Refraction of Light

- **Refraction:** Bending or change in the direction of light as it passes from one medium to another
- Refraction of light occurs because of change in the speed of light due to a change in the medium.
- When light enters an optically denser medium from an optically rarer medium, the speed of light slows down and light bends towards the normal.
- The opposite happens when light enters an optically rarer medium from an optically denser medium.

- **Effect on various characteristics of light on reflection and refraction:**

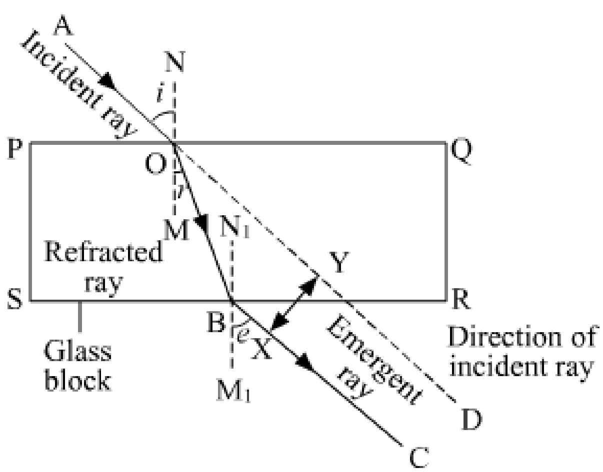
Characteristics	Partially reflected light	Partially refracted light	
		Rarer to denser	Denser to rarer
Speed of light	No change	Decreases	Increases
Frequency of light (*f*)	No change	No change	No change
Wavelength of light (λ=vf)	No change	Decreases	Increases

Refraction of light through a rectangular glass slab

Key points of refraction

- When a light ray enters from air (rarer medium) to glass (denser medium), it bends towards the normal.
- When a light ray emerges from the glass (denser medium) to air (rarer medium), it bends away from the normal.
- when a light ray is incident on a glass slab normally, it gets out straight without any deflection i.e., $i = 0$, $r = 0$.

Lateral Displacement
The perpendicular distance between the path of emergent ray BC and the direction of incident ray OD is known as **lateral displacement** (here XY).



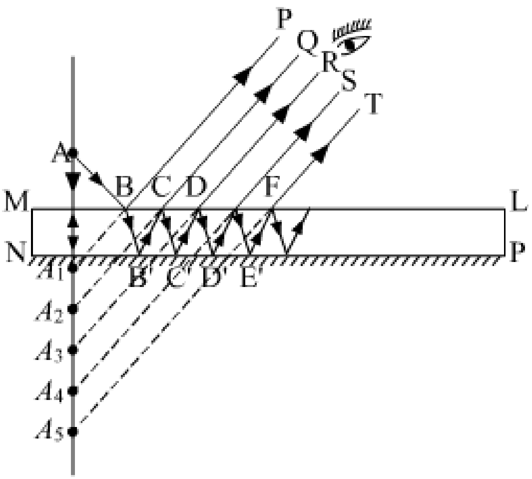
Refraction through a rectangular glass block

The lateral displacement is:

- directly proportional to angle of incidence
- directly proportional to the thickness of the block or medium
- directly proportional to the refractive index of the medium. As refractive index increases with decrease in wavelength of light, this means lateral displacement increases with decrease in the wavelength of light.

Multiple Images in a Thick Plane Glass Plate or Thick Mirror

When an illuminated object is placed in front of a plane glass mirror of adequate thickness and is viewed obliquely, a number of images are seen. And from all the images, the second image is the brightest, while rest are of decreasing brightness.



Multiple reflections in a thick mirror

The image A_2 is the brightest image because it is due to the light suffering a strong first reflection at the silvered surface PN.

- Real and apparent depth of object placed in different medium
- Apparent bending of an object when partially placed in a different medium
- Sun appears a few minutes earlier before it actually rises above the horizon. Also, it is seen for a few minutes longer after it actually sets.

Refraction through a Prism

- When light passes through a prism , it suffers two refractions .

- The net deviation suffered by the ray when it passes through the prism of angle A is given by δ.

- Relation between the angle of incidence i , angle of emergence e, the angle of prism and the net deviation is given by $A+\delta=i+e$.

- The deviation of the light ray through the prism is minimum when angle of incidence (i) is $i=A+\delta m2$.

    - For the minimum deviation, angle of incidence at both the surfaces of the prism are equal.

- The prism formula is given as $\mu=\sin(A+\delta m)/2\sin A/2$.

  where δ_m is the minimum deviation of the light when passed through prism.

Factors affecting angle of deviation

- Angle of incidence (i)
- Angle of prism (A)
- Refractive index (μ) of the material of the prism
- Colour or wavelength (λ) of light

- **Condition for total internal reflection:**

If a ray of light travelling from an optically denser medium to an optically rarer medium is incident at an angle greater than the critical angle for the pair of media in contact, the ray is totally reflected back into the denser medium, thereby causing total internal reflection.

μba=1sinC

- **Applications of total internal reflection:**

Multiple internal reflections in diamond ($i_c \cong 24.4°$), totally reflecting prisms and mirage are some examples of total internal reflection.

Optical fibres

- Optical fibres consist of glass fibres coated with a thin layer of material with a lower refractive index 1.5; this is called **cladding**.
- The central part of the fibres,called **core**, is made up of material with refractive index 1.7.
- Any light that is incident at an angle at one end comes out from the other after multiple internal reflections, even if the fibre is bent.
- Optical fibres are used for transmitting audio and video signals to long distances.
- They are used in endoscopes for medical examinations of inner parts of the body of a patient.

- **Differences between a spherical mirror and a lens:**

Spherical mirror	Spherical lens
Image is formed by reflection of light.	Image is formed by refraction of light.
A spherical mirror has only one focus.	A spherical lens has two foci.
The centre of the spherical mirror is termed as its pole.	The centre of the spherical lens is termed as its optical centre.

- Centre of curvature = Centre of the sphere of which the lens surfaces is a part of (Same as Spherical mirror)
- Optical centre is a point at the centre of the lens. It always lies inside the lens and not on the surface
- The straight line joining the two centers of curvature and the optical centre is called the principal axis of the lens.
- Focus = Where parallel rays meet after refraction (On principal axis = principal focus)

- **Convex lens and Image**
  - Virtual and erect images – when the object is placed between F1 and the optical centre (Magnifying glass)
  - Image size = object size when object at 2F (= Centre of curvature)

- **Concave lens and Image**
  - Virtual and erect at all object positions

- **Lens Formula**

  For concave lens f = –ve

  convex lens f = +ve

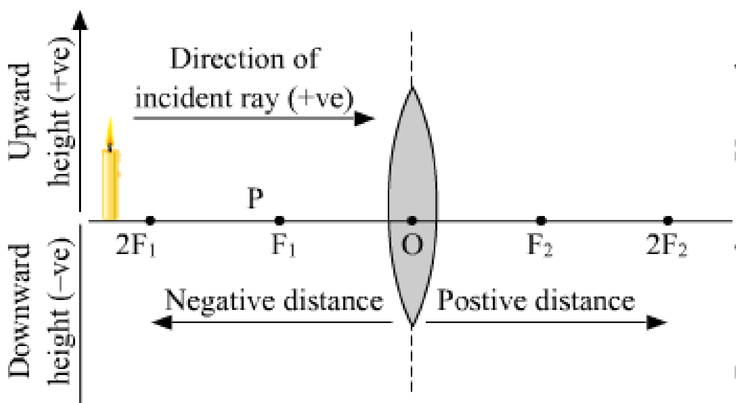
- **Magnification**

$$m = \frac{\text{Image height}}{\text{Object height}} = \frac{v}{u} (\text{Same as mirror})$$

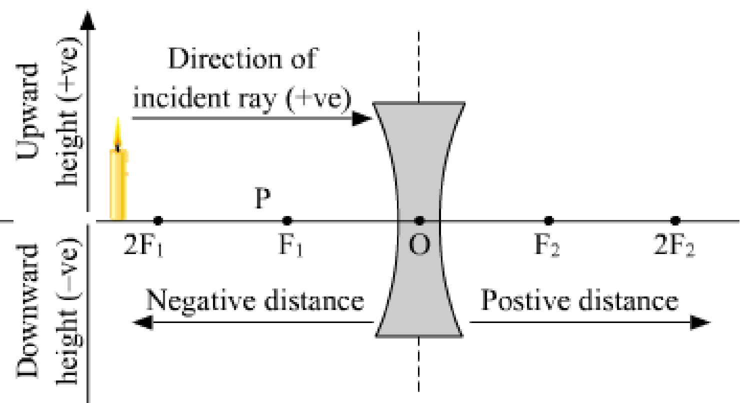
- **Lens power**

$$\text{P} \left(\text{Unit dioptre}\right) = \frac{1}{f\,(\text{in}\, m)}\, f = -\text{ve for concave}$$

- **Sigh Convention for Lenses:**



Convex mirror



Concave mirror

- **Lens Formula**

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

For concave lens $f = -\text{ve}$

convex lens $f = +\text{ve}$

- **Magnification**

$$m = \frac{\text{Image height}}{\text{Obhect height}} = \frac{v}{u} (\text{Same as mirror})$$

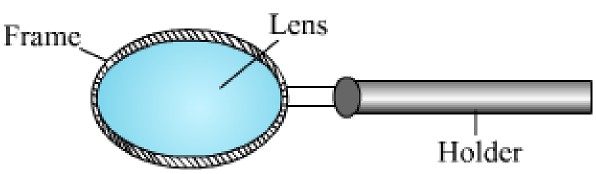
- **Lens power:** Power of lens is the reciprocal of its focal length.

$$\text{P} \ (\text{Unit dioptre}) = \frac{1}{f\,(\text{in}\, m)} = -\text{ve for concave}$$

and + ve for convex lens.

Simple Microscope or Magnifying Glass

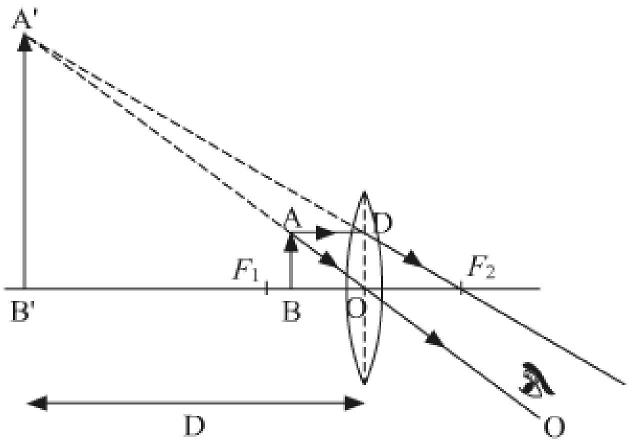
Construction : It uses a convex lens of short focal length which is mounted in a lens holder.



Magnifying glass (or simple microscope)

Principle: Simple microscope is placed in front of our eye at such a distance that the object lies within the focal length of its lens so as to enable the lens to form an erect, virtual and magnified image on the same side and behind the object at a distance *D*. This image is now seen distinctly by our eye because magnified image is subtending an angle greater than 1' on the eye.

Ray diagram of the image formed by a convex lens



Ray diagram for location of image in a magnifying glass

Magnifying power (*m*) of a simple microscope or magnifying glass

m=1+Df .....(1)

where *f* is the focal length of the lens and *D* is the least distance of distinct vision.

Uses of simple microscope

- To read small letters
- Used by watch makers while manufacturing and repairing watches
- In optical instruments such as travelling microscope, spectrometer, etc. as a reading lens to read the vernier scale accurately.

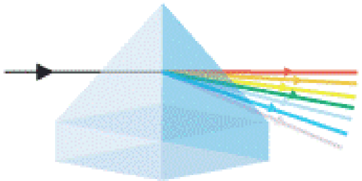
Experimental determination of focal length of convex lens by different methods

(1) Distant object method
(2) Auxiliary plane mirror method
(3) One pin method using an optical bench

Application of Lenses

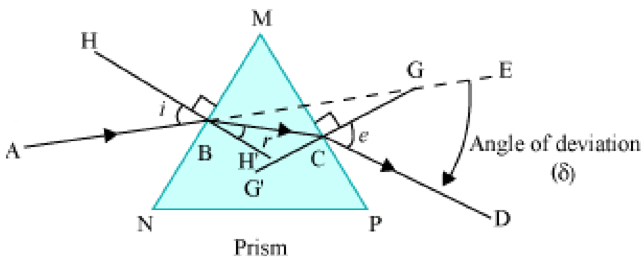
- A convex lens is used as an objective lens in telescope, camera, slide projector, etc.
- Eye has lens which is convex in nature.
- A convex lens is used in a simple microscope and collimator of a spectroscope.
- A concave lens is used in the Galilean telescope as an objective lens to obtain the final erect image of an object.
- Spectacles having concave lens is worn by people suffering myopia. (Myopia is an eye defect in which person is unable to see distant object clearly)

1. White light is composed of seven colours − red, orange, yellow, green, blue, indigo, and violet.
2. A rainbow consists of all the seven colours of white light.
3. A prism splits white light into its seven constituent colours.

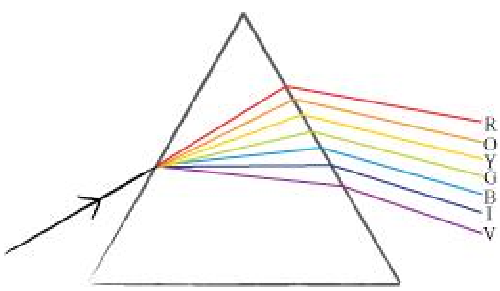


4. A Newton disc is a disc with seven segments in rainbow colours. It was invented by Isaac Newton.

- **Refraction through a prism**
  - Light bends because of refraction that takes place at points **B** and **C .**
  - The extent of deviation of the light ray from its path BE to path CD is known as the angle of deviation (δ)



- The splitting of a beam of white light into its seven constituent colours, when it passes through a glass prism, is called the **dispersion of light.**



  - Red → Disperses least
  - Violet → Disperses most
  - Yellow → Average of all lights
- Formation of rainbow is a natural phenomenon in which white sunlight splits into beautiful colours by water droplets.
- Scattering is the phenomenon of absorption and re-emission of light.
- The phenomenon of scattering of light by the colloidal particle gives rise to **Tyndall effect**.
- Atmospheric particles, smoke, tiny water droplets, suspended particles of dust, and air molecules scatter sunlight. Therefore, the path of light becomes visible.
- **Sky is blue**- because light near blue wavelength scatters most.
- Danger signs are red in colour- because red light scatters least.

- Different electromagnetic waves:

•	Type	Wavelength range
(a)	Radio waves	>0.1 m
(b)	Microwave	0.1 m to 1 mm
(c)	Infra-red	1 mm to 700 nm
(d)	Visible light	700 nm to 400 nm
(e)	Ultra-violet	400 nm to 1 nm
(f)	X-rays	1 nm to 10^{-3} nm
(g)	Gamma rays	$<10^{-3}$ nm

- Uses of electromagnetic radiations:

Electromagnetic radiations	**Uses**
Visible Light	In photography, in photosynthesis in plants and in enabling us to see objects around us
Infrared	to identify molecular structure of compounds, ion long distance photography, diagnosing tumors, in TV remote and solar energy operated devices.
UV	Used as sterilizer, in fluorescent lamps, treatment of diseases skin and bone, in radiography, to study of crystal structure.
X-rays	in treatment of cancer and skin diseases, locate fractured bones, in radiography, to study of crystal structure.
γ-rays	in treatment of cancer, used as catalyst in manufacturing of some chemicals, to produce photoelectric effect, and in radiography.
Microwave	In RADAR, satellite communication and ovens.
Radio wave	In communication, TV and Radio broadcasting.