What is Light

It is a form of energy that enables us to see. Light starts from a source and bounces off objects which are perceived by our eyes. Then the brain processes the signal which enables us to see.

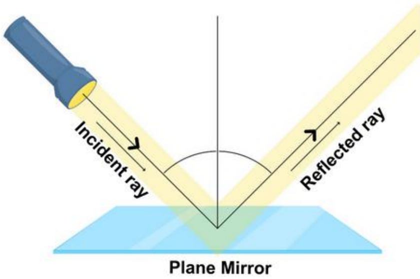
Properties of Light

Light always follows the following properties:

i. Light always travels in a straight path.
ii. When light falls on a surface, it is either reflected or refracted or absorbed.
iii. Light waves are transverse waves and hence light does not need any medium to propagate.
iv. Speed of light is $3 \times 10^8\ m/s$ which makes it the fastest thing in the universe.
v. Light has dual nature i.e. it acts as wave as well as particle.

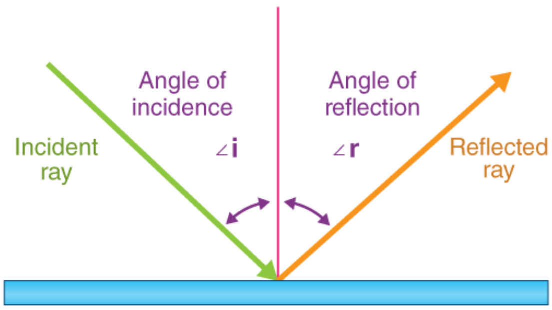
Reflection of Light

The phenomenon of bouncing back of light into the same medium by a smooth surface is called reflection of light.



Laws of Reflection

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

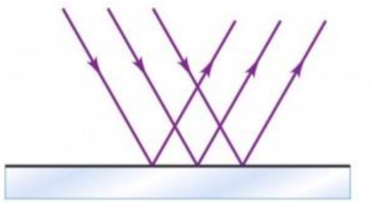
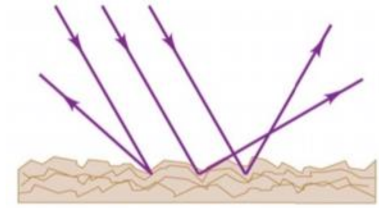


> "Normal" is an imaginary line drawn perpendicular to the plane of reflection/refraction.

> These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.

Types of Reflection

Based on the surface, the reflections are of two types:

Regular or specular reflection	Irregular or diffused reflection.
When the reflecting surface is smooth and well-polished, the parallel rays falling on it are reflected parallel to one another. Such reflections are known as specular reflection. 	When the reflecting surface is rough, the parallel rays falling on it reflected in different directions. Such reflections are known as diffuse reflection. 

Images

Image is an optical appearance produced when light rays coming from an object are reflected from a mirror or refracted through lens. An image is formed at the point where atleast two light rays actually meet or appear to meet.

Types of Images

Real Image	Virtual Image
i. A real image is formed when light rays after reflection or refraction **actually intersect** at a point. ii. Real images can be **obtained on screen**. E.g. Images formed on a movie screen. iii. Real images are **always inverted**. iv. Real images are mostly formed by converging mirrors.	i. A virtual image is formed when light rays after reflection or refraction only **appear to intersect** at a point, and do not actually intersect physically. ii. Virtual images **cannot be obtained on screen.** They can only be seen only by looking into a mirror. iii. Virtual images are **always upright**. iv. Virtual images are mostly formed by diverging mirrors.

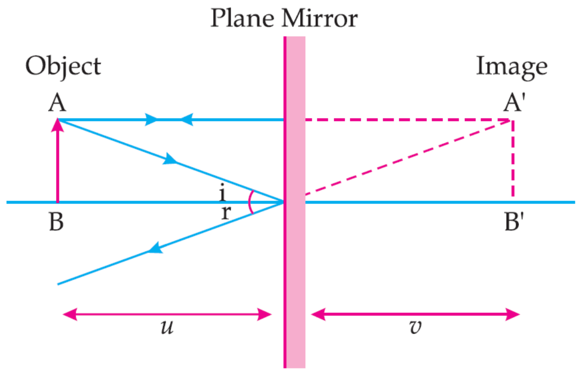
Mirrors

Any polished surface that has almost no irregularities on its surface and reflect light is called a mirror.

Plane mirrors

✓ **Lateral Inversion:** The phenomenon due to which the right side of the object appears left side of the image and vice-versa. i.e. the image is inverted sideways.
E.g. The word AMBBULANCE is written as ƎƆNA⅃UBMA so that it can be read correctly in rea view mirror of vehicles going in front of it.

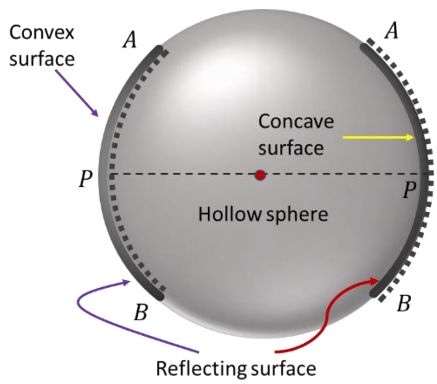
<u>Characteristics of images formed by a plane mirror:</u>



1. Images are virtual and upright.
2. Size of the image (h') is equal to the size of the object (h).
3. Distance of the image (v) from the mirror is equal to the distance of the object (u) from the mirror.
4. Images are laterally inverted.

Spherical Mirrors

Spherical mirrors whose reflecting surface is either curved inward or outward are known as spherical mirrors. These mirrors are part of a hollow sphere of glass.



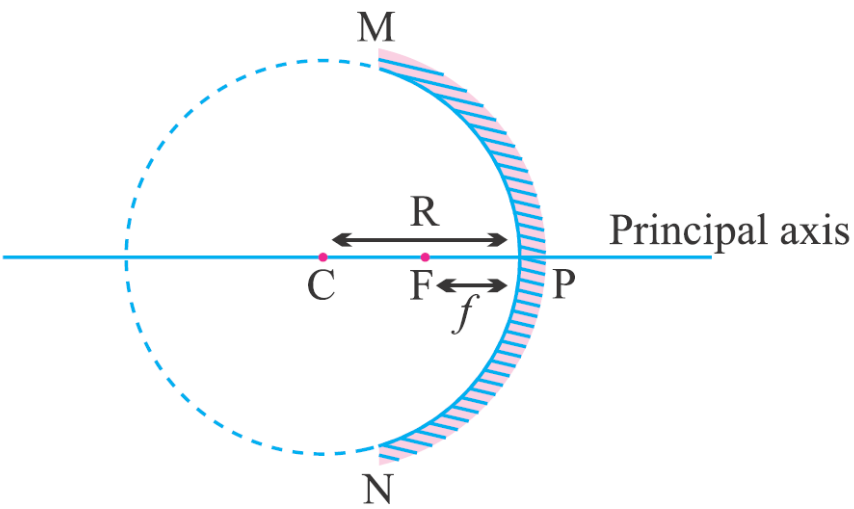
- **Concave Mirrors:** Spherical mirrors in which the reflecting surface is curved inwards are called concave mirrors.
- **Convex Mirrors:** Spherical mirrors in which the reflecting surface is curved outwards are called concave mirrors.

Terms Related to Spherical Mirrors

- **Centre of Curvature (c):** The centre of curvature of a spherical mirror is the centre of the hollow sphere of glass, of which the spherical mirror is a part and is usually represented by C.
- **Radius of Curvature (R):** The radius of curvature of a spherical mirror is the radius of the hollow sphere of glass, of which the spherical mirror is a part and is usually represented by R.
- **Pole (P):** The centre of the reflecting surface of a spherical mirror is called the pole of the mirror and it is usually represented by P.
- **Principal Axis:** The horizontal line passing through the centre of curvature and pole of the spherical mirror is known as principal axis.
- **Focus (F):** It is the point on principal axis through which the rays of light pass after reflection or they appear to be arising from this point.
- **Focal Length (f):** The focal length of a spherical mirrors is the distance between its Pole and Principal focus. It is denoted by letter 'f'.

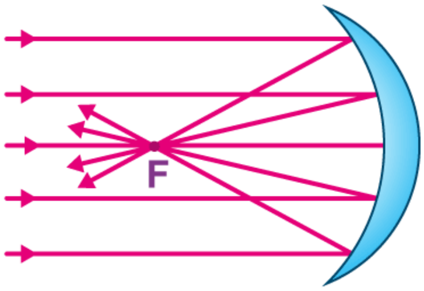
  It is always half in length of the radius of curvature. i.e. $\boldsymbol{f = \frac{R}{2}}$
- **Aperture:** The aperture of a spherical mirror is the diameter of the reflecting surface of the mirror.

  It is double in length of the radius of curvature i.e. $\boldsymbol{A = 2R}$



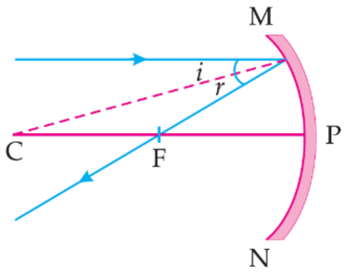
Concave Mirrors

In concave mirrors, the reflecting surface is **curved inwards**. Here, light rays after reflection meet (converges) at the focus (F) in front of the reflecting surface. As it converges a parallel beam of light rays at the focus, they are also known as **converging mirrors**.

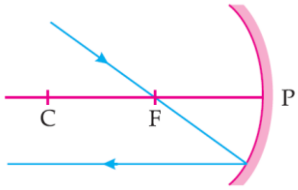


Rules For Making Ray Diagrams By Concave Mirrors

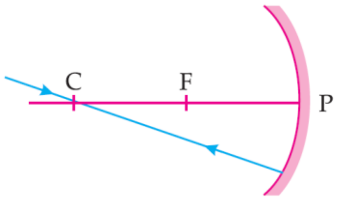
1. A ray parallel to the principal axis will pass through the principal focus, after reflection.



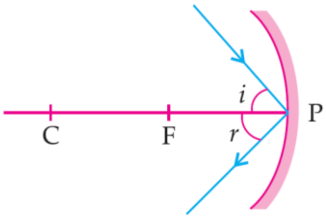
2. A ray passing through the principal focus of concave mirror will be parallel to principal axis after reflection.



3. 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 at the mirror surface.

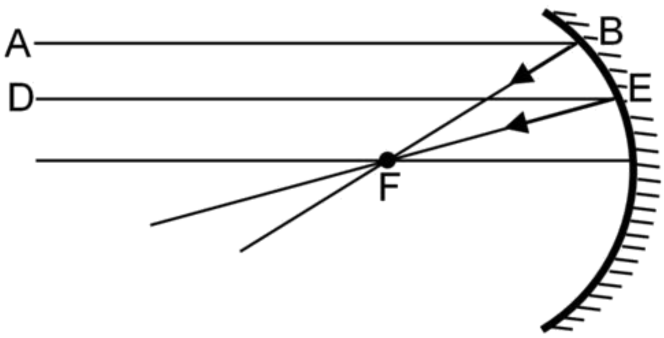


4. A ray incident obliquely to the principal axis of a concave mirror is reflected obliquely making equal angle with the principal axis.



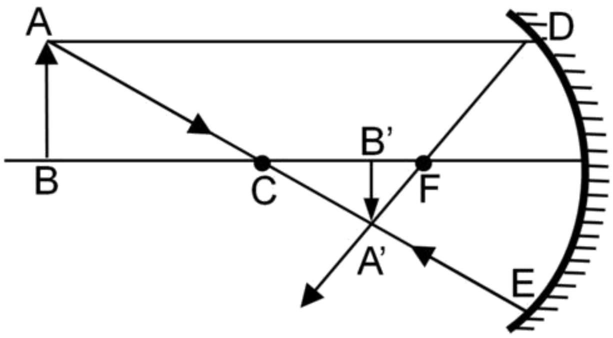
Formation of different types of images by a concave mirror

1. When the object is at infinity:



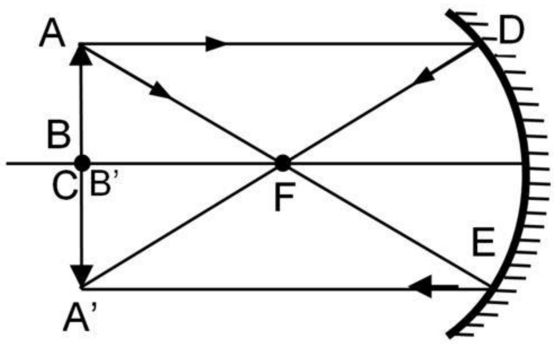
Position of Object	Position of Image	Size of Image	Nature of Image
Infinity	At focus	Point sized / Highly diminished	Real & Inverted

2. When the object is beyond the Centre of Curvature (C):



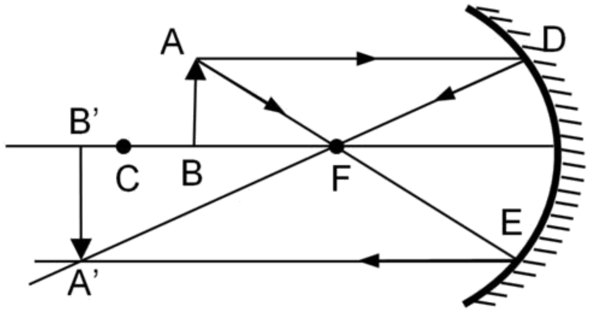
Position of Object	Position of Image	Size of Image	Nature of Image
Beyond C	In between C and F	Diminished in size	Real & Inverted

3. When the object is at the Centre of Curvature (C):



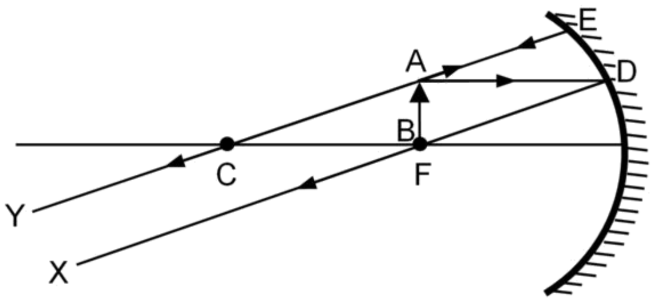
Position of Object	Position of Image	Size of Image	Nature of Image
At C	At C	Equal in size	Real & Inverted

4. When the object is in between Centre of Curvature (C) and Focus (F):



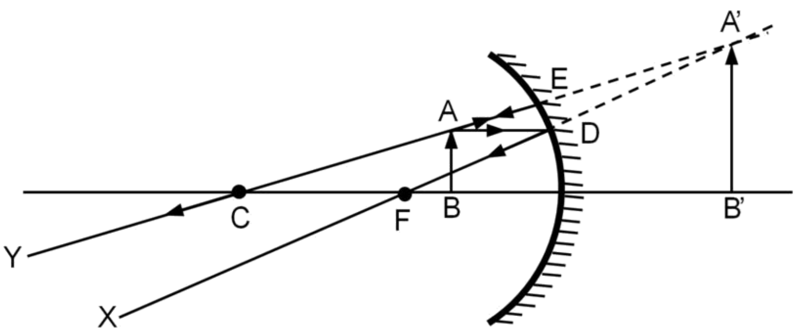
Position of Object	Position of Image	Size of Image	Nature of Image
In between C and F	Beyond C	Enlarged in size	Real & Inverted

5. When the object is at the focus (F):



Position of Object	Position of Image	Size of Image	Nature of Image
At F	At infinity	Highly enlarged	Real & Inverted

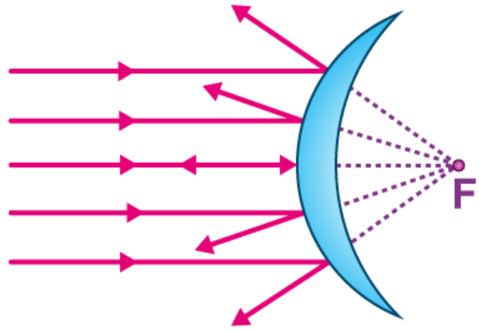
6. When the object is in between Focus (F) and Pole (P):

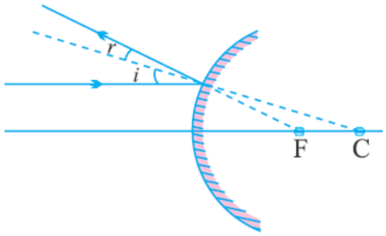
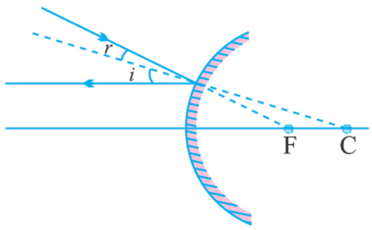
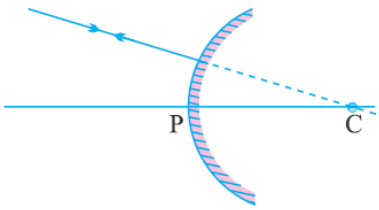
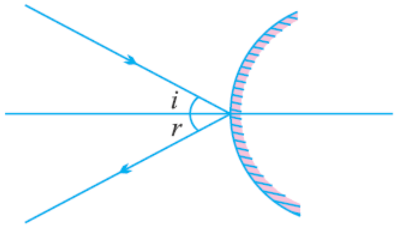


Position of Object	Position of Image	Size of Image	Nature of Image
In between F and P	Behind the mirror	Enlarged in size	Virtual & Upright

Convex Mirrors

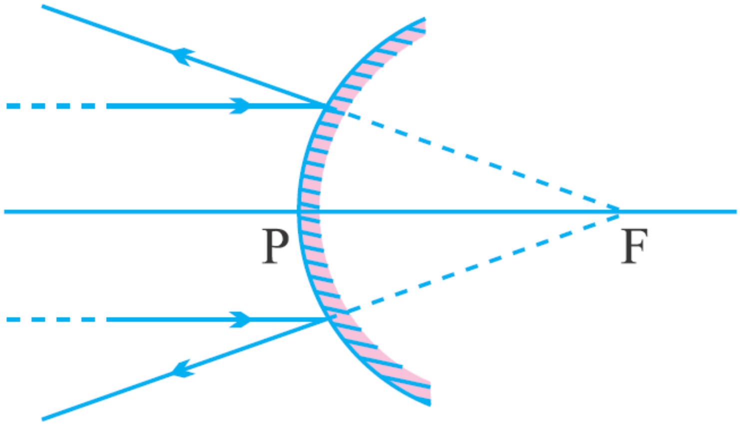
In concave mirrors, the reflecting surface is **curved outwards**. Here, light rays after reflection appears to meet (diverges) at the focus (F) behind of the reflecting surface (Virtual Focus). As it diverges a parallel beam of light rays at the focus, they are also known as **diverging mirrors**.



Rules For Making Ray Diagrams By Convex Mirrors
1. A ray parallel to the principal axis will appear to diverge from the principal focus, after reflection. 
2. A ray which is directed towards the focus of the convex mirror will emerge parallel to the principal axis after reflection. 
3. A ray directed towards the centre of curvature of a convex mirror is reflected back along the same. 
4. A ray incident obliquely to the principal axis is reflected obliquely. 

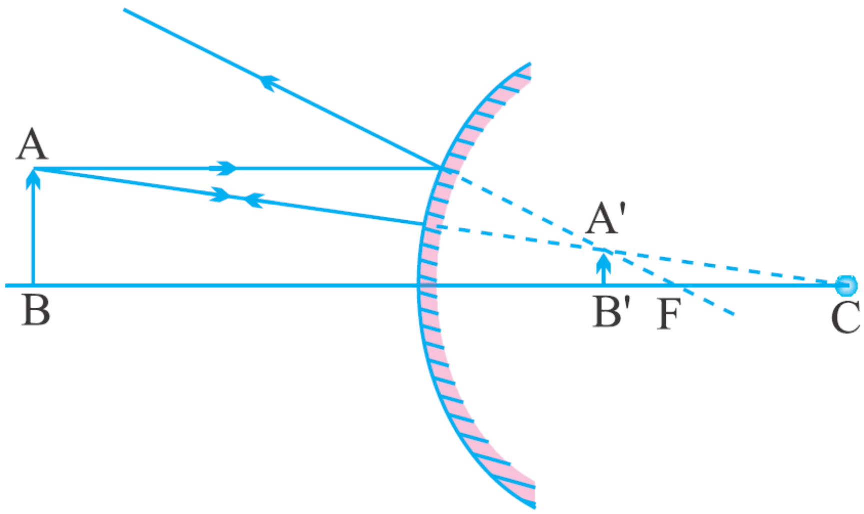
Formation of different types of images by a convex mirror

1. <u>When the object is at infinity:</u>



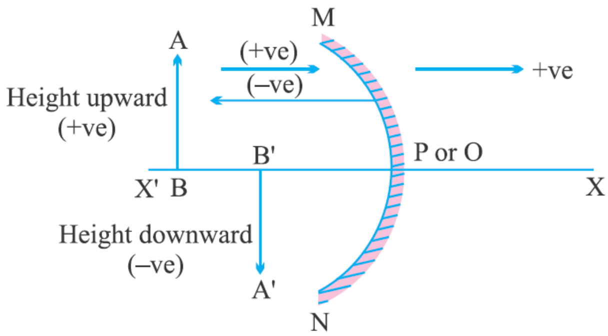
Position of Object	Position of Image	Size of Image	Nature of Image
Infinity	At focus, behind the mirror	Point sized / Highly diminished	Virtual & Upright

2. <u>When the object is in between Infinity and Pole (P):</u>



Position of Object	Position of Image	Size of Image	Nature of Image
In between Infinity and P	Between P and F behind the mirror	Diminished in Size	Virtual & Upright

Sign Convention for Reflection by Spherical Mirrors



Rules to follow:

- ✓ The object is placed to the left of the mirror.
- ✓ All distances parallel to the principal axis are measured from the pole of the mirror.

Mirror Formula

If $\boldsymbol{u}$ is the distance of the object from the pole of the mirror, $\boldsymbol{v}$ is the distance of the image from the pole of the mirror and $\boldsymbol{f}$ is the focal length of the mirror, then:

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

Magnification of Spherical Mirrors

It is the ratio of the height of image to the height of object. i.e. $\boldsymbol{m} = \frac{\text{Height of image } (h')}{\text{Height of object } (h)}$.

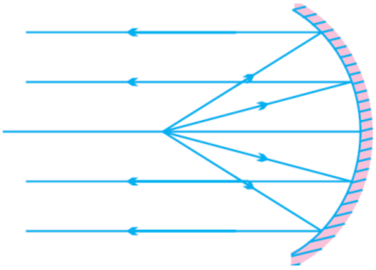
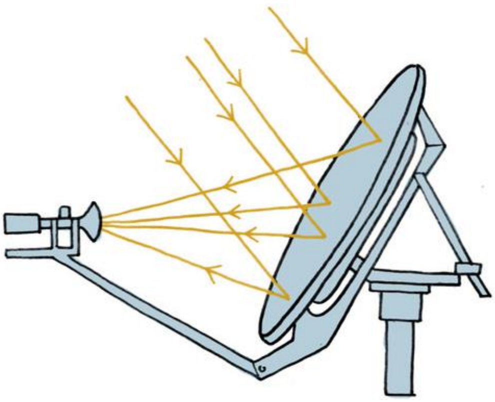
It can also be found from the ratio of image distance to the object distance. i.e. $\boldsymbol{m} = -\frac{\text{Image distance}}{\text{Object distance}}$

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

Information That You Should Know

- ✓ If $h' = h$, then $m = 1$ i.e. image size is equal to object size.
- ✓ If $h' > h$, then $m > 1$ i.e. image is enlarged.
- ✓ If $h' < h$, then $m < 1$ i.e. image is diminished.
- ✓ If $'m'$ is $-ve$, image is real and if $'m'$ is $+ve$, image is virtual.
- ✓ If $'m'$ is $+ve$ and less than 1, it is a convex mirror.
- ✓ If $'m'$ is $+ve$ and greater than 1, it is a concave mirror.
- ✓ If $'m'$ is $-ve$, it is a concave mirror.

Uses of Concave & Convex Mirrors

Concave Mirrors	Convex Mirrors
1. Commonly used in torches, search-lights, headlights of vehicles etc to get powerful beam of light 	**1.** Commonly used as rear view mirrors in vehicles as they give upright and diminished image. 
2. Used by dentists to see larger image of teeth of patients by placing the teeth between pole and focus of the mirror. 	**2.** Used at blind turns and on points of merging traffic to facilitate vision of both sides. 
3. Concave dishes are used in TV dish antennas to receive TV signals from the distant communications satellite. 	**3.** Used in shops as security mirrors due to its large field of view. 

Medium

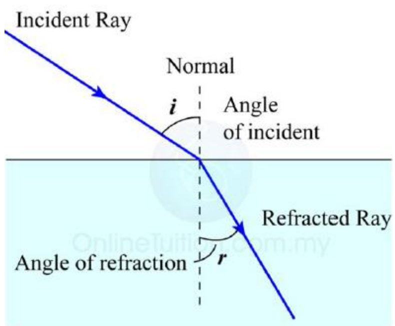
A transparent substance in which light travels is known as a medium. Medium can be divided into two types:

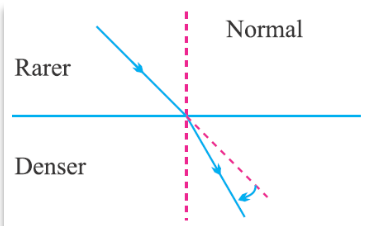
I. **Optically Rarer Medium:** A medium with low density in which the speed of light is faster is known as a optically rarer medium. E.g. Air

II. **Optically Denser Medium:** A medium with high density in which the speed of light is slower is known as a optically denser medium. E.g. Glass

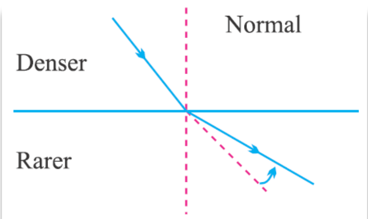
Refraction of Light

The phenomenon of changing the direction of light (or bending of light) when it passes from one medium to another is called refraction of light. It occurs due to the change in speed of light when it passes from one medium to another.





✓ When a light ray travels from a rarer medium to a denser medium, the light ray bends **towards the normal**.



✓ When a light ray travels from a denser medium to a rarer medium, the light ray bends **away from the normal**.

Examples of refraction in real life

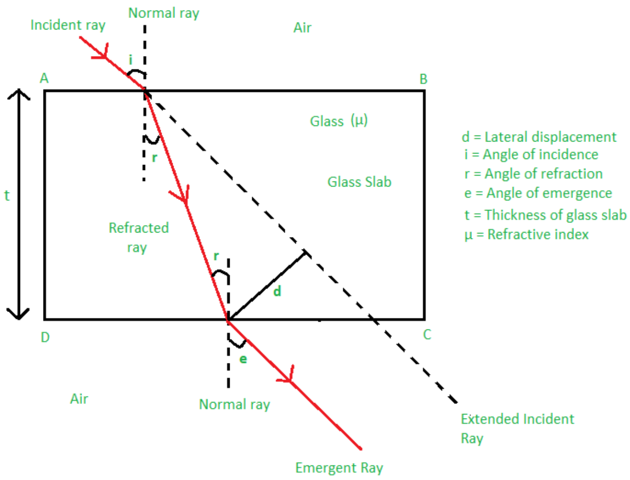
I. The bottom of a swimming pool appears higher.

I. A spoon partially immersed in water appears to be bent at the interface of water and air.

II. Letters of a book appear to be raised when seen through a glass slab.

Refraction through a glass slab

When light rays pass through a rectangular glass slab, the light goes through two refractions. One while going from **air to glass** and the other while going from **glass to air**.



When the incident ray is incident on the surface of the glass slab from air to the glass, it bends towards the normal as the ray enters a denser medium from a rarer medium.

After travelling the glass slab, the refracted ray bends away from the normal as the ray enters a rarer medium from a denser medium. This ray is now called an Emergent ray.

The emergent ray is parallel to the incident ray and the distance between them is called Lateral displacement.

Laws of Refraction

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

ii. The ratio of $sine$ of angle of incidence to the $sine$ of angle of refraction is always a constant (η). This law is also known as Snell's law of refraction.

If i is the angle of incidence and r is the angle of refraction, then $\frac{\sin i}{\sin r} = \eta$

This constant value is called the refractive index of the second medium with respect to the first medium. It is denoted by η_{21}.

The reciprocal of the refractive index of the second medium gives the refractive index of the first medium. It is denoted by $\eta_{12} = \frac{1}{\eta_{21}}$.

Relative Refractive Index

The refractive index of a medium is defined as the ratio of speed of light in the medium to the speed of the light in another medium.

If $\boldsymbol{v_1}$ is the speed of light in **medium 1** and $\boldsymbol{v_2}$ is the speed of light in **medium 2**, then:

The refractive index of medium 2 with respect to medium 1 is given by $\eta_{21} = \frac{v_1}{v_2}$.

The refractive index of medium 1 with respect to medium 2 is given by $\eta_{12} = \frac{1}{\eta_{21}} = \frac{v_2}{v_1}$.

Absolute Refractive Index

The refractive index of a medium with respect to a vacuum or air is called the absolute refractive index of the medium. The speed of light in vacuum or air is approximately $c = 3 \times 10^8\ m/s$.

If c is the speed of light in vacuum and v is the speed of light in a medium, then the refractive index of the medium is given by $\boldsymbol{\eta_{medium} = \frac{c}{v}}$

Refractive index of diamond is the highest till date. It is 2.42 which means that speed of light is $\frac{1}{2.42}$ times less in diamond than in vacuum.

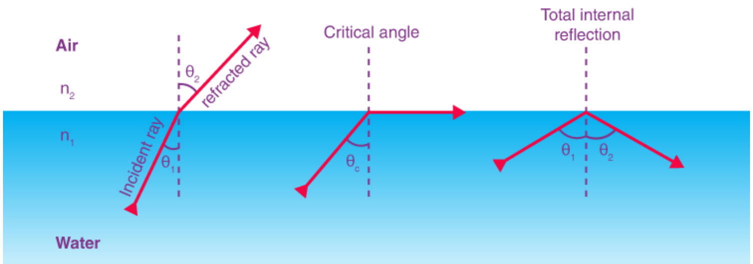
Conditions for No Refractions

Refraction will not take place under the following conditions:

1. When light is incident perpendicularly on the boundary of the medium i.e. angle of incidence $i = 0^0$
2. When the refractive index of both the mediums are equal.

Total Internal Reflection

When the light goes from a **denser to a rarer medium**, it bends away from the normal. The angle at which the incident ray causes the refracted ray to go along the surface of the two media parallelly is called the **critical angle**.

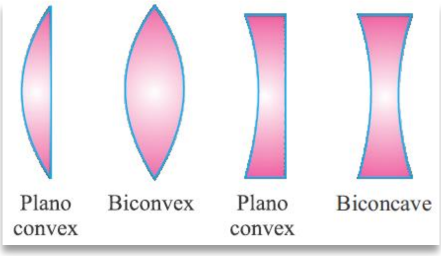


When the **incident angle is greater than the critical angle**, it reflects inside the denser medium instead of refracting. This phenomenon is known as Total Internal Reflection.

E.g. Mirages, Rainbows and working of optical fibres.

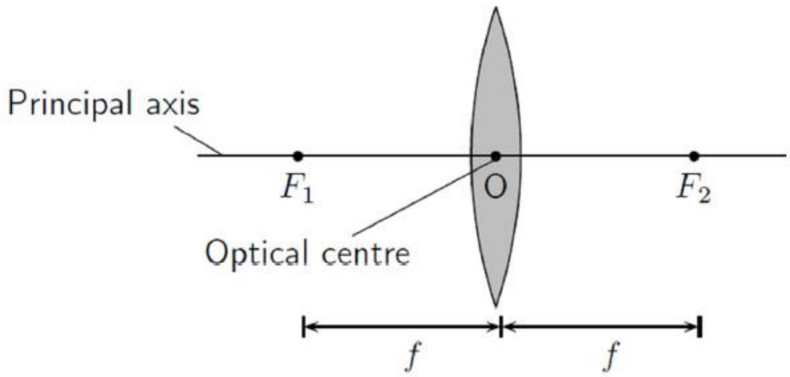
Spherical Lens

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



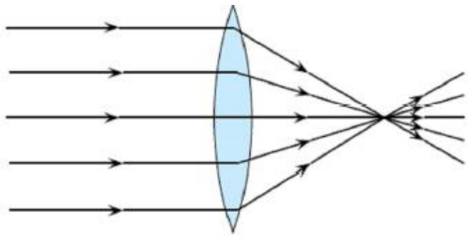
Terms Related to Spherical Mirrors

- **Centre of Curvature (c):** The centres of the spheres that the spherical lens was a part of. A spherical lens has two centres of curvature. They are denoted by C_1 & C_2.
- **Optical Centre (O) / Pole (P):** The midpoint or the symmetric centre of a spherical lens is known as its Optical Centre. It is also called the pole. The direction of light ray which pass through the optical centre remains unchanged.
- **Principal Axis:** The horizontal line passing through the centre of curvatures and the optical centre is known as principal axis.
- **Focus (F):** It is the point on the axis of a lens to which parallel rays of light converge or from which they appear to diverge after refraction. A spherical lens has two foci, denoted by F_1 & F_2.
- **Focal Length (f):** The focal length of a spherical mirrors is the distance between its optical centre and one of foci. It is denoted by letter 'f'.
- **Aperture:** The aperture is the diameter of the circular outline of a spherical lens is called its aperture.



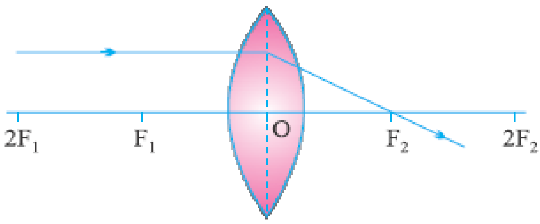
Convex Lens

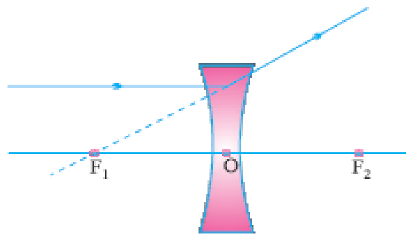
The lens having one or both spherical surfaces bulging outwards is called a convex lens. Convex lens converges light rays at the focus on the opposite side. Hence it is also called **converging lens**.



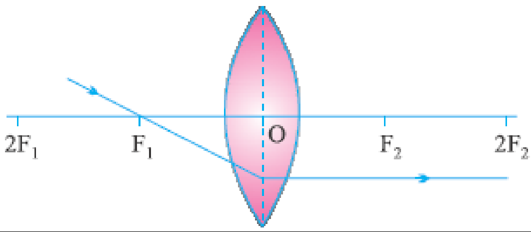
Rules For Making Ray Diagrams By Convex & Concave Lens

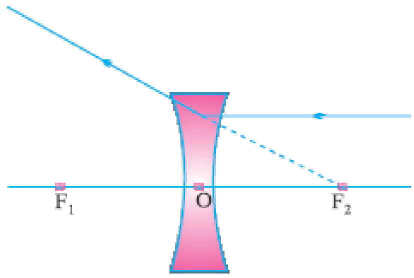
1. In a **convex lens**, a ray parallel to the principal axis will pass through the principal focus on the other side of the lens. In a **concave lens**, the ray appears to diverge from the focus on the same side of the lens.



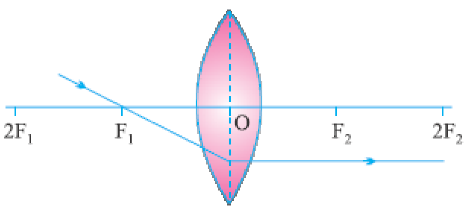


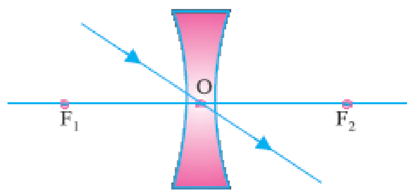
2. In **convex lens**, a ray passing through the principal focus of will emerge parallel to principal axis after refraction. In a **concave lens**, a ray appearing to meet at the principal focus will emerge parallel to the principal axis.





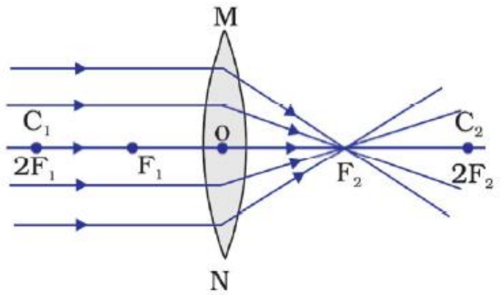
3. A ray of light passing through the optical centre a convex or concave lens will emerge without any deviation.





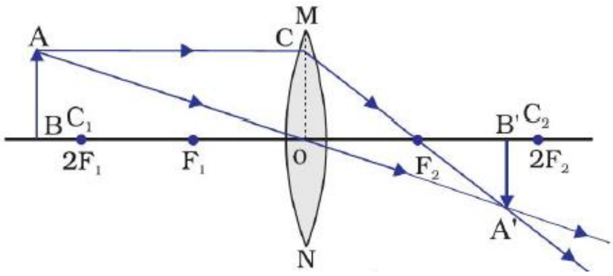
Formation of different types of images by a convex lens

1. **When the object is at infinity:**



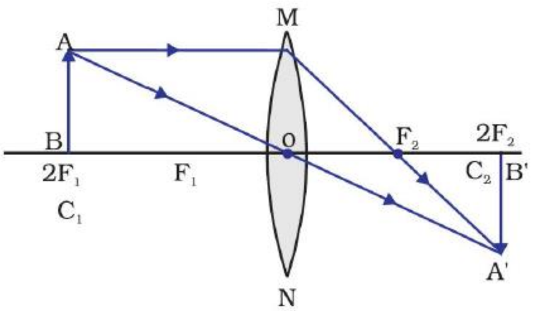
Position of Object	Position of Image	Size of Image	Nature of Image
Infinity	At focus, F_2 On the opposite side	Point sized / Highly diminished	Real & Inverted

2. **When the object is beyond the Centre of Curvature** $(C_1\ or\ 2F_1)$:



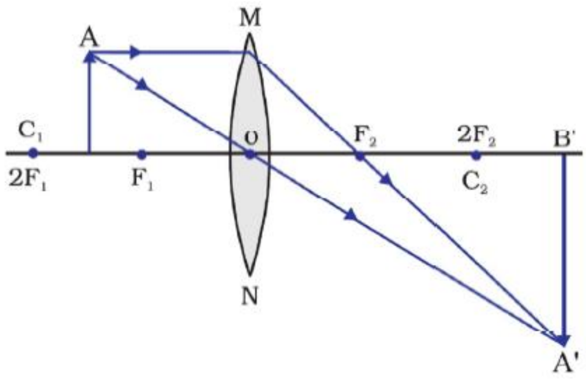
Position of Object	Position of Image	Size of Image	Nature of Image
Beyond C_1 $(or\ 2F_1)$	In between F_2 and $2F_2$ On the opposite side	Image is diminished	Real & Inverted

3. **When the object is at the Centre of Curvature** $(C_1\ or\ 2F_1)$:



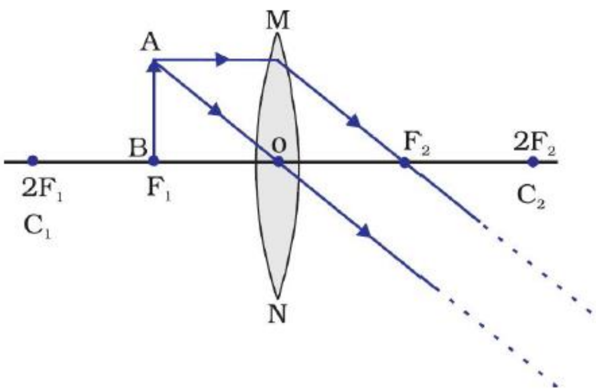
Position of Object	Position of Image	Size of Image	Nature of Image
At C_1 $(or\ 2F_1)$	At $2F_2$ on the opposite side	Image is same size as the object	Real & Inverted

4. <u>When the object is in between Centre of Curvature</u> $(C_1\ or\ 2F_1)$ <u>and Focus</u> (F_1):



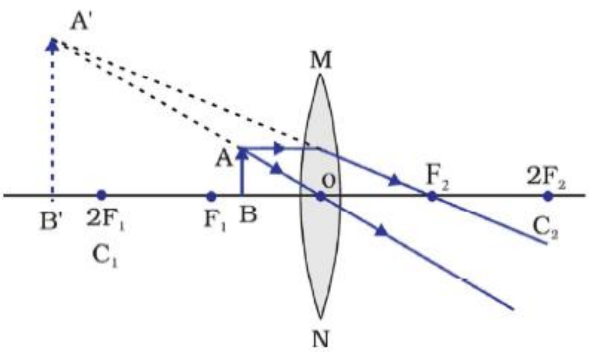
Position of Object	Position of Image	Size of Image	Nature of Image
In between C_1 $(or\ 2F_1)$ and Focus (F_1)	Beyond $2F_2$ on the opposite side	Image is Enlarged	Real & Inverted

5. <u>When the object is at Focus</u> (F_1):



Position of Object	Position of Image	Size of Image	Nature of Image
At Focus (F_1)	At infinity on the opposite side	Image is Highly Enlarged	Real & Inverted

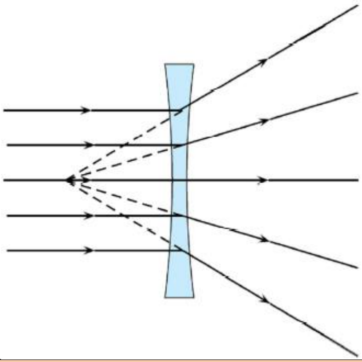
6. <u>When the object is in between Focus</u> (F_1) <u>and Optical Centre</u> (O):



Position of Object	Position of Image	Size of Image	Nature of Image
In between Focus (F_1) & Optical Centre (O)	Beyond $2F_2$ on the same side	Image is Enlarged	Virtual & Upright

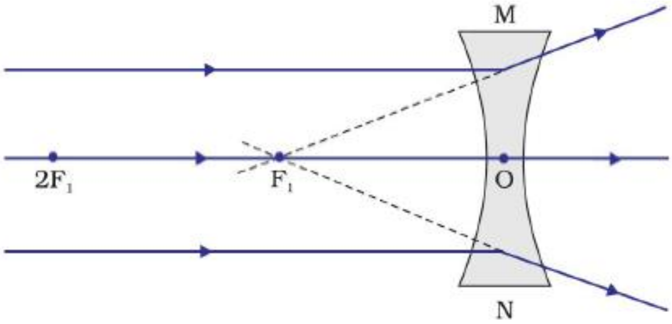
Concave Lens

The lens having one or both spherical surfaces bulging inwards is called a convex lens. A concave lens is also known as **diverging lens** because the parallel beam of light rays after refraction through it, appear to diverge from a single point.



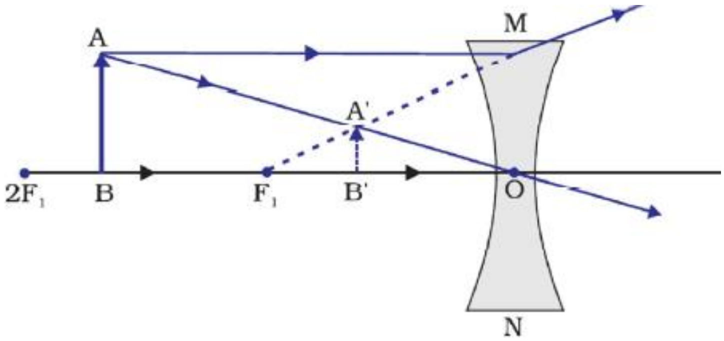
Formation of different types of images by a convex lens

1. When the object is at infinity:



Position of Object	Position of Image	Size of Image	Nature of Image
Infinity	At focus, F_1 On the same side	Point sized / Highly diminished	Virtual & Upright

2. When the object is in between infinity and Optical Centre:

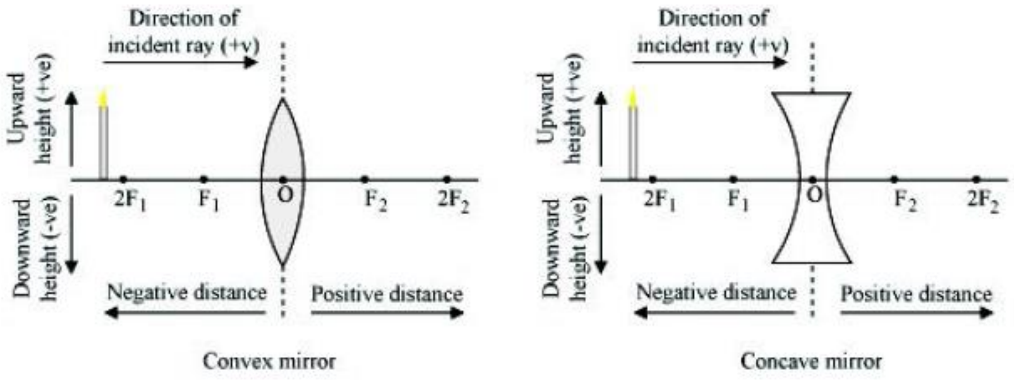


Position of Object	Position of Image	Size of Image	Nature of Image
In between Infinity and O	In between focus, F_1 and O on the same side	Diminished in size	Virtual & Upright

Sign Convention for Reflection by Spherical Mirrors

Rules to follow:

- ✓ All distances are measured from the optical centre of the lens.
- ✓ The object is placed to the left of the lens and $'u'$ is always $-ve$.
- ✓ The focal length of a convex lens is $+ve$ and that of a concave lens is $-ve$.
- ✓ The distance of real image is $+ve$ and that of a virtual image is $-ve$.



Lens Formula

If $\boldsymbol{u}$ is the distance of the object from the optical centre of a lens, $\boldsymbol{v}$ is the distance of the image from the optical centre of a lens and $\boldsymbol{f}$ is the focal length of the lens, then:

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

Magnification of Lens

It is the ratio of the height of image to the height of object. i.e. $m = \frac{Height\ of\ image\ (h')}{Height\ of\ object\ (h)}$.

It can also be found from the ratio of image distance to the object distance. i.e. $m = \frac{Image\ distance}{Object\ distance}$

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

Information That You Should Know

- ✓ If the magnification is $+ve$, the image is virtual and upright.
- ✓ If the magnification is $-ve$, the image is real and inverted.
- ✓ Magnification produced by a convex lens is $'\boldsymbol{either\ positive\ or\ negative}'$ and it is also $'\boldsymbol{m > 1\ or\ m = 1\ or\ m < 1}'$.

Power of a lens

It is defined as the reciprocal of focal length. It is denoted by $\boldsymbol{P}$.

i.e. It is given by

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

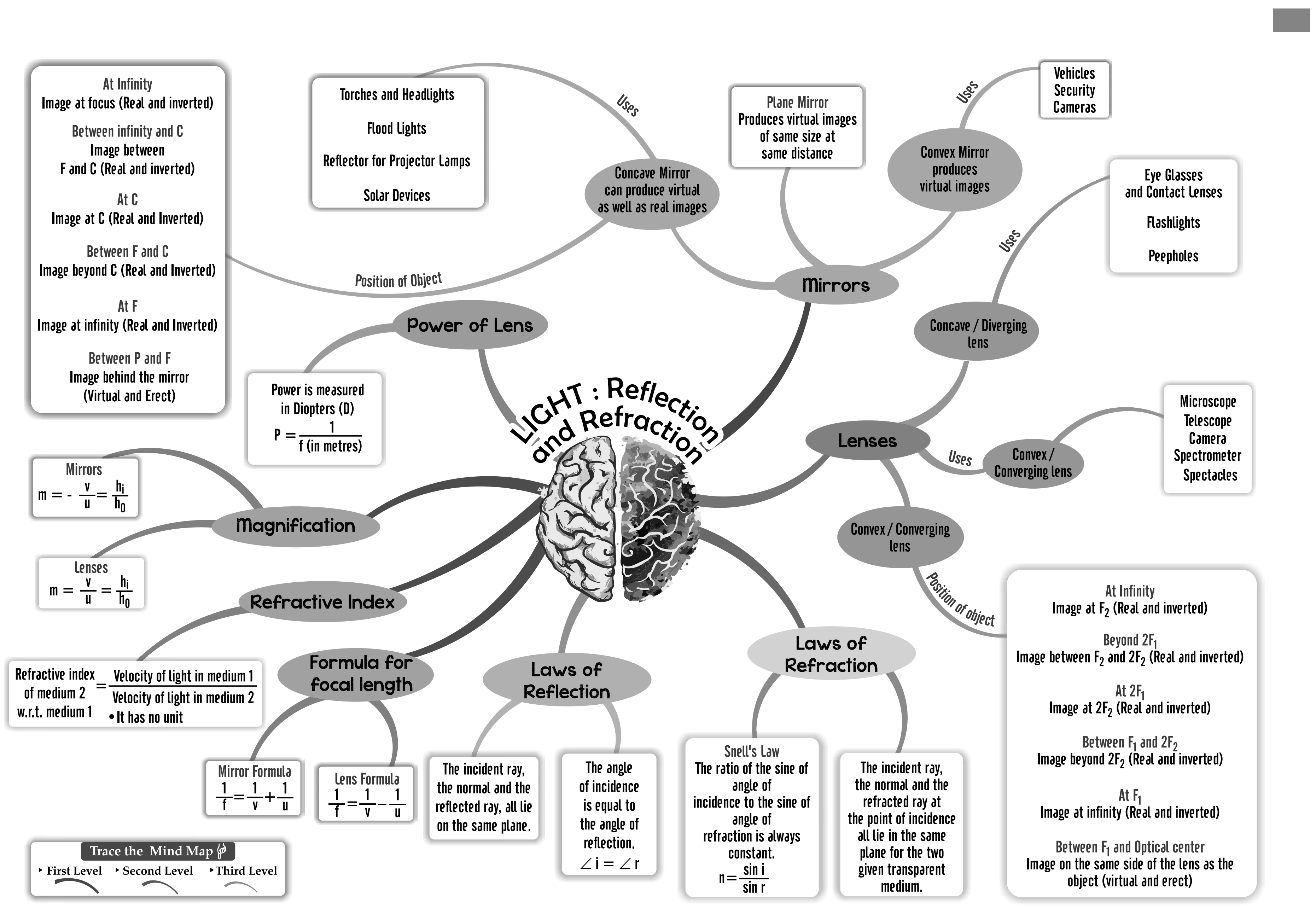
The SI unit of power of a lens is $'\boldsymbol{Dioptre}\ (\boldsymbol{D})$".

Information That You Should Know

- ✓ $1\ Dioptre\ or\ 1D$ of power is defined as a lens whose focal length is 1 metre.
- ✓ Power of convex lens is $+ve$.
- ✓ Power of concave lens is $-ve$.
- ✓ If $P_1,\ P_2,\ P_3, \ldots \ldots \ldots$ etc are the powers of different lenses then the power of their combination is given by $P = P_1 + P_2 + P_3 + \cdots \ldots \ldots$

Uses of Lens

Convex Lens	Concave Lens
• It is used as magnifying glass	• It is used as a spy hole in doors
• It is used to make microscope	• It is used in flashlights to widen the beam produced by the bulb.
• It is used to correct Hypermetropia	• It is used to correct Myopia


LIGHT : Reflection and Refraction
Mirrors
Plane Mirror
Produces virtual images of same size at same distance
Convex Mirror produces virtual images
Uses
Vehicles
Security Cameras
Concave Mirror can produce virtual as well as real images
Uses
Torches and Headlights
Flood Lights
Reflector for Projector Lamps
Solar Devices
Position of Object
At Infinity
Image at focus (Real and inverted)
Between infinity and C
Image between F and C (Real and inverted)
At C
Image at C (Real and Inverted)
Between F and C
Image beyond C (Real and Inverted)
At F
Image at infinity (Real and Inverted)
Between P and F
Image behind the mirror (Virtual and Erect)
Power of Lens
Power is measured in Diopters (D)
$P = \frac{1}{f \text{ (in metres)}}$
Magnification
Mirrors
$m = -\frac{v}{u} = \frac{h_i}{h_0}$
Lenses
$m = \frac{v}{u} = \frac{h_i}{h_0}$
Refractive Index
Refractive index of medium 2 w.r.t. medium 1 = $\frac{\text{Velocity of light in medium 1}}{\text{Velocity of light in medium 2}}$
• It has no unit
Formula for focal length
Mirror Formula
$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$
Lens Formula
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
Laws of Reflection
The incident ray, the normal and the reflected ray, all lie on the same plane.
The angle of incidence is equal to the angle of reflection.
$\angle i = \angle r$
Laws of Refraction
Snell's Law
The ratio of the sine of angle of incidence to the sine of angle of refraction is always constant.
$n = \frac{\sin i}{\sin r}$
The incident ray, the normal and the refracted ray at the point of incidence all lie in the same plane for the two given transparent medium.
Lenses
Concave / Diverging lens
Uses
Eye Glasses and Contact Lenses
Flashlights
Peepholes
Convex / Converging lens
Uses
Microscope
Telescope
Camera
Spectrometer
Spectacles
Convex / Converging lens
Position of object
At Infinity
Image at F_2 (Real and inverted)
Beyond $2F_1$
Image between F_2 and $2F_2$ (Real and inverted)
At $2F_1$
Image at $2F_2$ (Real and inverted)
Between F_1 and $2F_2$
Image beyond $2F_2$ (Real and inverted)
At F_1
Image at infinity (Real and inverted)
Between F_1 and Optical center
Image on the same side of the lens as the object (virtual and erect)
Trace the Mind Map
First Level
Second Level
Third Level