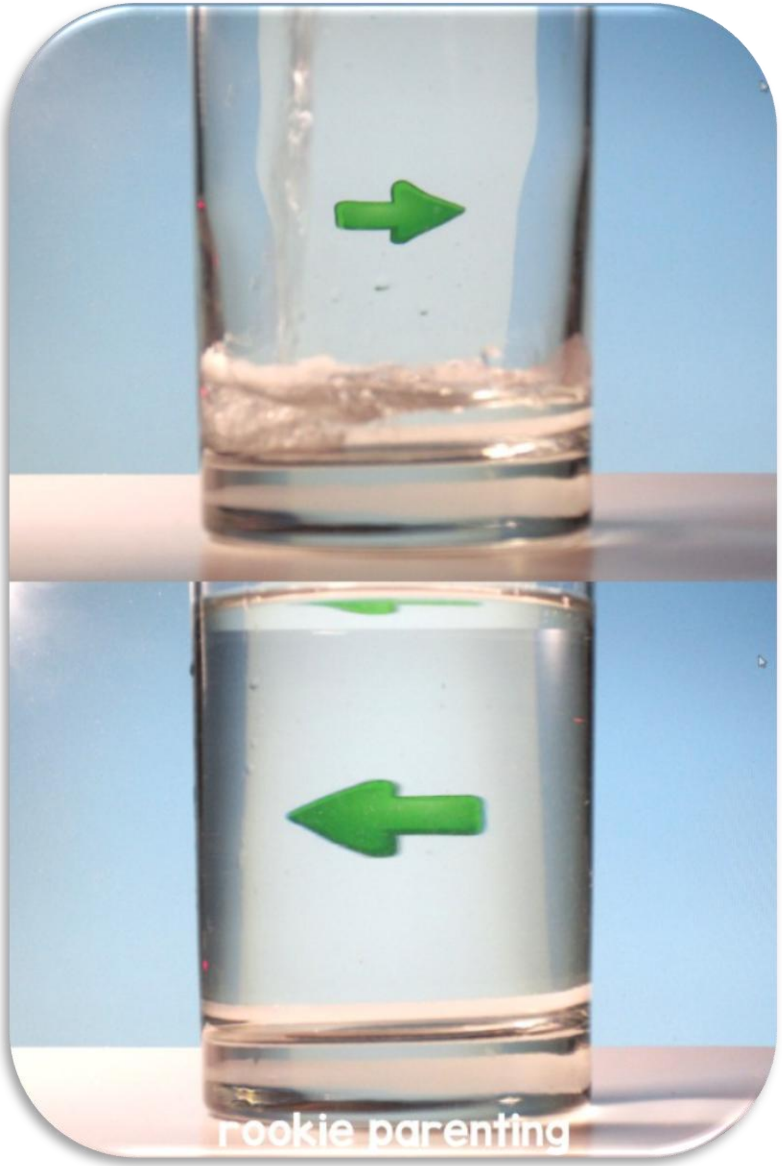
LIGHT { REFRACTION }

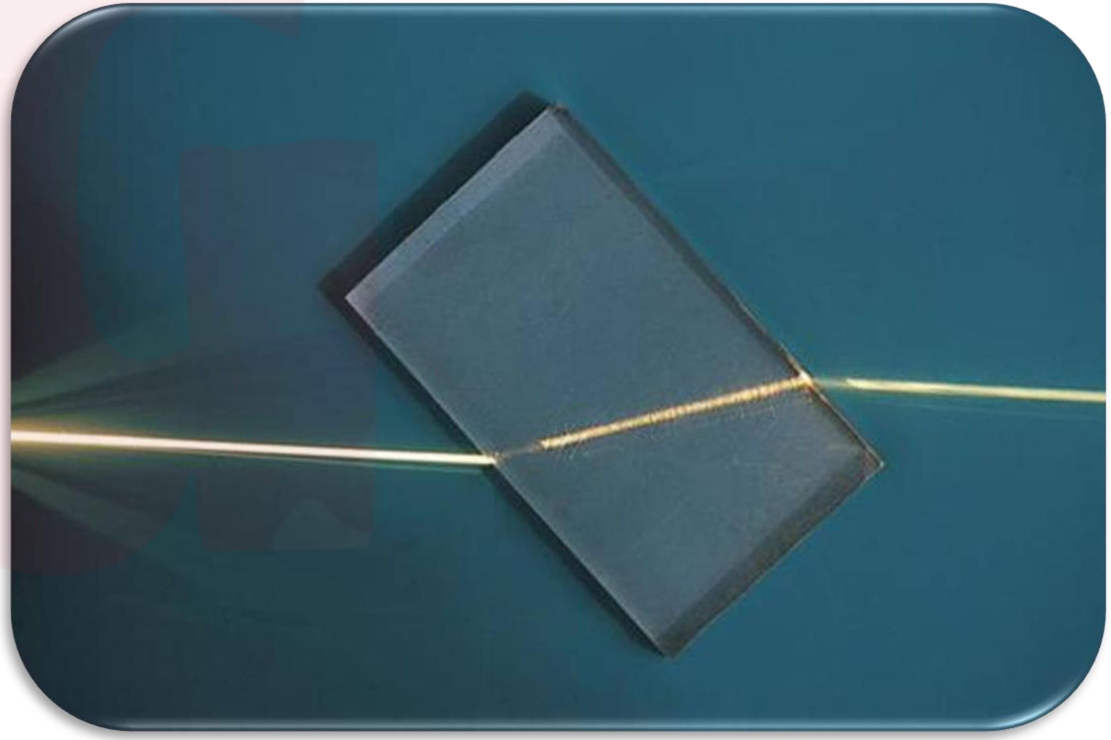


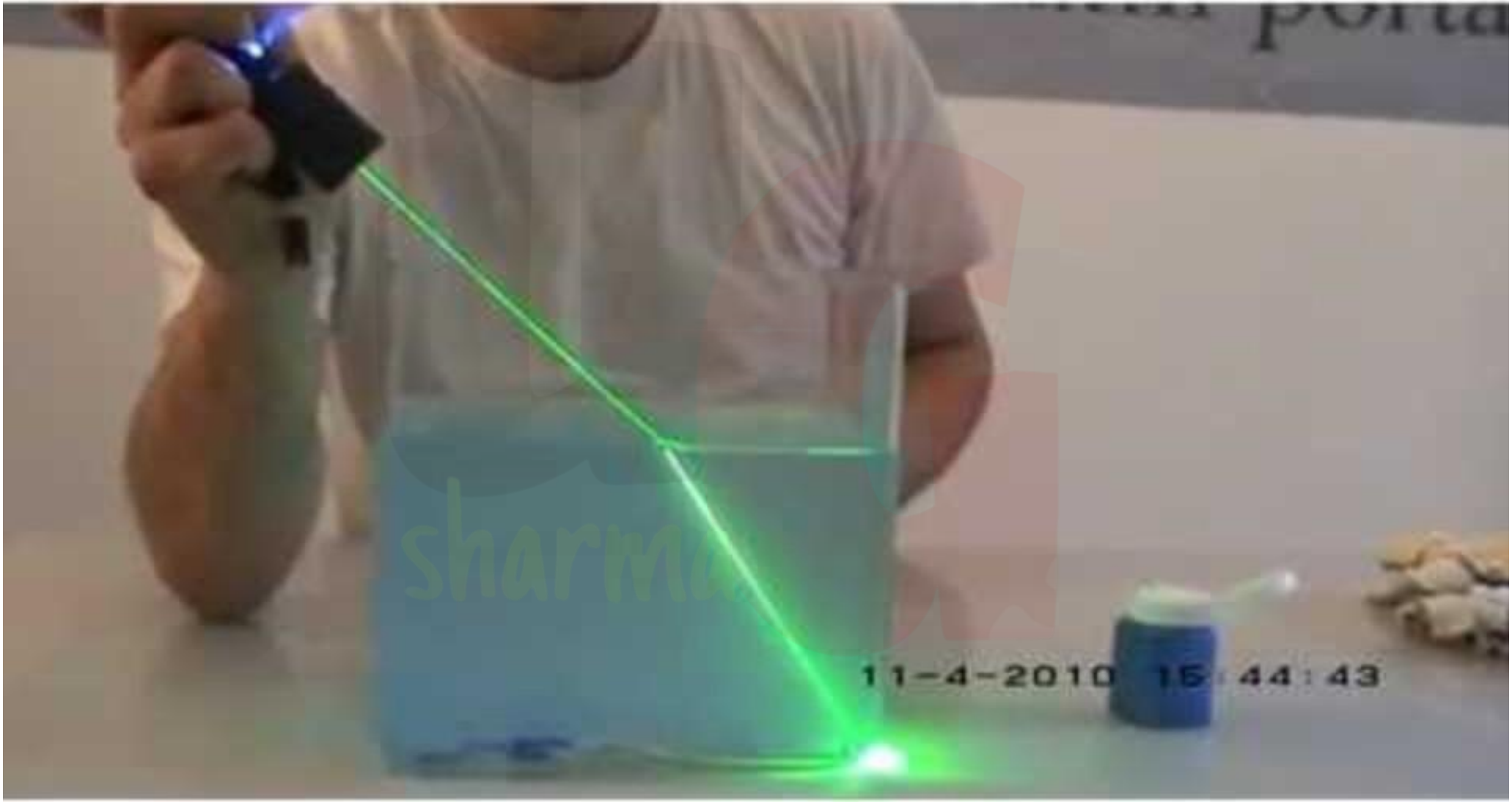
LIGHT { REFRACTION }

Refraction :- The bending of light when it passes from one medium to another is called refraction of light.

Although light travels in straight lines in a transparent material. It changes direction at the boundary between two medium.

The refraction of light is due to the change in the speed of light on going from one medium to another.

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Medium

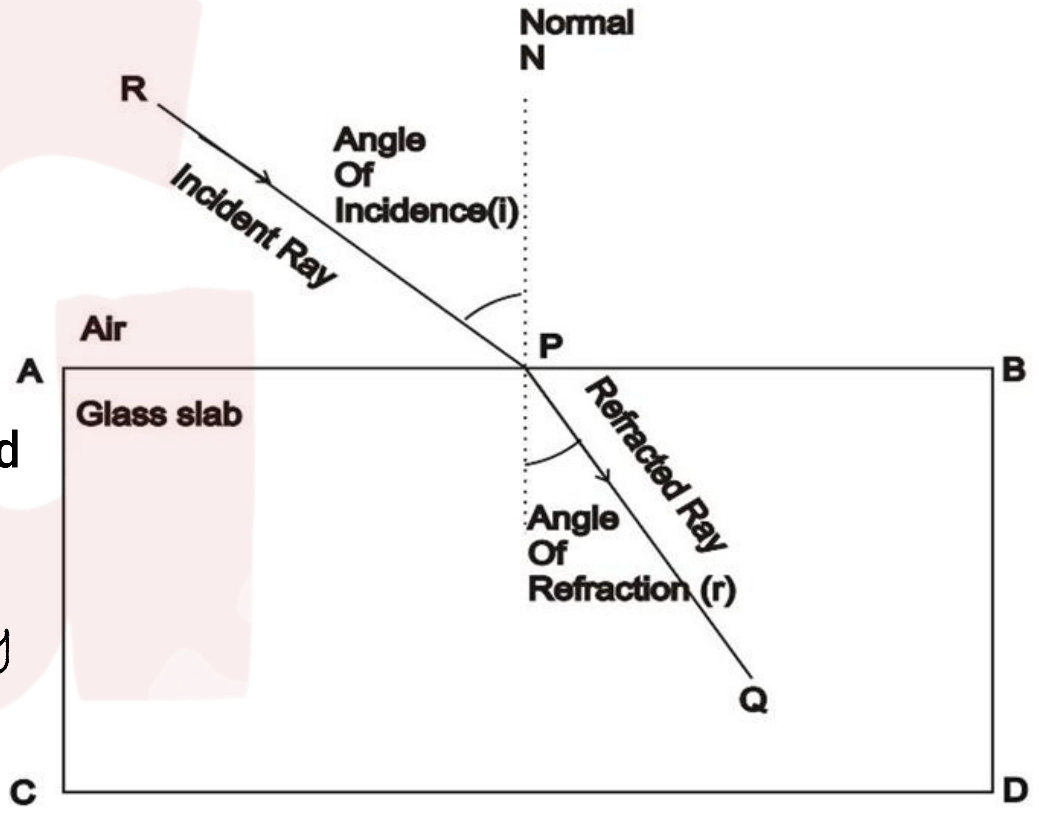
Medium :- A transparent Substance in which light travel is known as medium.
E.g :- Air, water, glass, alcohol, etc.

There are two types of medium :-

Optically rarer medium :- A medium in which the speed of light is more is known as optically rarer medium.

Optically denser medium :- A medium in which the speed of light is less is know as optically denser medium.

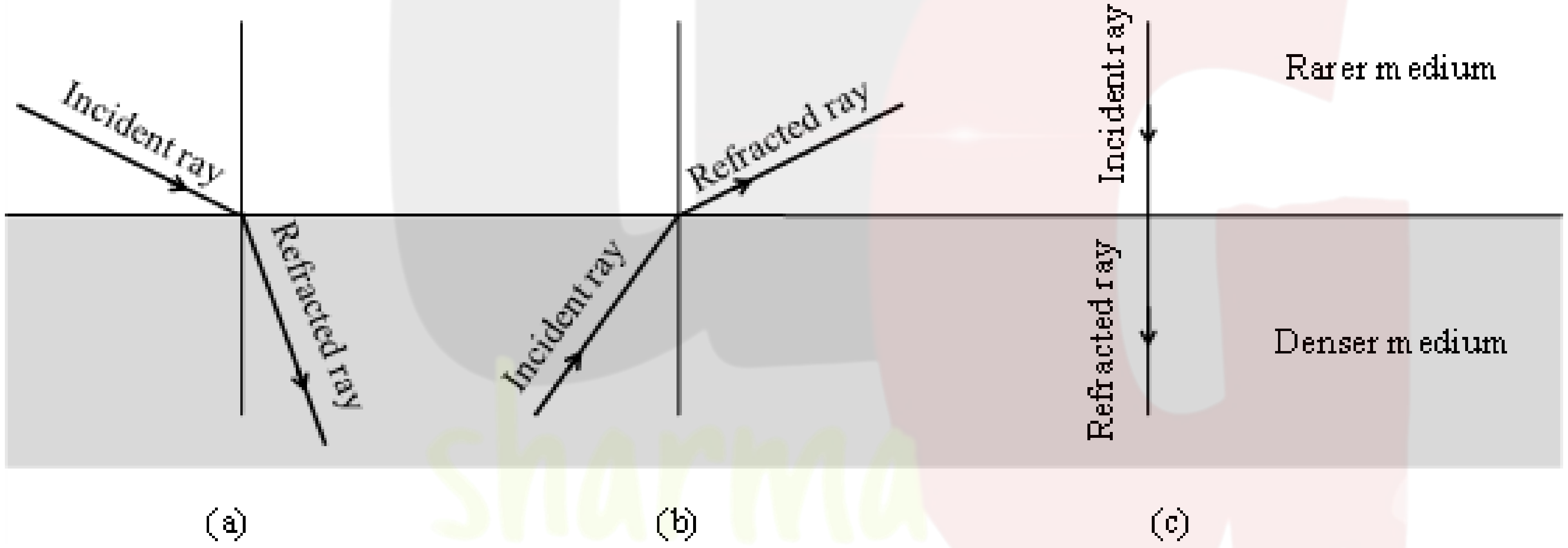
Water is optically denser medium than air but it is optically rarer than glass.



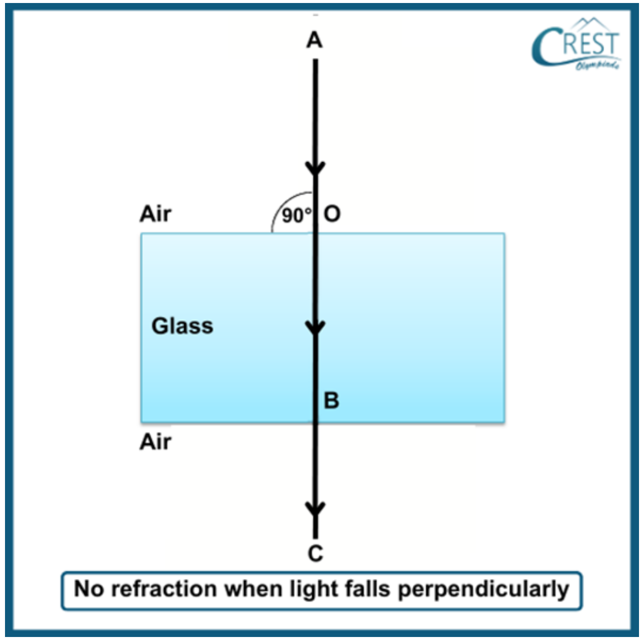
It is experimentally found that :-

- When a ray of light goes from rarer medium to denser medium, it bends towards normal.

- When a ray of light goes from denser medium to rarer medium, it bends away from normal.



Behaviour of a light ray when it moves from one medium to another



- If the incident ray fall normally or perpendicularly to the surface of a medium, then there is no bending of the ray of light, and it goes straight

- The perpendicular distance between original path of incident ray and the emergent ray coming out of the glass slab is called lateral displacement of the emergent ray of light.

- Lateral displacement is directly proportional to angle of incidence, thickness of glass slab, and refractive index.

- The angle which emergent remakes with normal is called angle of emergence.

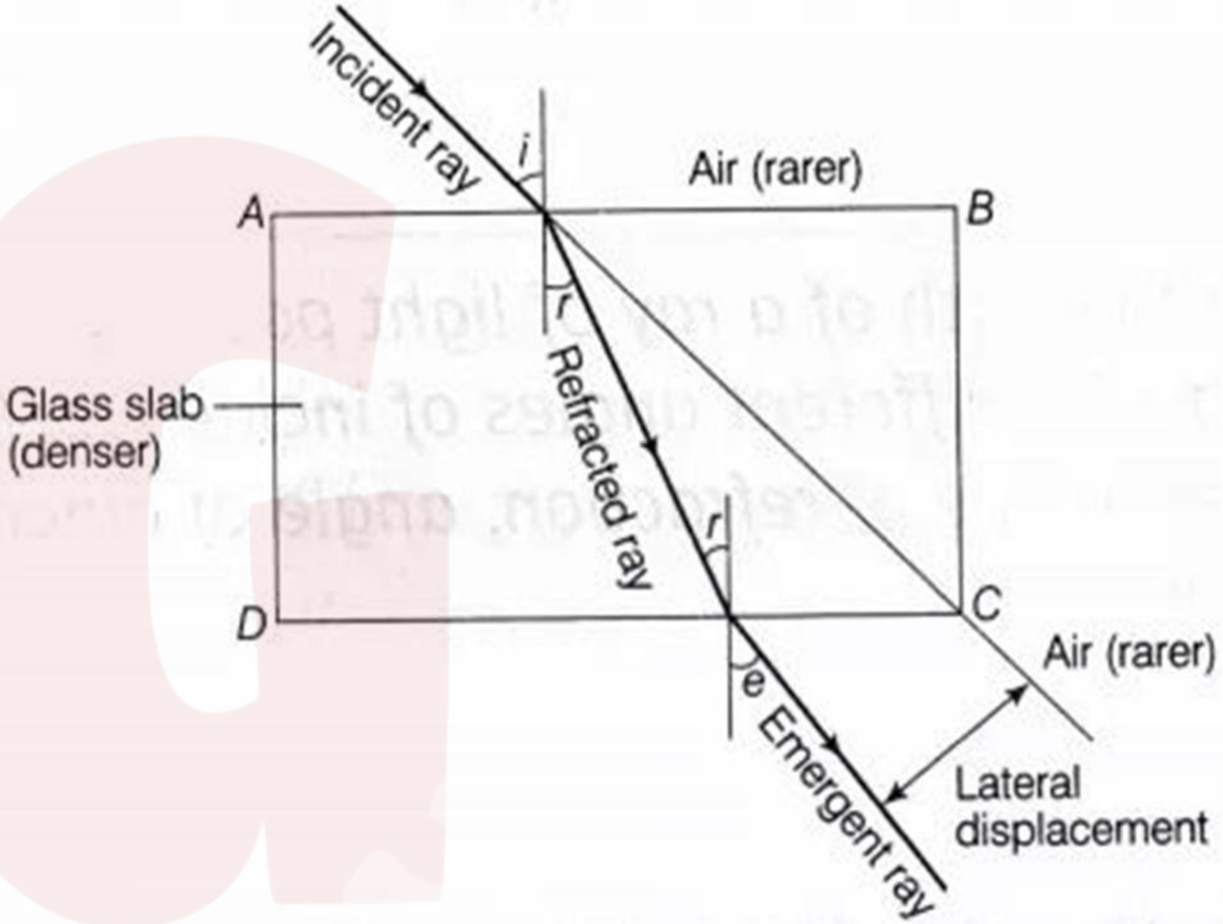


Fig. 2 Refraction through a rectangular glass slab

Laws of Refraction

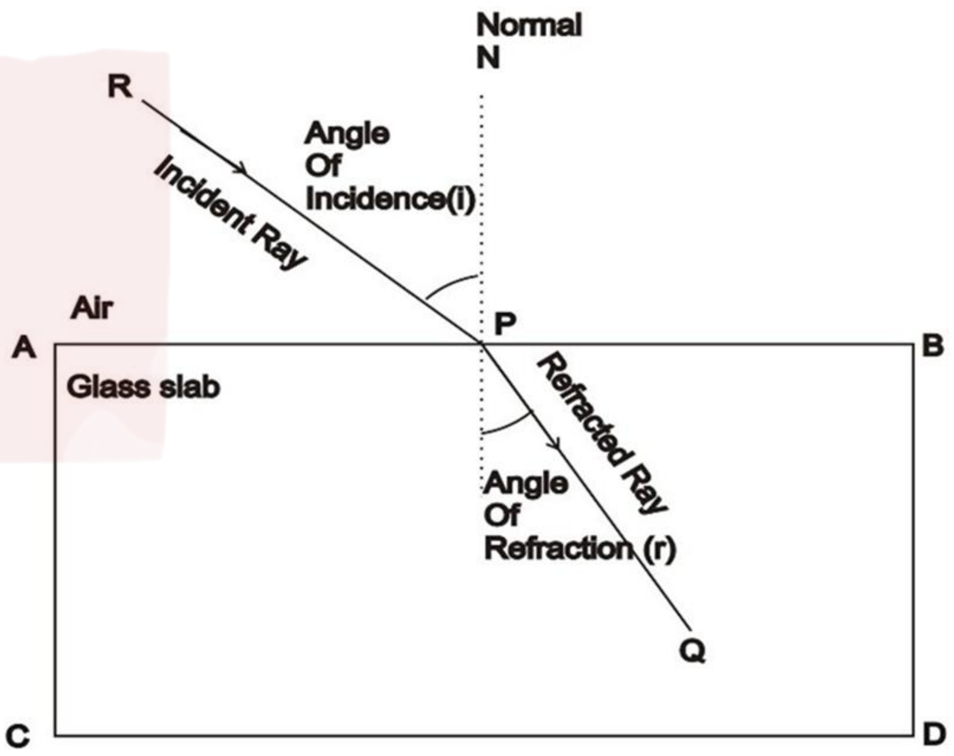
1. The incident ray, the reflected ray and the normal to the interface of two transparent media at the point of incidence, all lies in the same plane.

2. The ratio of sign of angle of incidence to sign of angle of refraction is a constant, for the light of a given colour and for the given pair of media.

   This law was given by snell in 1621. So, this law is known as Snell 's law of refraction.

$$\frac{\text{Sin i}}{\text{Sin r}} = n = \text{Constant}$$

This constant is known as refractive index.



Refractive index :- The amount of change in the speed of light in medium depends upon the properties of the medium. This property is known as refractive index of medium.

Refractive index and speed of light

- The refractive index (n) can also be written as a ratio of speed of light into media.
- The relative refractive index, in simple terms, describes how much the speed of light changes when it moves from one medium to another

Relative Refractive index :-

When light is going from one medium (other than vacuum or air) to another medium then the value of refractive index is called relative refractive index.

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

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

$n_{21} = v_1/v_2$

Refractive index is also denoted by ${}_1n_2$ / ${}^1n_2$ or ${}_1\mu_2$ ${}^1\mu_2$

Refractive index and speed of light

Absolute Refractive index :-

When light is going from vacuum or air to another medium then the value of refractive index is called absolute refractive index.

If Medium 1 is vacuum,

our formula becomes

$$n = c/v$$

$$\textit{Refractive index of Medium 2 with } \textbf{\textit{respect to Vacuum}} = \frac{\text{Speed of Light in Vacuum}}{\text{Speed of Light in Medium 2}}$$

n = absolute reproductive index
C = speed of light in vacuum
V = speed of light in medium

$$\textbf{\textit{Absolute Refractive index of Medium 2}} = \frac{\text{Speed of Light in Vacuum}}{\text{Speed of Light in Medium 2}}$$

Absolute refractive index is also denoted by μ

Refractive index and speed of light

- Absolute refractive index of a medium is always greater than 1.
- Relative refractive index may be greater than 1 or less than 1
- If any two media are optically exactly the same, then no bending occurs when light passes from one medium to another.
- A substance having higher refractive index is optically denser than another substance having lower refractive index.

The refractive index for light going from medium 1 to medium 2 is equal to the reciprocal of the refractive index from for light going from medium 2 to medium 1.

$$n_{21} = \frac{1}{n_{12}}$$

Absolute Refractive Index of Different Materials

Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Canada Balsam	1.53
Ice	1.31		
Water	1.33	Rock salt	1.54
Alcohol	1.36		
Kerosene	1.44	Carbon disulphide	1.63
Fused quartz	1.46	Dense flint glass	1.65
Turpentine oil	1.47	Ruby	1.71
Benzene	1.50	Sapphire	1.77
Crown glass	1.52	Diamond	2.42

Questions

Question 2 Page 176 - Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass? The speed of light in vacuum is 3 × 10 8 m s –1

View Answer

Question 3 Page 176 - Find out, from Table 10.3, the medium having highest optical density. Also find the medium with lowest optical density

View Answer

Question 4 Page 176 - You are given kerosene, turpentine and water. In which of these does the light travel fastest? Use the information given in Table 10.3

View Answer

Question 5 Page 176 - The refractive index of diamond is 2.42. What is the meaning of this statement?

View Answer

- If refractive index of water is 4/3 and that of glass is 3/2. Find the refractive index of glass w.r.t. water.

- Solution: $\mu_w = 4/3$, $\mu_g = 3/2$

Refractive index of glass w.r.t. water $({}^w\mu_g) = {}^a\mu_g \, / \, {}^a\mu_w$

$= 3/2 \, / \, 4/3$

$= 3/2 \times 3/4$

$= 9/8$

- The refractive index of water is 1.33. The speed of light in water will be
  (a) 1.33×10^8 m/s
  (b) 3×10^8 m/s
  (c) 2.26×10^8 m/s
  (d) 2.66×10^8 m/s (Ans c)

- You are given three media A, B and C of refractive index 1.33, 1.65 and 1.46. The medium in which the light will travel fastest is
  (a) A
  (b) B
  (c) C
  (d) equal in all three media (Ans a)

- The refractive index of water is 1.33. The speed in water will be
  (a) 1.33×10^8 m/s
  (b) 3×10^8 m/s
  (c) 2.26×10^8 m/s
  (d) 2.66×10^8 m/s (Ans c)

- Light ray enters from medium A to medium B and bends away from the normal. The refractive index of medium B relative to A will be
  (a) greater than unity
  (b) less than unity
  (c) equal to unity
  (d) zero

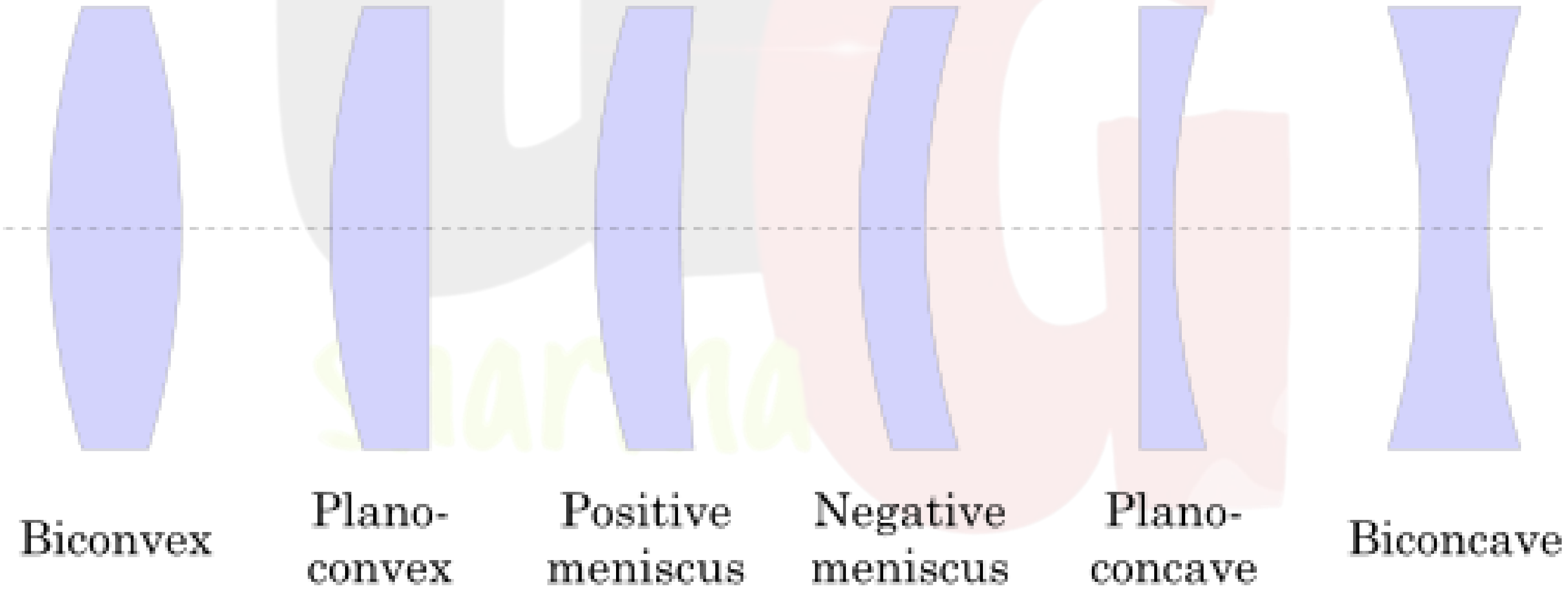
NUMERICALS

1. The refractive index of medium 'X' with respect to medium 'Y' is 2/3 and refractive index of medium 'Y' with respect to medium 'Z' is 4/3. Find the refractive index of medium 'Z' with respect to medium 'X'.
2. The refractive index of water with respect to air is 4/3. What is the refractive index of air with respect to water?
3. The refractive index of glass with respect to air is 1.65 and that of water w.r.t air is 1.33. Calculate refractive index of water w.r.t to glass.
4. In an experiment with a glass slab, a student observed that a ray of light incident at an angle of 60°with the normal on one face of the slab, after refraction, strikes the opposite face of the slab before emerging out in air making an angle of 42°with the normal. Draw a labelled diagram to show the path of this ray. What would be the value of angle of refraction and angle of emergence?
5. Refractive index of water and benzene w.r.t air are 1.33 and 1.50 respectively. Calculate refractive index of benzene w.r.t water?
6. The absolute refractive index of 2 media 'A' and 'B' are 2.0 and 1.5 respectively. If the speed of light in medium 'B' is 2×10^{8} m/s, calculate the speed of light in: (i) vacuum (ii) medium 'A'.
7. The absolute refractive index of glass and water are 4/3 and 3/2 respectively. If the speed of light in glass is 2×10^{8} m/s, calculate the speed of light in: (i) vacuum (ii) water.
8. If the angle of incidence (i) for a light ray in air be 45°and the angle of refraction (r) in glass be 30°, find the refractive index of glass w.r.t air.
9. Refractive index of air w.r.t is 1.33. What is the value of refractive index of air w.r.t water?

LENS

A lens is a piece of transparent glass bound by two spherical surface.

The working of a lens is based on the refraction of light rays when they pass through it.

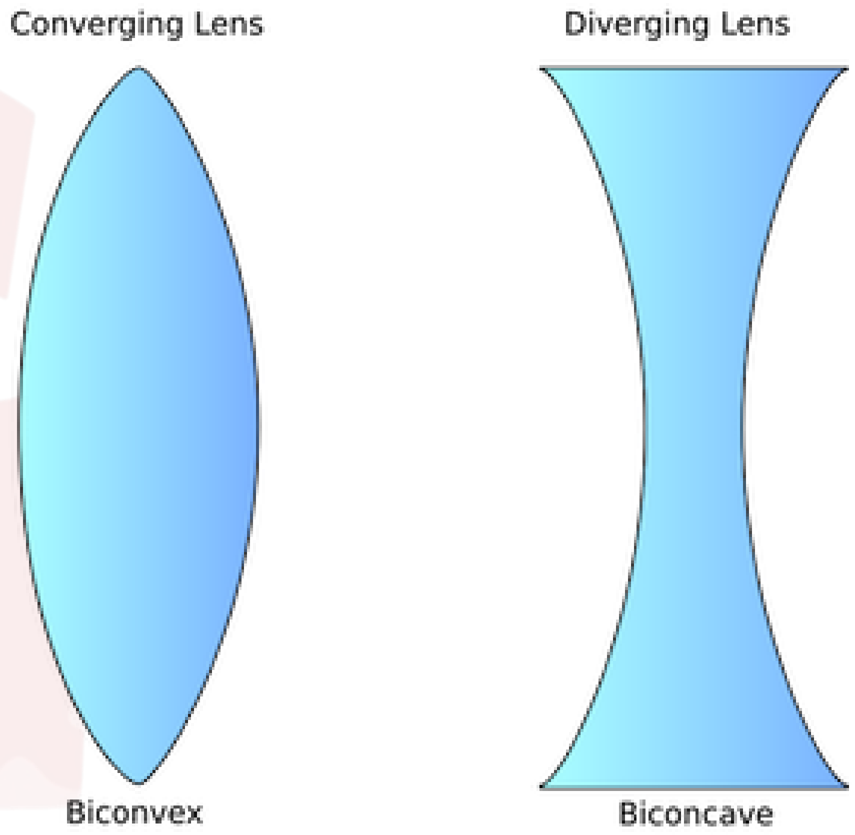


lens

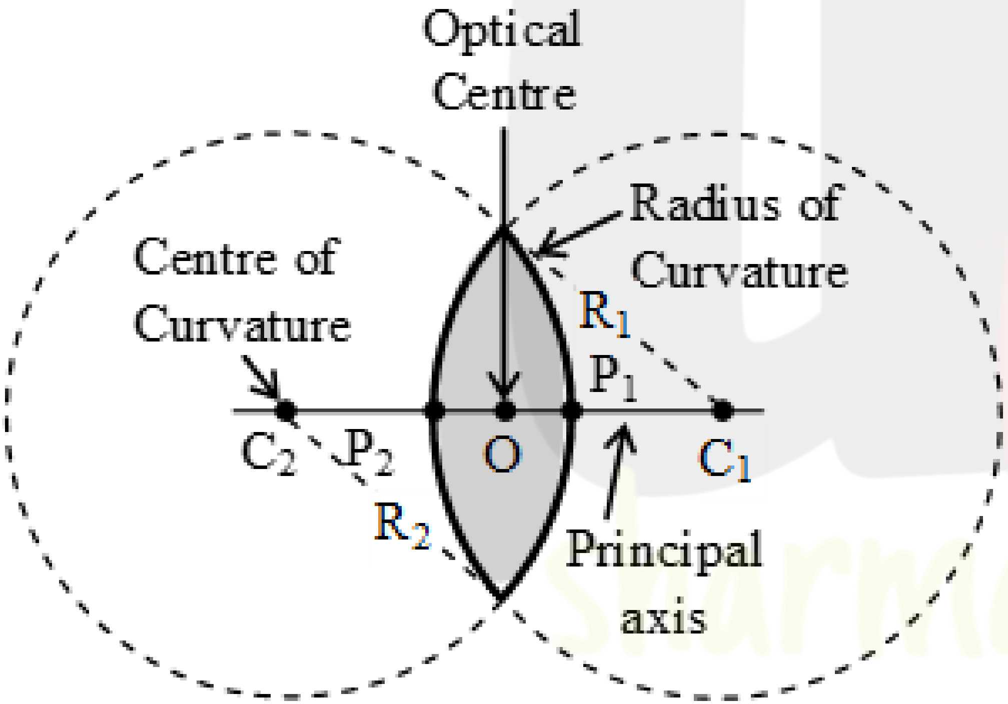
- Convex lens (Converging lens)
- Concave lens (Diverging lens)

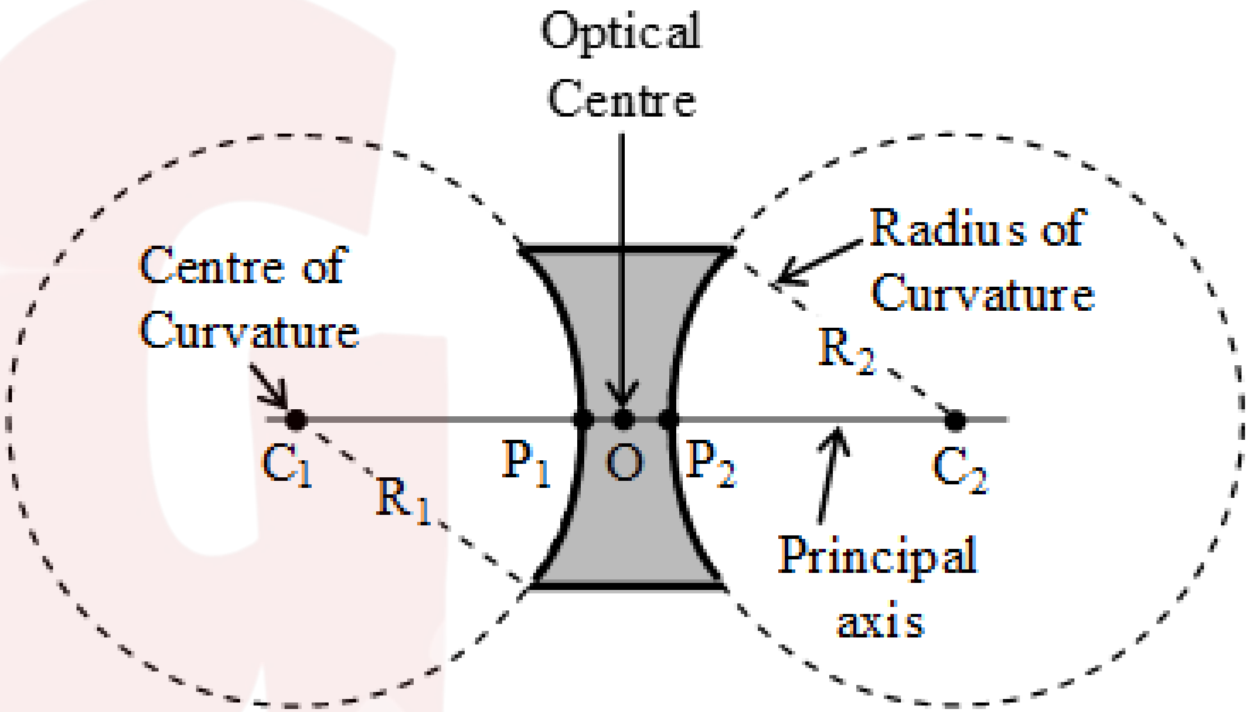
Convex lens :- A lens that is thick at the center and thin at the edges is called a convex lens. Also known as converging lens.

Concave lens :- A lens that is thin in the middle and thick at the edges is called a concave lens. Also known as diverging lens.



Terminology related to spherical lenses





Optical center (O): The central point of the lens, where the principal axis intersects.

Centres of Curvature:

The centres of the two imaginary spheres of which the lens is a part are called **centre of curvature** of the lens. It represented by C_1, C_2. A lens has two centres of curvature with respect to its two curved surfaces.

Radii of Curvature:

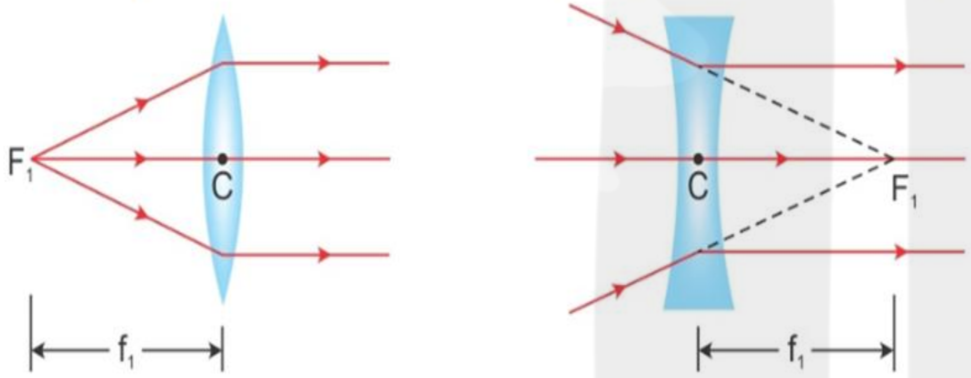
The radii of the two imaginary spheres of which the lens is a part are called **radii of curvature** of the lens. A lens has two radii of curvature. These may or may not be equal.

Principal Axis:

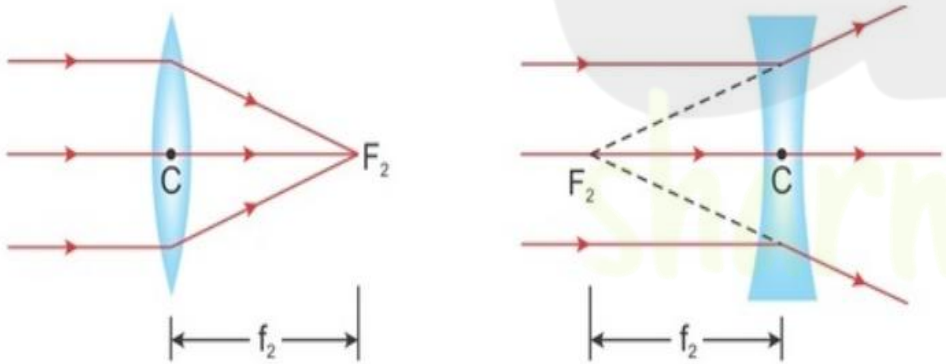
Lens is bounded by two spherical surfaces, and therefore, has two centres of curvature c_1 and c_2. The imaginary line joining them is called the **Principal Axis** of the lens.It passes through the optical centre.

Principal Focus

First Principal Focus It is a point on the principal axis of lens, the rays starting from or directed to which become parallel to principal axis after refraction.



Second Principal Focus It is the point on the principal axis at which the rays coming parallel to the principal axis converge on the other side of lens (convex) or appear to meet on the same side of lens (concave) after refraction from the lens.



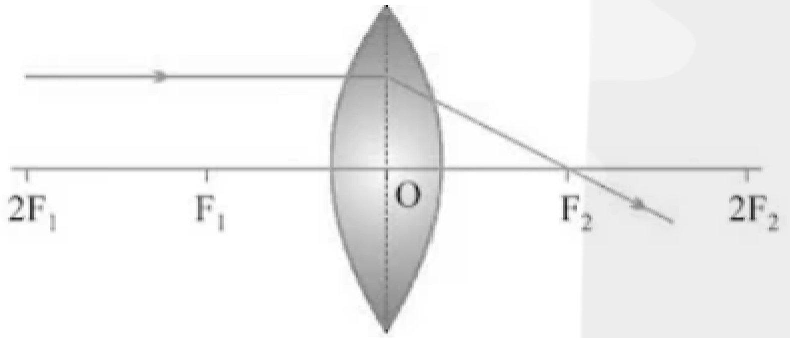
Both the foci of convex lens are real while that of concave lens are virtual.

Focal Length:

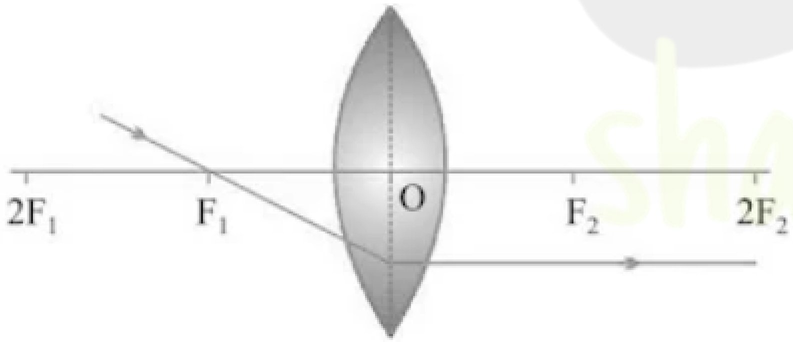
The distance between optical centre of a lens and the point where the parallel beam of light converge or appear to diverge from i.e. focus is called **focal length.**

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.

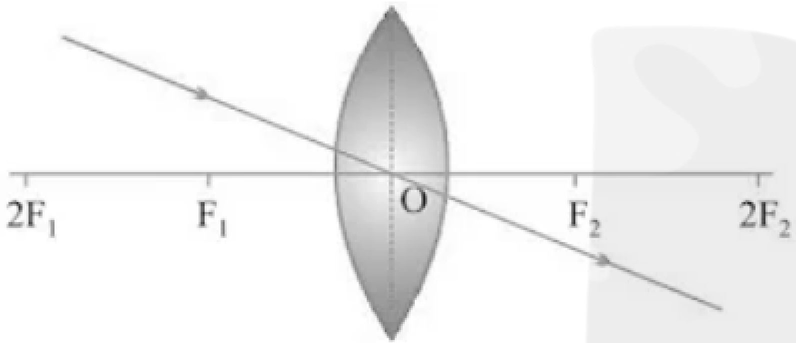


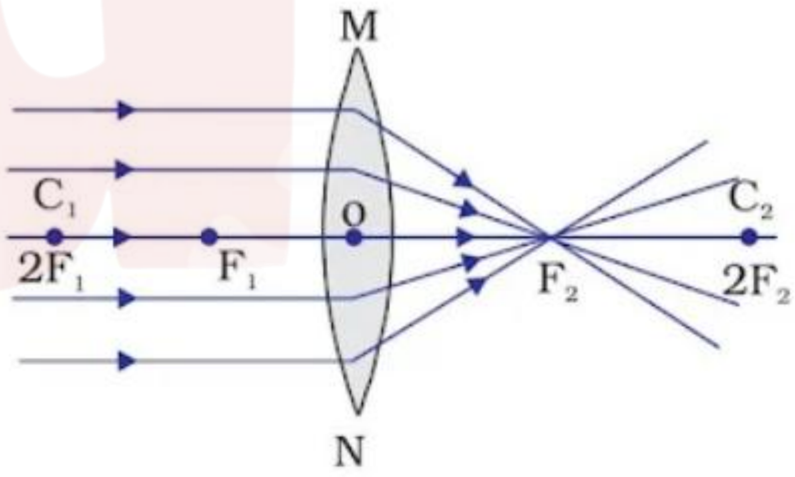
Image formed by convex lens

(i) When object is at infinity

Image Position – At 'F 2'

Nature of image – Real, inverted

Size – Point sized or highly diminished

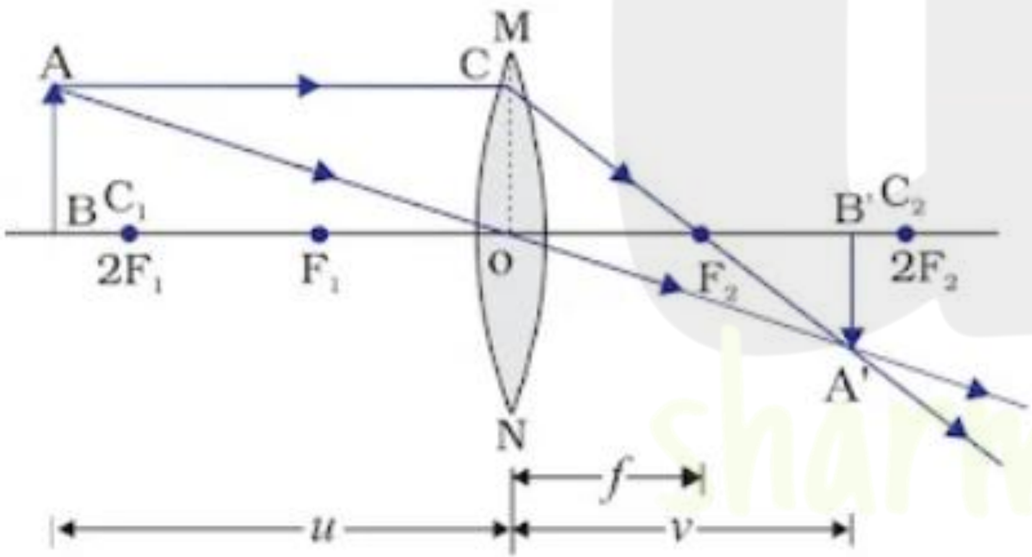


(ii) When object is beyond '2F1'

Image Position – Between 'F2' and '2F2'

Nature of image– Real, inverted

Size – Diminished

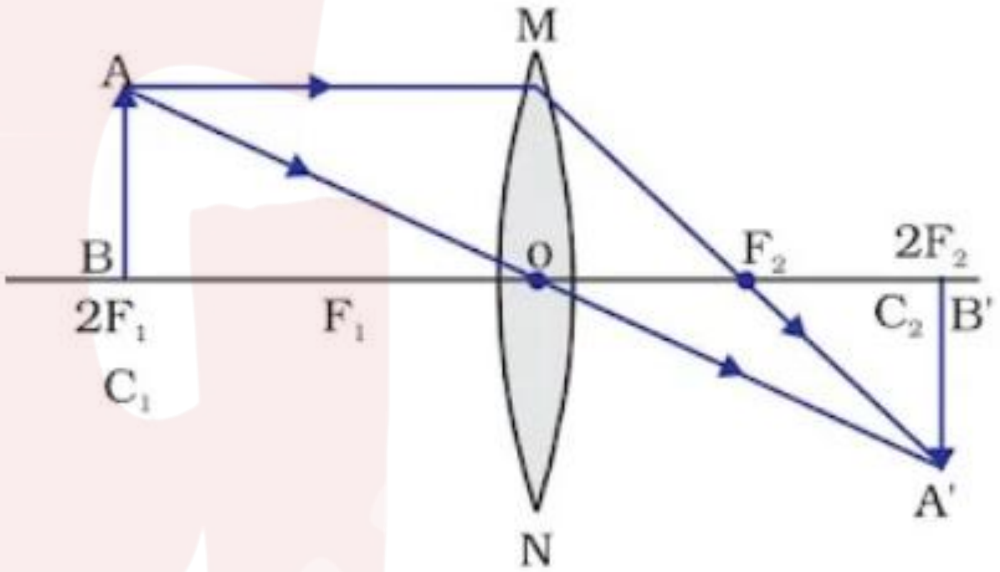


(iii) When object is at '2F1 '

Image Position – At '2F2 '

Nature of image – Real, inverted

Size – Same size

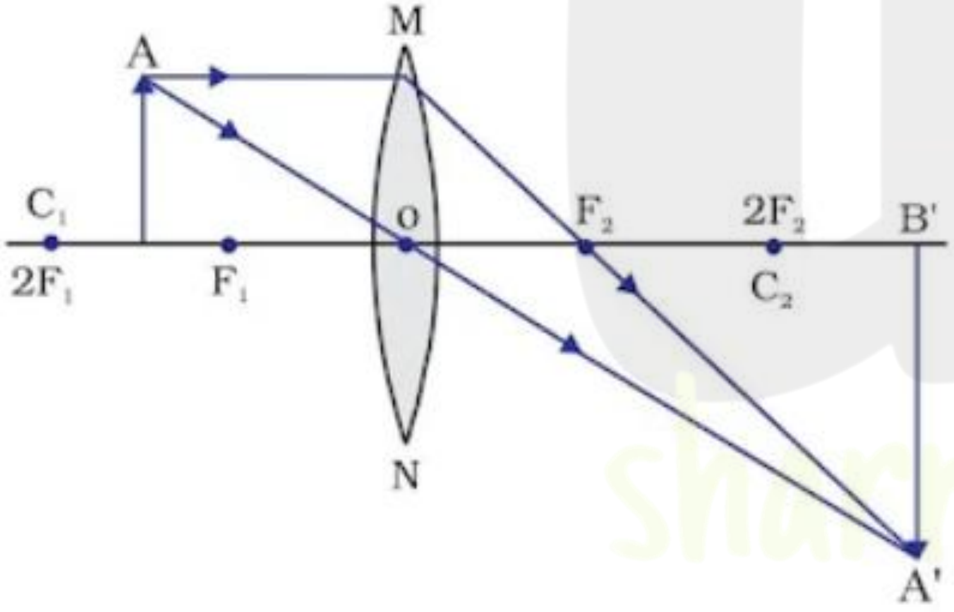


(iv) When object is between ‘F1’ and ‘2F1’

Image Position – Beyond ‘2F2’

Nature of image – Real, inverted

Size – Enlarged

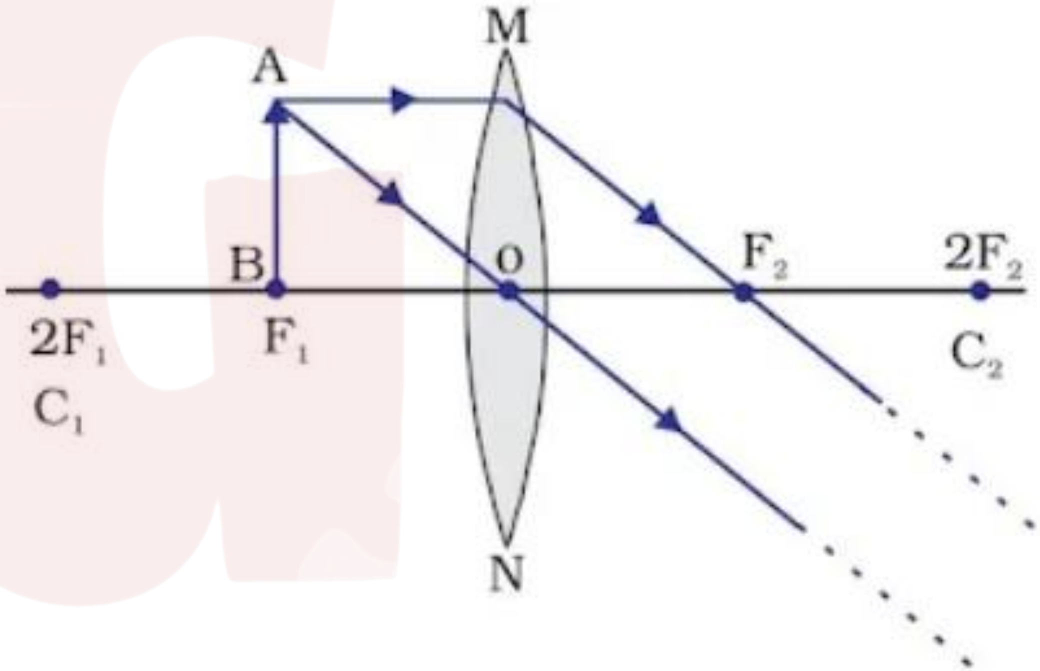


(v) When object is at ‘F1’

Image Position – At Infinity

Nature of image – Real, inverted

Size – Highly enlarged

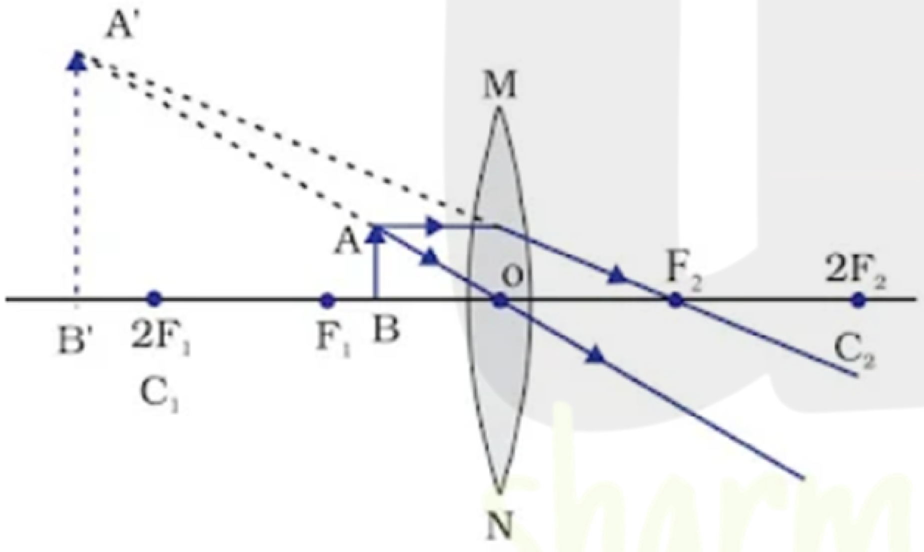


(vi) When object is between 'F1' and optical centre

Image Position – On the same side of the lens as object

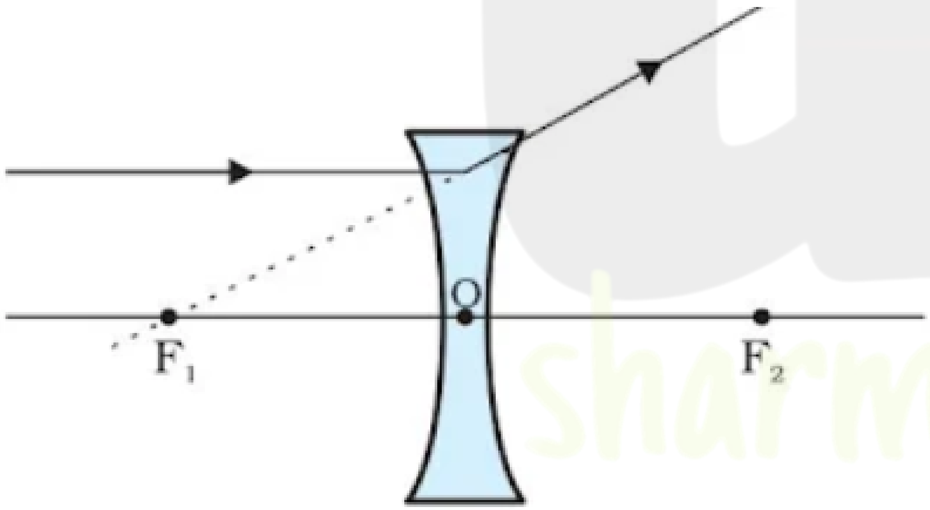
Nature of image – Virtual and erect

Size – Enlarged

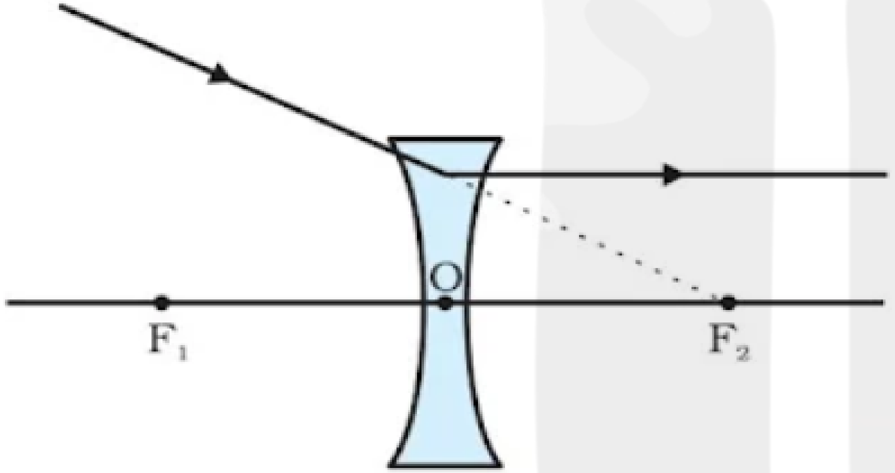


Rules for image formed concave mirror

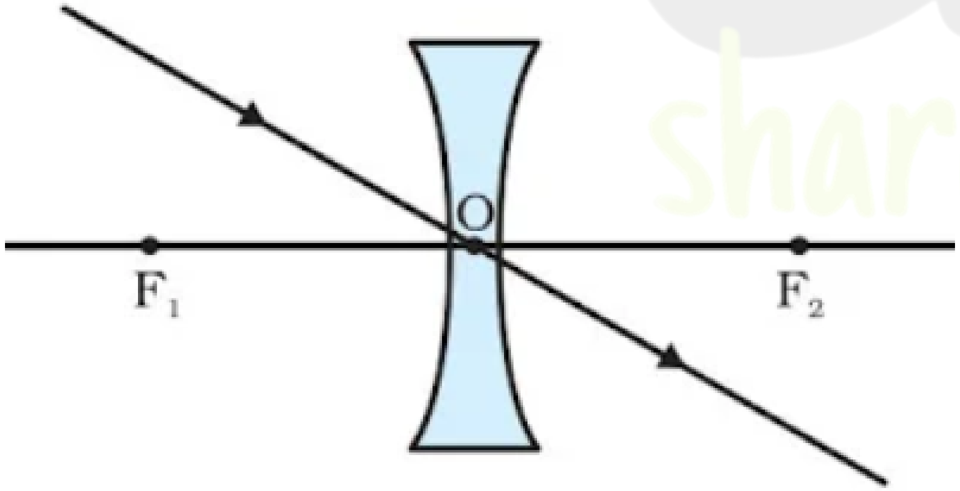
(i) A ray of light parallel to the principal axis appear to diverge from the principal focus located on the same side of the lens.



(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.



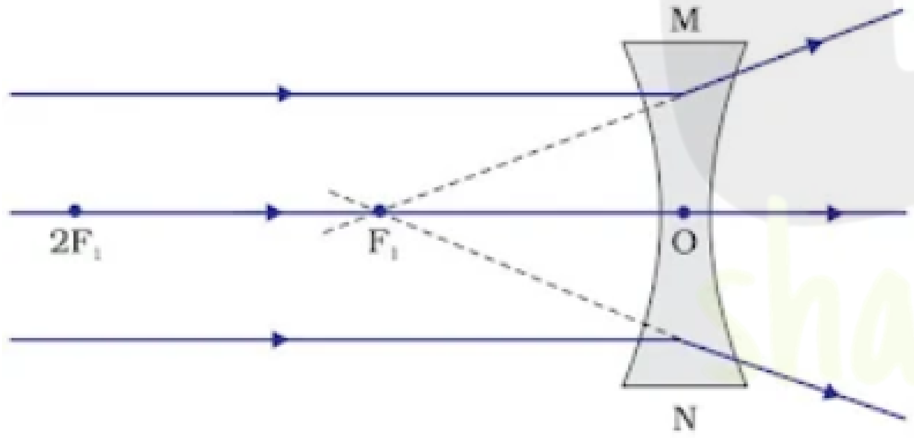
Ray Diagrams of Images Formed by a Concave Lens

(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

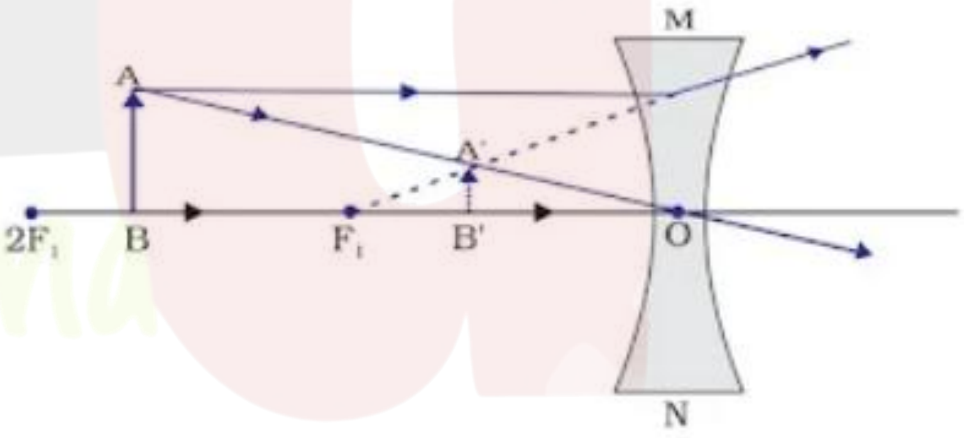


Table 9.4 Nature, position and relative size of the image formed by a convex lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Image would not be formed	
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

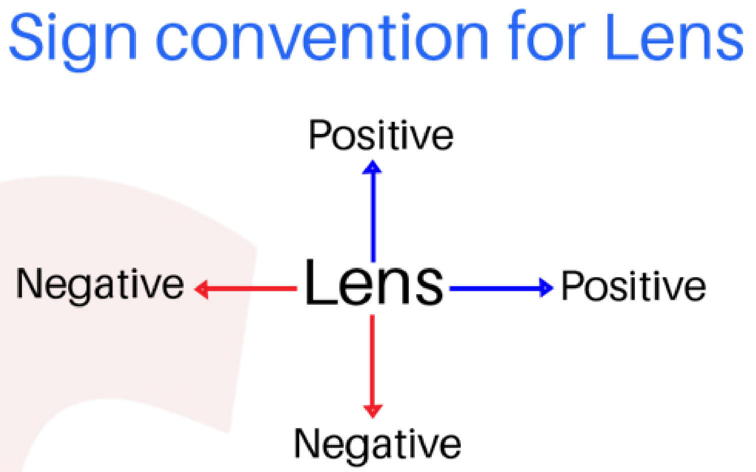
Table 9.5 Nature, position and relative size of the image formed by a concave lens for various positions of the object

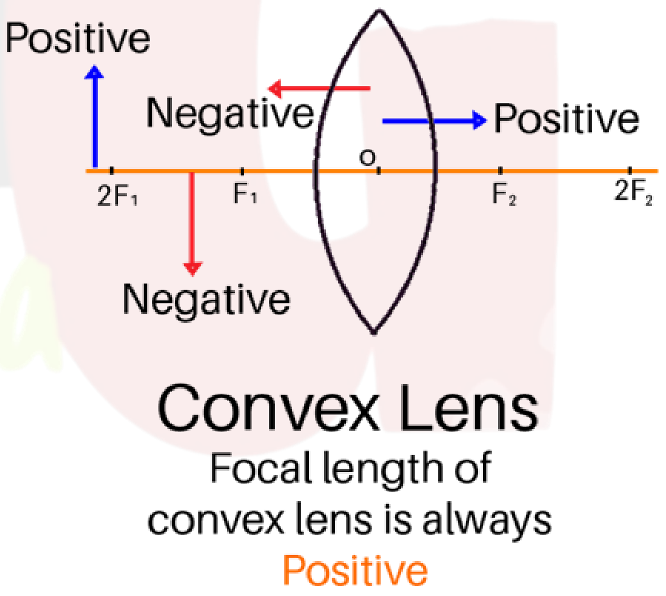
Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between focus F_1 and optical centre O	Diminished	Virtual and erect

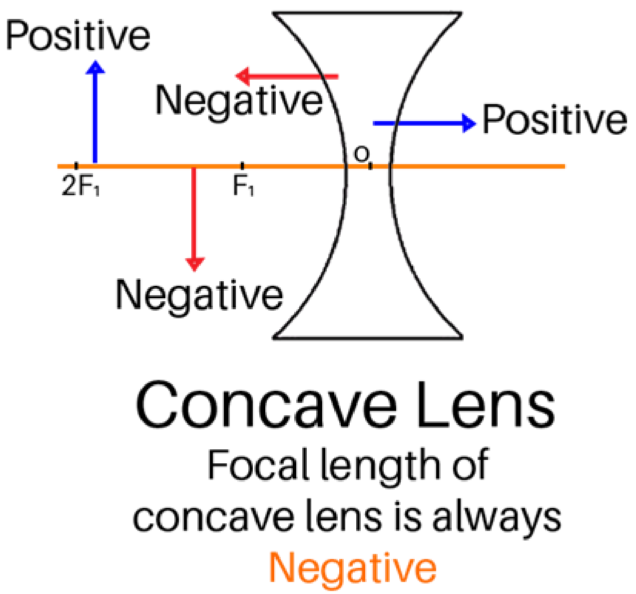
Sign convention for spherical lenses

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

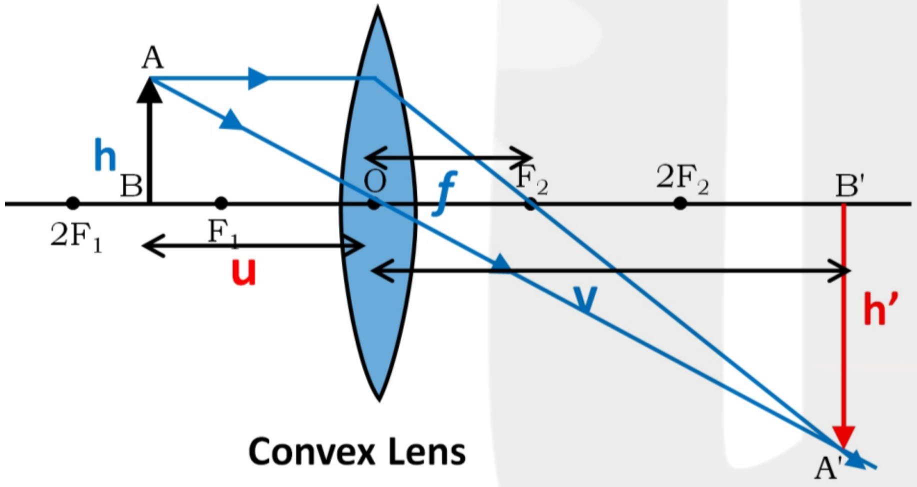
- Focal length of convex lens = Positive
Focal length of concave lens = Negative



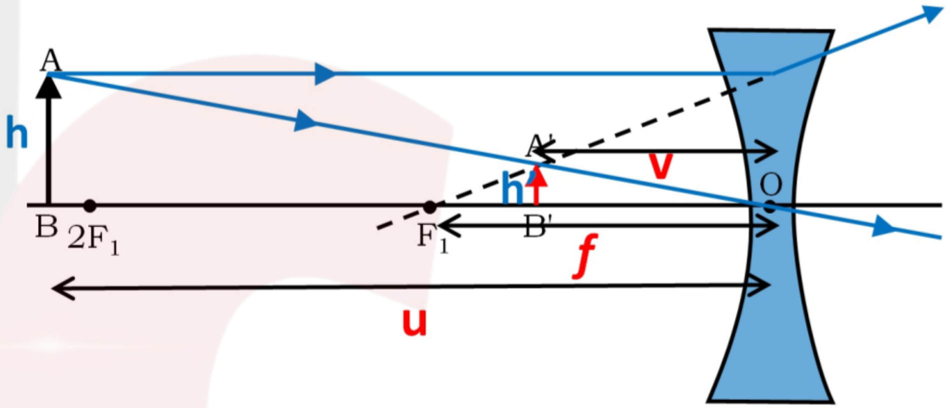




Lens Formula and Magnification



Convex Lens



Concave Lens

Lens Formula:

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

Magnification

$$m = \frac{Height\ of\ image}{Height\ of\ Object}$$

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

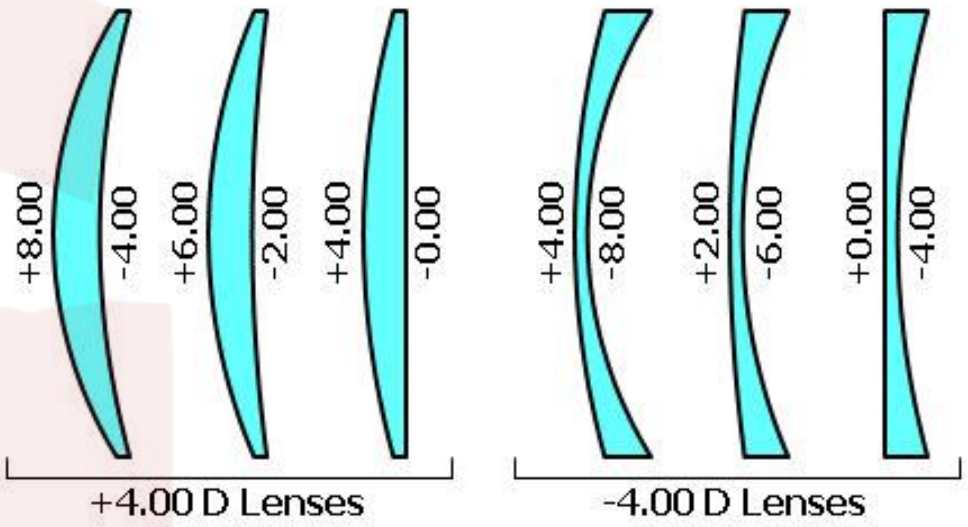
Power of lenses

The power of a lens is defined as the reciprocal of its focal length. Mathematically, it is expressed as:

$$P = \frac{1}{\text{Focal Length}}$$

The SI unit of power is the **dioptre** (D). One dioptre is the power of a lens with a focal length of 1 meter.

Additionally, the power of a **convex lens** is positive, while the power of a concave lens is negative.

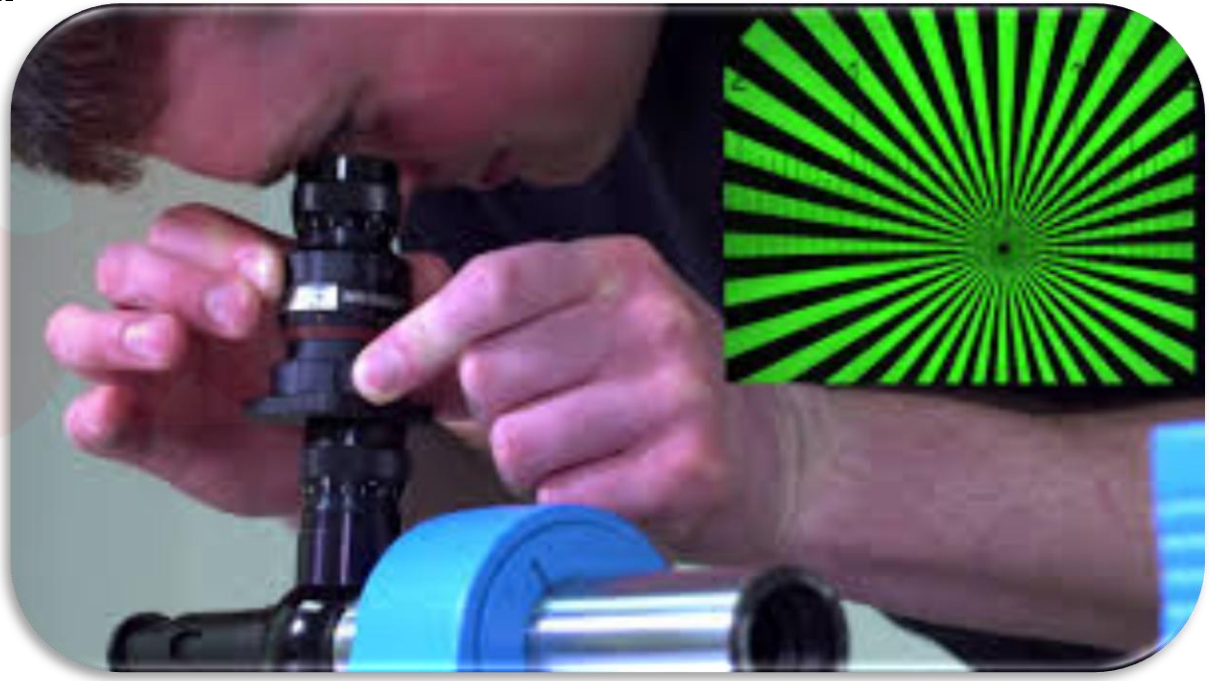


Lens Form Comparisons

NOTE:-

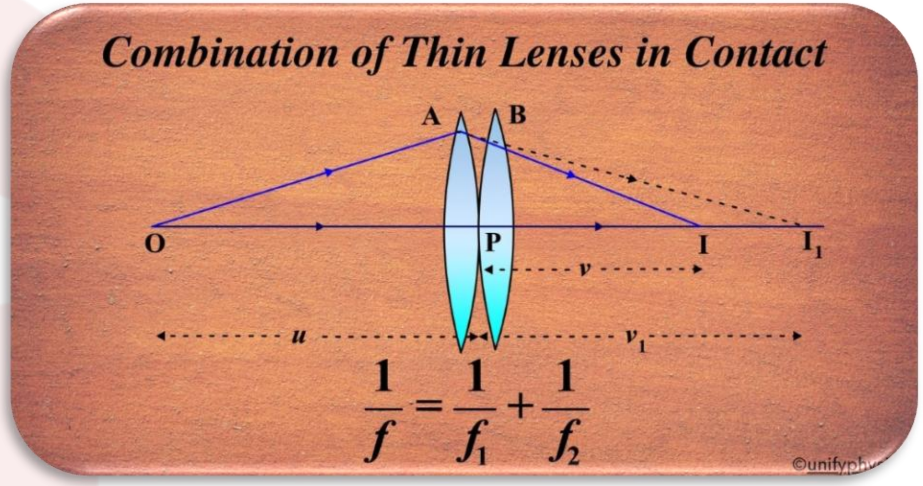
- The power of lens is a measure of the degree of convergence or divergence of light rays falling in it.

- The power of a lens can be measured directly by using an instrument called dioptometer.



Power of Combination of Lens

If more than 1 one lens are used together, it is called Combination of Lens



Power of Combination of Lens is

Simple Algebraic sum of all the Lenses

Power of Combination of Lens = Power of Lens 1 + Power of Lens 2

$P = P_1 + P_2$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Example 9.3

A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens? Also, find the magnification produced by the lens.

Example 9.4

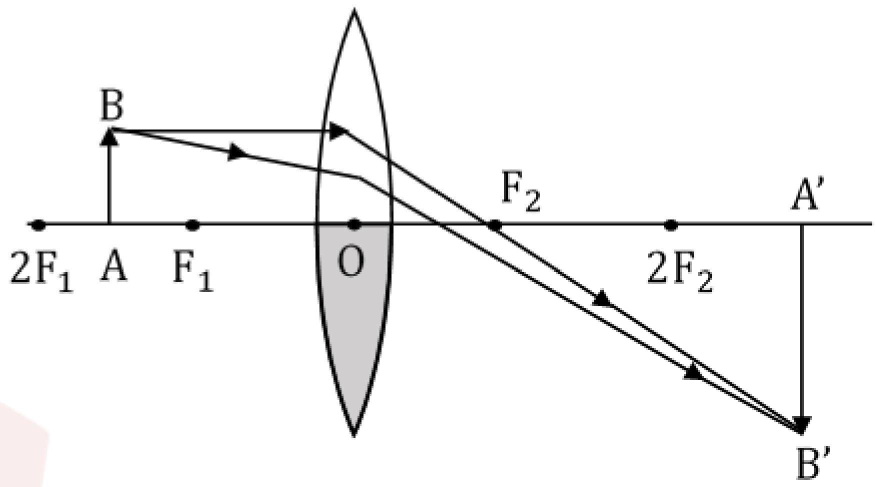
A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

QUESTIONS

1. Define 1 dioptre of power of a lens.
2. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object? Also, find the power of the lens.
3. Find the power of a concave lens of focal length 2 m.

3. Where should an object be placed in front of a convex lens to get a real image of the size of the object?
   (a) At the principal focus of the lens
   (b) At twice the focal length
   (c) At infinity
   (d) Between the optical centre of the lens and its principal focus.
4. A spherical mirror and a thin spherical lens have each a focal length of –15 cm. The mirror and the lens are likely to be
   (a) both concave.
   (b) both convex.
   (c) the mirror is concave and the lens is convex.
   (d) the mirror is convex, but the lens is concave.
5. No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be
   (a) only plane.
   (b) only concave.
   (c) only convex.
   (d) either plane or convex.
6. Which of the following lenses would you prefer to use while reading small letters found in a dictionary?
   (a) A convex lens of focal length 50 cm.
   (b) A concave lens of focal length 50 cm.
   (c) A convex lens of focal length 5 cm.
   (d) A concave lens of focal length 5 cm.

9. One-half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object? Verify your answer experimentally. Explain your observations.



10. An object 5 cm in length is held 25 cm away from a converging lens of focal length 10 cm. Draw the ray diagram and find the position, size and the nature of the image formed.

11. A concave lens of focal length 15 cm forms an image 10 cm from the lens. How far is the object placed from the lens? Draw the ray diagram.

16. Find the focal length of a lens of power – 2.0 D. What type of lens is this?

17. A doctor has prescribed a corrective lens of power +1.5 D. Find the focal length of the lens. Is the prescribed lens diverging or converging?

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sharma