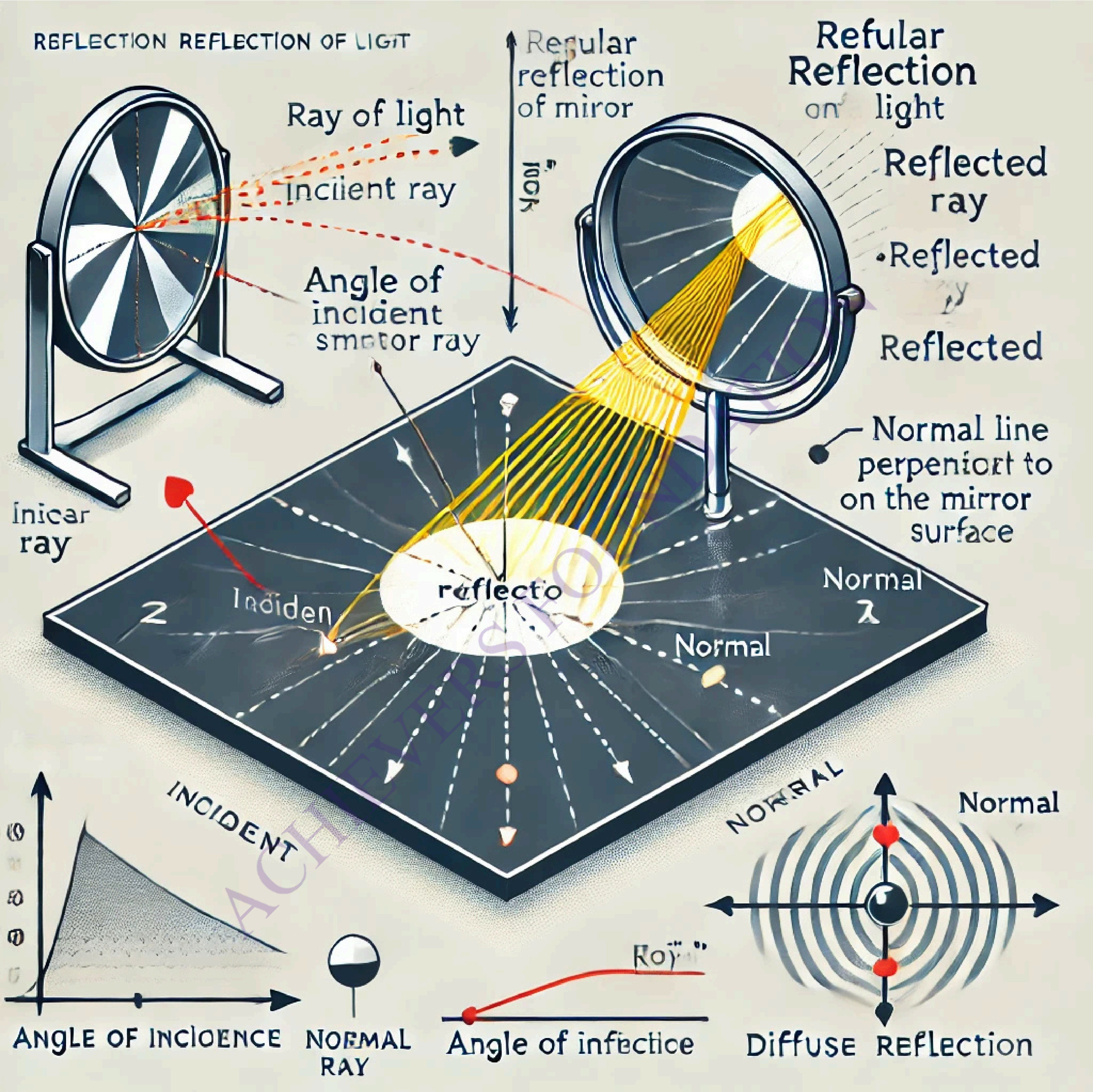
LIGHT



REFLECTION REFLECTION OF LIGIT
Ray of light
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Regular reflection of miror
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DIFFUSE REFLECTION

Reflection of Light

Reflection is the phenomenon of light bouncing back after striking a smooth and shiny surface, such as a **plane mirror**. This principle allows us to see ourselves in mirrors—light rays from our body strike the mirror and are reflected back to our eyes, forming a **virtual image**.

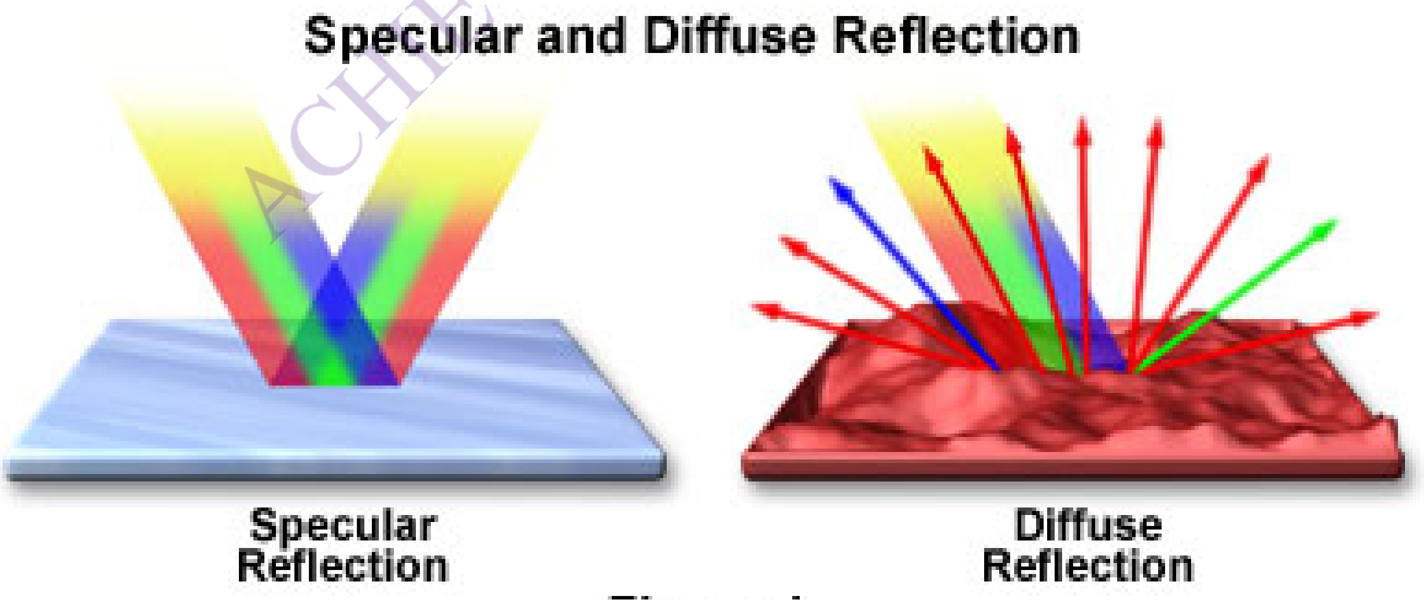
Reflection is not limited to light waves alone; it occurs across various types of waves including:

- **Light waves**
- **Electromagnetic waves**
- **Sound waves**
- **Water surface waves**

Types of Reflection

There are two main types of reflection based on the nature of the reflecting surface:

1. **Regular (Specular) Reflection**
    - Occurs on smooth surfaces like plane mirrors, where parallel light rays remain parallel after reflection.
    - Results in clear, defined images.
2. **Diffuse Reflection**
    - Happens on rough or uneven surfaces.
    - Reflected rays scatter in different directions, resulting in no clear image.



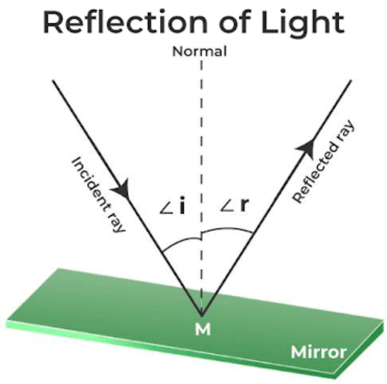
Differences Between Regular and Irregular Reflection

Feature	Regular Reflection	Irregular (Diffuse) Reflection
Surface Type	**Occurs on smooth surfaces like plane mirrors, calm water, etc.**	**Occurs on rough or uneven surfaces like wood, paper, or stone.**
Ray Behavior	**Incident and reflected rays remain parallel** after reflection.	**Reflected rays scatter** in different directions.
Image Formation	**A clear, well-defined image is formed.**	**A distorted or no clear image is formed.**
Visibility	**The image is easily visible and sharp.**	**The image is not clearly visible or is blurred.**
Law of Reflection	**Still follows the laws of reflection at every point.**	**Also obeys laws of reflection, but uneven surface causes scattering.**

Terminologies in the Reflection of Light

- **Normal:** A perpendicular drawn to the reflecting surface at point M (known as the point of incidence) is called the normal to the reflecting surface.
- **Incident Ray:** A ray of light that falls on the reflecting surface from a light source or an object is called the incident ray.
- **Reflected Ray:** A ray of light that arises from the reflecting surface after reflection from it is called a reflected ray.
- **Angle of Incidence:** The angle between the incident ray and normal to the point of incidence on the reflecting surface is known as the incident angle or Bugle of incidence. It is denoted by $\angle i$.
- **Angle of Reflection:** The angle between the reflected ray and the normal to the point of incidence on the reflecting surface is known as the angle of reflection. It is denoted by $\angle r$.

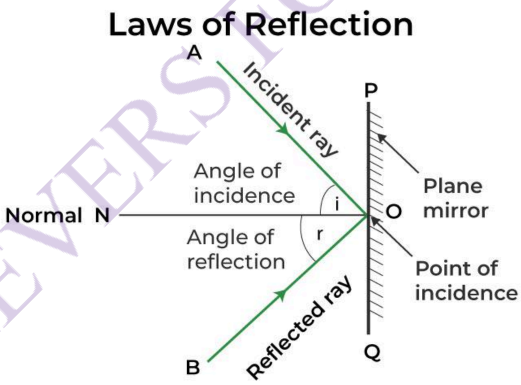
- **Principal axis:** It is defined as a line that divides the two mediums or the reflecting surface is called the principal axis.



Laws of Reflection

Reflection of light adheres to two fundamental **Laws of Reflection**:

1. **Law 1: The Angle of Incidence is Equal to the Angle of Reflection**
   - If a ray of light strikes a mirror at an angle (called the **angle of incidence**), it is reflected at the same angle (called the **angle of reflection**) on the opposite side of the normal.
2. **Law 2: The Incident Ray, Reflected Ray, and the Normal All Lie in the Same Plane**
   - This ensures the geometric consistency of reflection, meaning all vectors involved in the reflection process are co-planar.



Reflection of Light from a Plane Mirror

When light rays strike a plane (flat) mirror, they bounce back in a way that follows the laws of reflection:

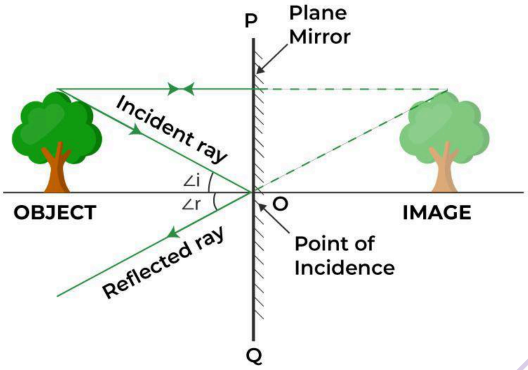
- The incident ray (incoming light) hits the mirror at a certain angle.
- The reflected ray (bounced light) leaves the mirror at the same angle on the opposite side of the normal.
- This satisfies the Law of Reflection, which states:
  - $\angle i = \angle r$ (angle of incidence = angle of reflection)
  - All rays and the normal lie in the same plane

The image appears to form behind the mirror surface.

This image is:

- Virtual: It cannot be projected on a screen.
- Erect: Upright, just like the object.
- Laterally inverted: Left and right are flipped.
- Same size and distance from the mirror as the object.

Image formation by a Plane Mirror



Spherical Mirrors

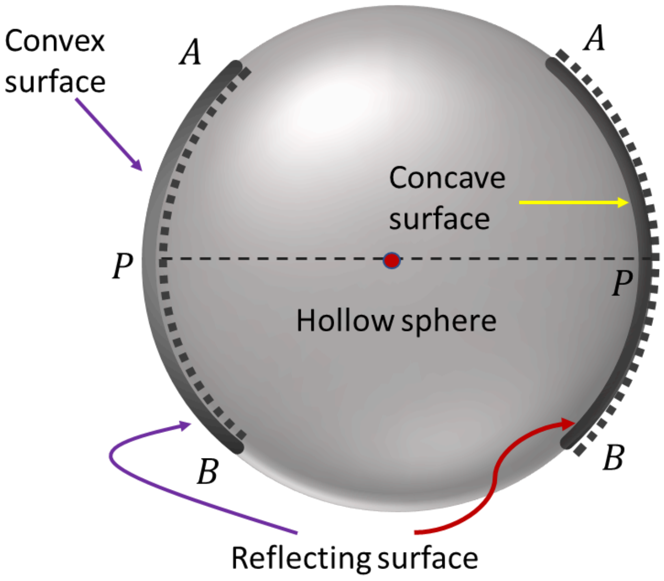
Spherical mirrors are mirrors that have a **curved reflecting surface** formed from a **portion of a hollow glass sphere**. They are primarily constructed from **glass**, where:

- One side is **silvered** (coated with a reflective material),
- The other side is **polished** to allow reflection.

Depending on the **curvature** and the **reflective side**, spherical mirrors are classified into two types:

Type	**Reflecting Side**	**Shape**	**Common Use**
Concave Mirror	Inner (curved inward)	Looks like a cave	Used in torches, shaving mirrors, and headlights
Convex Mirror	Outer (curved outward)	Bulges out toward you	Used in vehicle side mirrors, security mirrors

Spherical Mirrors



Uses of Concave Mirror

- Converging mirrors are most widely used in shaving because they have reflective and curved surfaces.
- A concave mirror is used in the ophthalmoscope
- These mirrors are also widely used in making astronomical telescopes. In an astronomical telescope, a converging mirror of a diameter of about 5 meters or more is used as the objective.
- Converging mirrors are widely used in headlights of automobiles and in motor vehicles, torchlights, railway engines, etc. as reflectors.
- Large converging mirrors are used to focus the sunlight to produce heat in the solar furnace.

Uses of Convex Mirror

- Convex mirrors are used inside buildings so that people can see all around the building at once.
- The convex mirror is used in vehicles. Convex mirrors are commonly used as rear-view mirrors in the case of automobiles and vehicles because they can diverge light beams and make virtual images.
- These mirrors are mostly used for constructing magnifying glasses. In industries, to construct a magnifying glass, two convex mirrors are placed back to back.
- Diverging mirrors are also used for security purposes in many places. They are placed near ATMs to let the bank customers check whether someone is behind them or not.

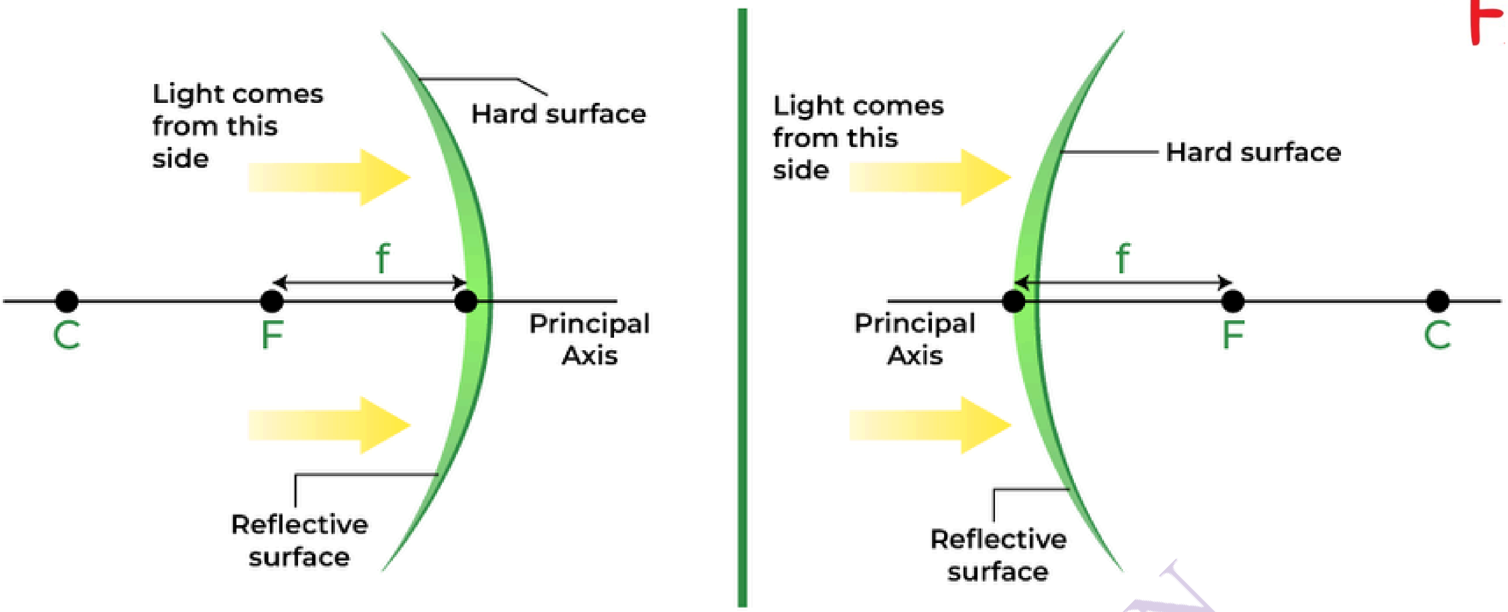
- Convex mirrors are also widely used in various other places for example streetlight reflectors because they can spread light over bigger areas.

Uses of Convex mirror

Uses of concave mirror

Basic Terminologies for Spherical Mirrors

- **Centre of Curvature:** The point in the centre of the mirror surface that passes through the curve of the mirror and has the same tangent and curvature at that point. It is represented by the capital letter C.
- **Radius of Curvature:** It is considered the linear distance between the pole and the centre of curvature. It is represented by the capital letter R, R=2f
- **Principal axis:** An imaginary line that passes through the optical centre and from the centre of curvature of a spherical mirror. All the measurements are based on this line.
- **Pole:** The midpoint or the centre point of the spherical mirror. It is represented by capital P. All the measurements are made from it only.
- **Aperture:** An aperture of a mirror is a point from which the reflection of light actually takes place or happens. It also gives an idea about the size of the mirror.
- **Principal Focus:** Principal Focus can be called the Focal Point also. It is present on the axis of a mirror where the rays of light parallel to the principal axis converge or appear to converge or diverge after reflection.
- **Focus:** It is any given point on the principal axis where light rays parallel to the principal axis will converge or appear to converge after getting reflected from the mirror.



Here, F = Focal Point ; C = Center of Curvature ;
f = Focal Length ; P = Pole

Sign Conventions

1. **All distances are measured from the mirror's pole (P)** — the central point of the mirror's surface.
2. **Distances measured in the direction of incoming light (left to right)** are taken as **positive**.
3. **Distances measured against the direction of light (right to left)** are taken as **negative**.
4. **Heights above the principal axis** are considered **positive**, and **below** are **negative**.
5. **For concave mirrors:**
   - The **focal length (f)** is **negative**
   - Real images are formed on the **same side as the object**, so **image distance (v)** is usually **negative**
6. **For convex mirrors:**
   - The **focal length (f)** is **positive**
   - Images are **virtual and erect**, formed on the **opposite side**, so **image distance (v)** is **positive**

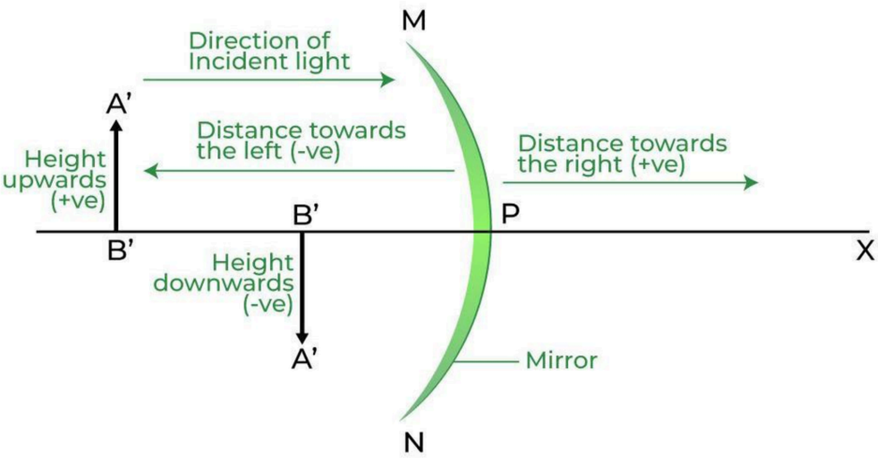
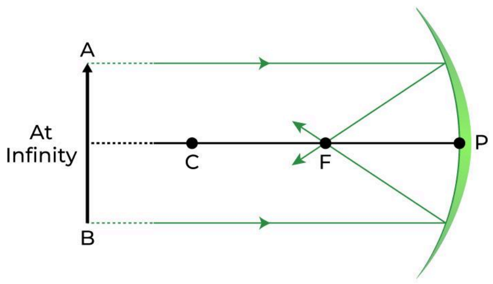
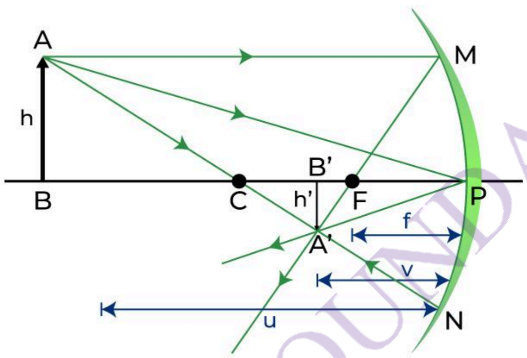


Image Formation by Spherical Mirrors

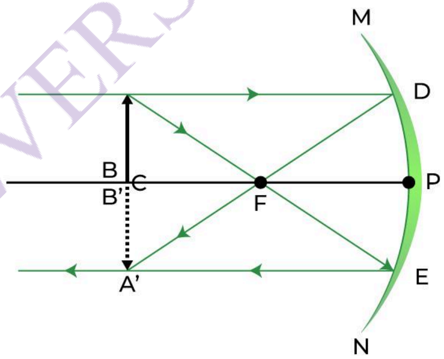
1.When the object is placed at infinity



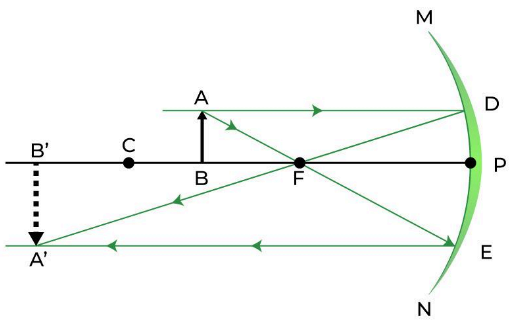
2.When the object is placed between infinity and the Centre of Curvature



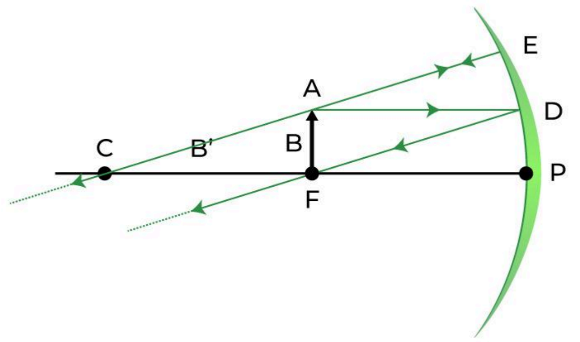
3.Object at Centre of Curvature (C)



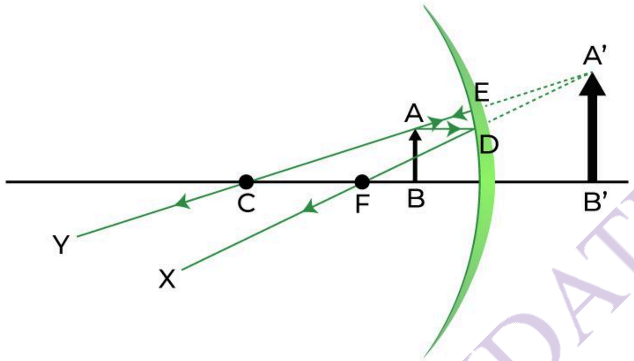
4.The object is kept between the Centre of curvature (C) and Principal Focus (F)



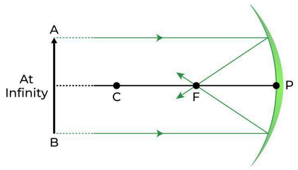
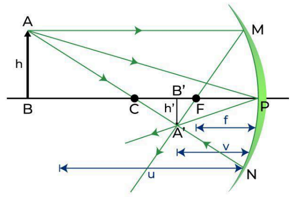
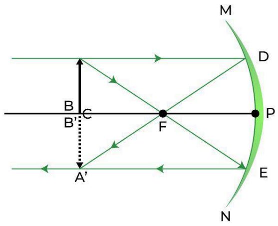
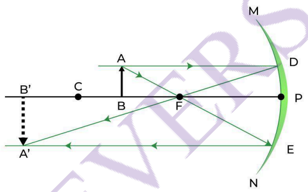
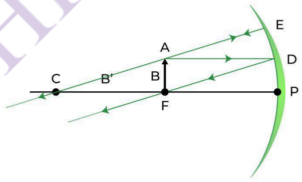
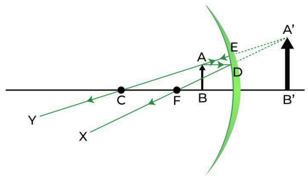
5.Object at Principal Focus (F)



6.The object between Principal Focus (F) and Pole (P)



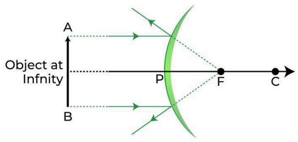
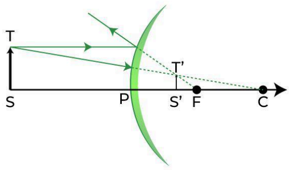
Images Formed by Concave Mirrors

Position of Object	Ray Diagram	Position of Image	Nature of Image
At Infinity (∞)		At the Principal Focus (F)	Real, inverted and extremely smaller in Size
Beyond the Centre of Curvature (C)		Between principal Focus (F) and Center of Curvature (C)	Diminished, Real and Inverted
At the Centre of Curvature (C)		At the Center of Curvature (C)	Same size as the object, Real and Inverted
Between Focus (F) and Center of Curvature (C)		Beyond Center of Curvature (C)	Magnified, Real, and Inverted
At the Principal Focus (F)		At Infinity (∞)	Highly Magnified
Between the Pole (P) and Focus (F)		Behind the Mirror	Magnified, Virtual, and Erect

Properties of the Image formed by Concave Mirrors

- Point-sized image, highly diminished in size, Real and inverted image.

- The parallel lines which come from the very distant object at infinity after striking the reflecting surface of the concave mirror get reflected back and meet at a point, or we can say in this case converge at a point. This point is known as the principal focus of the concave mirror.

Images Formed by Convex Mirrors			
Position of Object	**Ray Diagram**	**Position of Image**	**Nature of Image**
At Infinity (∞)		**Behind the mirror at Principal Focus (F)**	**Highly Diminished, Virtual, and Erect**
Between infinity and pole (P) of the mirror		**Between Pole (P) and Focus (F), behind the mirror**	**Highly Diminished, Virtual, and Erect**

Properties of the Image formed by Convex Mirrors

- The image formed is highly diminished in size, virtual, and erect.
- The parallel lines which come from the very distant object at infinity after striking the reflecting surface of the convex mirror get reflected back and appear to meet at a point, or we can say in this case diverge from the surface and appear to meet at a point. This point is known as the principal focus of a convex mirror.

Mirror Formula

The **spherical mirror formula** is a mathematical expression that relates:

- **Object distance** (denoted by **u**),
- **Image distance** (denoted by **v**), and
- **Focal length** (denoted by **f**)

of a **concave** or **convex** mirror.

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

The focal length of the mirror is equal to half of the radius of curvature of the spherical mirror and is given by the relation:

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

In spherical mirrors, light rays parallel to the **principal axis** reflect and converge (concave) or appear to diverge (convex) at the **focal point**, which lies exactly halfway between the **pole (P)** and the **center of curvature (C)**.

- For a **concave mirror**, f and R are both **negative**.
- For a **convex mirror**, f and R are both **positive**.

Magnification

The magnification produced by a spherical mirror tells us how large or small the image is in comparison to the object. It also indicates the nature of the image—whether it is erect or inverted, real or virtual.

$$M = \frac{h'}{h} = \frac{-v}{u}$$

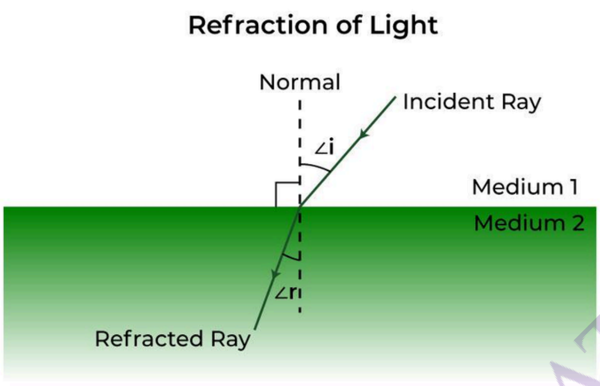
Where:

- M = magnification
- h' = height of the image
- h = height of the object
- v = image distance (from the pole of the mirror)
- u = object distance (from the pole of the mirror)

Mirror Type	Nature of Image	Sign of M	Interpretation
Concave	Real & Inverted	**-ve**	Smaller image
Concave	Virtual & Erect	**+ve**	Larger image
Convex	Virtual & Erect	**+ve**	Diminished image

Refraction of Light

Refraction of light is the bending of a light wave when it passes from one medium to another due to a change in the speed of light.



As shown in the above figure, light travels from Medium 1 to Medium 2. Please note that these mediums can be different materials or substances with different densities. So when an incident ray from medium 1 travels to another medium 2, the refracted ray bends either towards the normal or away from the normal (depending upon the densities of the mediums).

Why Refraction Happens?

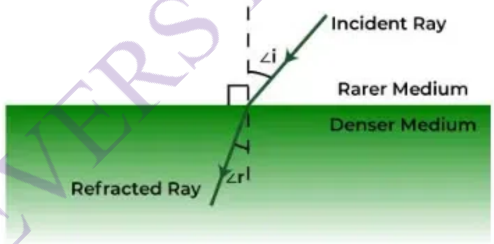
- Light **slows down** in a **denser medium** (like glass or water). light bends **toward the normal**
- Light **speeds up** in a **rarer medium** (like air). light bends **away from the normal**

Speed of light changes⇒Direction changes⇒Refraction occurs

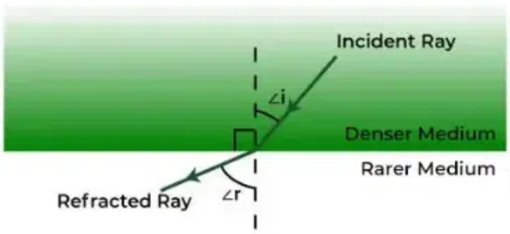
Key Terms

Term	Meaning
Incident Ray	The incoming light ray hitting the surface
Refracted Ray	The light ray that bends inside the second medium
Normal	An imaginary line perpendicular to the surface at the point of incidence
Angle of Incidence (∠i)	Angle between the incident ray and the normal
Angle of Refraction (∠r)	Angle between the refracted ray and the normal

1. When light rays pass through rarer to a denser medium, the light rays bend towards the normal. Due to this the angle of refraction is smaller than the angle of incidence.



2. When light rays pass from denser to rarer medium, the light rays bend away from the normal. Due to this the angle of refraction becomes more than the angle of incidence



Laws of Refraction

📌 Law 1

The **incident ray**, **refracted ray**, and the **normal** to the surface **all lie in the same plane** at th point of incidence.

📍 This means all the light bending action happens in one flat plane.

📌 Law 2 – Snell's Law (Law of Sines)

The ratio of the **sine of the angle of incidence (∠i)** to the **sine of the angle of refraction (∠r)** is **constant** for two given media.

This constant is the **refractive index** and is written as:

$$\frac{\sin i}{\sin r} = \text{constant} = \frac{n_2}{n_1}$$

Where:

- i = angle of incidence
- r = angle of refraction
- n_1 = refractive index of the first medium
- n_2 = refractive index of the second medium

This formula is known as **Snell's Law.**

Important Characteristics

1. **Frequency remains constant:**
   Light's **frequency does not change** during refraction.
2. **Speed and wavelength change:**
   - The **velocity** and **wavelength** of light **change** depending on the refractive index of the medium.
   - Light **slows down** in denser media and **speeds up** in rarer media.

Refractive Index

The **Refractive Index** of a medium tells us **how much the light slows down** when it passes through that medium. It is a **dimensionless number** and helps explain how much light **bends** or **refracts** between two media.

For a given material or medium, the refractive index is considered the ratio between the speed of light in a vacuum (c) to the speed of light in the medium (v) on which it goes.

$$n = \frac{c}{v}$$

Where:

- n = Refractive Index
- c = Speed of light in vacuum (approximately 3×10^8 m/s)
- v = Speed of light in the given medium

Refractive index is of two types:

- Absolute Refractive Index
- Relative Refractive Index

The **Absolute Refractive Index** of a material is defined as the **ratio of the speed of light in a vacuum** to the **speed of light in that medium**.

Formula:

$$n = \frac{c}{v}$$

Where:

- **n** = Refractive index of the medium (no unit)
- **c** = Speed of light in vacuum (≈ 3.00×10^8 m/s)
- **v** = Speed of light in the medium

The **Relative Refractive Index** is the refractive index of **one material medium with respect to another**. It measures how much light bends when moving **from one medium into another**.

Formula:

$$n_{21} = \frac{v_1}{v_2}$$

Where:

- n_{21} = Refractive index of **medium 2** with respect to **medium 1**
- v_1 = Speed of light in **medium 1**
- v_2 = Speed of light in **medium 2**

Key Points

- **Greater the refractive index**, **slower** the light moves through the medium.

- A refractive index of **1** means no refraction (like in vacuum).
- Refractive index is **always >1** for all transparent materials like glass, water, etc.

Typical Values

Medium	Refractive Index (n)
Vacuum	1.00
Air	~1.0003
Water	1.33
Glass	1.5 to 1.9
Diamond	2.42

Everyday Examples of Refraction

When you place a pencil in a glass of water, it appears bent or broken at the water's surface.

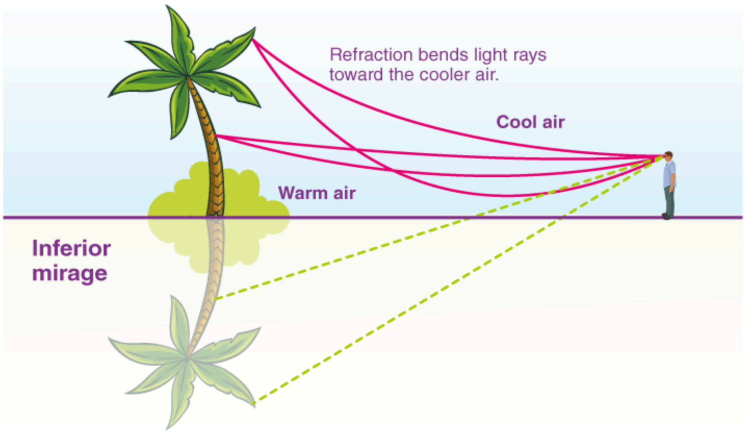
This happens because:

- Light travels slower in water than in air.
- As it passes from the water to the air (or vice versa), it bends at the surface.

The brain assumes light travels in a straight line, so the image formed appears shifted.

This also causes a slight magnification, making the pencil look thicker or angled differently.

- The stars twinkle in the night sky due to the refraction of their light.
- Looming and Mirage formation, both occur due to the optical illusions caused by the refraction of light.



- The formation of rainbows in the sky and VIBGYOR, when white light passes through the prism are also major examples of refraction.
- A swimming pool always seems or looks much shallower than it really is because of the light that comes from the bottom of the pool bends at the surfaces due to the refraction of light.

Applications of Refraction of Light

Refraction has many wide and common applications in optics and also in technology. A few of them are given below:

- A lens uses the refraction phenomenon to form an image of an object or body for various purposes, such as magnification.
- Spectacles that are worn by people with defective vision use the principle of refraction.
- Refraction is used in peepholes of the house doors for safety, in cameras, inside movie projectors, and also in telescopes.

LENS

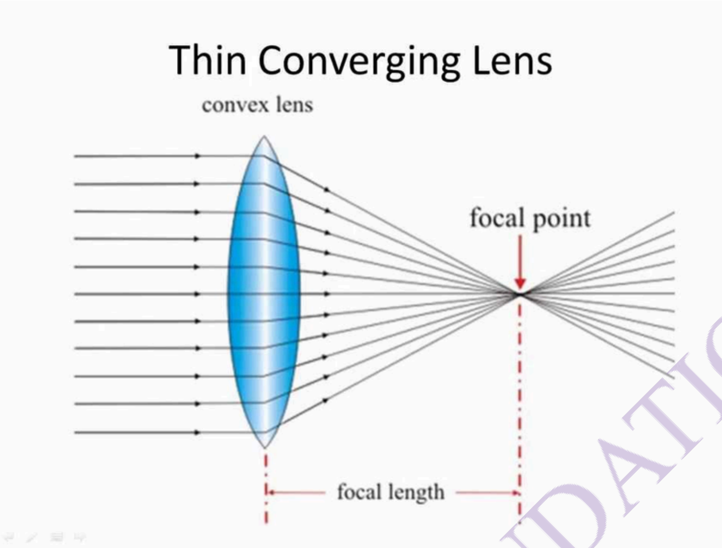
A lens is a piece of transparent material, typically made of glass or plastic, bounded by two surfaces, where at least one surface is curved. When light rays pass through a lens, they bend or refract, causing the light to either converge (focus) or diverge (spread out). This property allows lenses to form images of objects.

Types of Lenses

Lenses are mainly classified into two types:

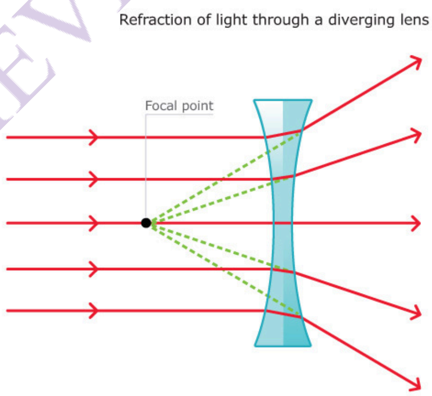
1. **Convex Lens (Converging Lens)**

- **Thicker at the center** and **thinner at the edges**.
- **Converges (bends inward)** parallel rays of light to a single point called the **focus**.
- **Forms real or virtual images**, depending on object distance.
- Used in: **magnifying glasses, cameras, human eyes (for farsightedness), microscopes.**



2. **Concave Lens (Diverging Lens)**

- **Thinner at the center** and **thicker at the edges**.
- **Diverges (spreads out)** parallel rays of light away from a point.
- **Forms only virtual, upright, and diminished images**.
- Used in: **eyeglasses for nearsightedness, peepholes, laser devices.**



Terminologies related to Spherical Lens

- **Pole (p)**: It is the middle point of the spherical lens or mirror.
- **Centre of curvature (C):** It is the centre of the sphere from which the mirror is formed.
- **Principal axis:** It is the lines passing through the pole and the centre of curvature of the lens.

- **Principal focus (F)**: It is the point at which a narrow beam of light converges or diverges
- **Focal length (f):** It is the distance between the focus and the poles of the mirror.

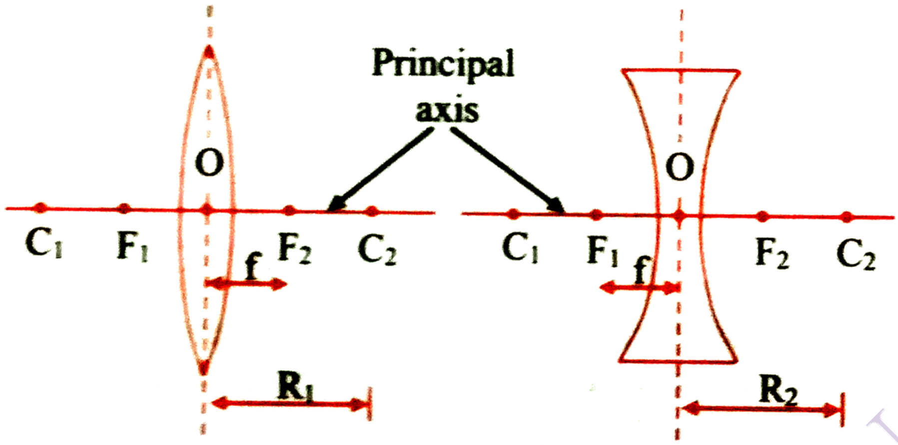
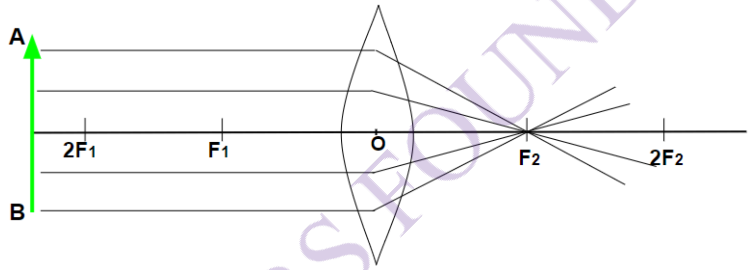
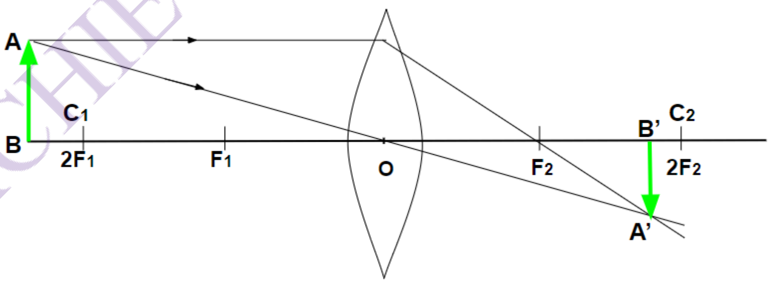


Image formed by the Convex Lens

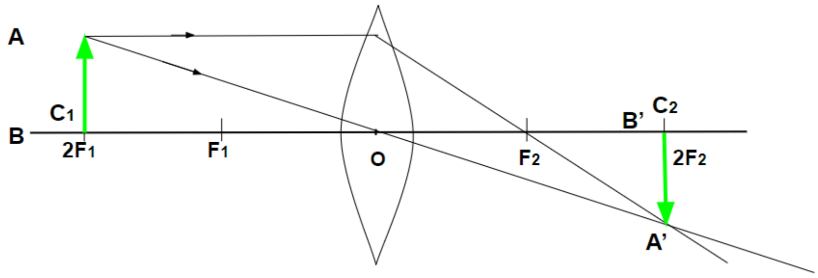
1.When an object is at infinity:



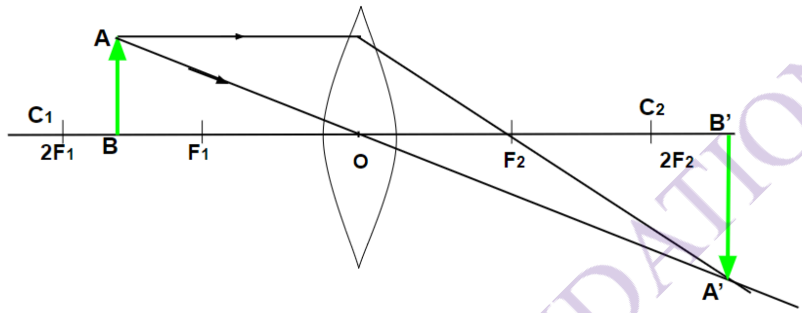
2.When an object is placed behind the Centre of Curvature (C_1)



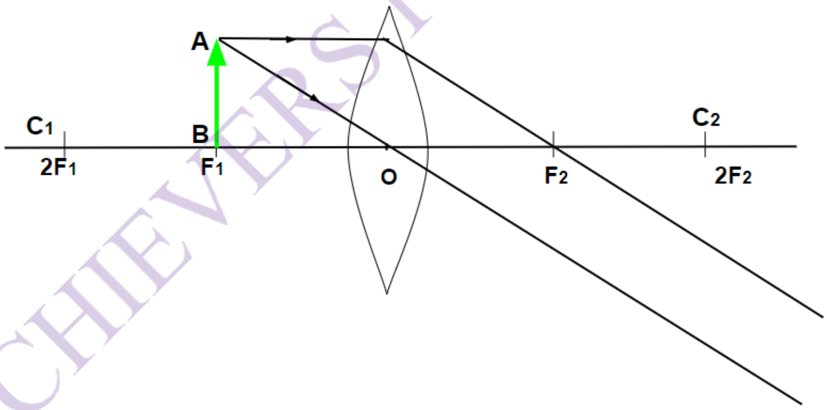
3.When the object is placed at the centre of curvature (C_1 or $2F_1$)



4.When the object is placed between $2F_1$ and F_1



5.When the object is placed at focus (F_1)



6.When the object is placed between pole and focus (O and F_1)

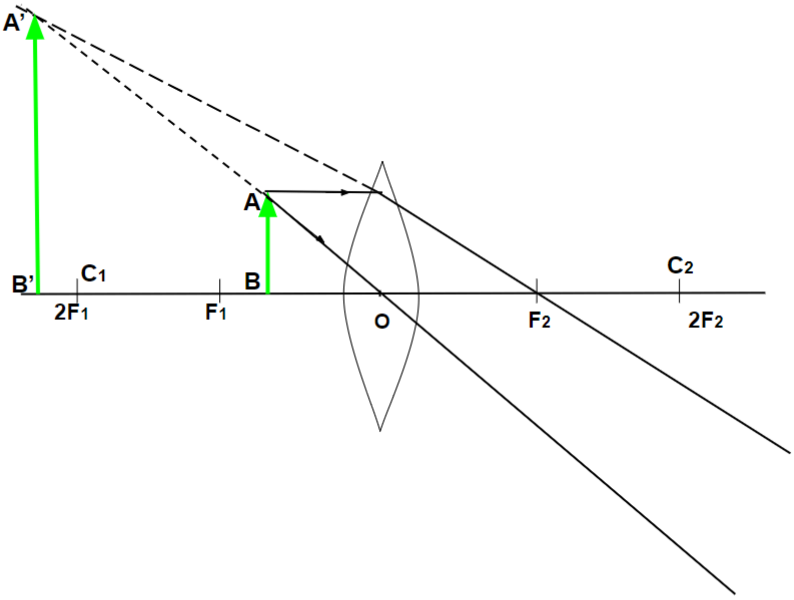
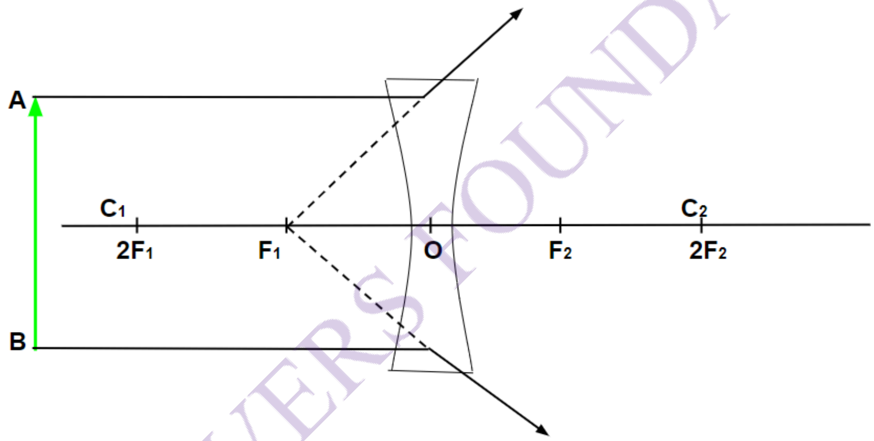
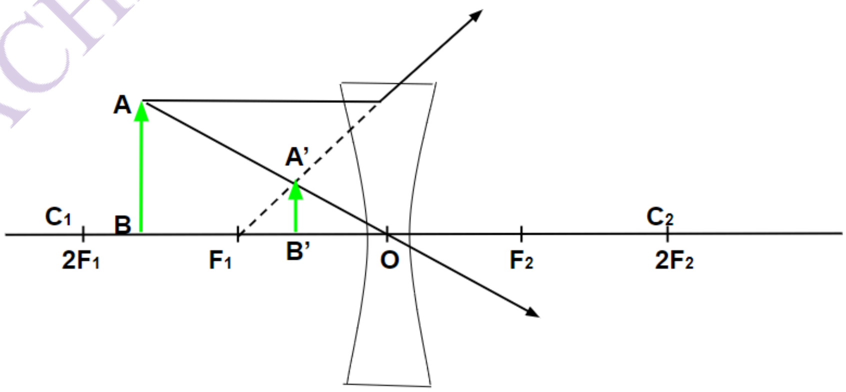


Image formed by Concave lens

1.When the object is placed at infinity



2.When the object is placed at a finite distance from the lens



Uses of Lenses in Daily Life

Convex Lens	Concave Lens
Magnifying glasses	Spectacles for nearsightedness
Cameras and projectors	Laser instruments
Human eye (natural convex lens)	Peepholes in doors
Microscopes and telescopes	Compact optical devices

Lens Formula

The **lens formula** relates the **object distance (u)**, **image distance (v)**, and **focal length (f)** of a lens.

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

f = focal length of the lens

v = distance of image from the optical center

u = distance of object from the optical center

Sign Conventions (for both lenses):

- Object is always placed on the **left** side of the lens → **u is always negative**.
- **v is positive** for real images (on right side), and **negative** for virtual images (on left side).
- **f is positive** for convex lenses, and **negative** for concave lenses.

Magnification by a Lens

Magnification (M) tells us how much bigger or smaller the image is compared to the object.

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

Where:

- hi = height of image
- ho = height of object

- **M > 1**: Image is **magnified**
- **M < 1**: Image is **diminished**
- **M is positive**: Image is **erect** (virtual)
- **M is negative**: Image is **inverted** (real)

Power of a Lens

The **power of a lens** is a measure of how strongly it **converges** or **diverges** light rays.

Definition

The power (P) of a lens is defined as the **reciprocal of the focal length (f)** of the lens in **meters**:

$$P = \frac{1}{f\,(\text{in meters})}$$

Unit of Power

- The **unit** of power is the **dioptre (D)**.
- **1 dioptre** = power of a lens whose focal length is **1 meter**.

Sign Convention

- **Convex (converging) lens → positive power**
- **Concave (diverging) lens → negative power**