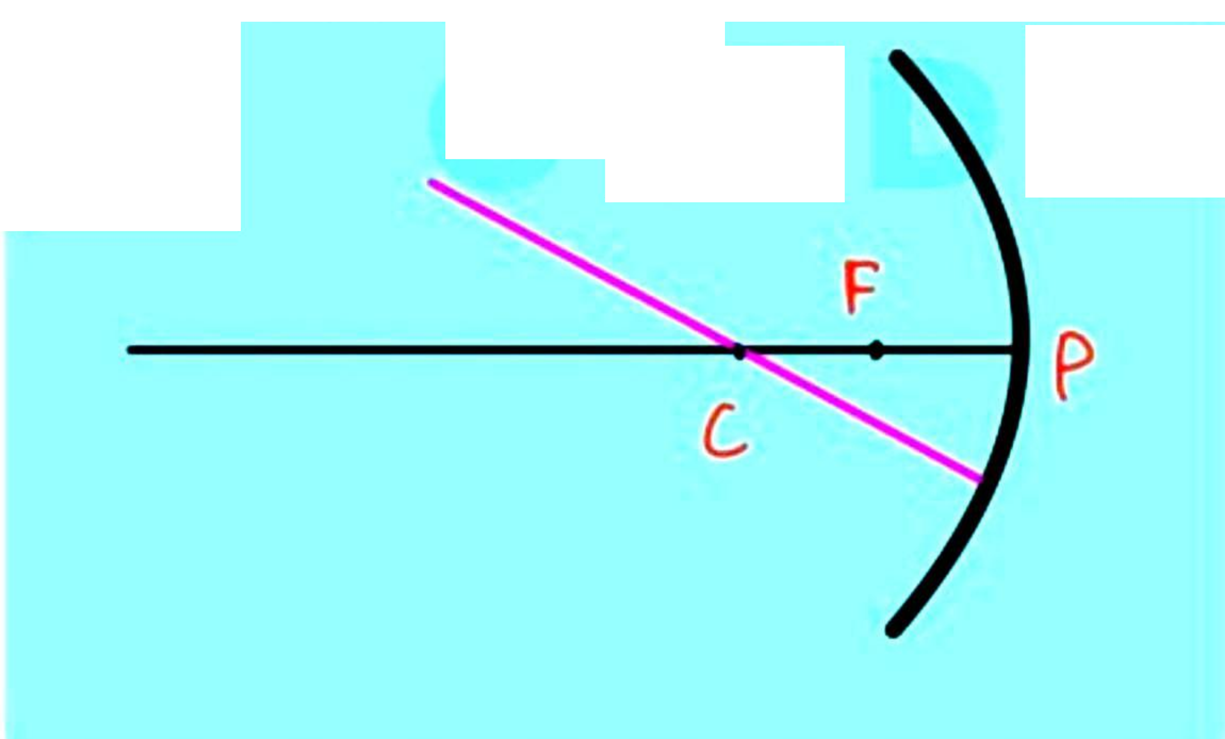


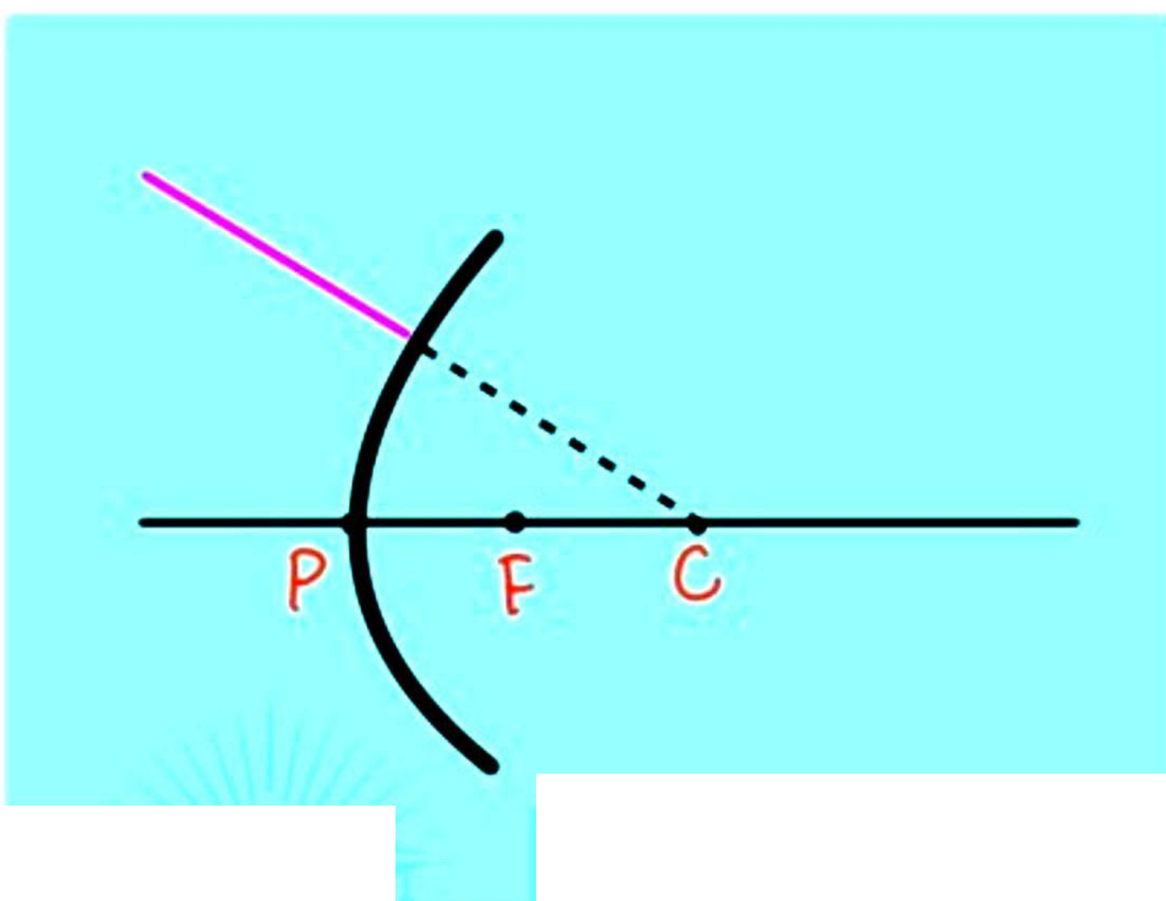
A ray parallel to the principal axis, after reflection will pass through the principal focus in case of a convex mirror or appear to diverge from the principal focus in case of a convex mirror



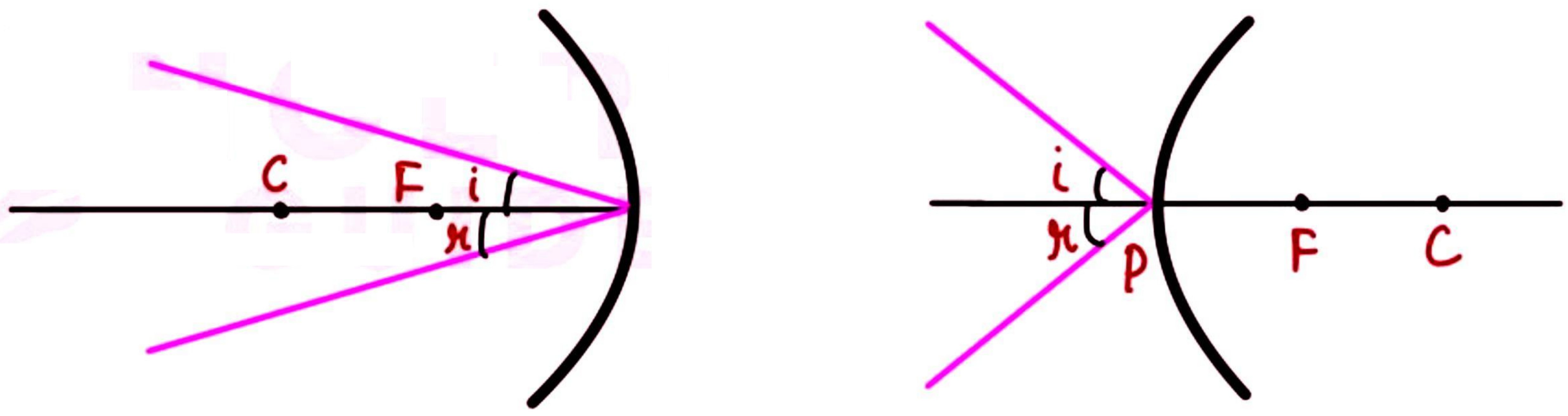


A ray passing through the principal focus of a concave mirror or a ray which is directed towards the principal focus of a convex mirror, after reflection will emerge parallel to the principal axis





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 book 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.

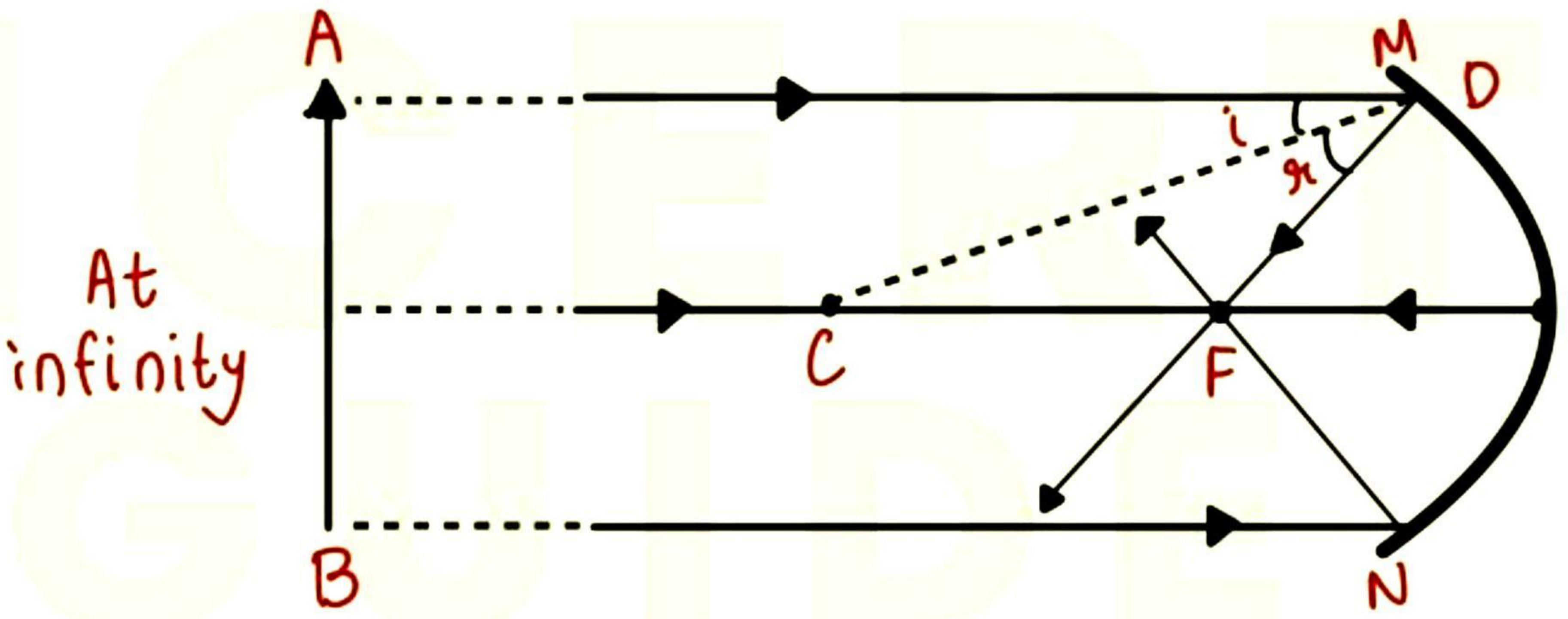


The ray incident obliquely to principal axis, towards a point P (pole of the mirror) on the concave mirror is reflected obliquently. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis.

➡ Image Formation by Concave Mirror

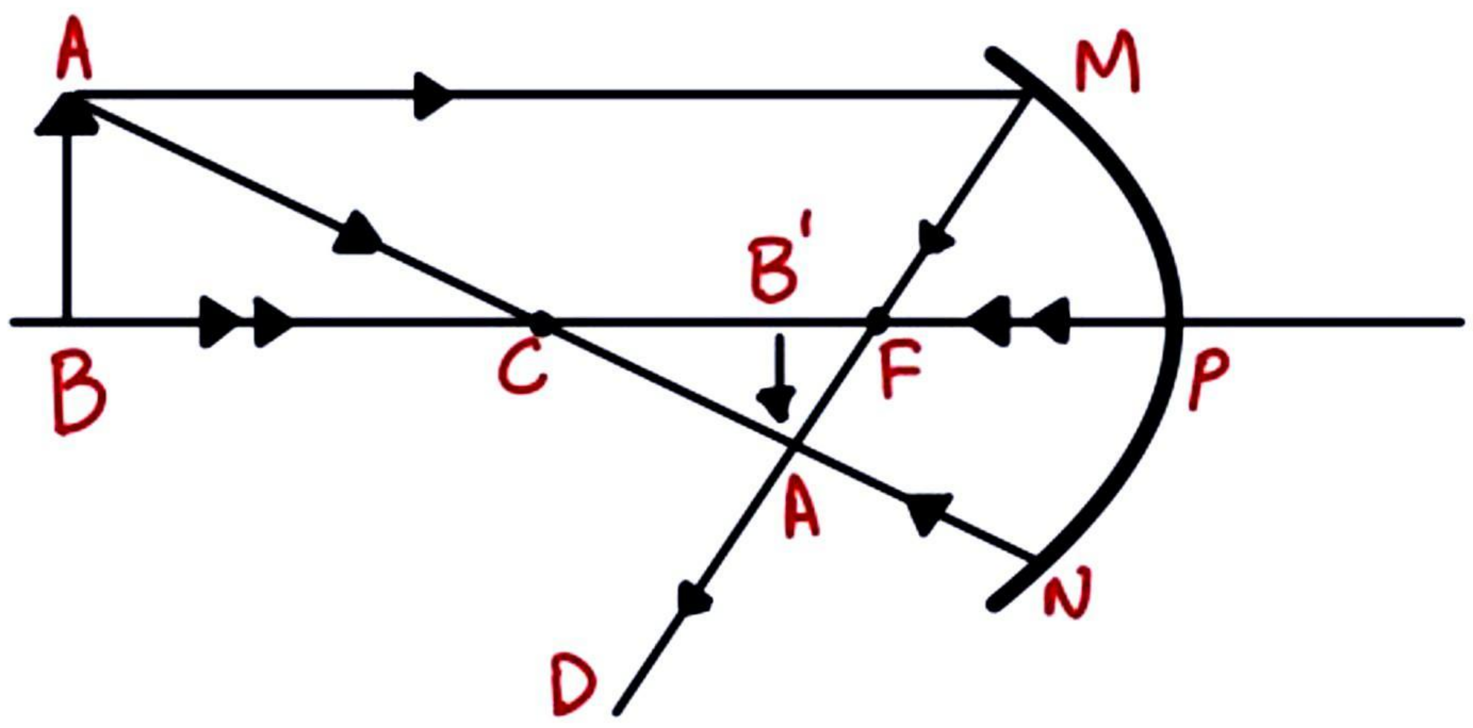
(i) When object is at infinity

Image position - At 'F'
Nature of image - Real, inverted
Size - Point sized or highly diminished



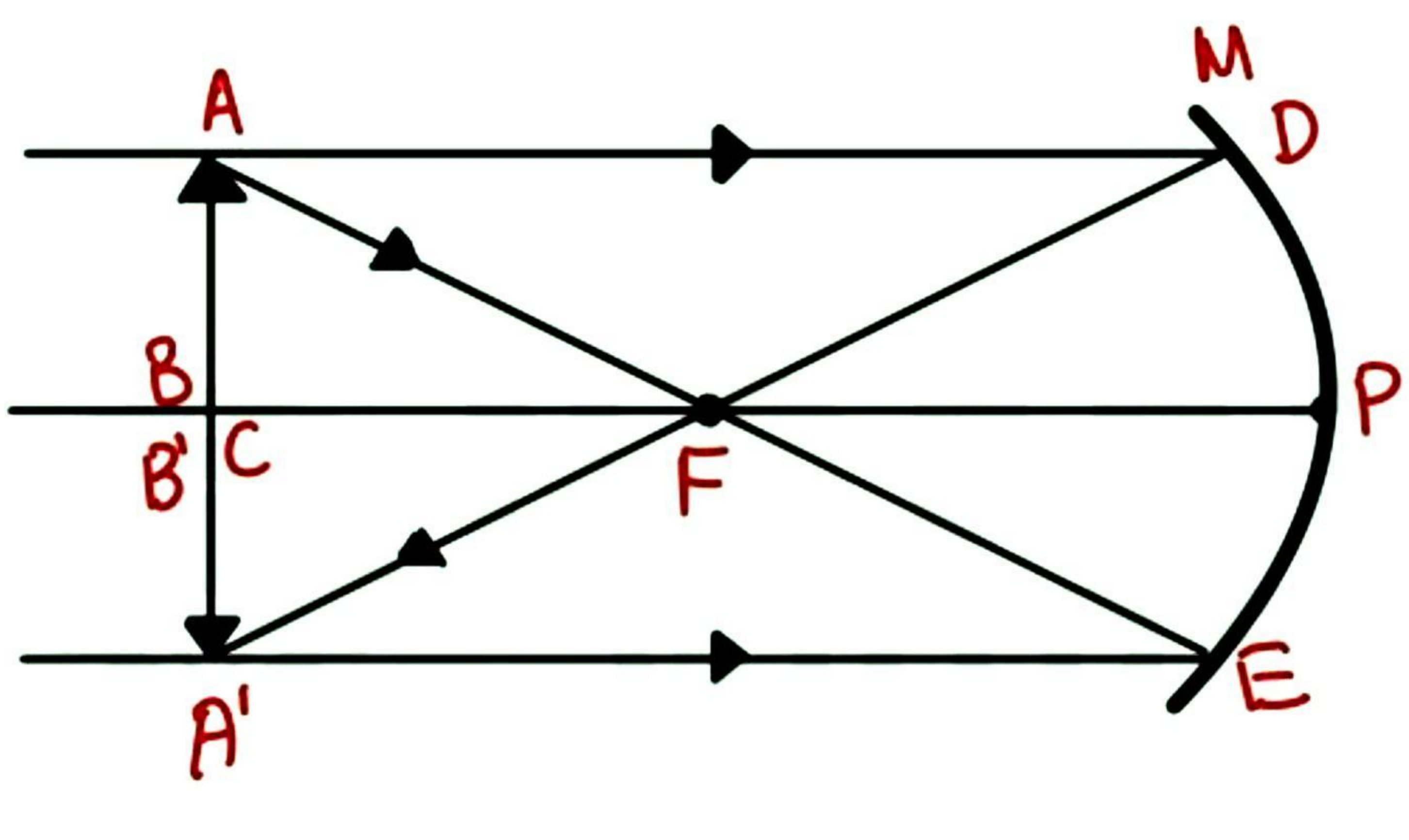
(ii) When object is beyond C

Image Position - Between 'F' and 'C'
Nature of Image - Real, inverted
Size - Diminished



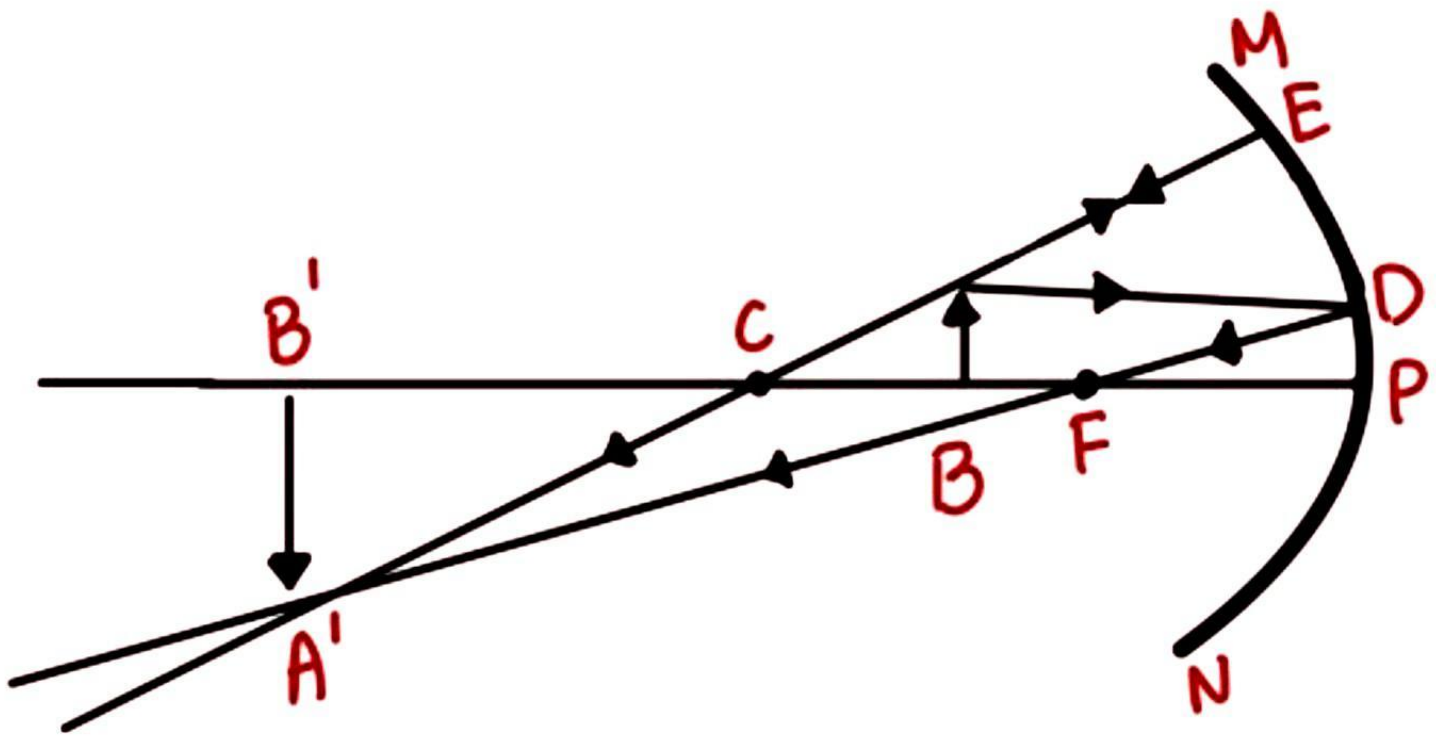
(iii) When object is at C

Image position - At 'C'
Nature of image - Real & Inverted
Size - Same size as that of object.



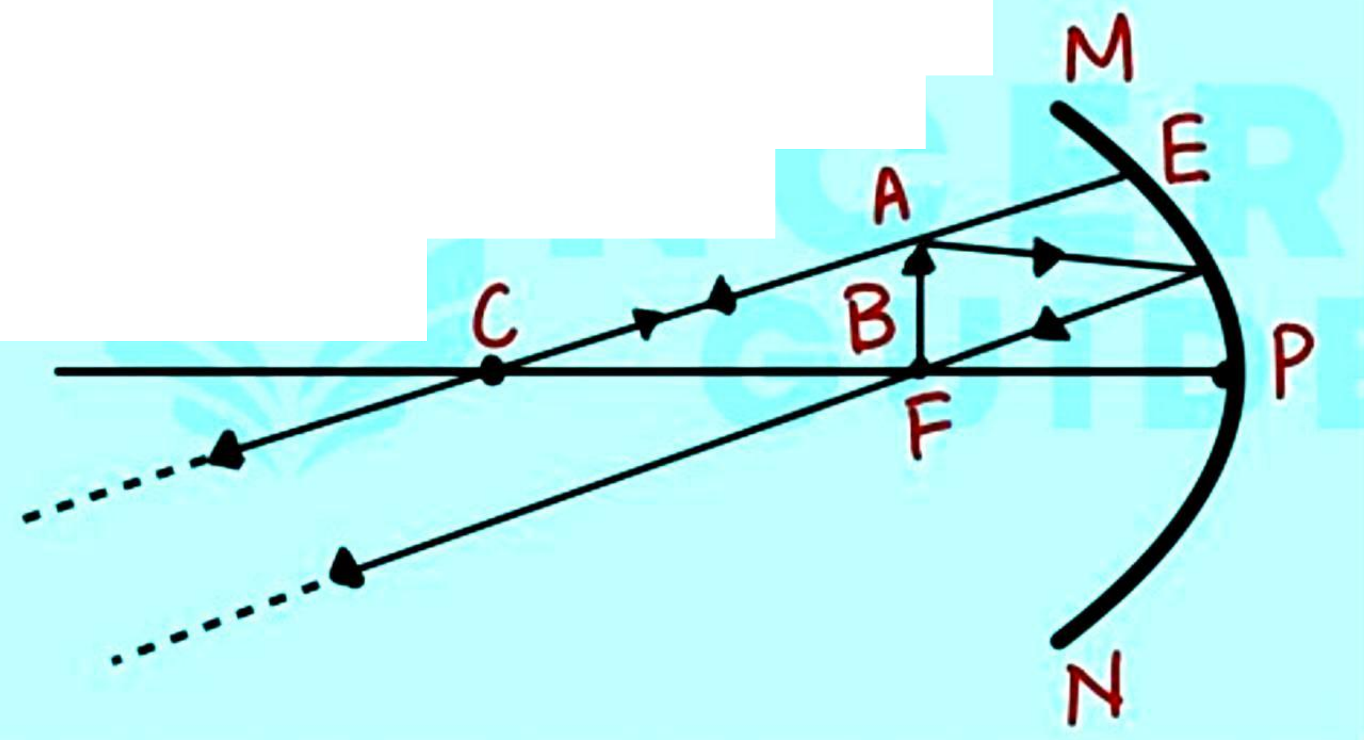
(iv) when object is placed between 'F'

Image position - Beyond 'C'
Nature of Image - Real and Inverted
Size - Enlarged



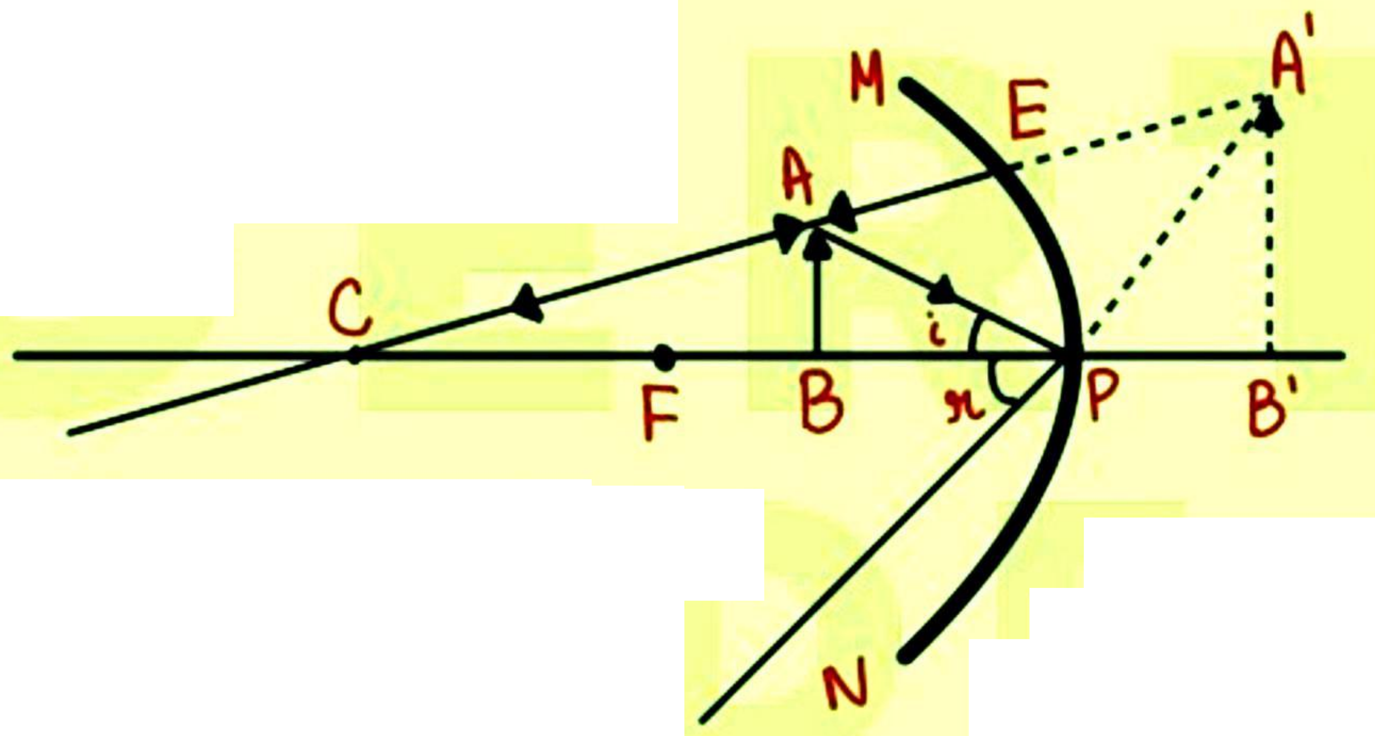
(v) When object is placed at 'F'

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

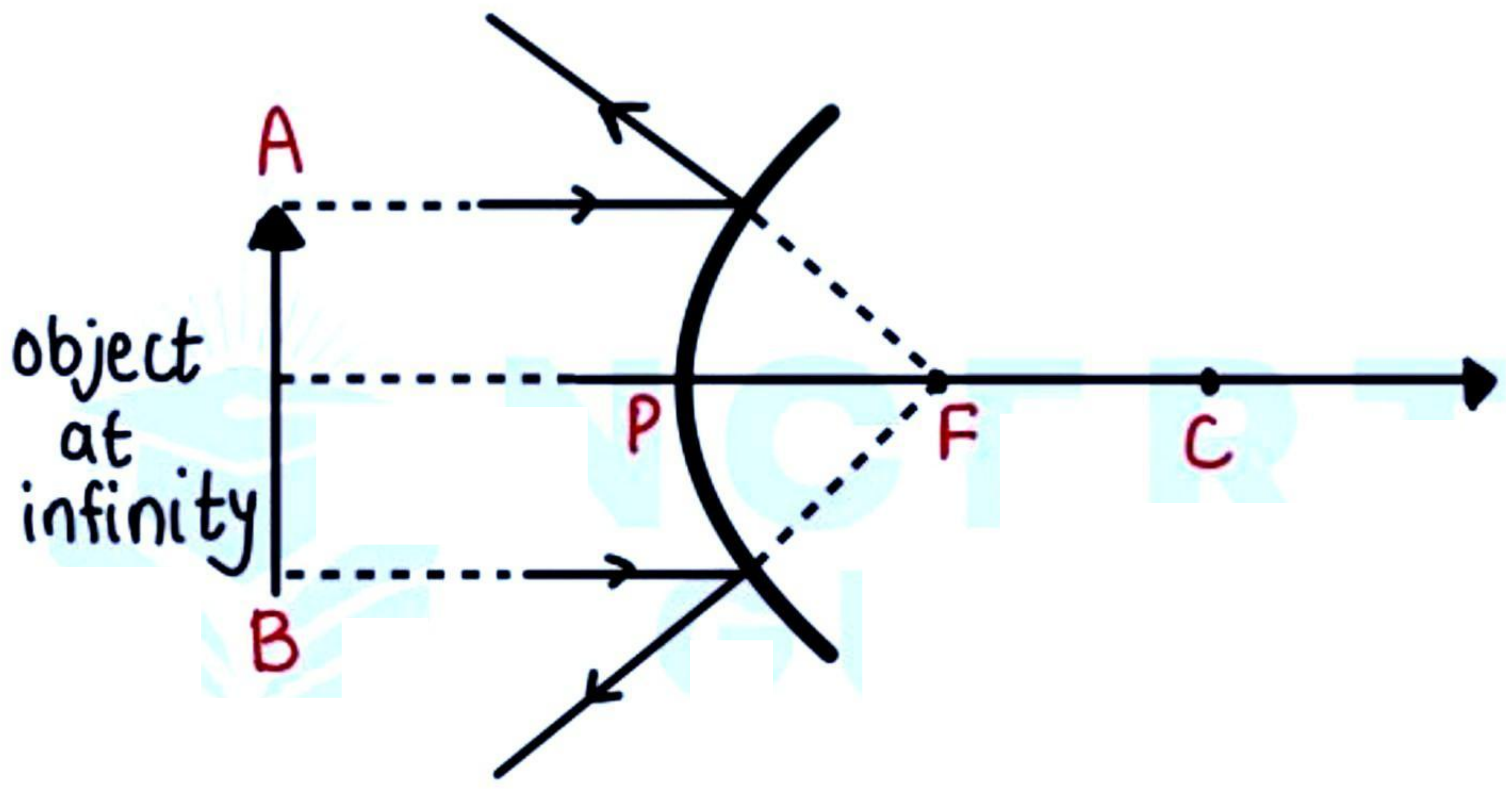


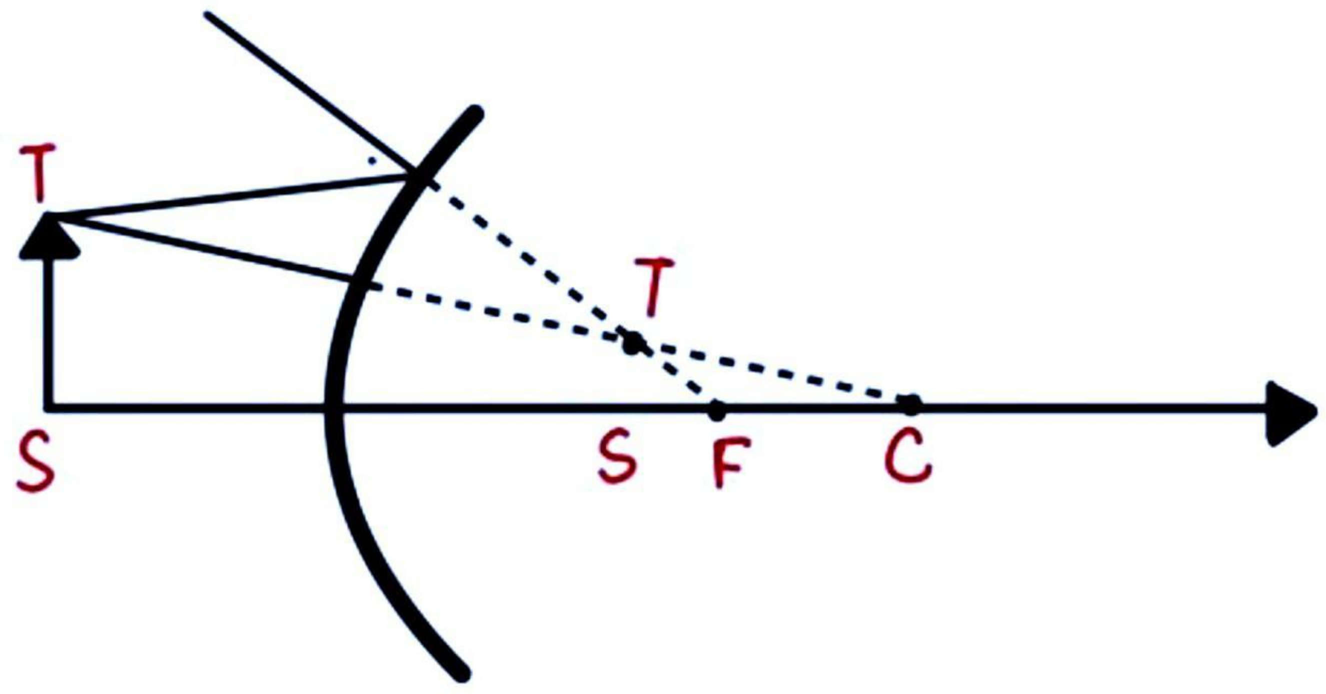
(vi) when object is between 'P' and 'F'

Image Position - Behind the mirror
Nature of Image - Virtual, erect
Size - Enlarged



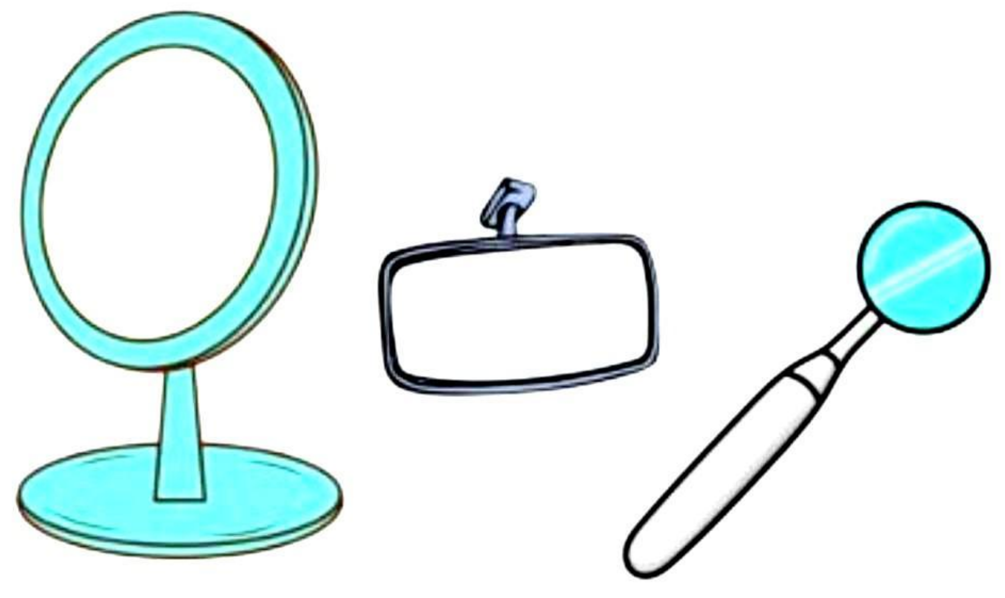
➡ Image Formation by Convex mirror



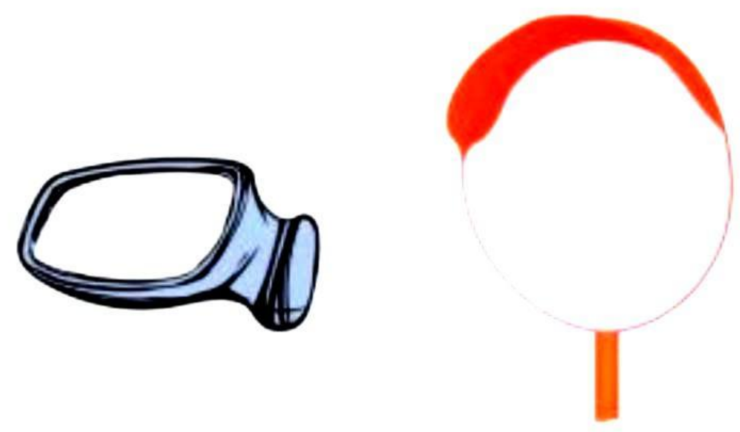


Position of the object	Position of the Image	Size of the Image	Nature of the Image
At Infinity	At Focus, F behind the mirror	Highly diminished and pointed in size	virtual and erect
Between infinity and the pole of the mirror	Between P and F, behind the mirror	Diminished	virtual and erect

➡ Uses of Spherical Mirrors



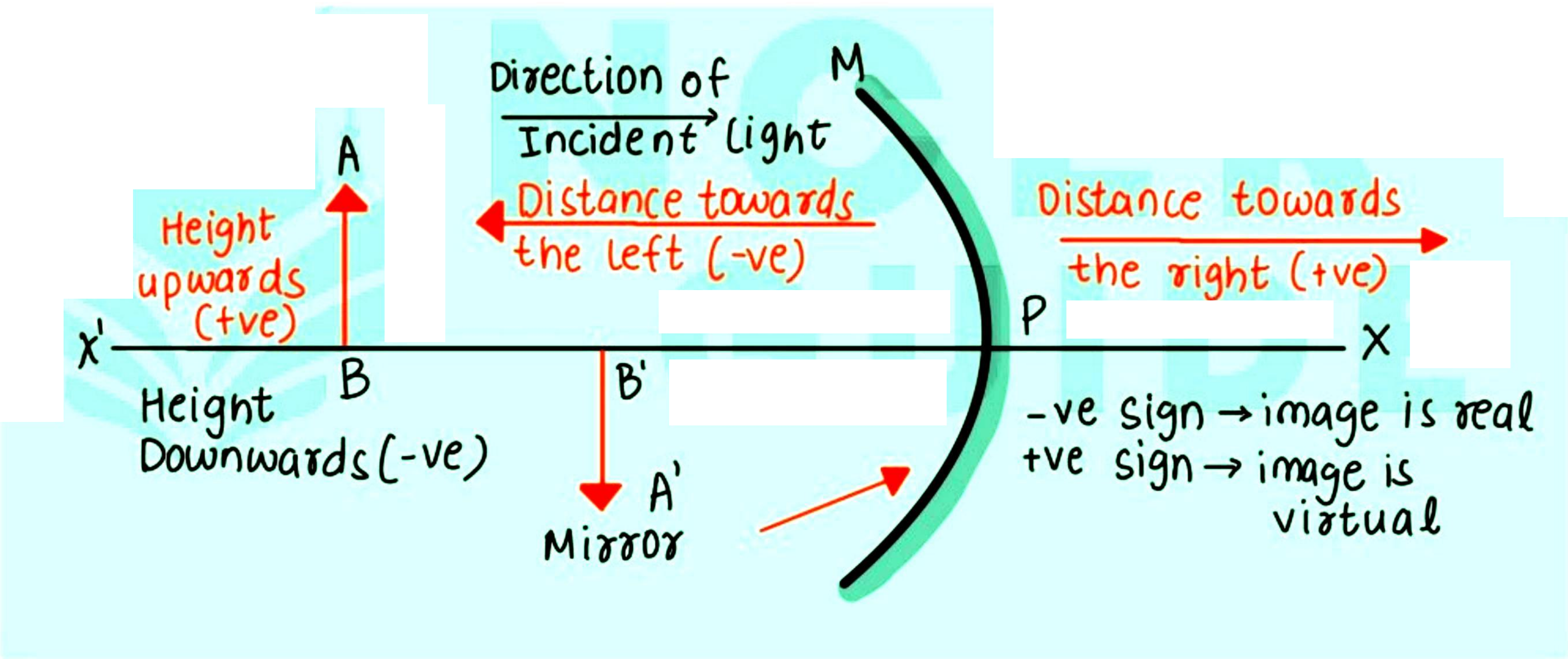
📌 **Concave (converging)** - Concave mirrors are used in torches, headlights, shaving mirrors, dental examinations, and solar furnaces for heat.



📌 **Convex (Diverging)** - $f = (+ve)$
convex mirrors are used in vehicle's rear-view mirrors to provide smaller but upright images and a wider field of view enhancing driver visibility

➡ Sign-Convention For Reflection By Spherical Mirror

- Object on the left, Light comes from the left.
- Start measuring from the mirror's pole.
- Left is negative, right is positive.
- Above the principal axis is positive.
- Below the principal axis is negative.



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

v = image distance
u = object distance
f = focal length

- (u) (object distance) always negative.
- (v) (image distance) is positive behind a concave mirror, negative in front of a concave mirror, and always positive for a convex mirror.

Magnification

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

$$m = \frac{h'}{h} = \frac{-v}{u} \Rightarrow \boxed{m = -\frac{v}{u}}$$

- The focal length (f) of a concave mirror is always negative, and that of a convex mirror is always positive.
- The height of an object is always positive.
- If the image is erect, the height is taken as positive; If inverted the height is negative.

➡ Refraction of light

The bending of light at the boundary between two mediums is called refraction. Examples include a spoon dipped in water and the appearance of the bottom of a glass tumbler filled with water.

➡ Refraction Index

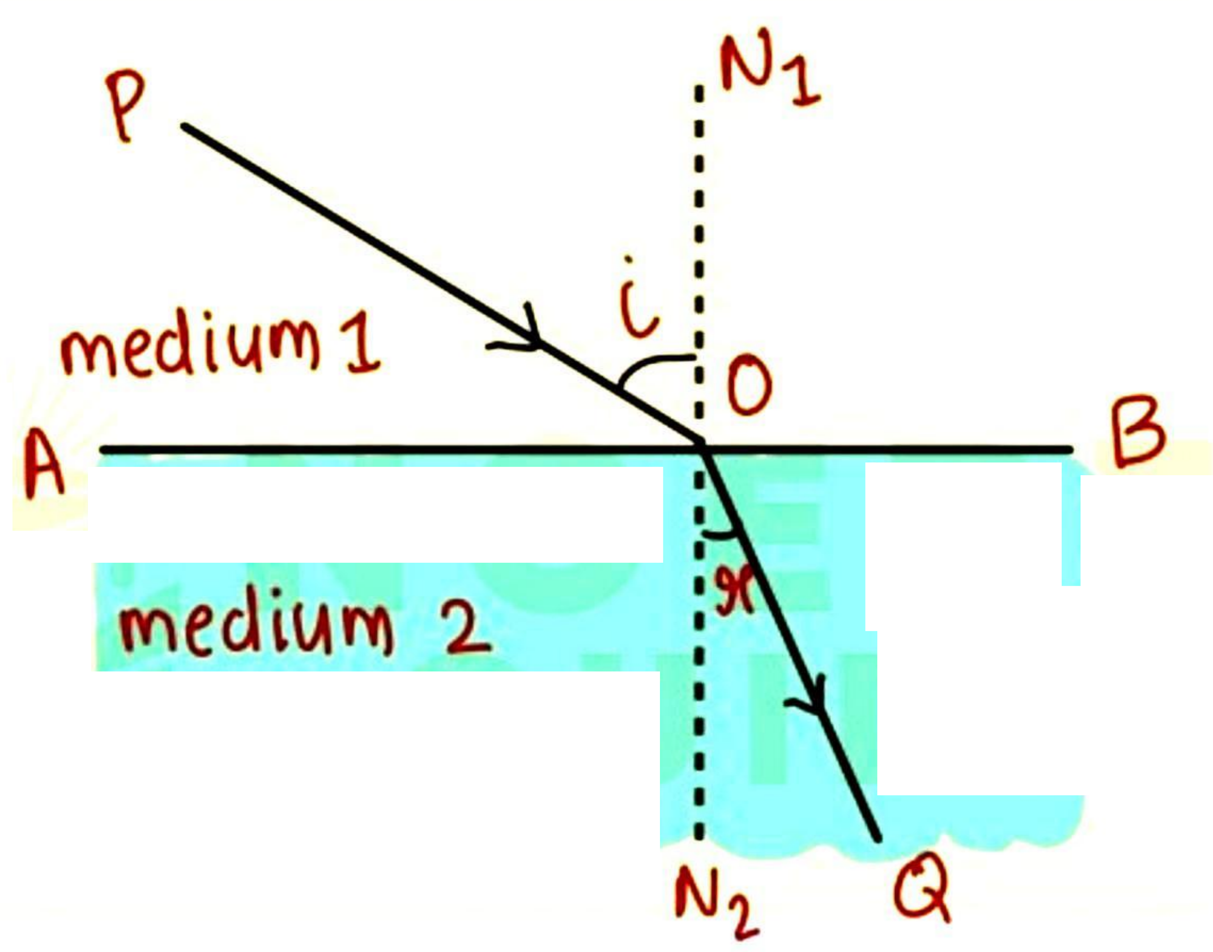
Light bends when moving between different mediums because of speed differences. Light travels at varied velocities in materials accelerating or decelerating upon entry into a new medium. This change alters the direction of light, known as refraction. The degree of bending depends on the extent of the speed change. Refraction is governed by the refractive index, indicating the ratio of light speed in vaccum to its speed in the medium.

➡ Laws of Refraction

- Incident Ray - Reflected ray and normal to the surface of two media at a point of incidence are coplanar.
- Snell's Law - The Ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given colour and pair of media $\frac{\sin i}{\sin r} = \text{constant} = \frac{n^2}{n'}$
- Refractive Index of the 2^{nd} medium with Respect to 1st medium

$$n_{21} = \frac{n_2}{n_1} = \frac{C/V_2}{C/V_1} = \frac{V_1}{V_2}$$

$$n_{21} = \frac{V_1}{V_2} \quad \text{Thus} \quad n_{12} = \frac{1}{n_{22}}$$

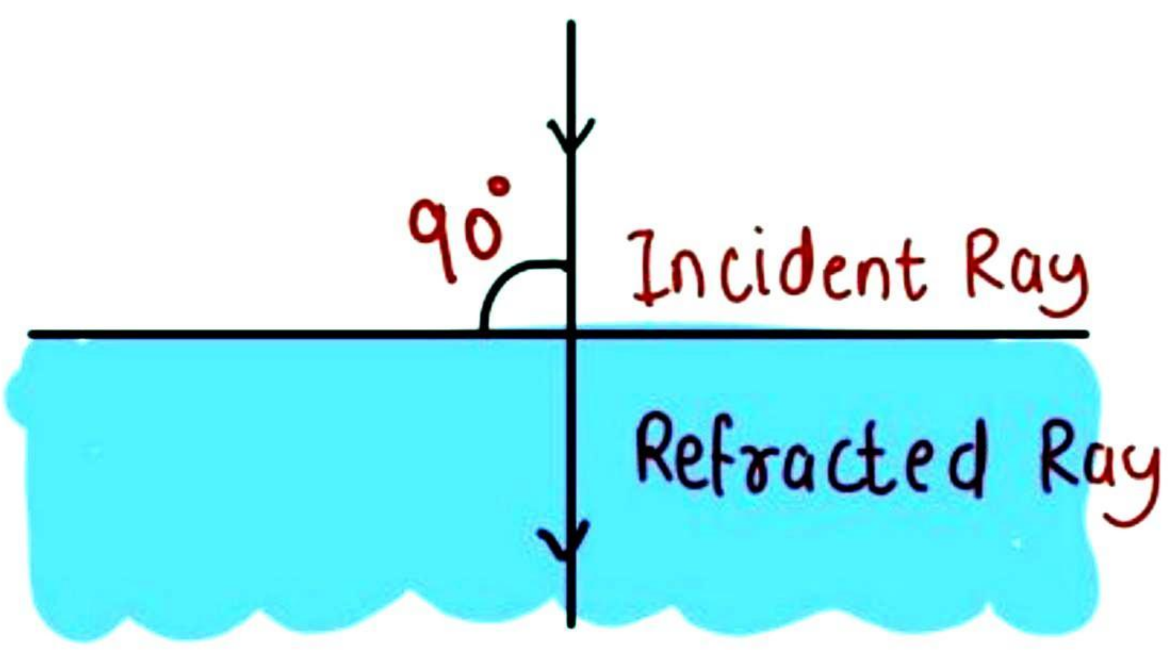


- If a ray falls perpendicularly on the refracting surface, it goes into the second medium without deviation.

when $i = 0$ $\frac{\sin i}{\sin r} = n$

$\frac{\sin 0}{\sin r} = n$

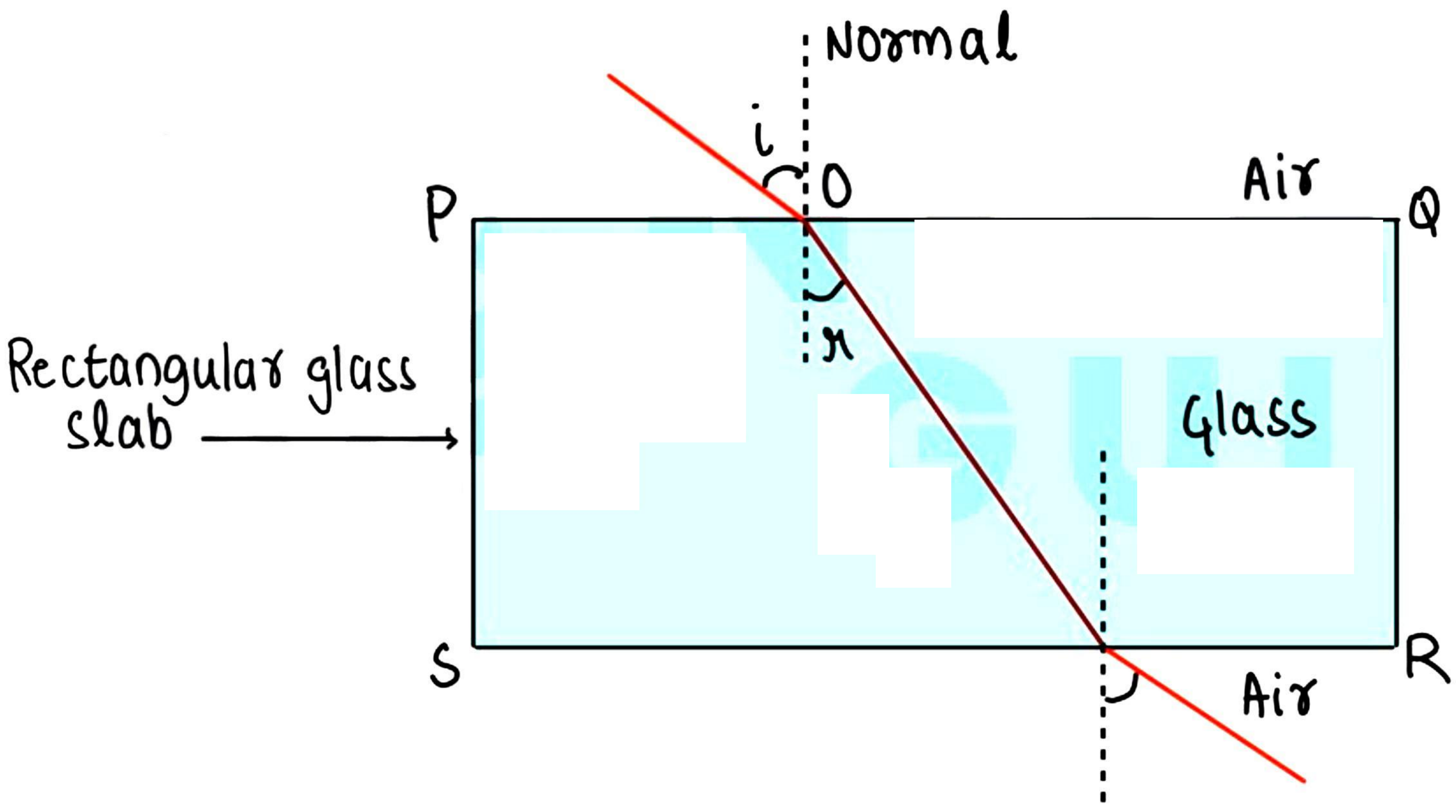
$\boxed{r = 0}$



But the speed of the light change

➡ Refraction through a Rectangular Glass slab

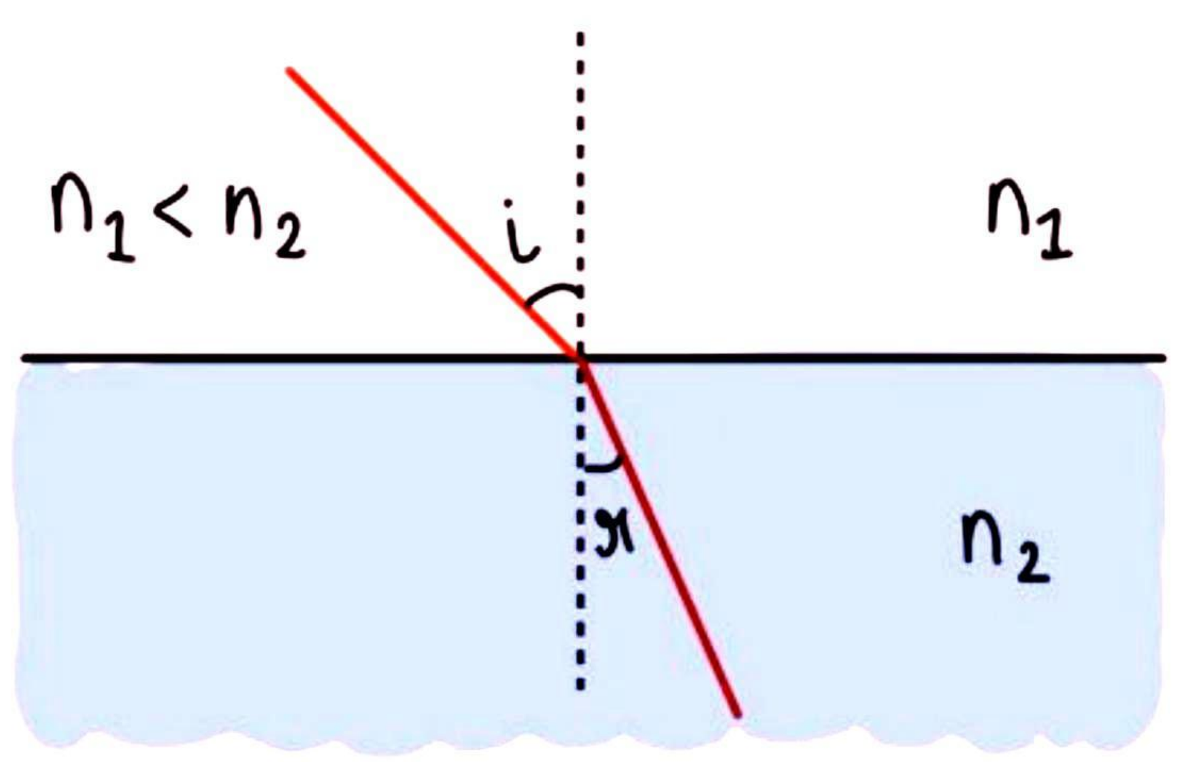
- Angle of Incidence = Angle of emergence $(\angle i) = (\angle e)$
- when a ray of Light is incident perpendicularly on a plane glass slab, it passes through undeviated. In this case, the angle of incidence $(\angle i)$ is $0°$, and therefore, the angle of refraction $(\angle r)$ is also $0°$

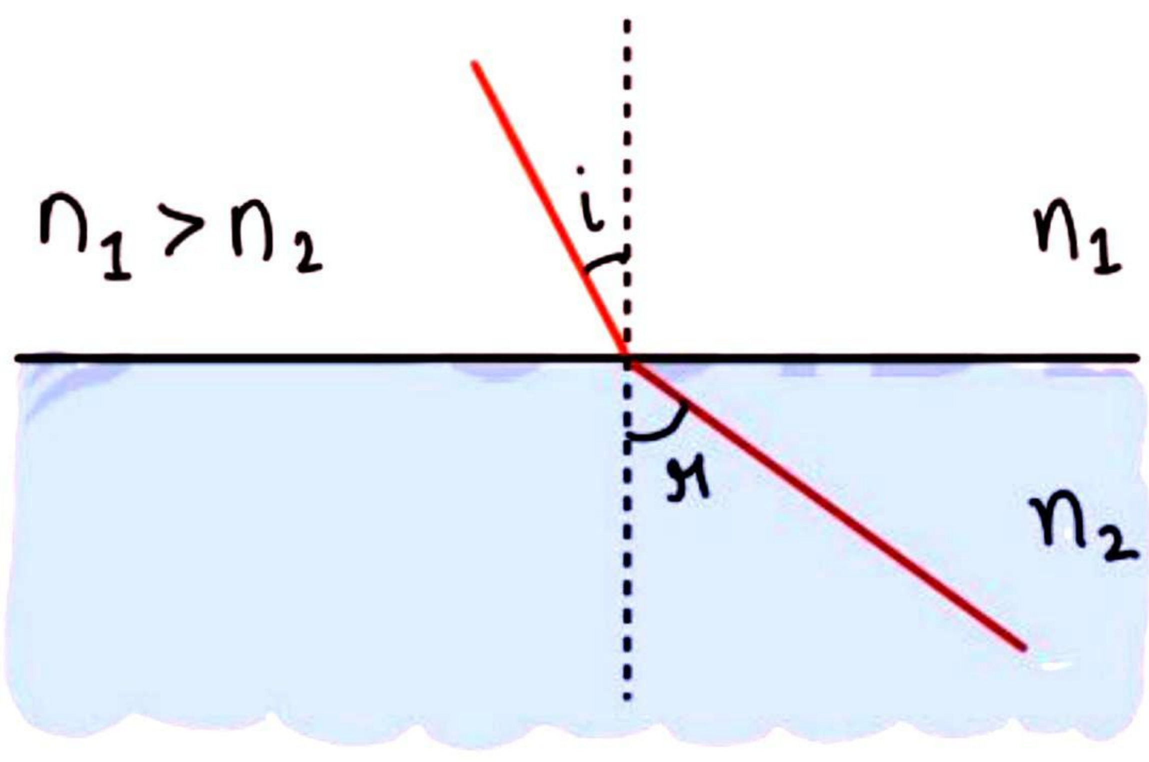


➡ Optically Denser And Rarer Media

A pair of transparent media, the one that has the higher refractive index is called optically denser medium of the two, while the one that has the lower refractive index is called optically rarer medium.

- Rarer ⟶ Denser ⟶ Bends towards normal (slow down)
- Denser ⟶ Rarer ⟶ Bends away from normal (speed up)





Optically denser does not mean greater mass density (mass per unit volume). Example - Kerosene is lighter than water (it float on water) but it has a higher refractive index, that is, it is optically denser than water.

➡ Refractive Index

Refractive index measures light bending when moving between materials, indicating speed variation. Crucial for understanding light behaviour and optical phenomena in diverse substances.

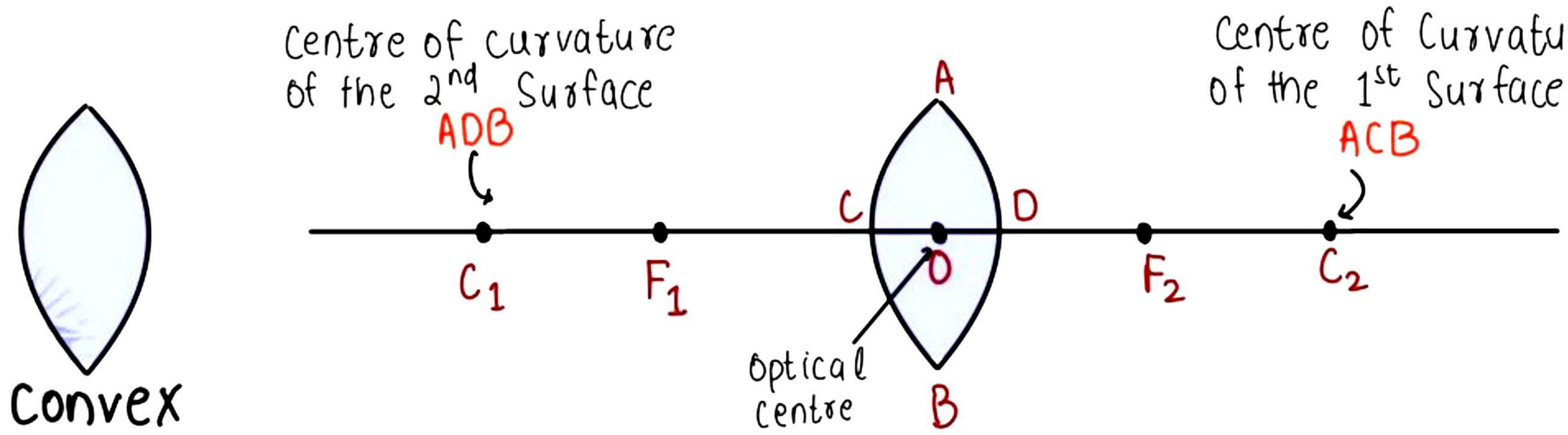
$$\text{Refractive index of medium 2 with respect to Medium 1} = \frac{\text{Speed of Light in medium 1}}{\text{Speed of light in medium 2}}$$

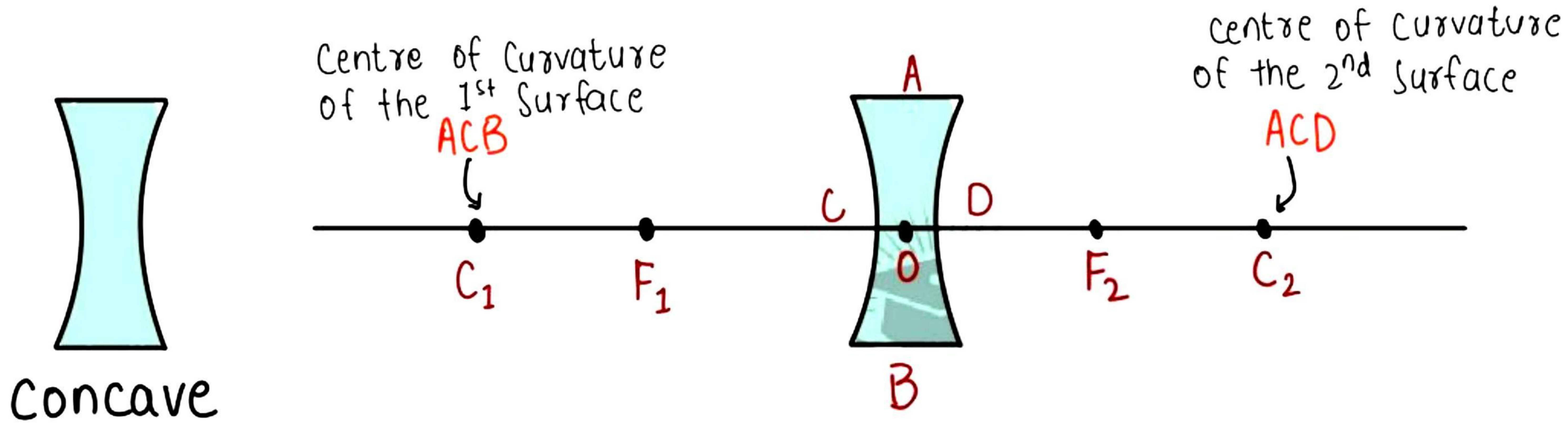
$$n_{21} = \frac{\text{Speed of Light in Medium 1}}{\text{Speed of Light in Medium 2}}$$

➡ Spherical Lens

Convex Lens - Thicker in the middle, converges light to a real focus

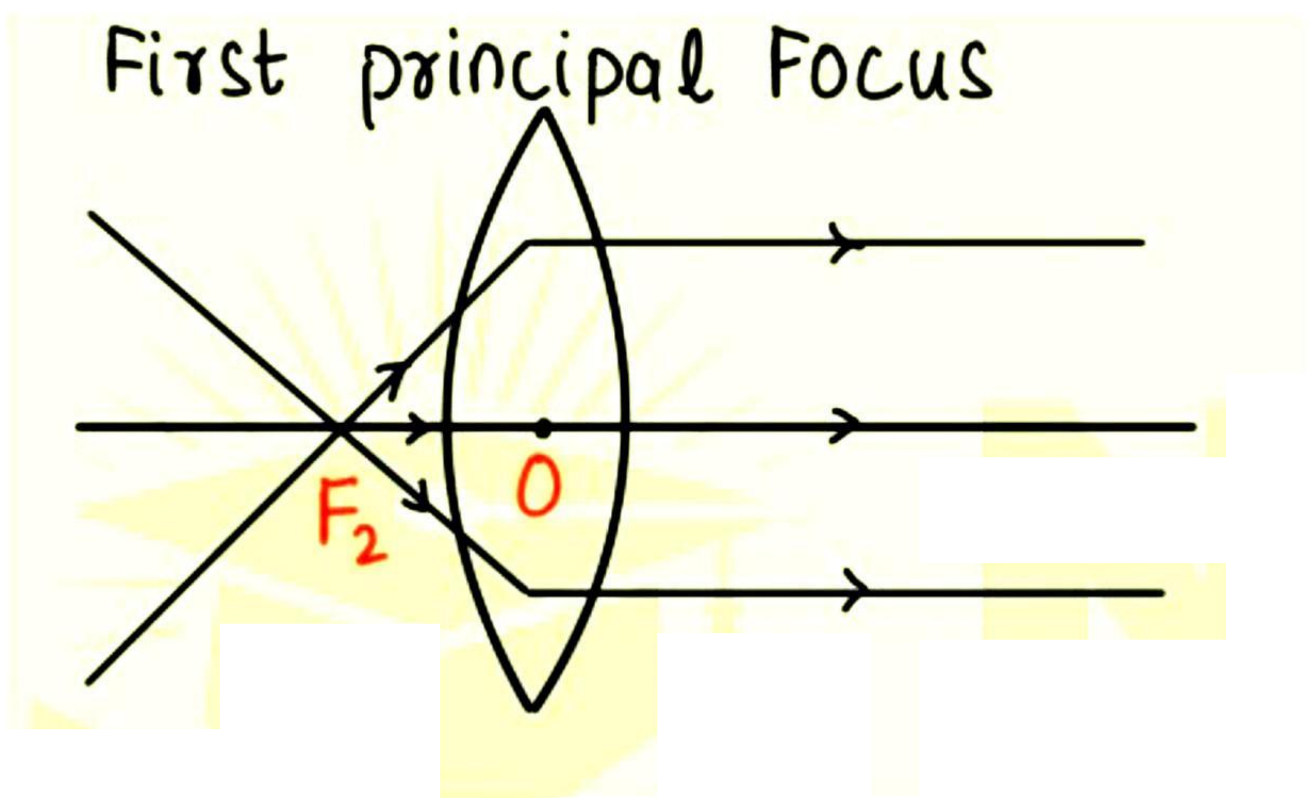
Concave Lens - Thicker at edges, diverges light to a virtual focus
Both are transparent materials with curved surfaces, forming lenses.

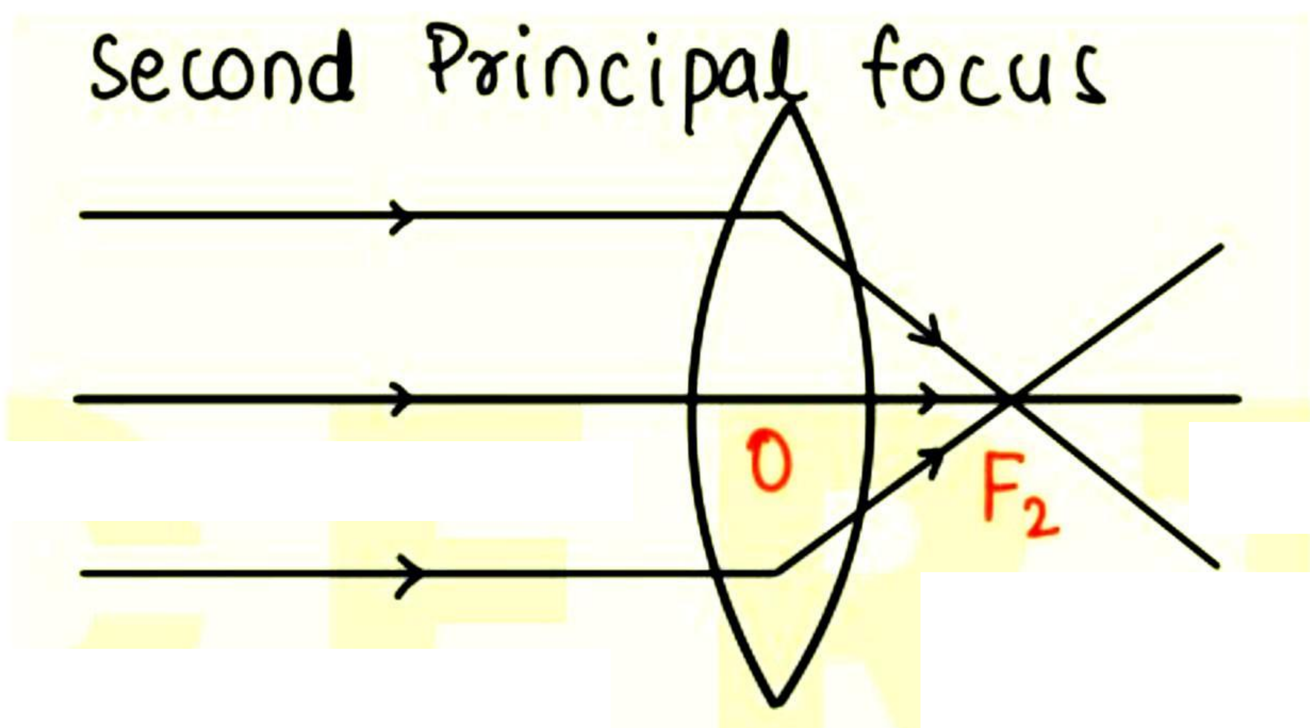


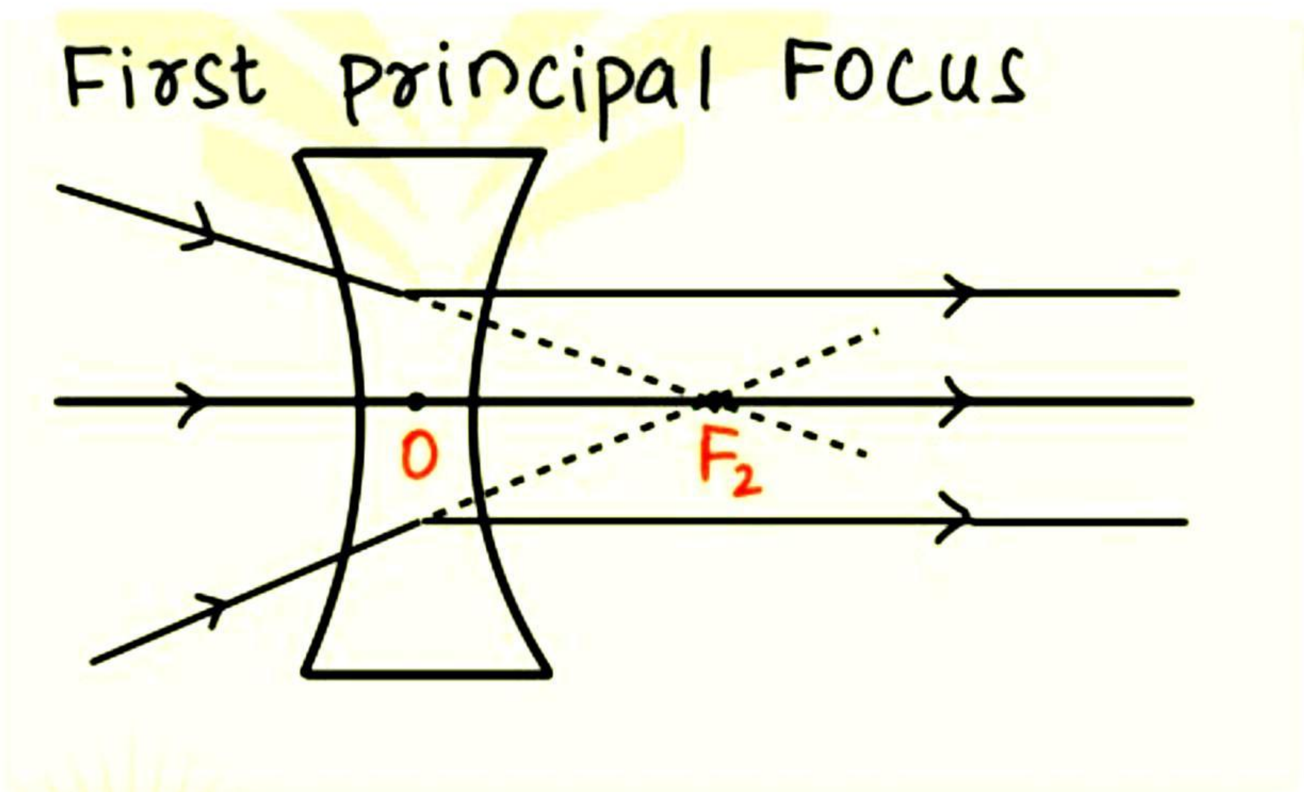


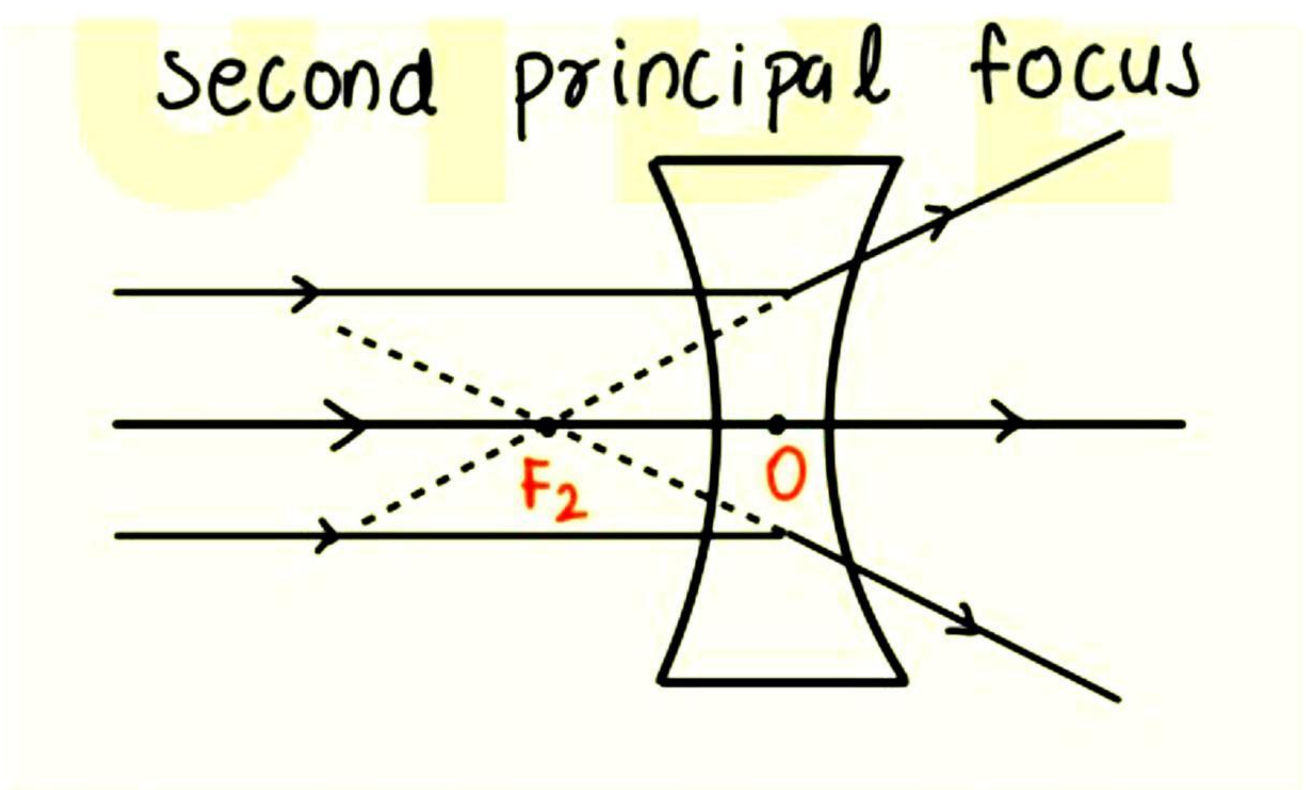
➡ Some Important terms of Spherical Lens

- Centre of Curvature - Point on the principal axis equidistant from the lens centre, defining its curvature.
- Principal Axis - Imaginary line through lens center of curvature.
- Principal Focus - Point where parallel rays converge (convex) or diverge (concave), two per lens.
- Aperture - Effective diameter of spherical lens.
- Optical Centre (O) : Point where light passes without bending
- Focal Length - Distance between principal focus and optical center.

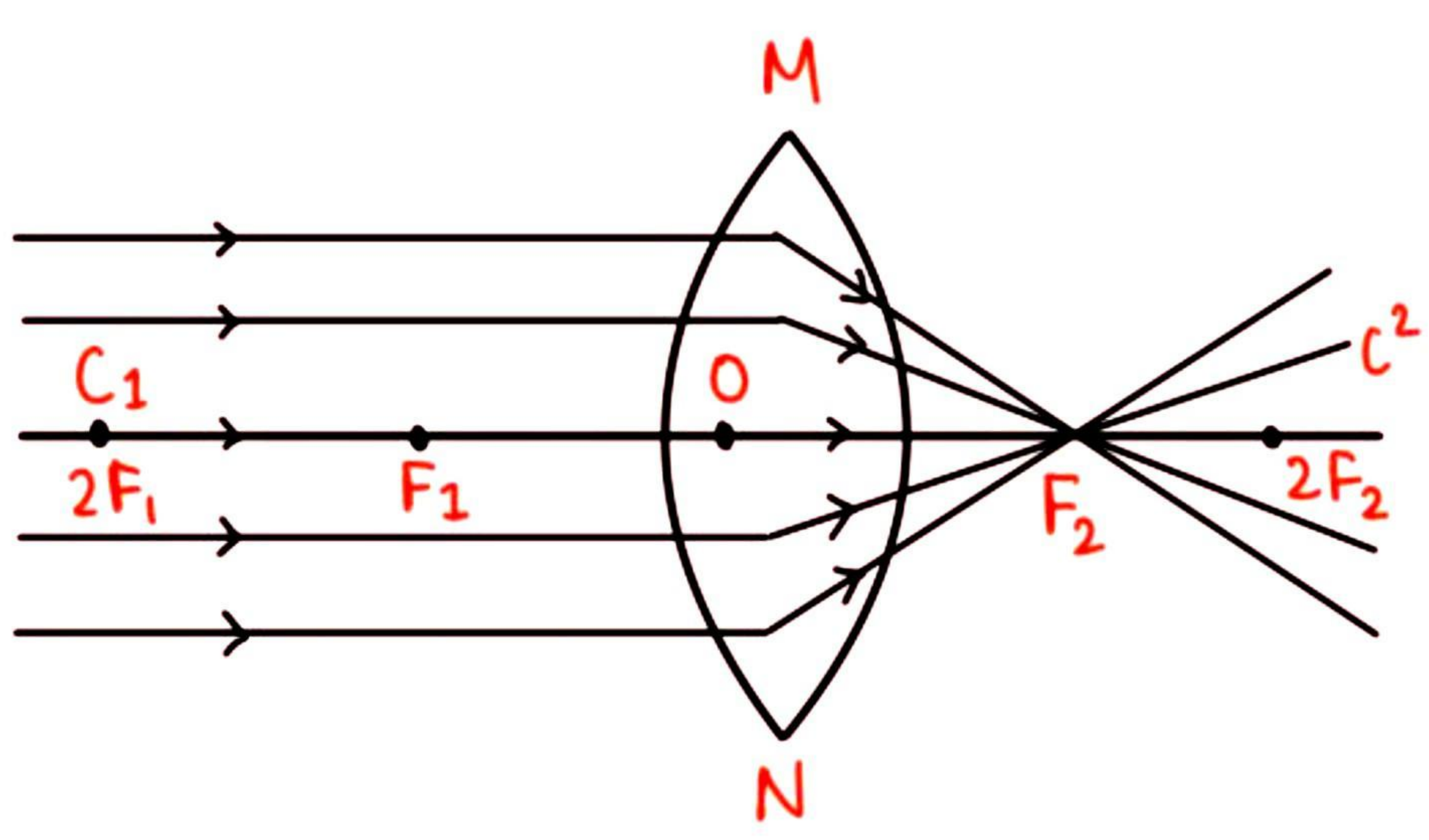




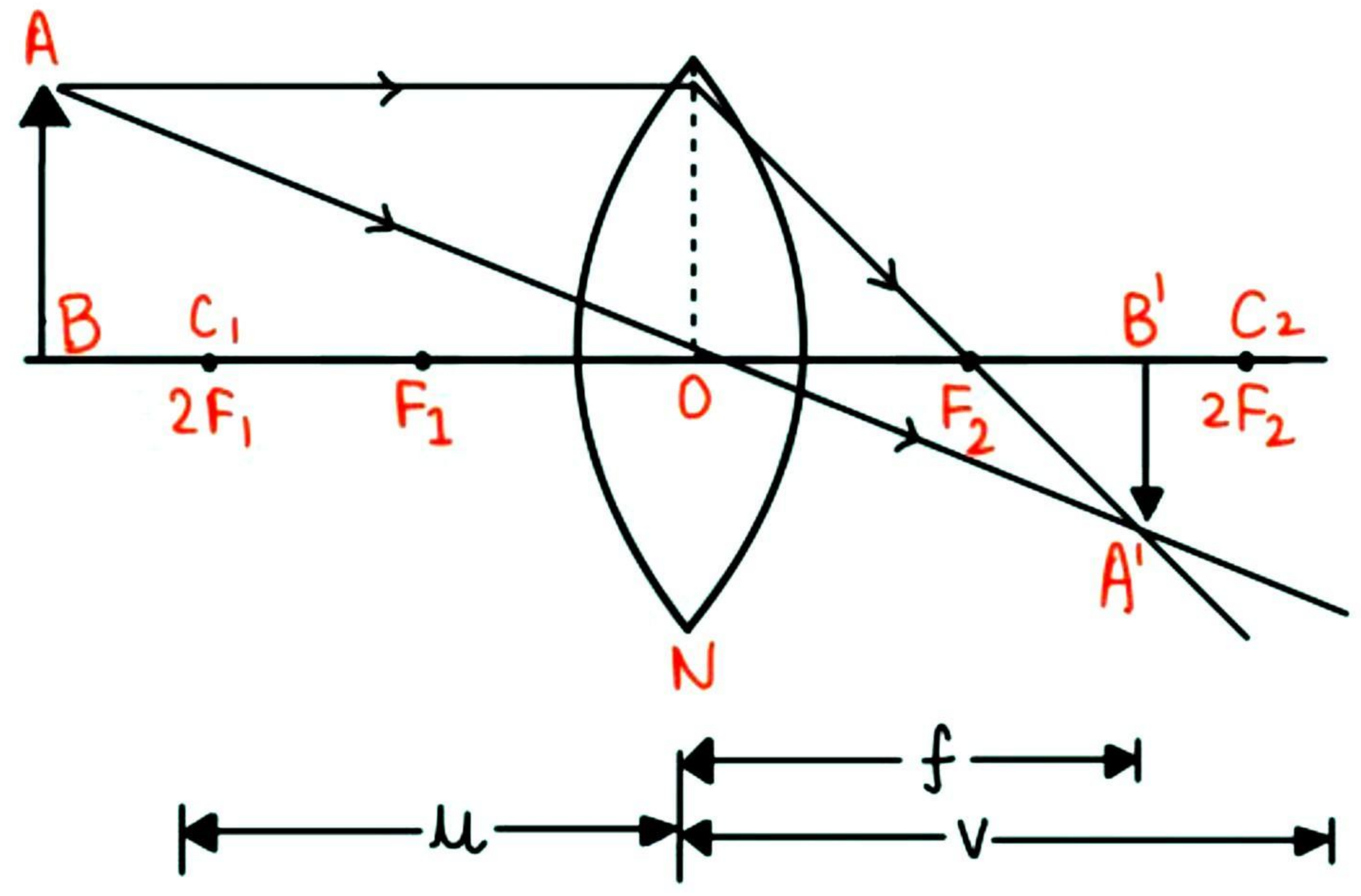




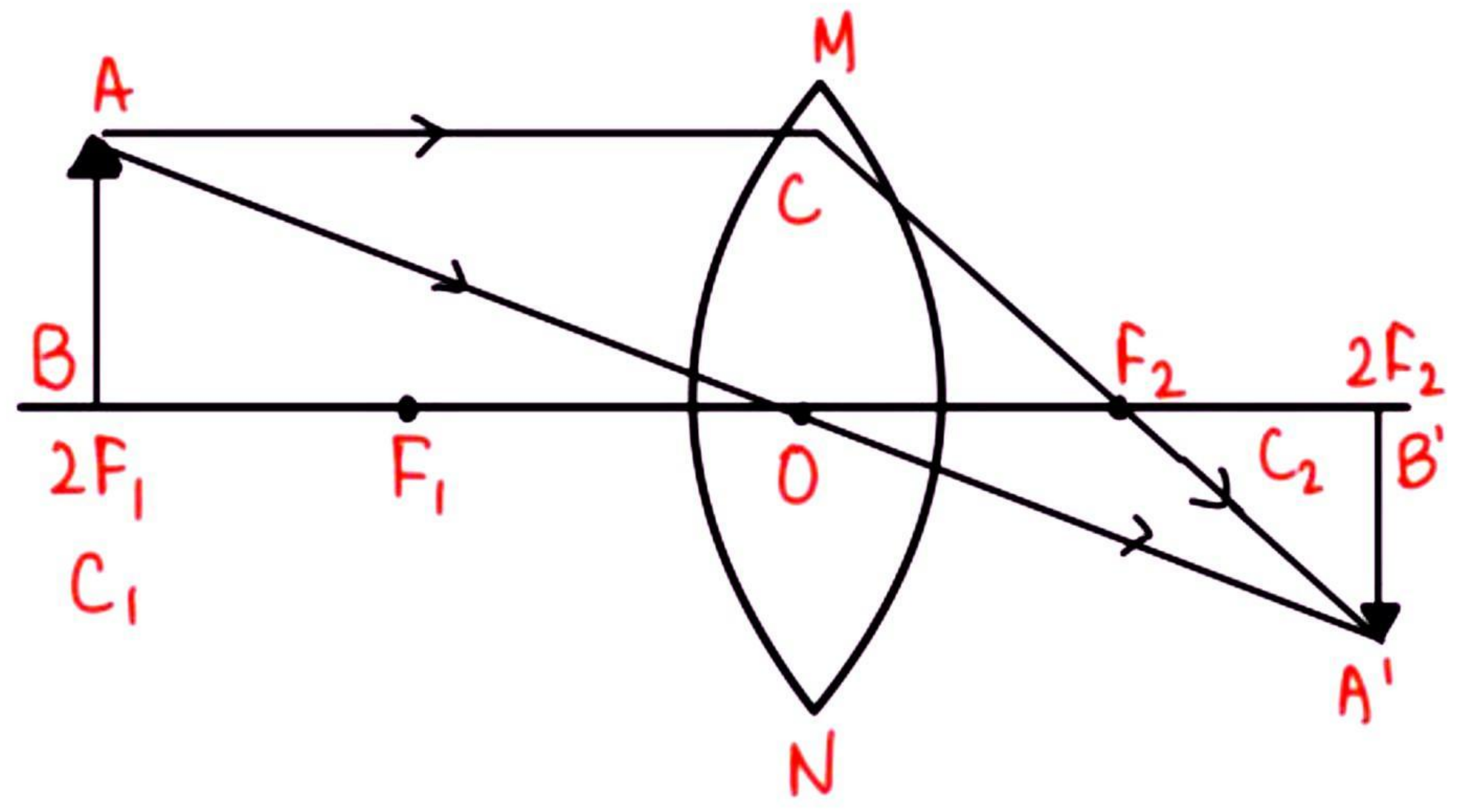
➡ Image Formed by Convex Lens



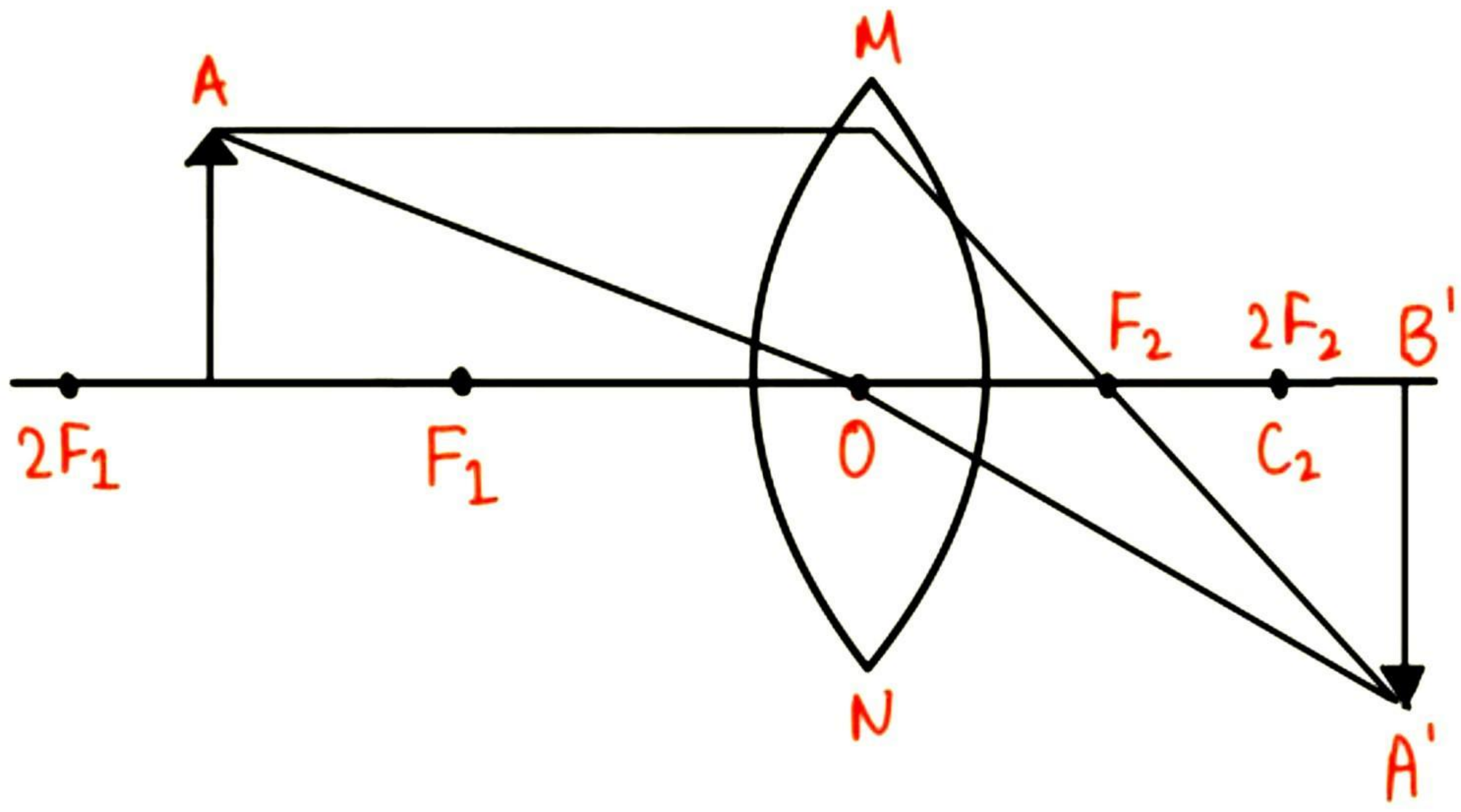
Object - At Infinity
Image - At Focus F_2 Highly diminished Point
Size - Real and inverted



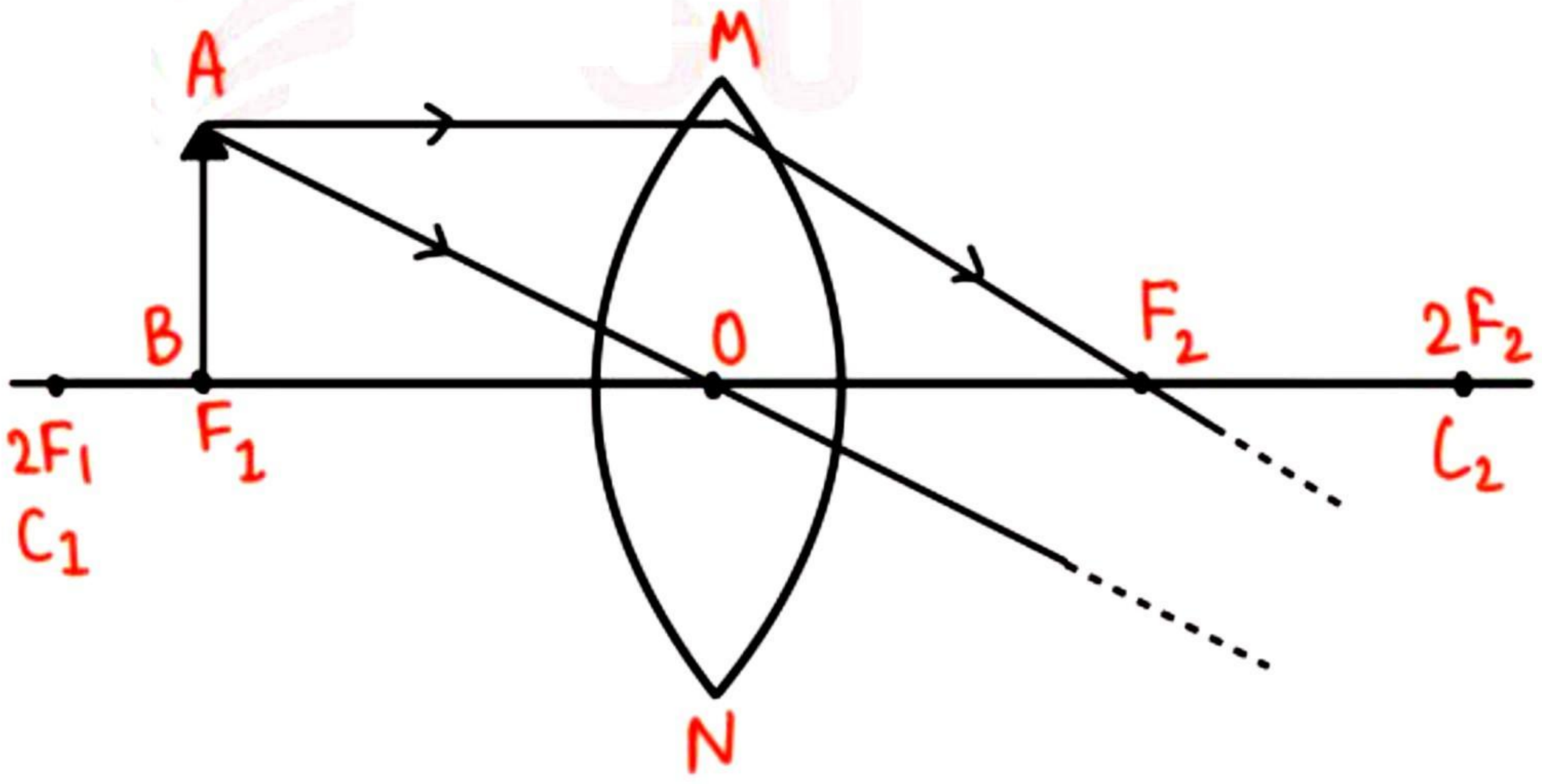
Object - Between Infinity and $2F_1$
Image - Between F_2 and $2F_2$
Size - Diminished, Real and Inverted.



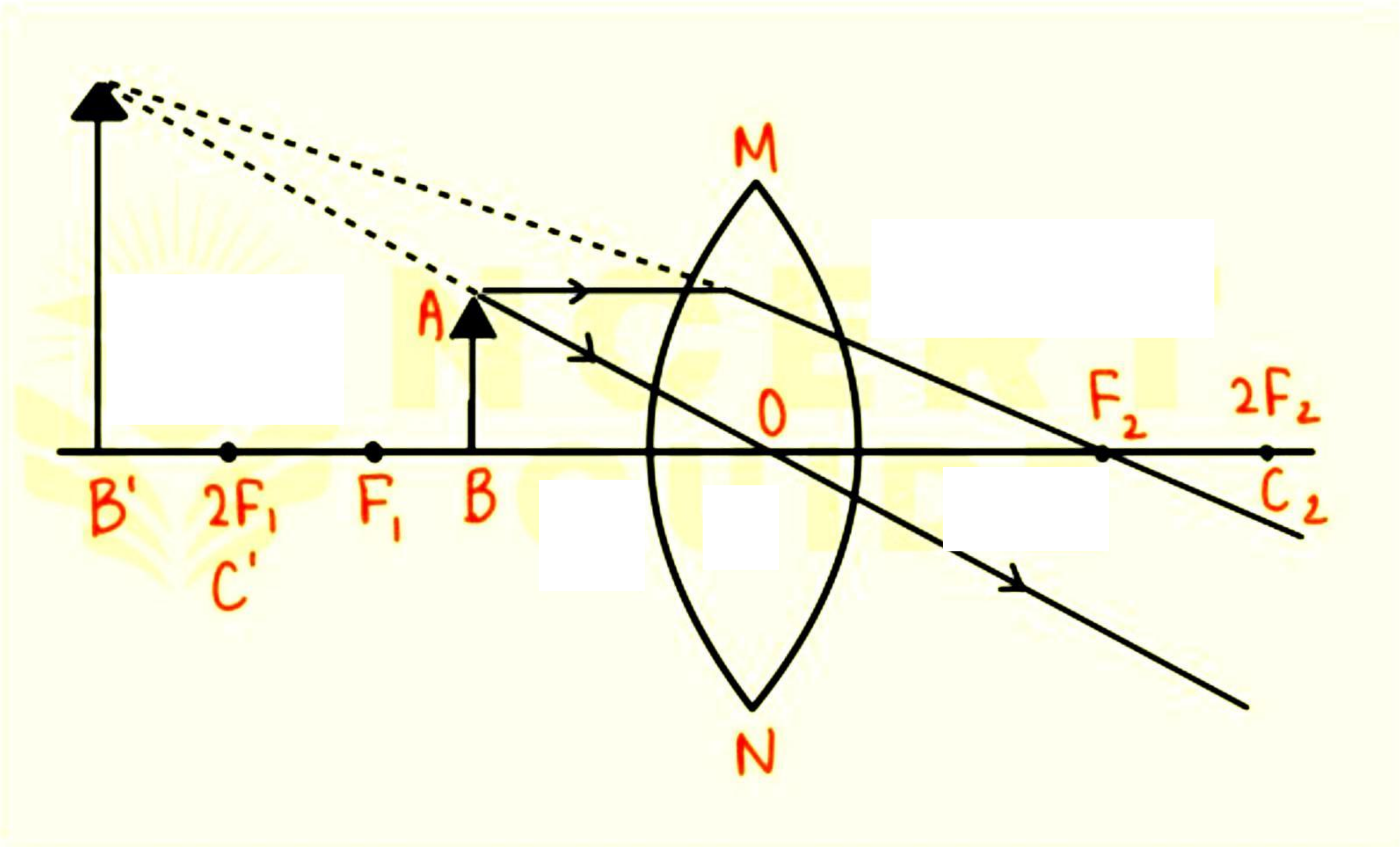
Object - At $2F_2$
Image - At $2F_2$
Size - Same size. Real and inverted



Object - Between F_1 and $2F_1$
Image - beyond $2F_2$
Size - Enlarged, Real and inverted

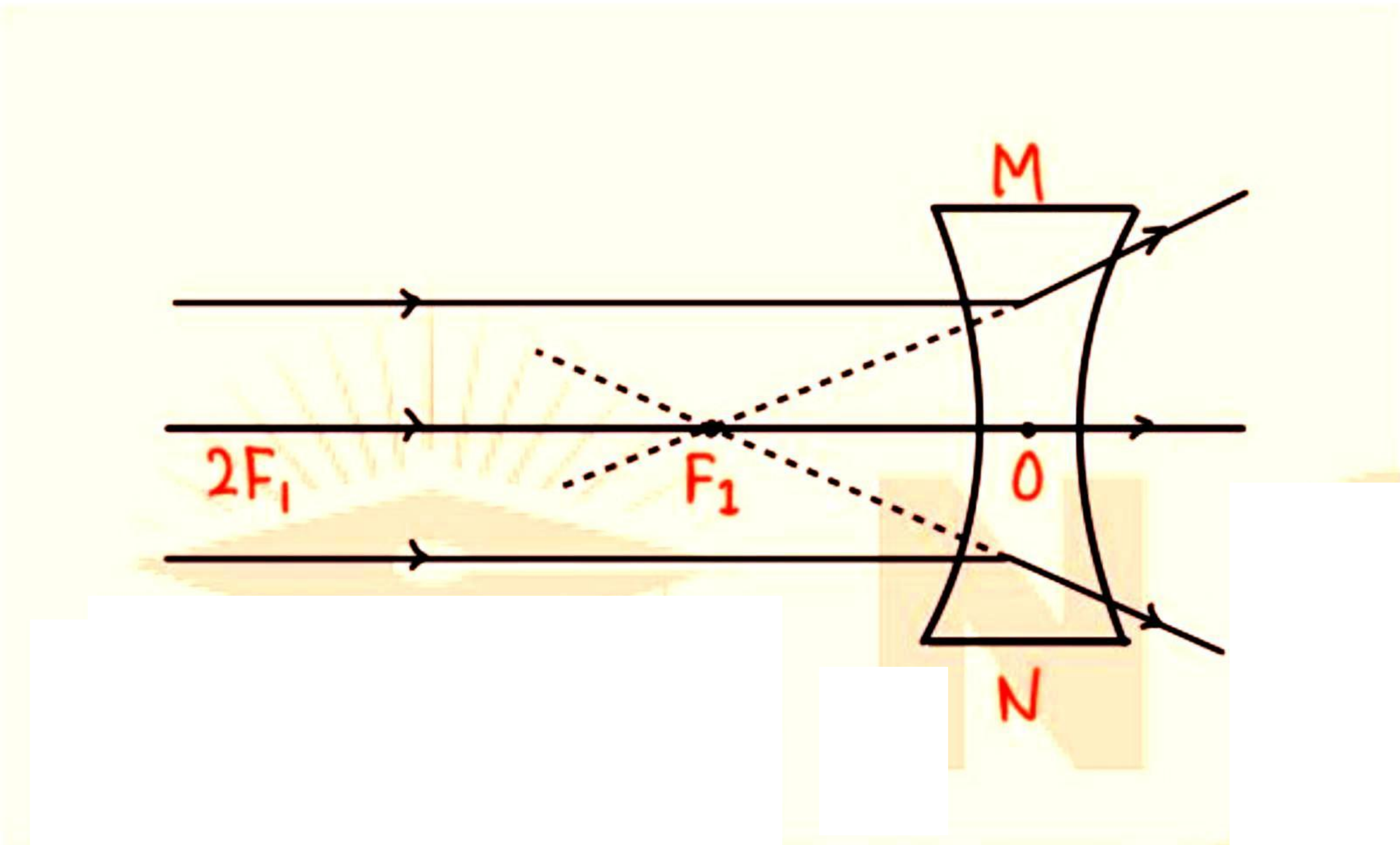


Object - At focus F_1
Image - At Infinity
Size - Highly enlarged, Real and inverted.

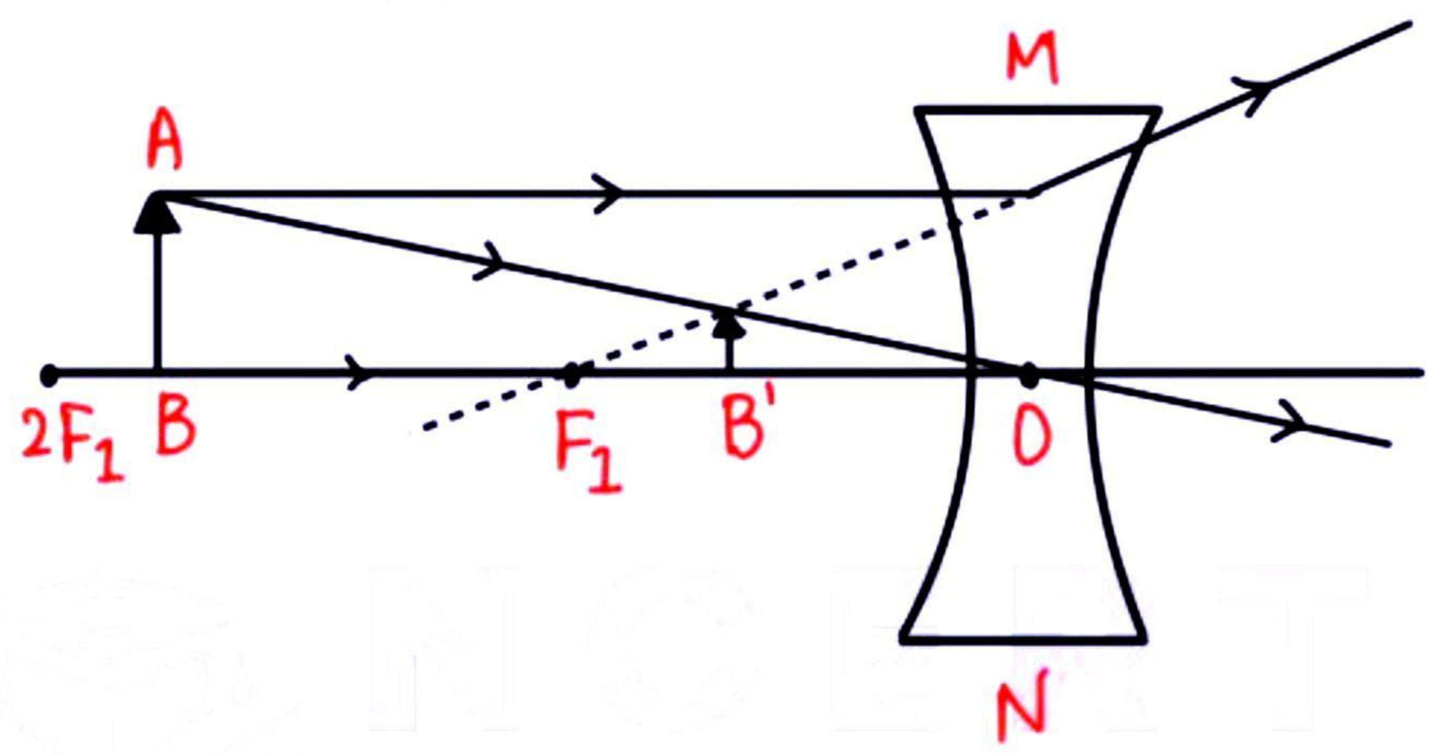


Object - Between focus F_2 and optical centre O
Image - Same side of the lens as the object
Size - Enlarged, virtual and Erect

➡ Image Formed by Concave lens



Object - At Infinity
Image - At focus F_1
Size - Highly diminishe, virtual and Erect



Object - between Infinity and optical centre O
Image - between focus F_1 and optical centre
Size - Diminished, virtual and Erect.

➡ Sign Convention for Spherical mirror

we use a sign rule like with mirrors. Measure from lens center convex lens has a positive focus, concave negative.

Lens Formula

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

v = image distance
u = Object distance
f = focal length

Magnification

$$m = \frac{\text{Height of the image}}{\text{Height of the object}} = \frac{-v}{u}$$

➡ Power Lens

Lens power measures light convergence/divergence, inversely proportional to focal length (F) in meters. Expressed in diopters (D), calculated as reciprocal of focal length

$$P = 1/f \text{ (meter)}$$

Lens		Mirror	Concave	Convex
Concave	v = -ve (real Image) v = +ve (virtual Image)	Object Distance Real Image Distance	-ve -ve	-ve does not exist
Convex	v = -ve (virtual Image) v = +ve (real Image)	Virtual Image Distance	+ve	+ve