PHYSICS

CHAPTER – 5- REFRACTION OF LIGHT

Optical density of a medium

The characteristics of each medium influence the speed of light that passes through the respective medium. Optical density is a measure that shows how a medium influences the speed of light passing through it.

Example: different medium has difference in speed of light because the optical density is different for different medium.

Medium	Speed of light (m/s)
Vacuum	3×10^8 m/s
Water	2.25×10^8 m/s
Glass	2×10^8 m/s (*approximately*)
Diamond	1.25×10^8 m/s

Q) arrange the above medium in increasing order of optical density?

Ans) vacuum < water <glass < diamond

Note: when speed of light increases optical density decreases i.e they are inversely proportional

Refraction of light

It is the difference in the optical densities that causes the deviation. When a ray of light entering obliquely from one transparent medium to another, its path undergoes a deviation at the surface of separation. This is refraction.

Example: refraction through a glass slab

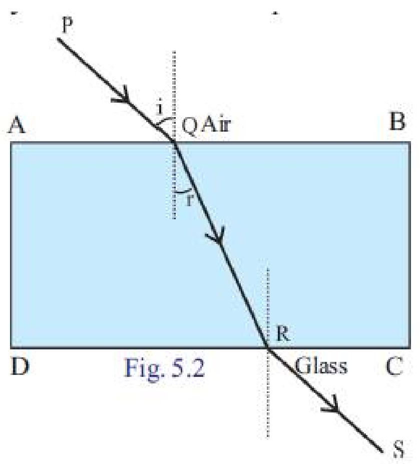


Fig. 5.2

- At the surface AB
  - PQ- incident ray
  - QR – refracted ray
  - i – angle of incident
  - r- angle of refraction
- At the surface DC
  - QR- incident ray
  - RS- refracted ray

Note:

- when light travel from air (rarer medium) to glass (denser medium) the refracted light bend towards normal
- when light travel from glass (denser medium)) to air (rarer medium the refracted light bends away from normal
- if light entering into a medium normally (perpendicular to medium of separation) then there is no refraction or deviation.

Example :

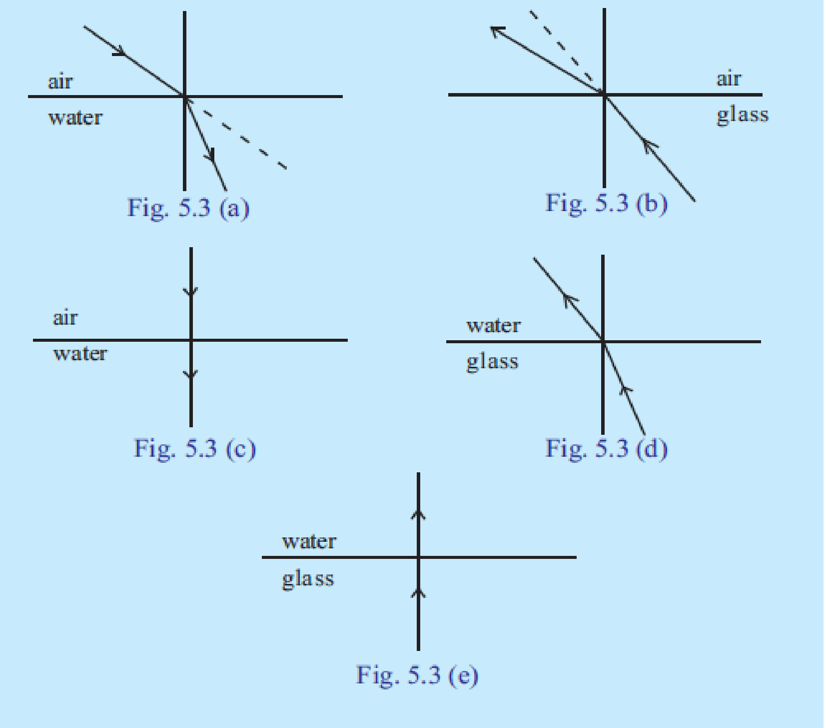


Fig. 5.3 (a) Fig. 5.3 (b) Fig. 5.3 (c) Fig. 5.3 (d) Fig. 5.3 (e)

Light travelling from denser medium to rarer medium: fig (b) (d)

Light travel from rarer medium to denser medium: fig (a)

Light falling normal to the medium: fig (c) , (e)

Law of Refraction

- **The angle of incidence, the angle of refraction and the normal at the point of incidence on the surface of separation of the two media will always be in the same plane.**
- **The ratio of the sine of the angle of incidence to the sine of the angle of refraction $\left(\frac{\sin i}{\sin r}\right)$ will always be a constant. This is known as Snell's Law.**

The constant from Snell's Law is known as refractive index. This is indicated by the letter n.

Note: refraction happens only when incident ray is obliquely falling to a medium

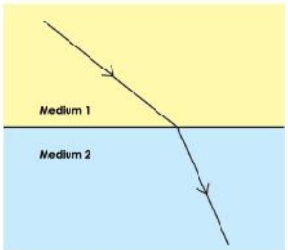
Relative refractive index (n_{12} or n_{21}) and absolute refractive index (n_m)

The refractive index of one medium with respect to another is called relative refractive index.

The refractive index of a medium with respect to vacuum is called absolute refractive index.

Speed of light and refractive index

Example:



Refractive index of first medium with respect to second medium

$(n_{12}) = \frac{speed\ of\ light\ in\ medium\ 2}{speed\ of\ light\ in\ medium\ 1} = \frac{V2}{V1}$

Refractive index of second medium with respect to first medium

$(n_{21}) = \frac{speed\ of\ light\ in\ medium\ 1}{speed\ of\ light\ in\ medium\ 2} = \frac{V1}{V2}$

V_1 – velocity of light in 1^{st} medium V_2- velocity of light in 2^{nd} medium

Absolute Refractive Index

Refractive index of a medium(n_m) = $\frac{speed\ of\ light\ in\ air\ (vacuum)}{speed\ of\ light\ in\ the\ medium} = \frac{C}{V}$

Q) the table shows refractive index of some medium. Answer the following questions

Medium	Refractive index
Water	4/3
Glass	3/2

a. **if speed of light in water is 2.25×10^8m/s calculate the speed of light in vacuum?**
b. **Calculate the speed of light in glass.**

Ans)

a. $n_w = c/v$

$n_w = 4/3$, c =? , v = 2.25×10^8m/s

$\frac{4}{3} = \frac{C}{2.25 \times 10^8}$

$C = 2.25 \times 10^8 \times \frac{4}{3} = 3 \times 10^8$ m/s

b. V = ? $n_g = c/v$

$\frac{3}{2} = \frac{3 \times 10^8}{v}$

$V = \frac{3 \times 10^8}{\frac{3}{2}} = 2 \times 10^8$m/s

Real life examples for refraction

- Position of pencil under water changes

- Coin in a glass of water disappeared when looking at a particular angle

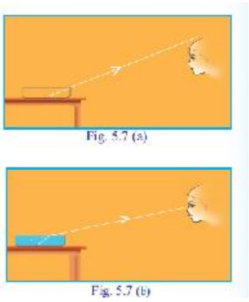


Fig. 5.7 (a)

Fig. 5.7 (b)

- Apparent position of image of a pencil when seen from a glass prism

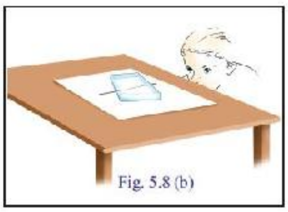


Fig. 5.8 (b)

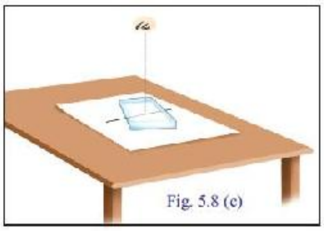


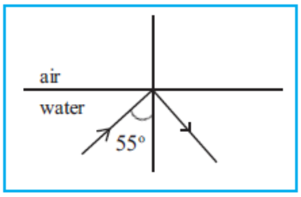
Fig. 5.8 (c)

Total Internal Reflection (TIR)

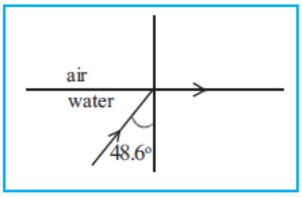
When a ray of light passes from a medium of higher optical density to a medium of lower optical density at an angle of incidence greater than the critical angle, the ray is reflected back to the same medium without undergoing refraction. This phenomenon is known as total internal reflection.

Q) Define critical angle of a medium?

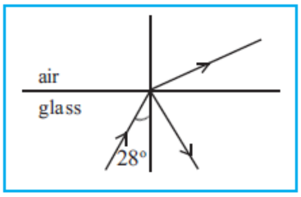
When a ray of light passes from a medium of greater optical density to that of lower optical density, the angle of incidence at which the angle of refraction becomes 90° is the critical angle. The critical angle in water is 48.6°.



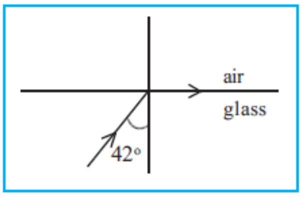
(a)



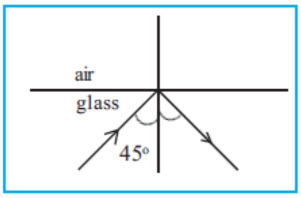
(b)



(c)



(d)



(e)

Figure (a) , (e) – total internal reflection

Figure (b), (d) – critical angles of water and glass

Figure(c)- refraction and reflection

Note: for total internal reflection 2 conditions are to be satisfied

1. Light ray must travel from denser medium to rarer medium
2. Angle of incident should be greater than that of critical angle of the medium($i>i_c$)

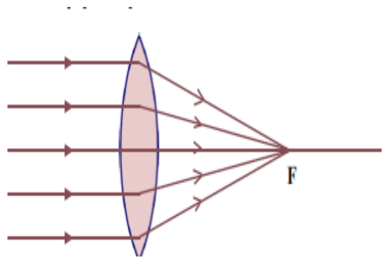
Uses of total internal reflection in day to day life

- Used in medical field- endoscope
- Used in telecommunication – optic fibre cables
- Brilliance of diamond
- Mirage formation

LENS

A lens is a transparent medium having spherical surfaces.

Light rays incident parallel and close to the principal axis after refraction converges to a point on the principal axis of a convex lens. This point is the principal focus of a convex lens.



Convex lens (converging lens)

> *Light rays incident parallel and close to the principal axis diverge from one another after refraction. These rays appear to originate from a point on the same side. This point is the principal focus of a concave lens.*

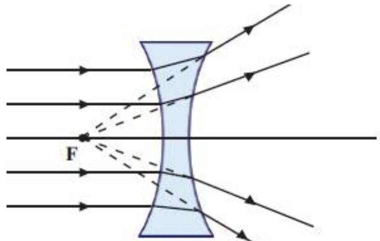


Fig. 5.20

Concave lens (diverging lens)

Note:

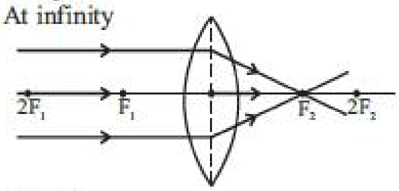
- The principal foci of convex lens are real
- The principal foci of concave lens are virtual
- The number of principal foci a lens have is equal to two
- Convex lens produces real image
- Concave lens produces virtual image

Image Formation by a Convex Lens

Position of object	Position of image	Nature of image/ size		
		Real/ virtual	Inverted/ erect	Magnified/ diminished/ same size
1. At infinity	At F	Real	Inverted	Diminished
2. Beyond 2 F	Between 2F and F	Real	Inverted	Diminished
3. At 2 F	At 2F	Real	Inverted	Same size
4. Between 2F and F	Beyond 2F	Real	Inverted	Enlarged
5. At F	At infinity	Real	Inverted	Huge / highly enlarged
6. Between F and lens	On the same side between F and 2F	Virtual	Erect	Enlarged

Image formation by a convex lens for various position of object

1. Object
At infinity

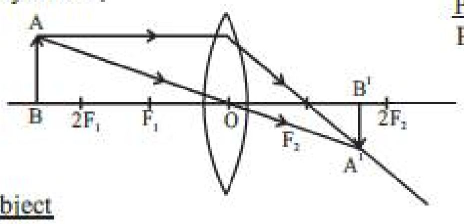


Position of Image
At focus
F_2

Size of Image
Highly diminished (point size)

Nature
Real & inverted

2. Object
Beyond $2F_1$

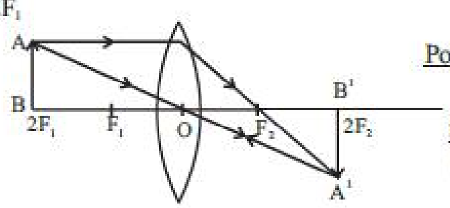


Position of Image
Between F_2 & $2F_2$

Size of Image
Small

Nature
Real & inverted

3. Object
At $2F_1$



Position of Image
At $2F_2$

Size of Image
Same size of object

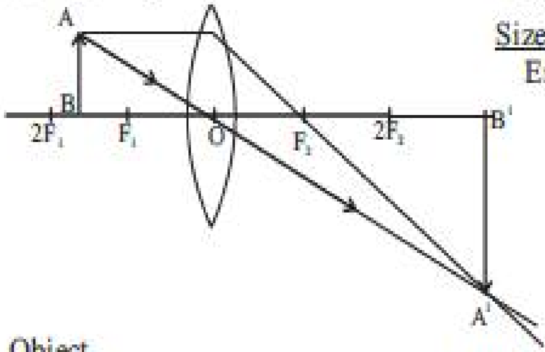
Nature
Real & inverted

4. **Object**
Between F_1 & $2F_1$

Position of Image
Beyond $2F_2$

Size of Image
Enlarged

Nature
Real & inverted

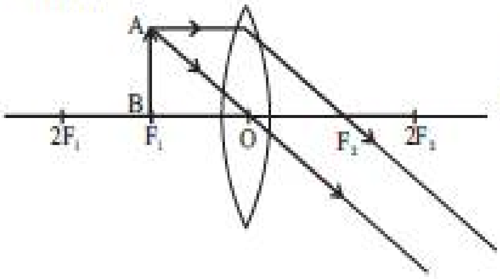


5. **Object**
At focus F_1

Position of Image
at infinity

Size of Image
Highly Enlarged

Nature
Real & inverted



6. (Special Case)
Object
Between F_1 and optical centre 'O'

Position of Image
On the same side of the object

Size of Image
Enlarged

Nature
Virtual & Erect

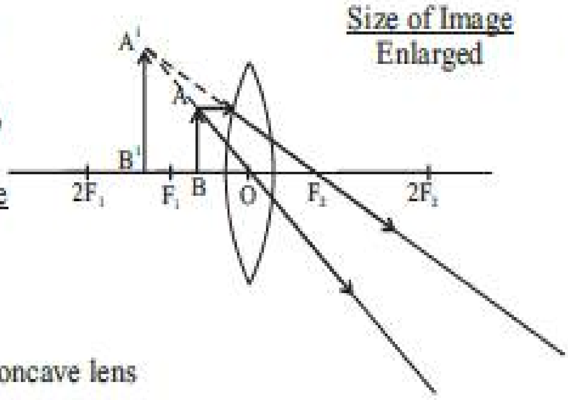


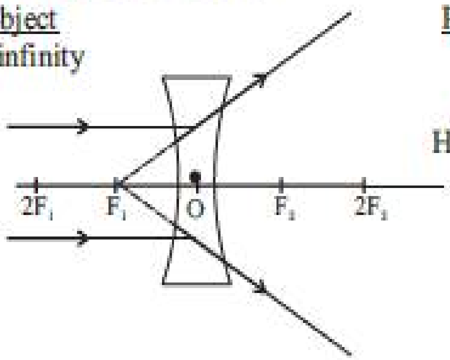
Image formation by concave lens

1. **Object**
Alt infinity

Position of Image
At F_1

Size of Image
Highly Diminished

Nature
Virtual & Erect

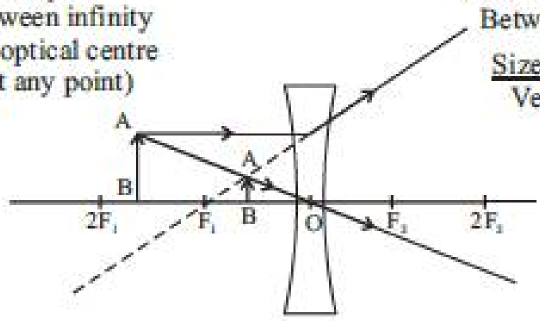


2. **Object**
Between infinity and optical centre (at any point)

Position of Image
Between F_1 & O

Size of Image
Very small

Nature
Virtual & Erect



LENS FORMULA

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

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

$$v = \frac{fu}{f+u}$$

$u = \frac{fv}{f-v}$,u = *distance to object,* v = distance to image, f = focal length

Note:

- The focal length of convex lens is positive
- The focal length of concave lens is negative
- Height of object is taken as positive
- Height of image is -ve for real image and + ve for virtual image

Magnification(m)

Magnification

Magnification is the ratio of the height of the image to the height of the object. It shows how many times the image is larger than the object.

$$\text{Magnification} = \frac{\text{Height of the image}}{\text{Height of the object}} = \frac{IM}{OB} = \frac{h_i}{h_o}$$

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

- If m > 1 → Image is magnified
- If m = 1 → Image is of same size
- If m < 1 → Image is diminished

Uses of lens

- In telescope
- In spectacles
- In cameras
- In microscope
- In binocular

Power of a Lens

Power is a term related to the focal length of a lens. Power of a lens is the reciprocal of focal length expressed in metres. Power

$$p = \frac{1}{f}$$

Unit of power is dioptre. It is represented by D.

Note:

- power of a convex lens is +ve and power of a concave lens is -ve
- 1D = 100 cm

Q) calculate the focal length of a lens having power +2D

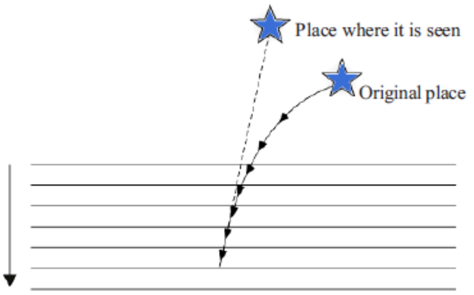
Ans) power, P = $\frac{1}{f}$

$$f = 1/p = \frac{1}{2D} = \frac{1}{\frac{2}{100}} = \frac{100}{2} = 50cm$$

<u>Atmospheric Refraction of Light</u>

The refraction of light in different layers of atmosphere having different optical densities is called atmospheric refraction of light.

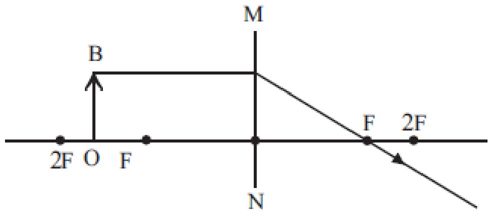
Q) explain the reason behind twinkling of stars
Ans)
Light coming from distant stars passes through different layers of air. Each layer is differing from another in their optical densities. Hence light undergo successive refraction. Since stars at a greater distance they appear like a point source. The rays of light appear to come from different points on reaching eye after refraction. This is the reason for twinkling of stars.



<u>Practice Questions</u>

2) The nature of images formed by two lenses are given.
   (i) An erect and magnified virtual image
   (ii) An erect and diminished virtual image
   (a) What type of lens is used in each case?
   (b) By using which type of lens will we get an image having the same size as the object? What is the position of the object?

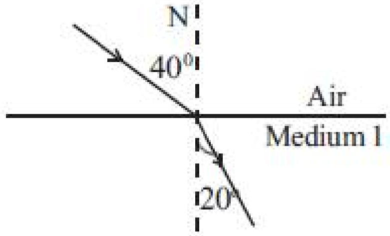
3)

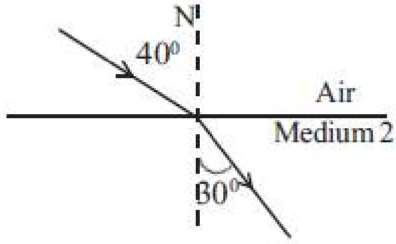


   (a) MN represents a lens. What type of lens is this?
   (b) What are the characteristics of the image?
   (c) Copy the ray diagrams in the science diary and complete it.

4. What do you mean by power of a lens? What is the SI unit of the power of a lens? Calculate the power of a concave lens of focal length 25 cm.

5) Observe the figure. Light falling on two different media are shown.





(a) Which medium has greater optical density? Why?

(b) Which medium has greater refractive index?

6) An object of height 3 cm is placed in front of a convex lens of focal length 20 cm at a distance of 30 cm.

(a) What is the distance to the image formed?

(b) What is the nature of the image?

(c) What is the height of the image?

7) In the table the absolute refractive indices of certain transparent media are given.

Medium	Refractive index
Air	1.0003
Water	1.33
Kerosene	1.44
Turpentine oil	1.47
Crown glass	1.52
Diamond	2.42

(a) Find out from the table the medium of highest and lowest optical densities.

(b) If the speed of light in air is 3×10^8 m/s, what will be the speed of light through kerosene?

(c) Will a ray of light deviate towards the normal or away from the normal when it enters from air to diamond obliquely?

(d) The refractive index of diamond is 2.42. What do you mean by this? Calculate the speed of light through diamond.