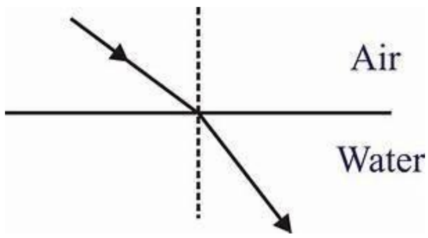
Refraction of light

The bending of light on passing from one medium to another, obliquely is called refraction of light.



Causes of Refraction

The **change in speed of light** on passing from one medium to another.

Types of medium

We have two types of mediums:

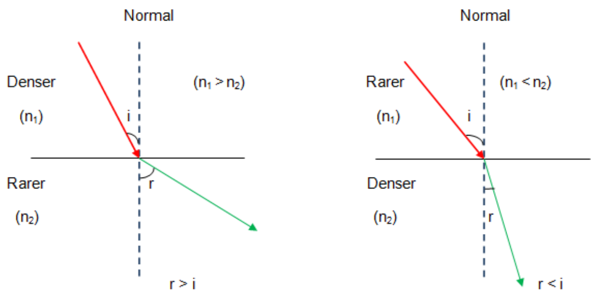
- Rarer medium
- Denser medium

Rarer medium- We can define rarer medium as the medium which has **less density** and **speed of light is more**. Example: air is rarer than water.

Denser Medium- It is that which has **more density** and **speed of light is lesser in it**. Example: water is denser than air.

Refraction when light passes from denser to rarer medium

When light passes from a denser to a rarer medium, it bends away from the normal and in this case the angle of refraction is greater than the angle of incidence.



Refraction when light passes from rarer to denser medium

When light passes from rarer to denser, it moves towards normal and in this case the angle of refraction is less than the angle of incidence.

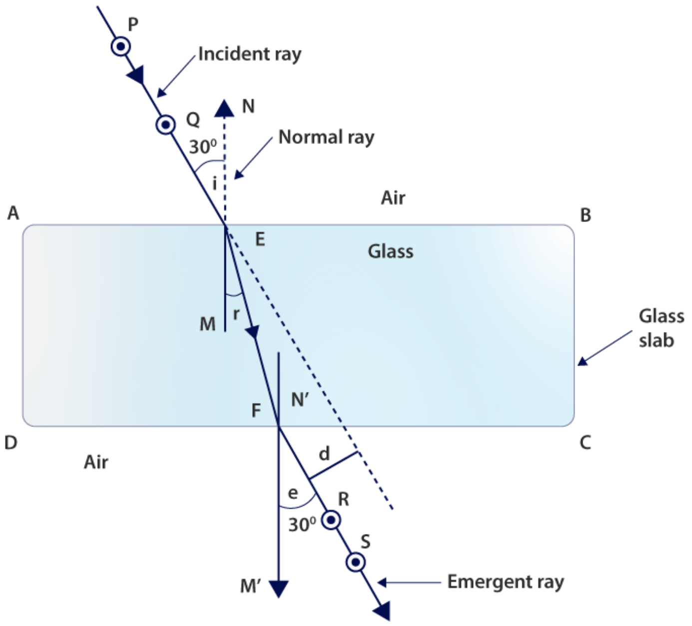
Law of Refraction

- Incident ray, normal ray and the refracted ray all lie in the same plane.
- The ratio of sine of angle of incidence to the sine of the angle of refraction is always constant for a particular pair of media.

i.e.: **sin i / sin r = constant (Snell's law)**

Ray Of Light Passing Through A Rectangular Glass Slab

Procedure



Refraction of light through a rectangular glass slab

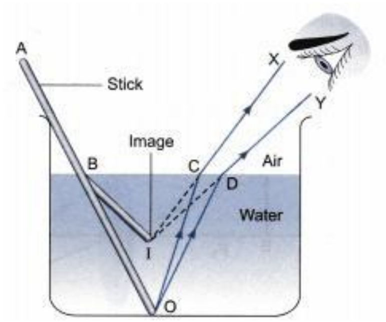
1. Fix a white sheet on the soft drawing board using thumb pins.
2. Using a sharp pencil, draw the outline boundary of the glass slab, place it at the of the white paper.
3. Let ABCD be the rectangular figure obtained by drawing.
4. Mark point E on AB and draw a perpendicular EN and label it as a normal ray.
5. Draw one angle of 30° with the help of protractor with EN. Fix pins at P and Q at 4-5 cm on the ray that is obtained by the angle.
6. Place the glass slab on the rectangular figure ABCD.
7. To fix R and S, see through the glass slab of side CD, such that when seen through the glass slab, all the pins P, Q, R, and S should lie in a straight line.
8. Draw a small circle around the pins P, Q, R, and S and remove the pins.
9. Remove the glass slab.
10. Join points R and S such that it meets CD at point F. Draw a perpendicular N'M' to CD at point F.
11. Using a pencil, join the points E and F.
12. Measure the angles formed at AB and CD, i.e, the incident angle, refracted angle, and emergent angle.
13. The lateral displacement is obtained by extending the ray PQ in a dotted line which is parallel ray to FRS.
14. Measure the lateral displacement.
15. Repeat the same procedure for angle 45° and 60°.

What is lateral displacement?

Lateral displacement is defined as the perpendicular shift in the path of light when it emerges out from the refracting medium. **It depends upon refractive index and thickness of glass slab.**

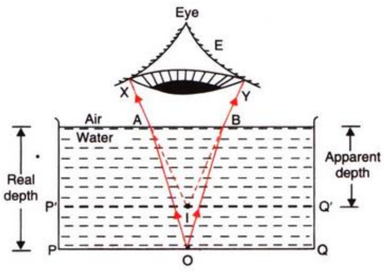
Conclusion

1. The **angle of incidence** and the **angle of emergence** are almost **equal.**
2. As the light is traveling from rarer to denser optical medium, the angle of refraction will be lesser than the angle of incidence.
3. For different angles of incidence, the lateral displacement will remain the same.
4. The light will bend towards the normal when it travels from an optically rarer medium to an optically denser medium.



Consequences of Refraction

- A stick immersed in water appears to be bent: A stick immersed in water reflects light rays. These rays when travelling in water, travel in a straight line path but when they go from water to air, they deviate from their path and get deflected away from the normal. When these refracted rays are produced, they appear to meet at point “I” which is higher than the actual point that is ‘O’. Therefore, a stick immersed in water appears to be bent due to refraction.



- The water level appears to be raised: When rays moves out from water to air, they will bend away from normal and when produced, they meet at point “I” which is above actual point ‘O’. So, apparent image is at ‘O’ and actual image is at ‘I’.

Refractive Index

• **Refractive index (n):** The ratio of speed of light in a given pair of media

n = Velocity of light in medium 1/Velocity of light in medium 2

→ n_{21} means refractive index of second medium with respect to first medium.

$n_{21} = v_1/v_2$

→ n_{12} means refractive index of second medium with respect to first medium.

$n_{12} = v_2/v_1$

• **Absolute Refractive Index**: Refractive index of a medium with respect to vaccum or air.

$n = (c/v)$ x $c = 3 \times 10^8$ m/s.

→ Refractive index of one medium is reciprocal of other's refractive index in a given pair.

$n_{12} = 1/n_{21}$

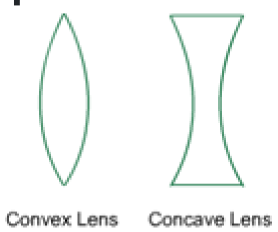
→ If refractive index of medium 1 w.r.t. air is given as ${}_1n^{air}$, and

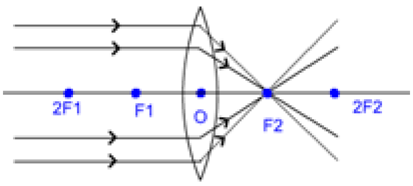
If refractive index of medium 2 w.r.t. air is given as ${}_2n^{air}$.

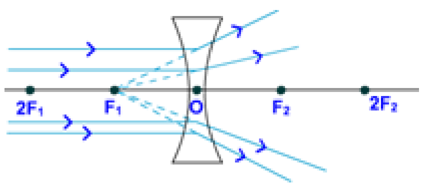
Then, refractive index of medium 1 w.r.t. medium 2 = $({}_1n^{air})/({}_1n^{air})$

→ 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.

Spherical Lens : Concave Lens and Convex Lens







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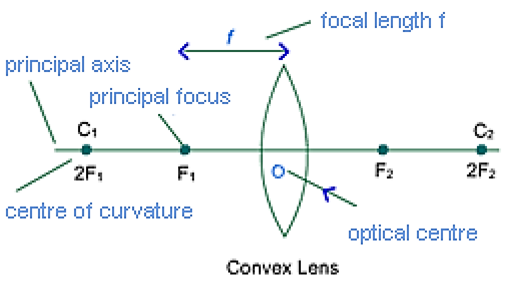
Important terms for spherical lens:

1. **Centre of curvature:** The centre of sphere of part of which a lens is formed is called the centre of curvature of the lens. Since concave and convex lenses are formed by the combination of two parts of spheres, therefore they have two centres of curvature.



One centre of curvature is usually denoted by C1 and second is denoted by C2.

2. **Focus:** Point at which parallel rays of light converge in a concave lens and parallel rays of light diverge from the point is called Focus or Principal Focus of the lens.

Similar to centres of curvature; convex and concave lenses have two Foci. These are represented as F1 and F2.

3. **Principal Axis:** Imaginary line that passes through the centres of curvature of a lens is called Principal Focus.
4. **Optical centre:** The central point of a lens is called its Optical Centre. A ray passes through optical centre of a lens without any deviation.
5. **Radius of curvature:** The distance between optical centre and centre of curvature is called the radius of curvature, which is generally denoted by R.
6. **Focal Length:** The distance between optical centre and principal focus is called focal length of a lens. Focal length of a lens is half of the radius of curvature. **R=2F**
   This is the cause that the centre of curvature is generally denoted by **2F** for a lens instead of C.

Lens Formula and Magnification:

The relation between distance of object, distance of image and focal length for a lens is called lens formula.

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

Where, v is the distance of image, u is the distance of object, and f is the focal length of lens. Distance of object and image is measure from the optical centre of the lens. The sign for distance is given as per convention.

The lens formula is valid for all situations for spherical lens.

Magnification:

The ratio of height of image and that of object or ratio of distance of image and distance of object gives magnification. It is generally denoted by 'm'.

$$m = \frac{\text{Height of image h'}}{\text{Height of object h}}$$

$$= \frac{\text{Distance of image v}}{\text{Distance of object u}}$$

The positive (+) sign of magnification shows that image is erect and virtual while a negative (-) sign of magnification shows that image is real and inverted.

Power of lens:

A convex lens with short focal length converges the light rays with greater degree nearer to principal focus and a concave lens with short focal length diverges the light rays with greater degree nearer to principal focus.

The degree of divergence or convergence of ray of light by a lens is expressed in terms of the power of lens. Degree of convergence and divergence depends upon the focal length of a lens. The power of a lens is denoted by 'P'. The power of a lens is reciprocal of the focal length.

$$\text{Power P} = \frac{1}{\text{Focal length f}}$$

Or, $P = \frac{1}{f}$

The SI unit of Power of lens is dioptre and it is denoted by 'D'.

Power of a lens is expressed in dioptre when the focal length is expressed in metre. Thus, a lens having 1 metre of focal length has power equal to 1 dipotre.

Therefore, 1 D = 1 m^{-1}

A **convex lens** has power in **positive** and a **concave lens** has power in **negative**.

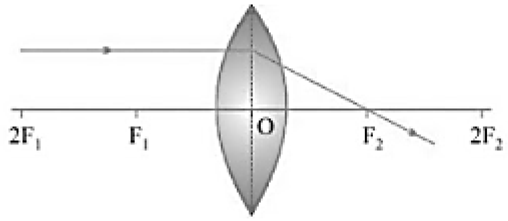
Power of optical instruments having multiple lenses:
If there is more than one lens used, then total power of lenses is equal to the sum of power of all individual lenses.

Example: If there are three lenses used in an optical device having powers equal to 1 D, 2D and 3D respectively,

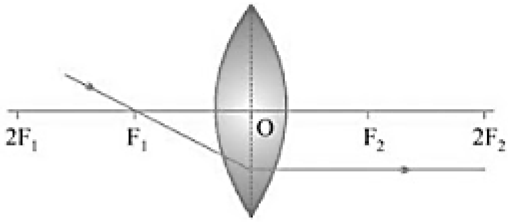
Therefore, the total power of the optical device =1D+2D+3D=6D

Rules for image formation by convex lens

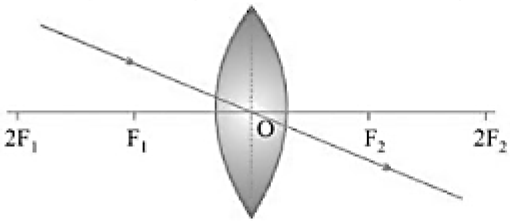
(i) A ray of light parallel to principal axis of a convex lens always pass through the focus on the other side of the lens.



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

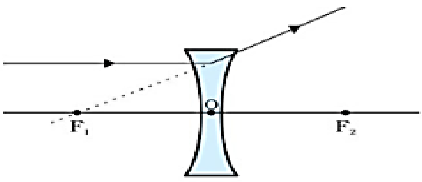


(iii) A ray of light passing through the optical center will emerge without any deviation.

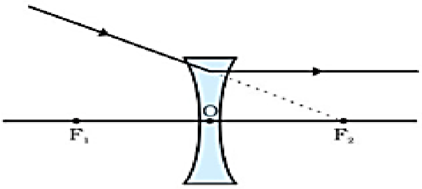


Rules for Image Formation by Concave Lens

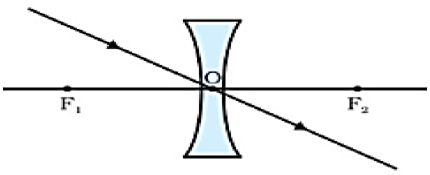
(i) A ray of light parallel to the principal axis appear to diverge from the principal focus located on the same side of the lens.



(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.



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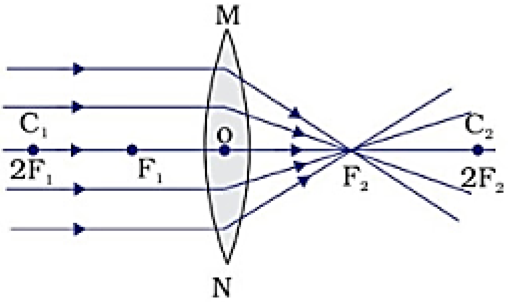
Ray Diagrams of Imag formed by Convex Lens

(i) When object is at infinity

Image Position - At 'F 2 '

Nature of image – Real, inverted

Size – Point sized or highly diminished

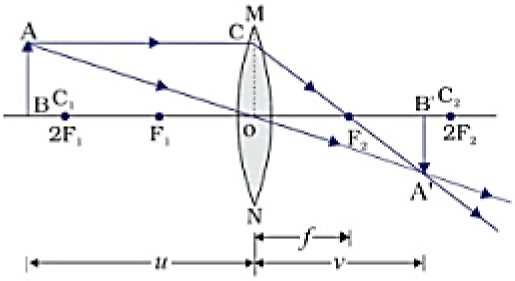


(ii) When object is beyond '2F1'

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

Nature of image– Real, inverted

Size – Diminished

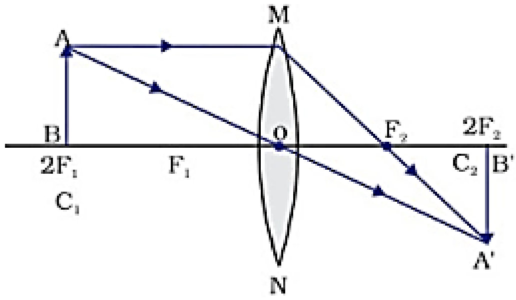


(iii) When object is at '2F1 '

Image Position – At '2F2 '

Nature of image – Real, inverted

Size – Same size

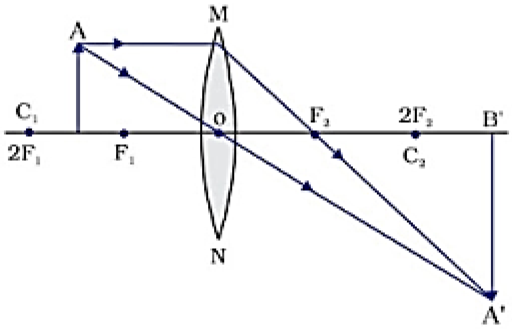


(iv) When object is between 'F1' and '2F1'

Image Position – Beyond '2F2'

Nature of image – Real, inverted

Size – Enlarged

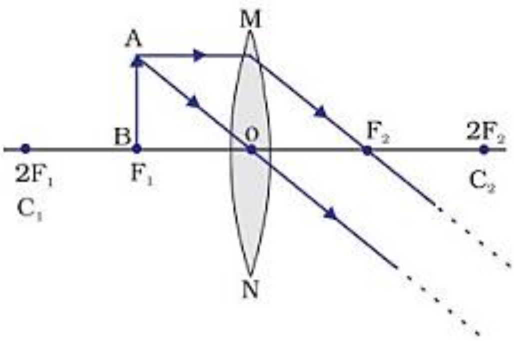


(v) When object is at 'F1'

Image Position – At Infinity

Nature of image – Real, inverted

Size – Highly enlarged

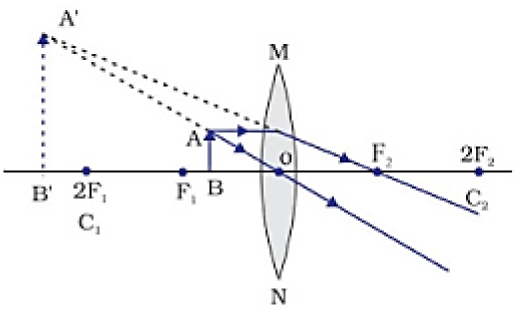


(vi) When object is between 'F1' and optical centre

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

Nature of image – Virtual and erect

Size – Enlarged



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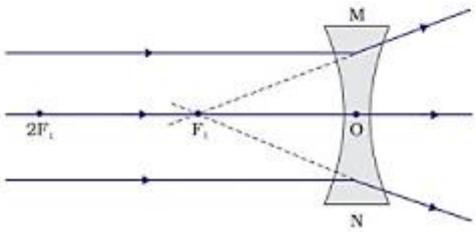
Ray Diagrams of Images Formed by a Concave Lens

(i) When object is placed at infinity

Image Position - At 'F1'

Nature of image – Virtual, erect

Size – Point sized or highly diminished

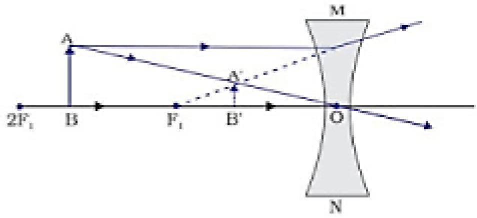


(ii) When object is placed between infinity and optical centre

Image Position – Between 'F' and 'O'

Nature of image – Virtual, erect

Size – Diminished



Concave lens	Convex lens
It is called diverging lens.	(i) It is called converging ler
This lens is thinner in the centre than at its edges.	(ii) This lens is thicker at th centre than at its edges.
The principal focus is virtual.	(iii) The principal focus is rea
The focal length is negative.	(iv) The focal length is positi
This lens is used to correct myopia.	(v) This lens can be used to correct hypermetropia.

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