Light

REFRACTION

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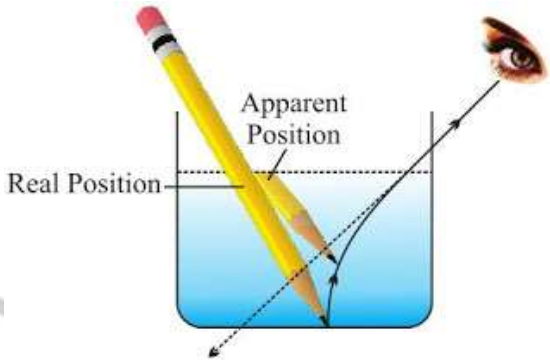
Introduction

→ Refraction is bending of light when it enters obliquely from one transparent medium to another.
→ Speed of light is maximum in vaccum. It is 3×10^8 m/s.
→ Cause of refraction: Change in speed of light.

• Some examples of refraction

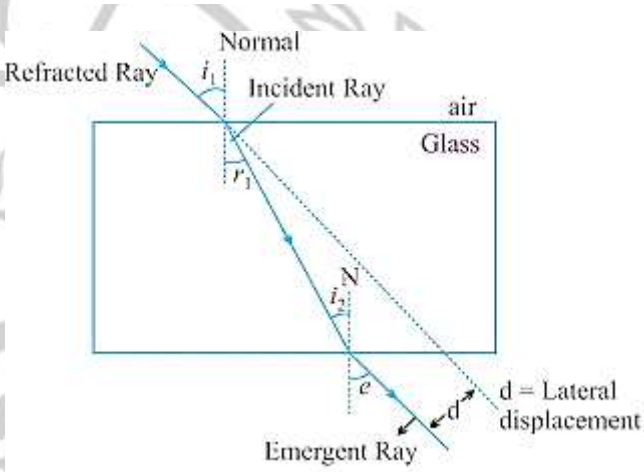
→ The bottom of swimming pool appears higher.
→ A pencil partially immersed in water appears to be bent at the interface of water and air.
→ Lemons placed in a glass tumbler appear bigger.
→ Letters of a book appear to be raised when seen through a glass slab.



Refraction

→ Bending of the light rays as it passes from one medium to another medium is known as refraction of light.
→ The extent of bending of ray of light at the opposite parallel faces of rectangular glass slab is equal and opposite, so the ray emerges parallel to incident ray.

The shortest path need not be the quickest path. Since light is always in a hurry, it bends when it enters a different medium as it is still following the quickest path. This phenomenon of light bending in a different medium is called refraction.



• Lateral displacement depends on :
→ Refractive index of glass slab
→ Thickness of the glass slab

Laws of Refraction

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

(ii) **Snell's law:** The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for a light of given colour and for a given pair of media.

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

Refractive Index

When light passes from one medium to another medium, it changes its direction. The extent to which the direction changes is expressed in terms of refractive index. The value of refractive index is dependent on the speed of light in two media. v_1 is the speed of light in medium 1 and v_2 is the speed of light in medium 2. The refractive index of medium 2 with respect to medium 1 is represented as n_{21}.

$$\mu_{21} = \frac{\textbf{speed of light in medium 1}}{\textbf{speed of light in medium 2}} = \frac{v_1}{v_2}$$

If medium 1 is vacuum or air, then the refractive index of medium 2 with respect to vacuum is known as absolute refractive index of the medium.

$$\mu_m = \frac{\textbf{speed of light in vaccum/air}}{\textbf{speed of light in medium}} = \frac{c}{v}$$

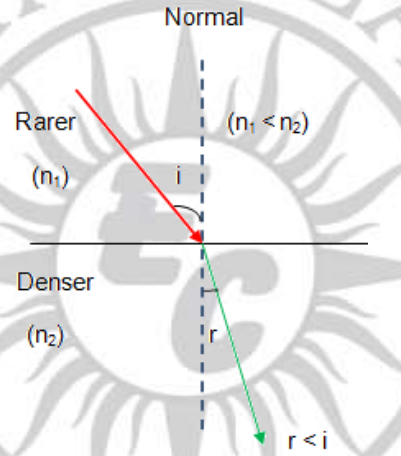
Where c is the speed of light in air, v is the speed of light in other medium and μ_m is the refractive index of the medium.

→ Refractive index of diamond is the highest till date. It is 2.42. It means speed of light is 1/2.42 times less in diamond than in vaccum.

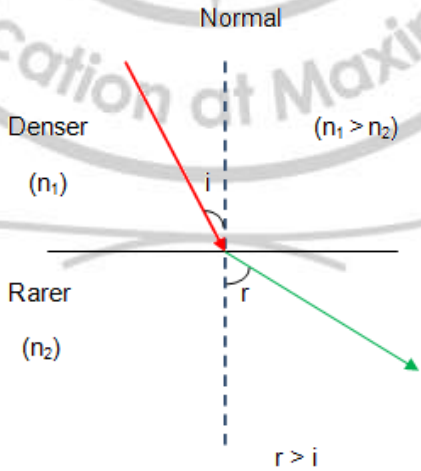
• **Optically denser medium:** Out of two given media, the medium with higher value of refractive index.

• **Optically rarer medium:** Out of two given media, the medium with lower value to refractive index.

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



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



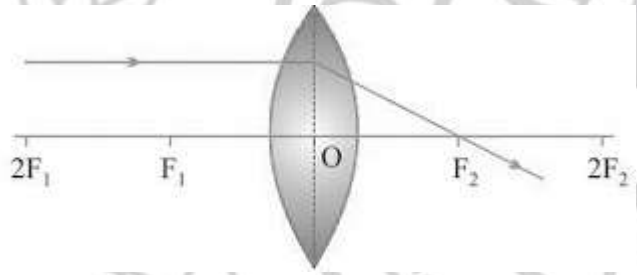
→ Refractive index of a medium does not depend on physical density.

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

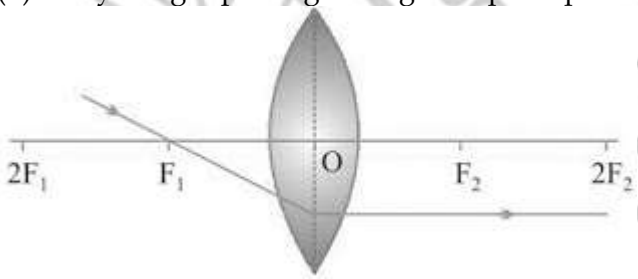
Convex Lens	Concave Lens
Thin from corners	Thick from corners
Thick at center	Thin at centre
Converging	Diverging

Rules for image formation by convex lens

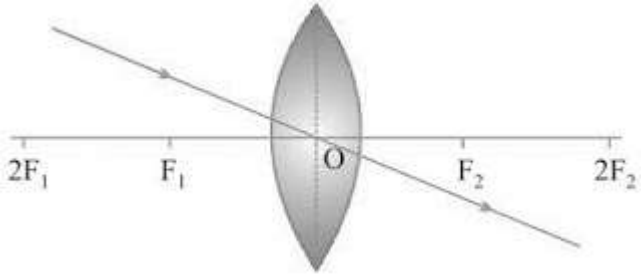
(i) A ray of light parallel to principal axis of a convex lens always pass through the focus on the other side of the lens.



(ii) A ray of light passing through the principal focus will emerge parallel to principal axis after refraction.

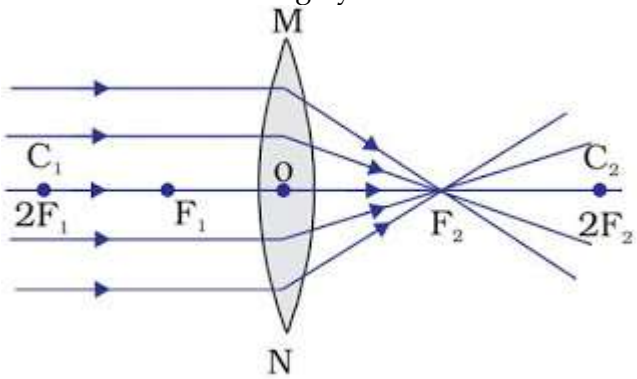


(iii) A ray of light passing through the optical center will emerge without any deviation.

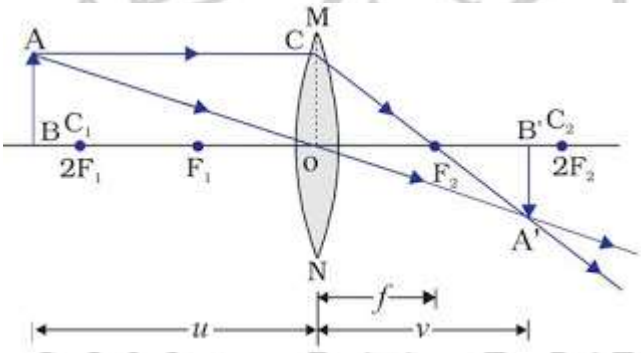


Ray Diagrams of Imag formed by Convex Lens

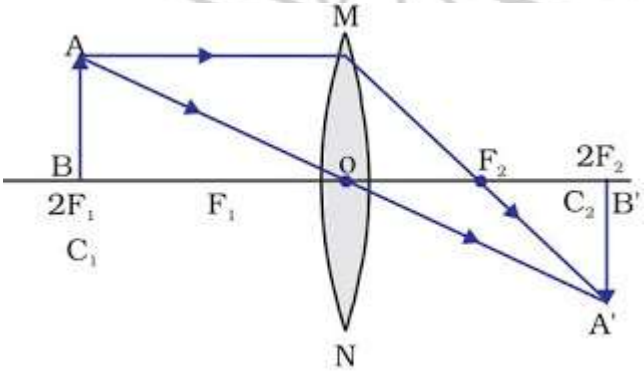
(i) When object is at infinity
Image Position − At 'F 2 '
Nature of image – Real, inverted
Size – Point sized or highly diminished



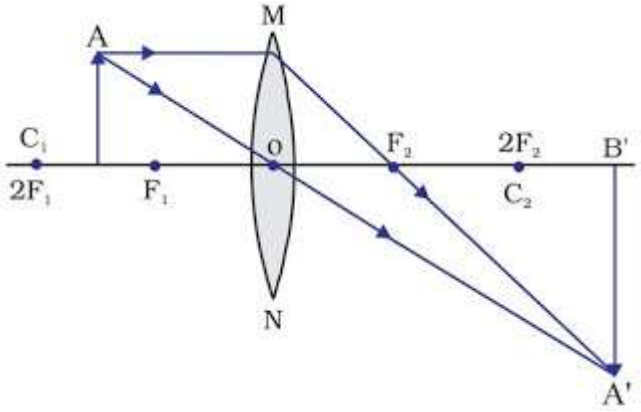
(ii) When object is beyond '2F1'
Image Position – Between 'F2' and '2F2'
Nature of image– Real, inverted
Size – Diminished



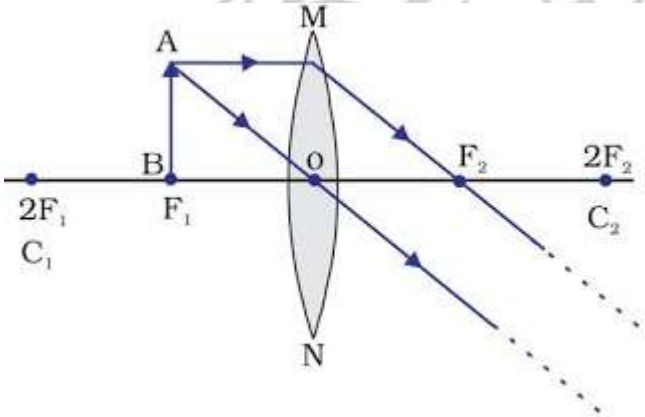
(iii) When object is at '2F1 '
Image Position – At '2F2 '
Nature of image – Real, inverted
Size – Same size



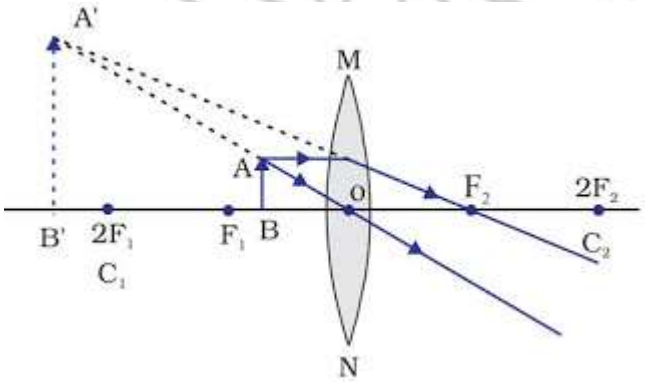
(iv) When object is between 'F1' and '2F1'
Image Position – Beyond '2F2'
Nature of image – Real, inverted
Size – Enlarged



(v) When object is at 'F1'
Image Position – At Infinity
Nature of image – Real, inverted
Size – Highly enlarged

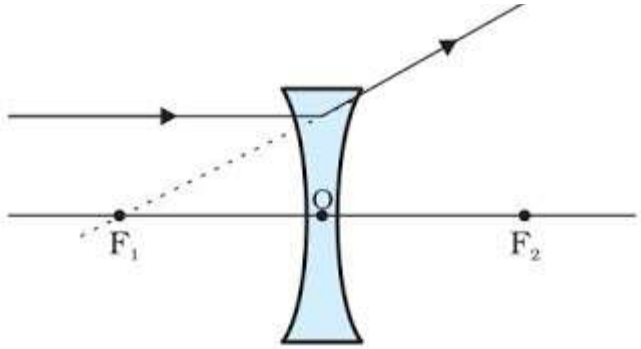


(vi) When object is between 'F1' and optical centre
Image Position – On the same side of the lens as object
Nature of image – Virtual and erect
Size – Enlarged

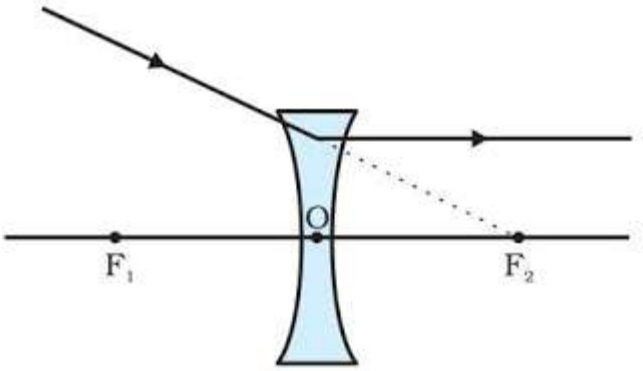


Rules for Image Formation by Concave Lens

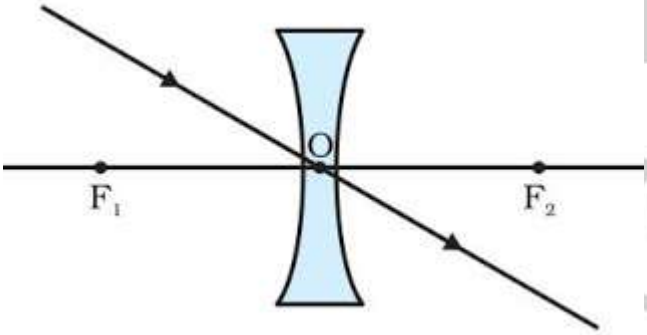
(i) A ray of light parallel to the principal axis appear to diverge from the principal focus located on the same side of the lens.



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



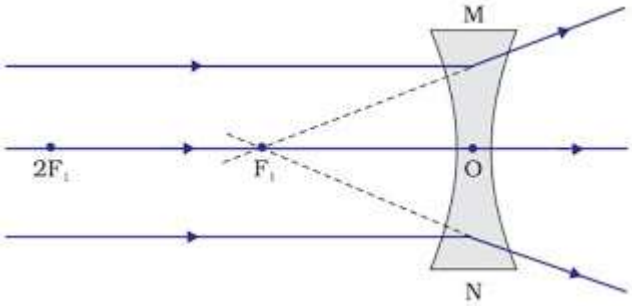
(iii) A ray of light passing through the optical centre of a lens will emerge without any deviation.



Ray Diagrams of Images Formed by a Concave Lens

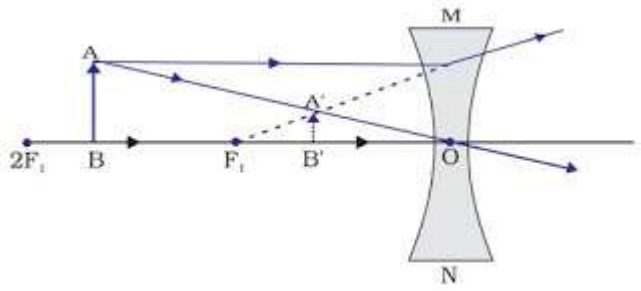
(i) When object is placed at infinity

Image Position − At 'F1'
Nature of image – Virtual, erect
Size – Point sized or highly diminished



(ii) When object is placed between infinity and optical centre

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



Sign convention for spherical lenses

• Sign conventions are similar to the one used for spherical mirrors, except that measurements are taken from optical center of the lens.

• Focal length of convex lens = Positive
Focal length of concave lens = Negative

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

Magnification
$m = h_i/h_o = v/u$

Power of a lens

→ It is defined as the reciprocal of focal length in meter.

→ The degree of convergence or divergence of light rays is expressed in terms of power.

Power (P) = $1/v - 1/u = 1/f$

→ SI unit of Power = dioptre = D

→ $1\ D = 1\ m^{-1}$

→ 1 dioptre is the power of lens whose focal length is one meter.

→ Power of convex lens = Positive

→ Power of concave lens = Negative

→ Power $\propto$ 1/(focal length or thickness)

→ Power of a lens combination (P) = $P_1 + P_2 + P_3$ .....

Practice questions

1. The following table gives the value of refractive indices of a few media.

	1	2	3	4	5	6
Medium	**Ice**	**Water**	**Kerosene**	**Flint glass**	**Ruby**	**Diamond**
Refractive index	**1·31**	**1·333**	**1·44**	**1·66**	**1·71**	**2·42**

   Name the medium having highest optical density and a medium having lowest optical density. (Similar to Text Book Question, CBSE 2012, 2016)
2. Refractive indices of kerosene, turpentine and water are 1.44, 1.47 and 1.333 respectively. Through which of these media, light travels fast ? Explain. (Similar to Text Book Question)
3. Since, refractive index of water (1.333) is less than the refractive indices of kerosene and turpentine, so light travels faster in water than in kerosene and turpentine. Refractive indices of media A, B, C and D are given below :

Media	Refractive index
A	1·33
B	1·44
C	1·52
D	1·65

   In which of these four media is the speed of light (i) maximum and (ii) minimum ? Find refractive index of medium D w.r.t. medium A. (New CBSE Sample Paper, CBSE 2011, 2013, 2016)
4. The following table gives the values of refractive indices of a few media

	1	2	3	4	5
Medium	**Water**	**Crown glass**	**Rock salt**	**Ruby**	**Diam**
Refractive index	**1·33**	**1·52**	**1·54**	**1·71**	**2·4**

   Use this table to give an example of (i) a medium pair so that light speeds up when it goes from one of these media to another, (ii) a medium pair so that light slows down when it goes from one of these media to another. (CBSE Sample Paper 2008)
5. Explain with the help of a diagram, why a pencil partly immersed in water appears to be bent at the water surface ? (CBSE (Delhi) 2008, 2011)
6. A ray of light, incident obliquely on a face of a rectangular glass slab placed in air, emerges from the opposite face parallel to the incident ray. State two factors on which the lateral displacement of the emergent ray depends. [Foreign]
7. An object 2 cm high is placed at a distance of 64 cm from a white screen. On placing a convex lens at a distance of 32 cm from the object it is found that a distinct image of the object is formed on the screen. What is the focal length of the convex lens and size of the image formed on the screen? Draw a ray diagram to show the formation of the image in this position of the object with respect to the lens.
8. The refractive index of water is 1.33 and the speed of light in air is 3 x 108 ms-1. Calculate the speed of light in water. [Foreign]
9. The refractive index of glass is 1.50 and the speed of light in air is 3 x 108 ms-1. Calculate the speed of light in glass. [Foreign]
10. At what distance should an object be placed from a convex lens of focal length 18 cm to obtain an image at 24 cm from it on the other side. What will be the magnification produced in this case?