5.Refraction of Light

Focus area

1. Relation between Speed of light and optical density
2. Refraction of Light
3. Refraction in different Media
4. Total Internal Reflection
5. Lenses -technical terms - image formation -ray diagrams - characteristics of image- power of lens.

1. Relation between Speed of light and optical density

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

* The speed of light through various media differs.

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.

* As the optical density of a medium increases, the speed of light through it decreases and vis-versa.

* Can the media given in the table be arranged in the increasing order of their optical densities?

decreases ◄—— Optical density ——► increases

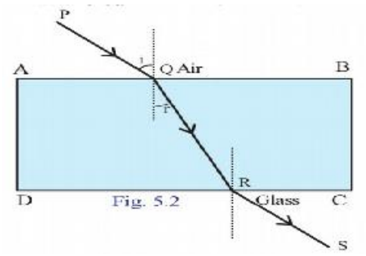
Air < Water < Glass < Diamond

increases ◄—— Speed of light ——► decreases

2. 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.

3. Refraction in different Media



- Which is the incident ray on the surface of separation CD?

* QR

- The angle between the incident ray and the normal is called the angle of incidence. If so, can you explain what is angle of refraction?

* The angle between the refracted ray and the normal

- Using a protractor measure the angle of incidence and the angle of refraction.

* Angle of incidence i = 45^0 , Angle of refraction r = 28^0

- Is the angle of refraction greater or lower than the angle of incidence when it goes from air to glass?

* Lower

- What about from glass to air?

* grater

- Which is of greater optical density air or glass?

* Glass

- While going from air to glass,(from a medium of lower optical density to that of a greater one) the refracted ray deviates towards the normal/ deviates away from the normal.

* Deviates towards the normal

- What happens while it goes from glass to air(from a medium of greater optical density to that of a lower one)?

* Deviates away from the normal.

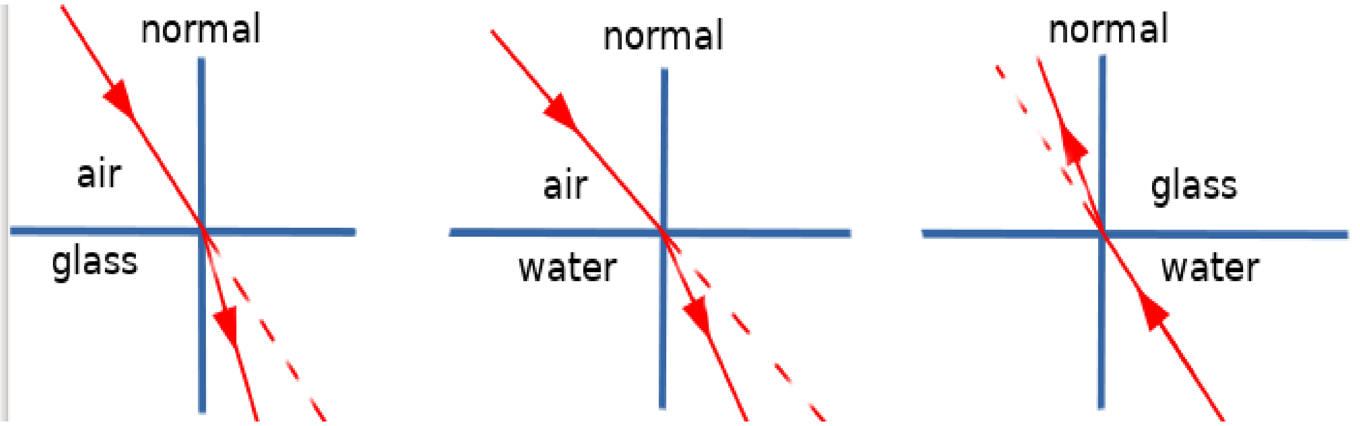
- Are the angle of incidence, angle of refraction and the normal at the point of incidence on the same plane?

* Yes

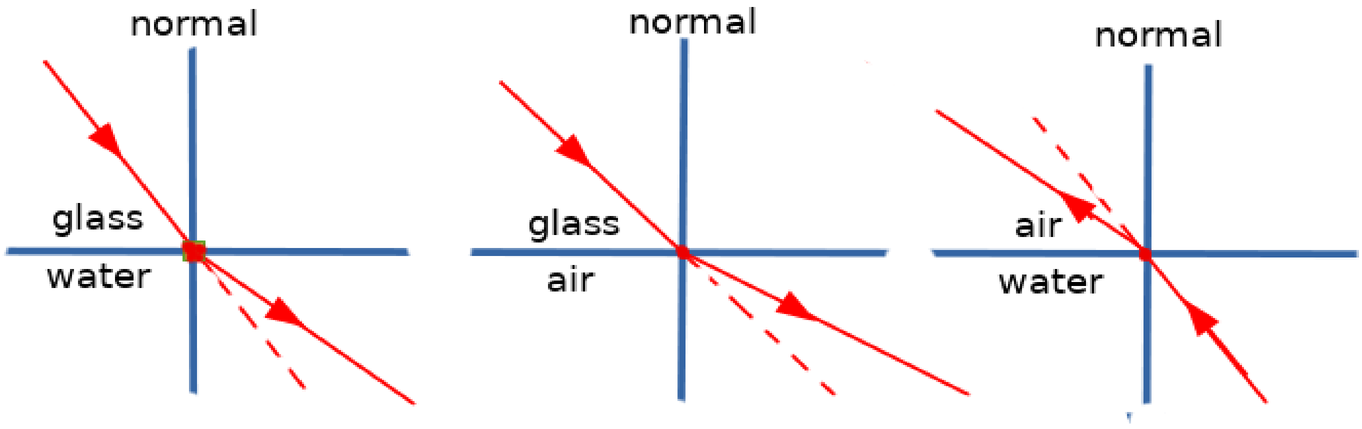
- Does refraction take place for a ray while entering a glass slab normal to it?

* No

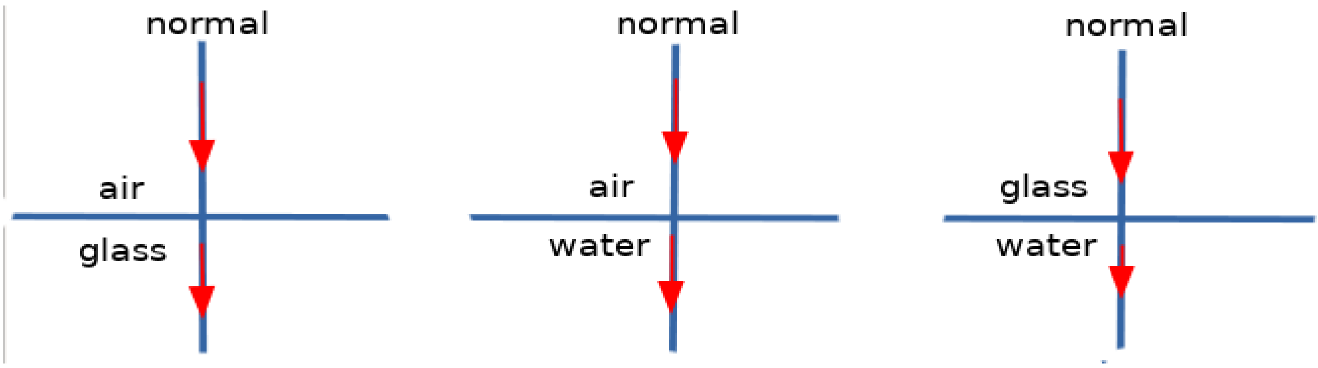
* From a medium of lower optical density to that of a greater one the refracted ray deviates towards the normal.



* From a medium of greater optical density to that of a lower one the refracted ray deviates away from the normal.

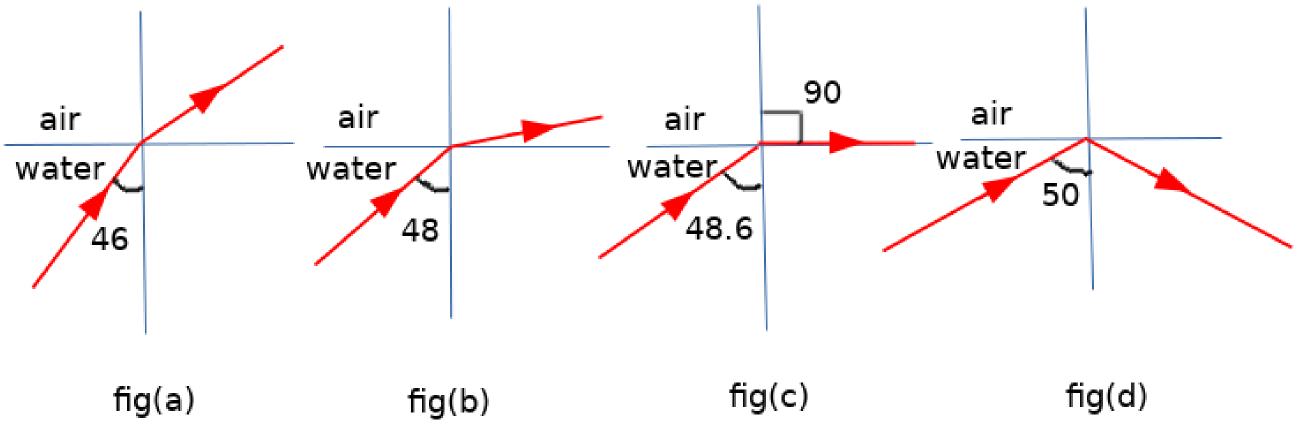


*No deviation takes place in the case of a light ray falling normally on a medium



4. Total Internal Reflection

When a ray of light passes from a medium of greater optical density to that of lower optical density, (ray of light passes from water to air)



Fig(a) angle of incidence = 46^0

- Refraction is taking place

Fig(b) angle of incidence = 48^0

- Refraction is taking place,
- The refracted ray approaches the surface of the water

Fig(c) angle of incidence = 48.6^0 (Critical angle).

- Refraction is taking place,
- Refracted ray passes along the surface of water
- Now the angle of refraction is 90^0

Fig(d) angle of incidence = 50^0

- Refraction doesn't taking place,
- The ray is reflected back to the same medium without undergoing refraction.

Critical angle

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 90^0 is the critical angle.

* The critical angle in water is $48.6\ ^0$
* The critical angle in glass is $42\ ^0$

Total internal reflection

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.

* The path of light in different media is shown in the figures. Analyse them and answer the following questions.

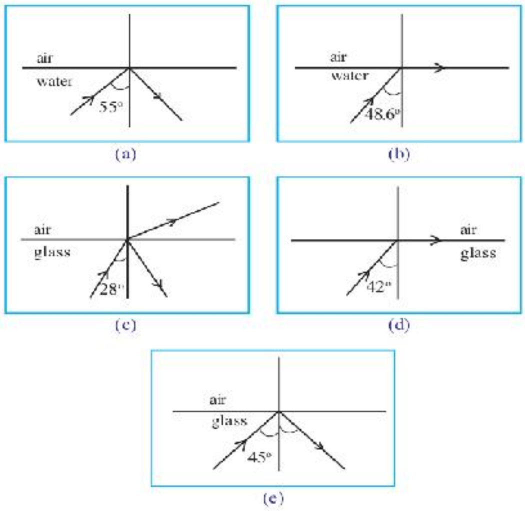


Fig. 5.13

- Which are the figures that show total internal reflection?
  * Fig (a) and (e)
- What is the critical angle of glass?

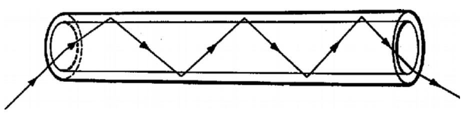
* $42\ ^0$

- Will total internal reflection take place when light passing through water is incident on the surface of separation with air at an angle of incidence of 45^0 ? Why?

* No. The critical angle of water is $48.6\ ^0$. Total internal reflection will take place only if the angle of incidence is greater than the critical angle.

* Find out the practical applications of total internal reflection in our day to day life.

Medical field → Endoscope.
In the field of telecommunications → Optical fibre cables.



5. Lenses -technical terms - image formation -ray diagrams - characteristics of image- power of lens.

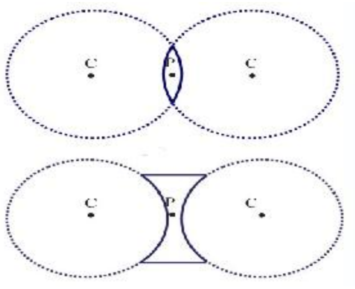
Lens

A lens is a transparent medium having spherical surfaces.

Terms and characteristics associated with convex and concave lenses.

1. Optic centre

Optic centre is the midpoint of a lens (P).



2. Centre of curvature

A lens has two spherical surfaces as parts of the lens. Centre of curvature (C) is the centre of the imaginary spheres of which the sides of the lens are parts.

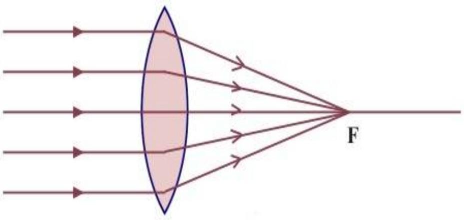
3. Principal axis

Principal axis is the imaginary line that passes through the optic centre joining the two centres of curvature.

4. Principal focus

a) Principal focus of a convex lens

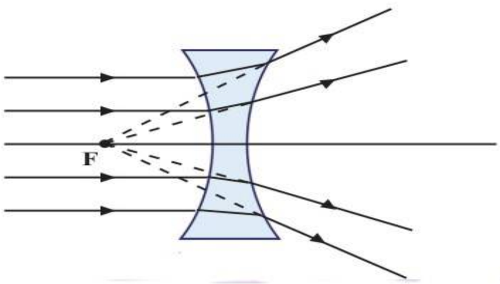
Light rays incident parallel and close to the principal axis after refraction converges to a point on the principal axis of a convex lens. This point is the principal focus of a convex lens



* The principal focus of a convex lens is real
* The convex lens has two focuses.

b) Principal focus of concave 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.



* The principal focus of a concave lens is virtual.
* The concave lens has two focuses.

Focal length

Focal length is the distance from the optic centre to the principal focus. This is denoted by the letter f'.

Formation of image using 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 2 F	Real	Inverted	Magnified
5. At F	At infinity	Real	Inverted	Very much magnified
6. Between F and lens	At behind the lens	Virtual	Erect	Magnified

Ray diagram of formation of images by lenses

The points to be taken care of while drawing ray diagrams

1. When a ray of light passes through the optic centre of a thin lens, it does not undergo deviation.

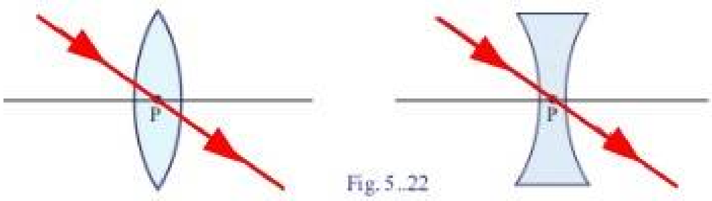


Fig. 5..22

2. A ray of light falling parallel to the principal axis of a convex lens passes through the principal focus after refraction.

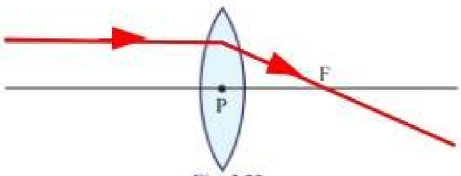


Fig. 5.23

3. A ray incident parallel to the principal axis of a concave lens appears to diverge from the focus on the same side of the lens.

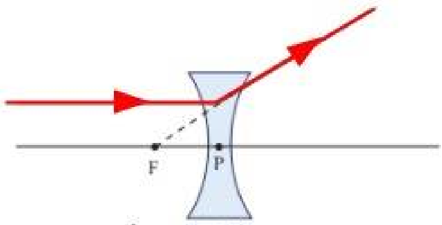


Fig. 5.24

4. A ray of light passing through the principal focus of a convex lens passes parallel to the principal axis after refraction.

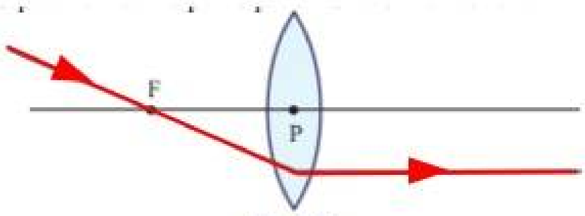
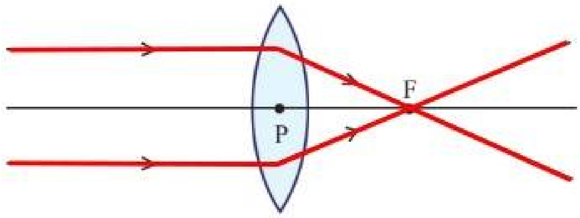


Fig. 5.25

Ray diagram of formation of images by convex lenses

1. Object at infinity



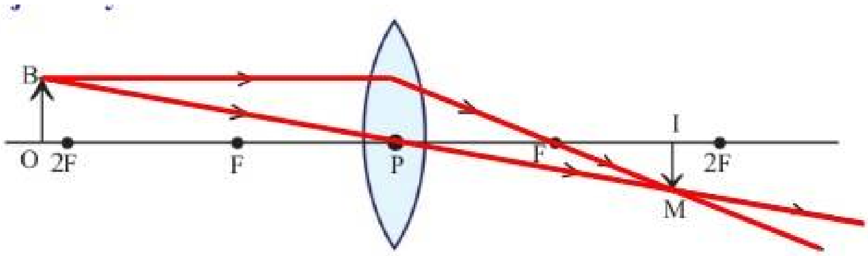
The characteristics of the image

Position of the image : At F

Nature of the image : Real, Inverted

Size of the image : Diminished

2. Object beyond 2F

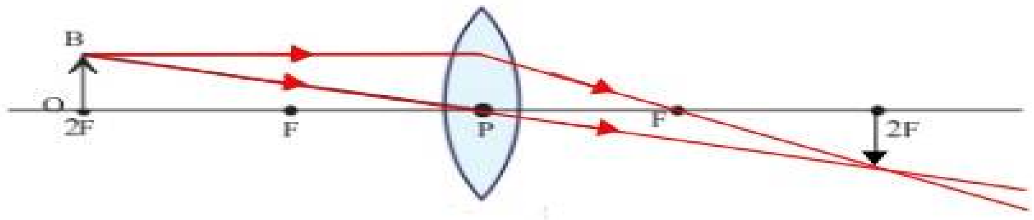


The characteristics of the image

Position of the image : Between F and 2F

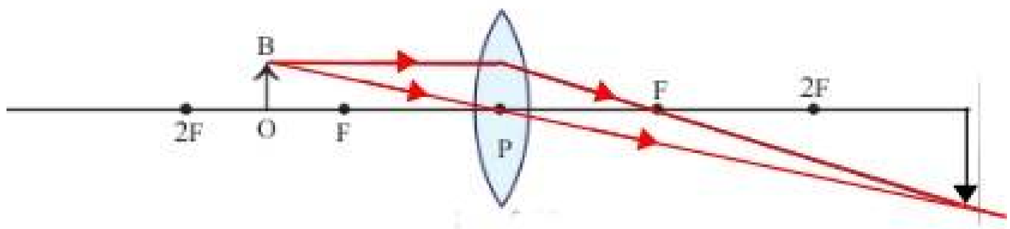
Nature of the image : Real, Inverted
Size of the image : Diminished

3. Object at 2F



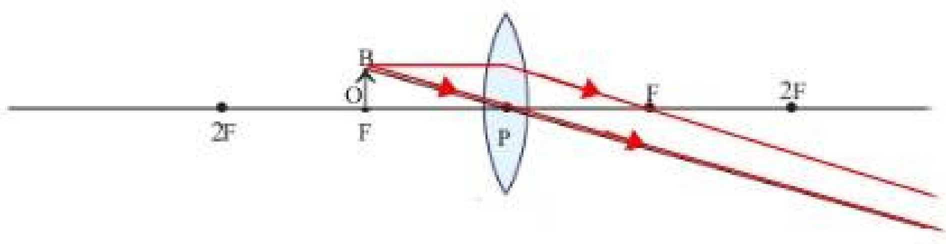
The characteristics of the image
Position of the image : 2F
Nature of the image : Real, Inverted
Size of the image : Same size

4. Object between F and 2F



The characteristics of the image
Position of the image :Beyond 2F
Nature of the image : Real, Inverted
Size of the image : Magnified

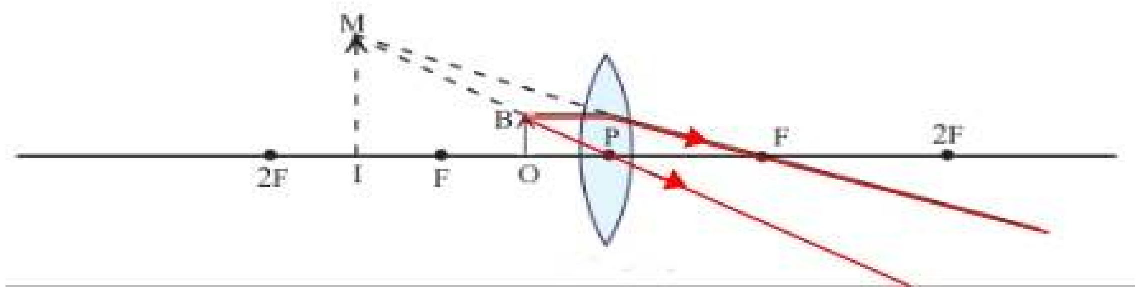
5. Object at F



The characteristics of the image
Position of the image : At infinity
Nature of the image : Real, Inverted

Size of the image : Magnified

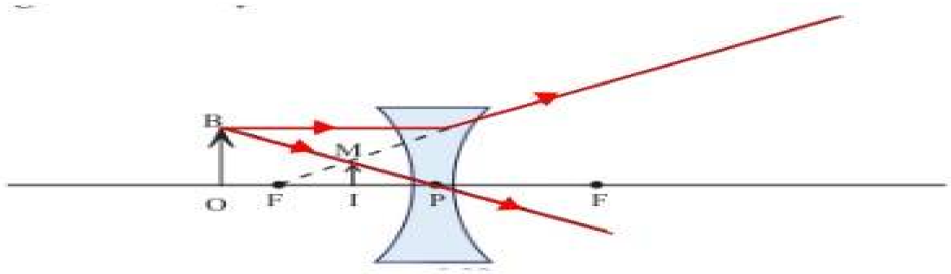
6. Object between F and lens



The characteristics of the image

Position of the image : At behind the lens
Nature of the image : Virtual, Erect
Size of the image : Magnified

Ray diagram of formation of images by concave lenses



The characteristics of the image

Position of the image : At behind the lens
Nature of the image : Virtual, Erect
Size of the image : Diminished

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.

$$\text{Power} = {}^{1}/_{f}$$

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

* The power of a convex lens is positive and that of a concave lens is negative.

1. What is the focal length of a lens of power +2D?

$$\text{Power (p)} = + 2\ D$$

$$\text{Power} = {}^{1}/_{f}$$

$$f = 1/p$$

$$= 1/2x10^{-2} = 100/2 = +50\ cm$$

Focal length of the lens = +50 cm