REFLECTION THROUGH LENS

A lens is a piece of transparent optical material with one or two curved surfaces to refract light rays. It may converge or diverge light rays to form an image. Lenses are mostly used in optical devices like microscopes and telescopes. Bi-convex and bi-concave lenses are the most popular ones in use among school labs. Lenses use the phenomenon of refraction of light to form the images. A Plano-convex lens has a convex surface on one side and a plane surface on the other. A Plano-concave lens is the one that has a concave surface on one side and a plane surface on the other. A concavo-convex lens has a concave surface on one side and a convex surface on the other.

Concave Lens

It is a lens that possesses at least one surface that curves inwards. A bi-concave lens has two inward bent surfaces. It is generally referred to as a concave lens. As the concave lens diverges the light incident on it, it is called a diverging lens. A concave lens is thinner at its centre than at its edges, and is used to correct short sightedness. Due to this the concave lenses always form diminished, virtual and erect images irrespective of the position of the object in front of them. Hence the magnification produced by these lenses is always less than one.

Convex Lens

A bi-convex lens is one with a surface that is bulged outwards on both the sides. It is generally referred to as a convex lens. A convex lens is thick in the middle and thin at its edge. When light rays pass through a convex lens, they bend inwards and converge at a common point to form an image of the source of light. So they are called the converging lenses. A convex lens makes the object magnified, when viewed through it. We can observe the magnified image of our palm when the lens is placed close to our palm. This is due the position of the object between the focus and the optic centre. The image formed when the object is placed close to a convex lens is virtual, erect and magnified. Virtual images cannot be caught on a screen. Images that are caught on a screen are called real images. When the object is placed at a distance from a convex lens, the image formed is real, inverted and diminished.

General Terms Related to Lenses

- ***Centre of Curvature (C)***: The centre of the imaginary glass sphere of which the lens is a part
- ***Radius of Curvature (R)*****:** The radius of the sphere of which the surface of the lens is a part.
- ***Principal Axis***: An imaginary line joining the centres of curvature of the two spheres, of which lens is a part
- ***Optic Centre (O)*****:** A point within the lens, where a line drawn through the diameter of lens meets principal axis
- ***Principal Focus of Convex Lens (F)*****:** It is a point on the principal axis of a convex lens, where parallel beam of light rays, travelling parallel to principal axis, after passing through the lens actually meet.
- ***Principal Focus for Concave Lens (F)*****:** It is a point on the principal axis of a concave lens, from where parallel beam of light rays, travelling parallel to principal axis, after passing through the lens, appears to come.
- ***Focal Length (f)*****:** The distance between principal focus and optical centre
- ***Aperture***: The effective diameter of the lens through which refraction takes place

Real And Virtual Images

The image that can be focussed on a screen is called a real image. The image that cannot be caught on a screen is called a virtual image. The following are the main differences between a real image and virtual image.

1. A real image can be caught on a screen whereas a virtual image cannot be caught on a screen.
2. A real image is always inverted whereas a virtual image is always erect.
3. A real image is formed when the rays of light after reflection or refraction actually meet at some point whereas a virtual image is formed when the rays of light after reflection or refraction appear to meet at a point.

Rules for Construction of Ray Diagrams for Lenses

Rule 1: A light ray incident parallel to the principal axis converges at the focal point in the case of a convex lens and appears to diverge from the focal point in the case of a concave lens.

Rule 2: A ray passing through the optic centre of a lens remains undeviated irrespective of its inclination on the principal axis.

Rule 3: A ray of light which comes through focus (of a convex lens) or appears to come towards focus (of a concave lens) becomes parallel to the principal axis after passing through the lens.

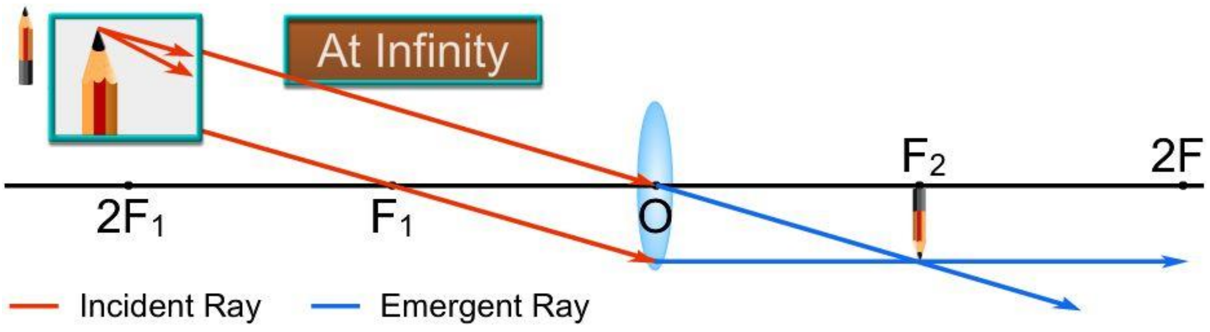
Behaviour of Light Rays Propagating Through a Convex Lens

Incident Ray	Emergent Ray
Is parallel to principal axis	Passes through focus
Passes through optic centre	Passes without deviation
Passes through focus	Passes parallel to principal axis

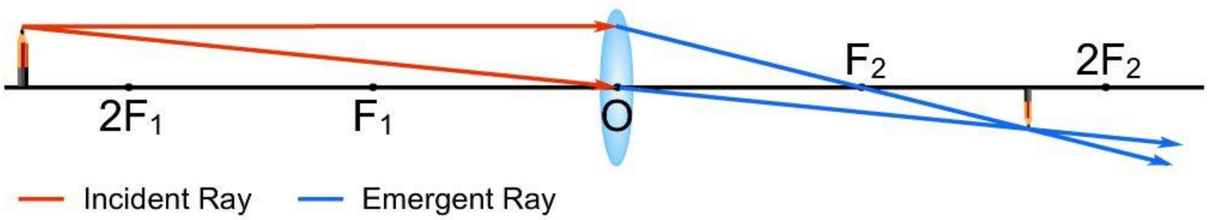
Location and Characteristics of Images Formed by a Convex Lens

Depending on the position of the object in front of the lens, the position, size and the nature of the image varies.

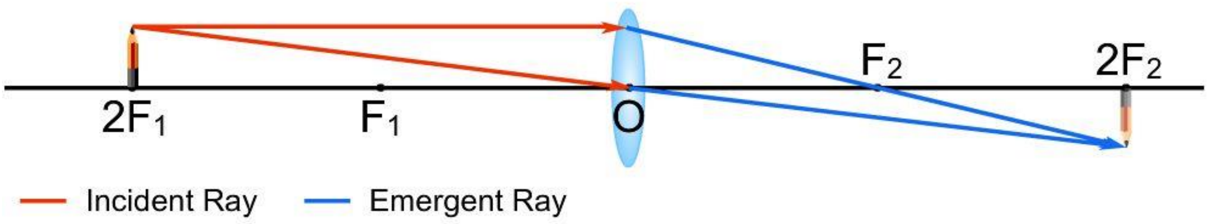
1. Object at infinity: A real, inverted, diminished image is formed at the focal point F on the other side of the lens.



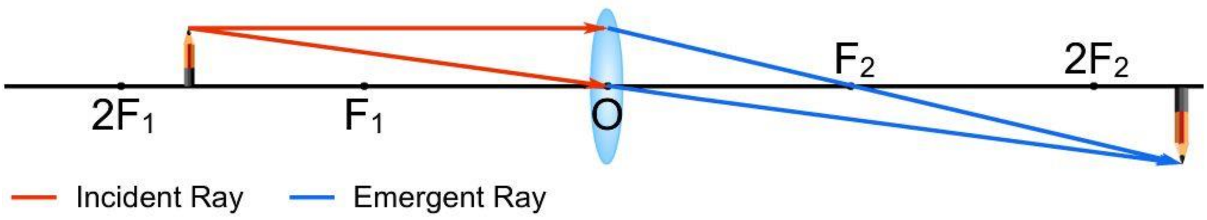
2. Object beyond 2F: A real, inverted, smaller image is formed between F and 2F on the other side of the lens.



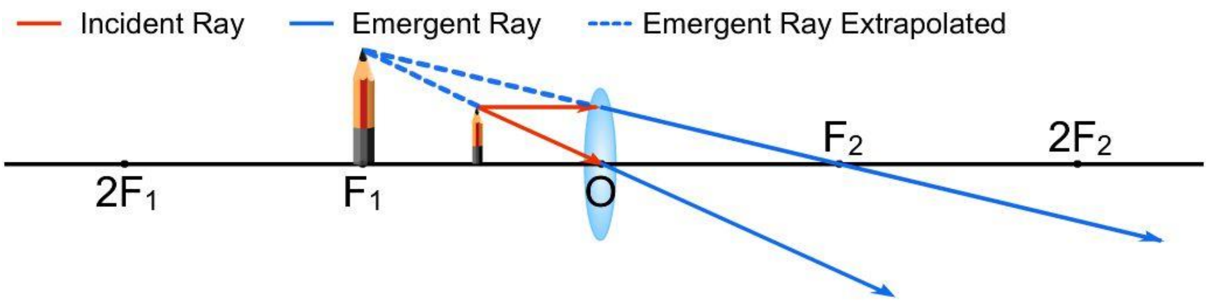
3. Object at 2F: A real, inverted, same sized image is formed at 2F on the other side of the lens.



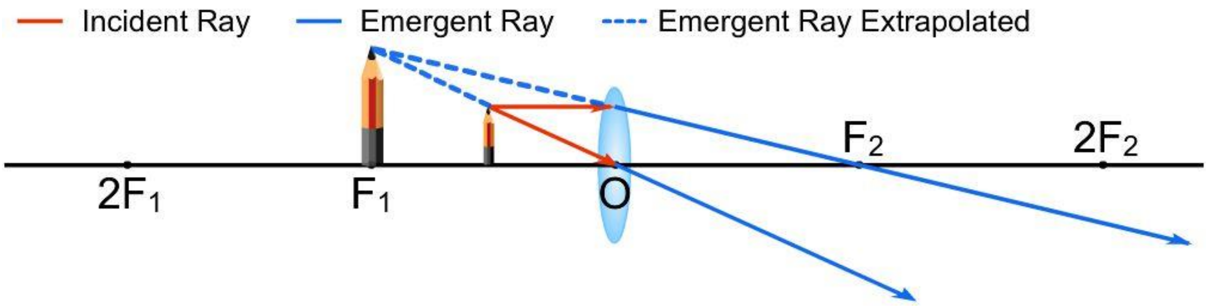
4. Object between F and 2F: A real, inverted, larger image is formed beyond 2F on the other side of the lens.



5. Object at F: A real, inverted, enlarged image is formed at infinity on the other side of the lens.



6. Object between F and O: A virtual, erect and enlarged image is formed on the same side of the lens.



Behaviour of Light Rays Propagating Through a Concave Lens

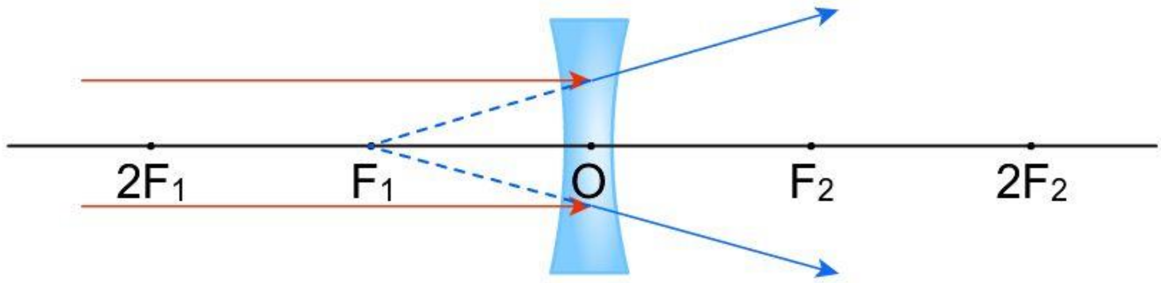
Incident Ray	Emergent Ray
Is parallel to principal axis	Appears to pass through focus
Passes through optic centre	Passes without deviation
Is directed towards focus	Passes parallel to principal axis

Object Location	**Image Location**	**Nature of Image**
Infinity	At F2	Real Inverted Highly diminished
Beyond 2F1	Between F2 and 2F2	Real Inverted Diminished
At 2F1	At 2F2	Real Inverted Equal in size to that of the object
Between 2F1 and F1	Beyond 2F2	Real Inverted Magnified
At F1	Infinity	Real Inverted Highly magnified
Between F1 and O	On the same side of the lens as the object	Virtual Erect Magnified

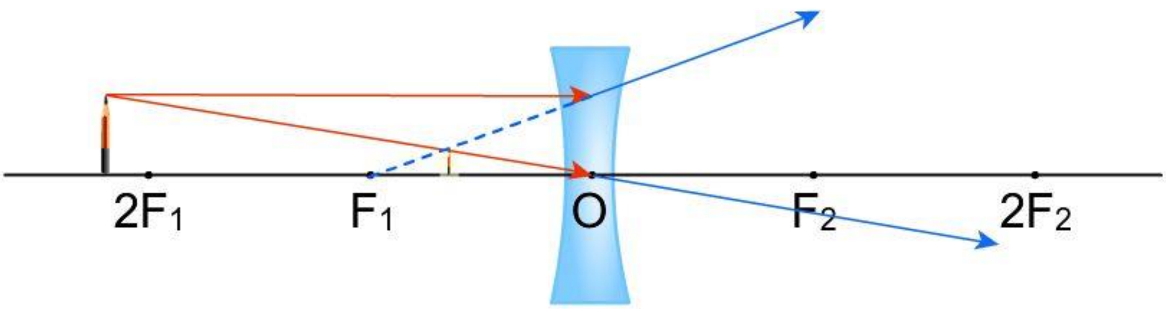
Image Formation by Concave Lens

Irrespective of the position of the object, a virtual, erect and diminished image is formed between the focus (F) and the (optic centre (O) of the concave lens, on the same side of the lens.

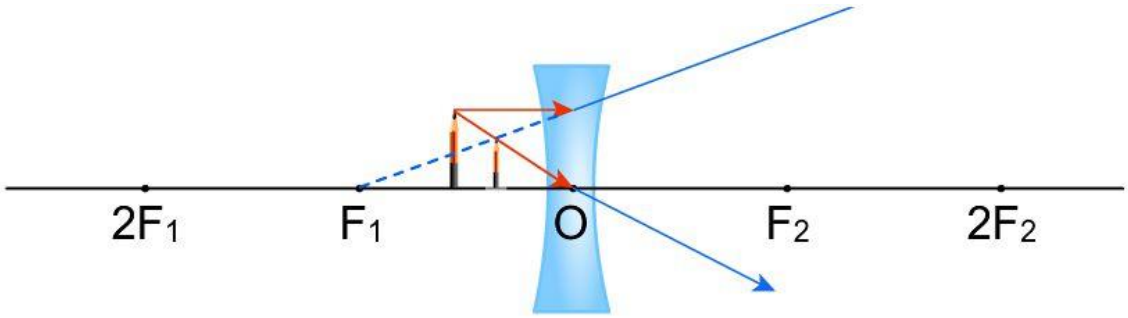
1. Object at infinity:



2. Object beyond 2F:



3. Object between F and O:



Location and Characteristic of the Images Formed by a Concave Lens

Object Location	Image Location	Nature of Image
Infinity	As a point at F1	Virtual Erect Highly Diminished
Beyond 2F1	Between F1 and O	Virtual Erect Diminished

Lens Formula and Sign Conventions

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

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

All the distances are to be measured from the optic centre of the lens. The distances measured in the direction of the incident light are taken as positive (+). The distances measured in the direction opposite to that of the incident light are taken as negative (-).

Magnification (m) is the ratio of the image size to the object size. It is also measured as the ratio of image distance to object distance.

$$m = \left(\frac{\text{Size of the image}}{\text{Size of object}}\right) \text{ Or } m = \left(\frac{\text{Image distance}}{\text{Object distance}}\right)$$

If m = 1; image size = object size

If m > 1: image size > object size
If m < 1: image size < object size

Power of A Lens

The converging or diverging capacity of a lens is ascertained by its power. Power of a lens is the reciprocal of its focal length expressed in metre.
P = 1 / f (measured in meters).

The SI unit of power of a lens is dioptre (D). Power of a convex lens is positive and that of a concave lens is negative.

Determination of Focal Length of a Convex Lens by Distant Object Method

- Mount the convex lens and an object needle on their respective uprights. place the upright carrying the object needle in front of the lens on an optical bench.
- Adjust a plane mirror at the back of the lens, such that its plane is vertical and perpendicular to the axis of the lens.
- Move the needle forward and backward and adjust its position to get real and inverted image of the needle formed by the lens, after reflection from the plane mirror.
- When the tip of the image in the plane mirror coincides with the tip of the optical needle, i.e., focus of the lens. The distance between the optical needle and the lens gives the focal lenght of the lens.
- The rays proceeding from the object at the principal focus after refraction through the lens are rendered parallel. These parallel rays are reflected from the plane mirror and after refraction through the lens, meet at the focus.

Determination of Focal Length of a Convex Lens by Auxiliary Method

- Place a convex lens on a plane mirror kept on the horizontal surface of the vertical stand and arrange a pin horizontally in the clamp such that its tip is vertically above the centre of the lens.
- Adjust the height of the pin until it has no parallax with its inverted image when seen from vertically above the pin. To check for parallax, the eye is moved side wards. If the pin and its image shift together, then parallax is moved.
- Measure the distance x of the pin from the lens and the distance y of the pin from the mirror, using the plumb line and a meter scale.
- Calculate the average of these two distances i.e., x and y, that gives the focal length of the lens.
- Focal length of the convex lens, $f = (x + y) / 2$
- Take three different observations and find the mean focal length of the convex lens.