CHAPTER – 9
LIGHT-REFLECTION & REFRACTION

Light is a **form of energy,** which enable us to see the object.

In this chapter we will study the phenomena of reflection and refraction using the property of light i.e. straight line propagation (Light wave travel from one point to another, along a straight line).

Reflection of Light

When the light is allowed to fall on highly polished surface, such as mirror, most of the light gets reflected.

Laws of Reflection

1. The angle of incidence is always equal to angle of reflection.
   $i = r$
2. The incident ray, reflected ray and the normal to the reflecting surface at the point of incidence lie in the same plane.

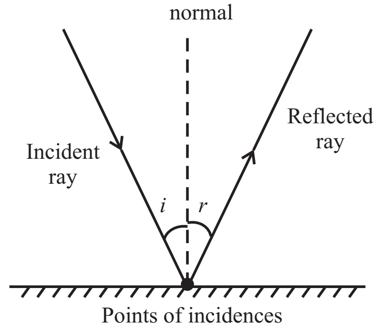
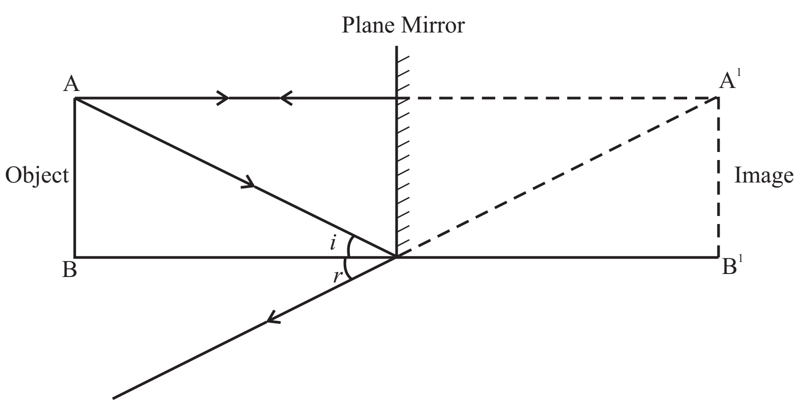


Image formed by Plane Mirror (Plane reflecting surface)



1) Virtual (imaginary) & **Erect (Virtual** The image that do not form on screen.)
2) Laterally inverted (The left side of object appear on right side of image)
3) The size of image is equal to that of object

4. The image formed is as for behind the mirror as the object is in front of it.

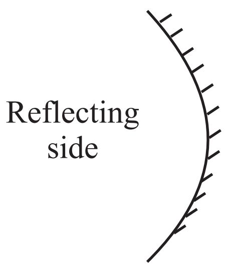
Reflection of light by spherical Mirrors

Mirrors, whose reflecting surface are curved inward or outward spherically are called spherical mirror.

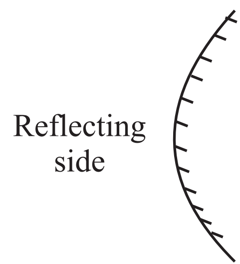
For example - Spoon } The curved surface of shinning spoon can be considered as curved mirror.

If it is curved inward Act as concave mirror

If it is curved outward Act as a convex mirror.

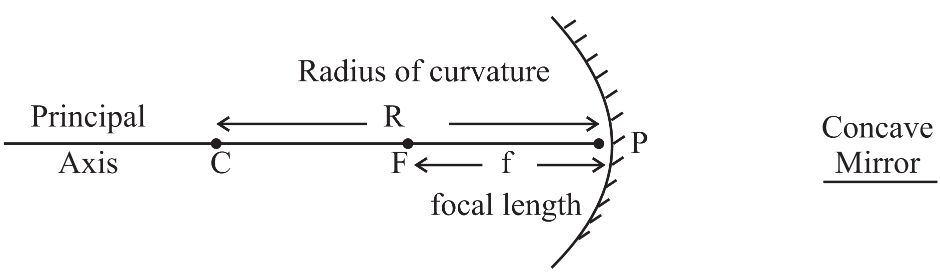


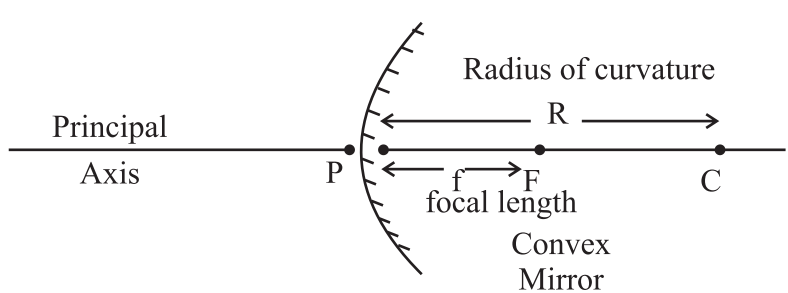
Concave
Mirror
OR CONVERGING
MIRROR



Convex
mirror
OR DIVERGING
MIRROR

Few Basic terms related to Spherical Mirror





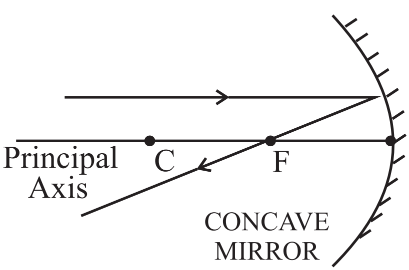
1. **Principal axis :** Line joining the pole and centre of curvature of the spherical mirror.
2. **Pole :** The geometrical central point of the reflecting spherical surface. (aperture), denoted by (P).
3. **Aperture :** The width of reflecting spherical surface.
4. **Centre of curvature :** The reflecting surface of a spherical mirror form a part of sphere. It has a centre, which is known as centre of curvature, denoted by (C)
5. **Radius of curvature :** The separation between the pole and the centre of curvature. ie. $\boxed{PC = R}$
6. **Focus point :** The point on the principal axis, where all parallel rays meet after reflection, denoted by (F)
7. **Focal length :** The length between the pole and focus point i.e. $\boxed{PF = f}$
8. **Relationship between focal length** and **Radius of curvature**.

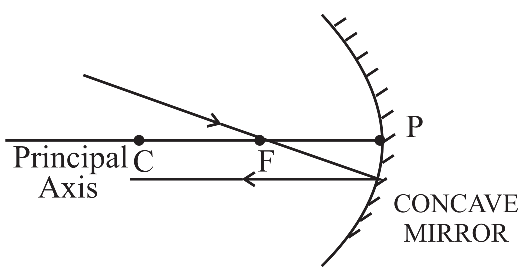
$$F = \frac{R}{2}$$

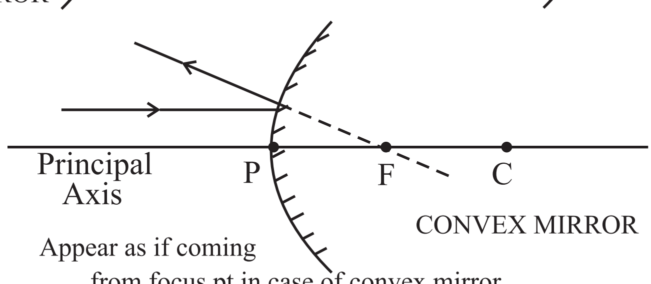
Image formation by spherical Mirror

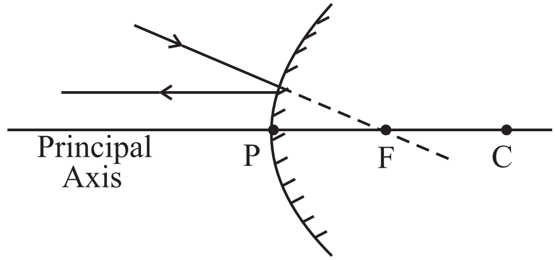
Before we learn the formation of image or ray diagram, let us go through few tips

a) Remember, A say of light which is parallel to principle axis always pass through focus (meet at focus) or **vice-versa**

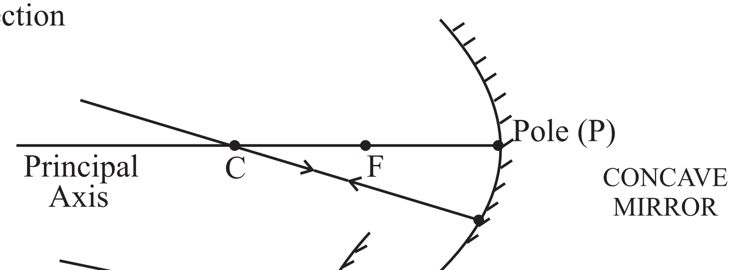


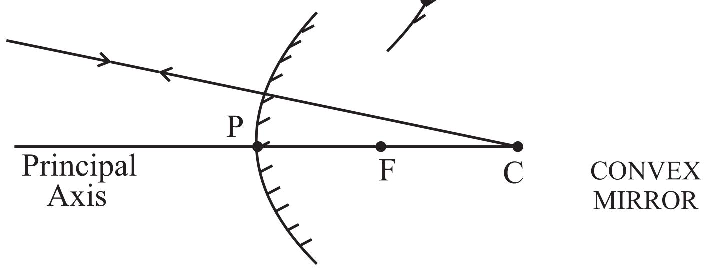




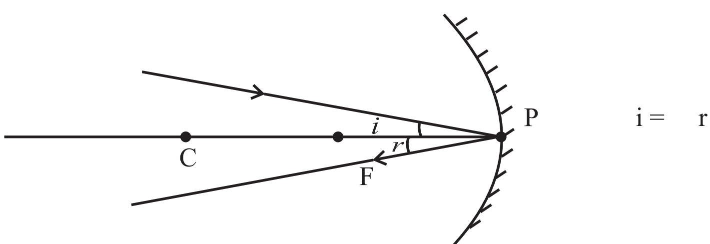


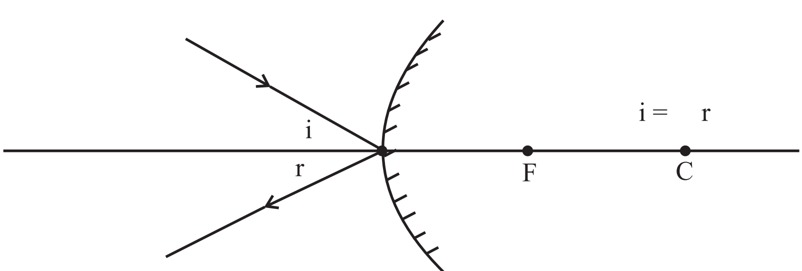
b) A ray of light which passes through centre of curvature (it is also known as normal at the point of incidence on spherical mirror) will retrace their path after reflection



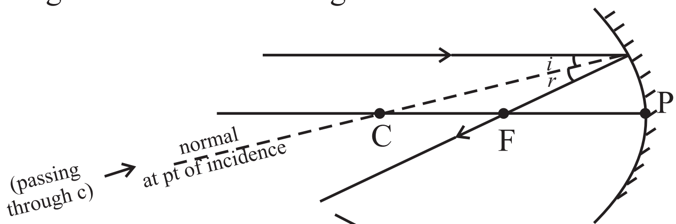


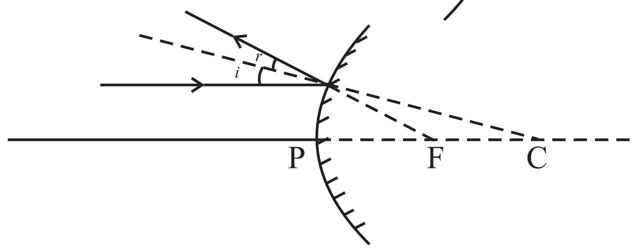
c) A ray of light falling on pole get reflected at the same angle on the other side of principal axis.





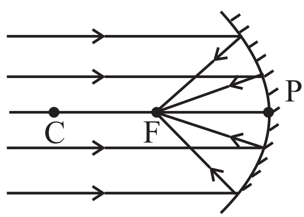
Note : A ray of light passes through centre of cus-valerie reflecting spherical surface is always act as normal at the point of incidence. If we know the normal we can draw angle of incidence and angle of reflection





Note : The image will only form when two or more rays meets at apoint. Image formation by a concave mirror for different position of the object

1. <u>Object</u>
At infinity

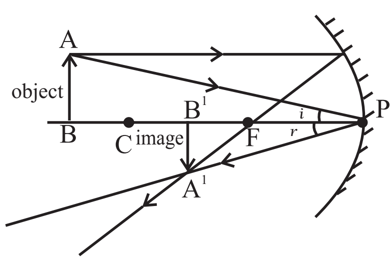


<u>Position of Image</u>
At focus

<u>Size of Image</u>
Highly diminished (point size)

<u>Nature</u>
Real and Inverted

2. <u>Object</u>
Beyond C

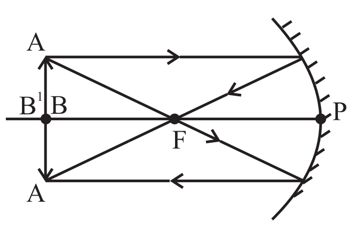


<u>Position of Image</u>
Between F&C

<u>Size of Image</u>
Small

<u>Nature</u>
Real and Inverted

3. <u>Object</u>
At C

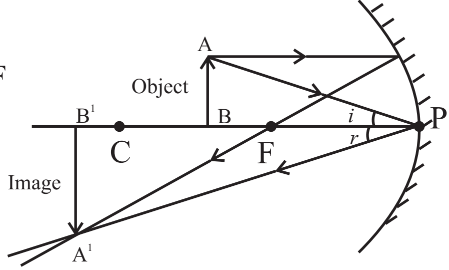


<u>Position of Image</u>
At C

<u>Size of Image</u>
Same Size of object

<u>Nature</u>
Real and Inverted

4. Object
Between C&F



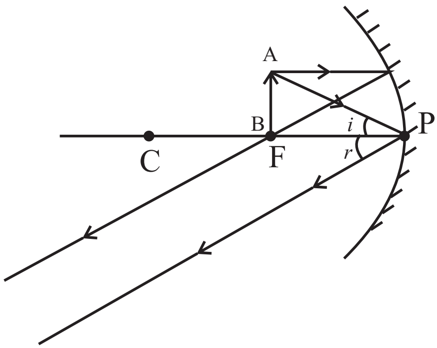
$i = r$

Position of Image
Beyond C

Size of Image
Enlarged

Nature
Real and Inverted

5. Object
At F



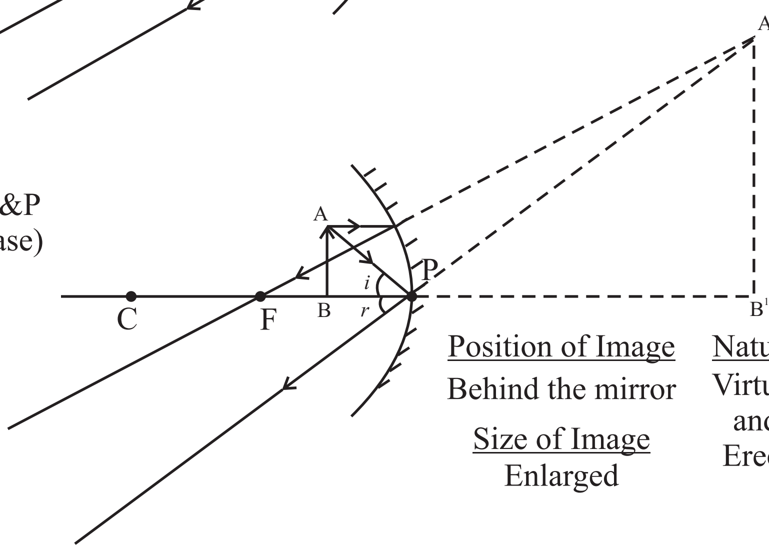
$i = r$

Position of Image
At (infinity)

Size of Image
Highly enlarged

Nature
Real and Inverted

6. Object
Between F&P
(Special Case)



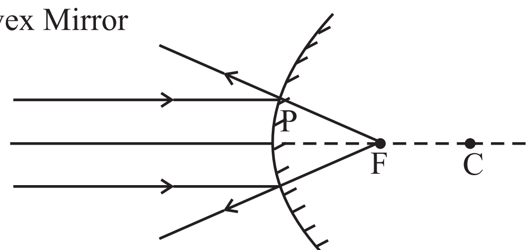
Position of Image
Behind the mirror

Size of Image
Enlarged

Nature
Virtual and Erect

Image formation by Convex Mirror

1. Object
At infinity

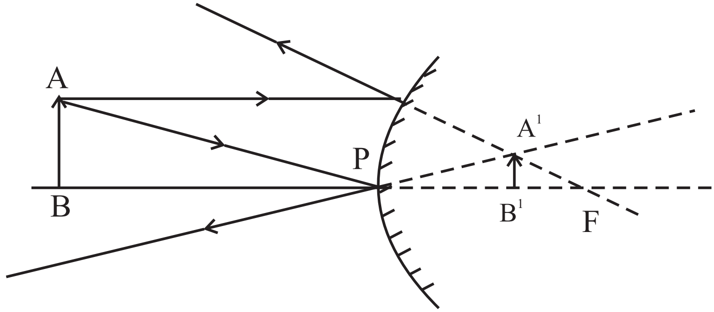


Position of Image
At focus

Size of Image
Highly diminished

Nature
Virtual & erect

1. Object
Anywhere between infinity and pole of the mirror



Position of Image	Size of Image	Nature
Between P & F	Very small	Virtual & erect

Uses of Concave Mirror

1. Used in torches, search light and headlight of vehicle.
2. Used to see large image of face as shaving mirror
3. Used by dentist to see large images of the teeth
4. Large concave mirror used to focus sunlight (heat) in solar furnaces.

Uses of Convex Mirror

1. Used as rear-view mirror in vehicles because it gives erect image. It also helps the driver to view large area.

Sign Convention for Reflection by Spherical Mirror

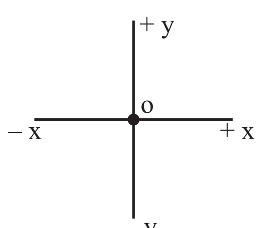
1. The object is always placed to the left side of mirror.
2. All distance should be measured from pole (P); parallel to principal axis.
3. Take **'P'** as **origin.** Distances measured

   Right of the origin (+ x - Axis) are **taken positive**

   Left of the origin (– x-Axis) are **taken negative**

   Perpendicular to and above principal axis (+y-Axis) are **taken positive**

   Perpendicular to and below principal axis (–y-Axis) are **taken negative**



(Cartesian system)

MIRROR FORMULA

$$\frac{1}{F} = \frac{1}{v} + \frac{1}{u}$$

where $f = \frac{R}{2}$

f distance between F and Pole

v distance of image from Pole

u distance of object from Pole

R distance between centre of curvature and pole.

MAGNIFICATION

It is expressed as the ratio of the height of the image to height of the object

$$m = \frac{\text{height of image}}{\text{height of object}} = \frac{h^1}{h} \quad \text{——— (1)}$$

It is also related to 'u' and 'v'

$$m = \frac{-v}{u} \quad \text{——— (2)}$$

from 1 and 2 equation

$$m = \frac{h^1}{h} = \frac{-v}{u}$$

where h^1 image height from principle axis

h^1 Object height from principle axis.

It magnitude $m > 1$ _____ Image is magnified

$m = 1$ _____ Image is of same size

$m < 1$ _____ Image is dimirushed

Few tips to remember sign convention for Spherical mirror

Object height (h) always positive | Image height (h^1) { Real - negative; Virtual - positive }

Object distance from pole (u) is always negative

Image distance from pole (v) { Real - Image always negative; Virtual - Image always positive }

Focal length (f) { Concave mirror – always negative; Convex mirror – always positive }

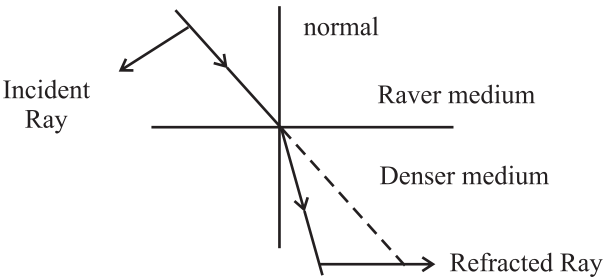
REFRACTION OF LIGHT

Refraction of Light : Happens in Transparent medium when a light travels from one medium to another, refraction takes place.

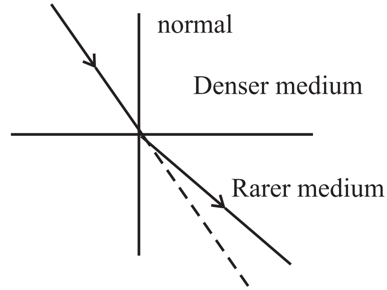
A ray of light bends as it moves from one medium to another

Refraction is due to **change in the speed of light** as it enters from one transparent medium to another.

Speed of light decreases as the beam of light travel from rarer medium to the denser medium.



When ray travel from Rarer to Denser it bends towards normal after refraction

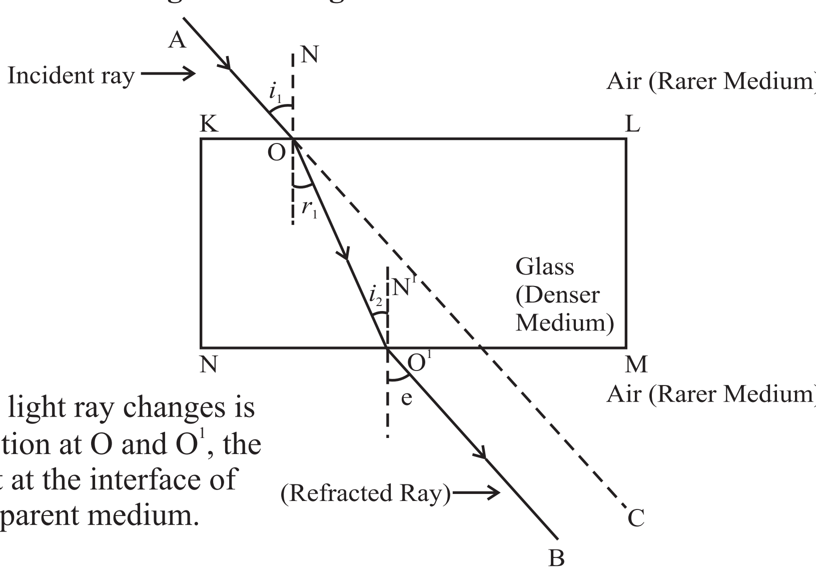


When ray travel from denser to rarer medium it bends away from normal

Some Commonly observed phenomenon due to Refraction

1. The stone at the bottom of water tub appear to be raised.
2. A fish kept in aquarium appear to be bigger than its actual size.
3. A pencil partially immersed in water appears to be displaced at the interface of air and water.

Refraction through a Rectangular Glass Slab



Here light ray changes is direction at O and O', the point at the interface of transparent medium.

When a incident ray of light AO passes from a rarer medium (air) to a denser medium (glass) at point. O on interface AB, it will bends towards the normal. At pt O^1, on interface DC the light ray entered from denser medium (glass) to rarer medium (air) here the light ray will bend away from normal $OO^1$is a refracted ray OB is an emergent ray. If the incident ray is extended to C, we will observe that emergent ray O^1B is parallel to incident ray. The ray will slightly displaced laterally after refraction.

Note : When a ray of light is incident normally to the interface of two media it will go straight, without any deviation.

Laws of refraction of light-

1. The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.
2. The ratio of sine of angle of incidence to the sine of angle of refraction is a constant ie.

$$\boxed{\frac{\text{Sin } i}{\text{Sin } r} = \text{constant } (r)}$$

for given colour and pair of media, this law is also known as Snells Law

Constant n is the refractive index for a given pair of medium. It is the refractive index of the second medium with respect to first medium.

$$\boxed{\frac{\text{Sin } i}{\text{Sin } r} = \frac{n_2}{n_1} = n_{21}}$$

Where 2 is for second medium and 1 is for first medium

Refractive Index

The refractive index of glass with respect is air is given by ratio of speed of light in air to the speed of light in glass.

$$n_{ga} = \frac{n_g}{n_a} = \frac{\text{Speed of light in air}}{\text{Speed of light in glass}} = \frac{c}{v}$$

C Speed of light in vacuum = 3 10^8 m/s
speed of light in air is marginally less, compared to that in vacuum.

Refractive index of air with respect to glass is given by

$$\begin{pmatrix} a & \text{air} \\ g & \text{glass} \end{pmatrix} n_{ag} = \frac{n_a}{n_g} = \frac{\text{Speed of light in glass}}{\text{Speed of light in air}} = \frac{v}{c}$$

The absolute refractive index of a medium is simply called refractive index

$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

Refractive index of water (n_w) = 1.33

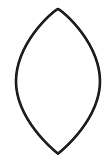
Refractive index of glass (n_g) = 1.52

Spherical Lens

A transparent material bound by two surface, of which one or both surfaces are spherical, forms a lens.

CONVEX LENS

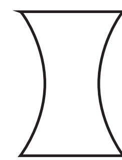
A lens may have two spherical surfaces, bulging outwards, is called double convex lens (or simply convex lens.



It is also known as converging lens because it converges the light.

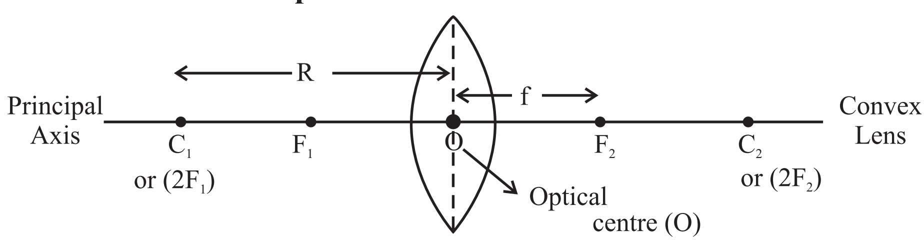
CONCAVE LENS

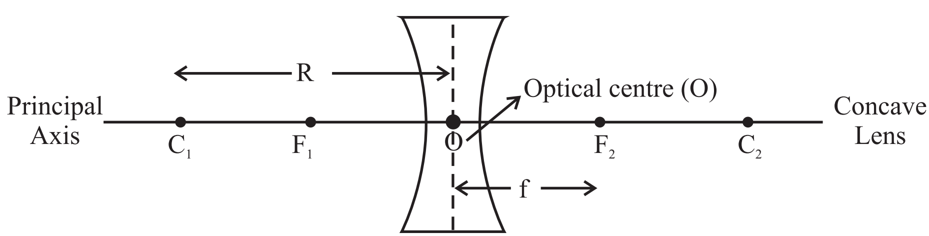
A lens bounded by two spherical surfaces, curved inwards is known as double concave lens (or simply concave lens)

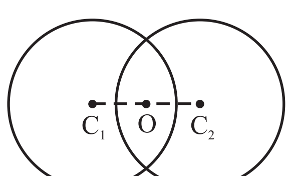


It is also known as diverging lens because it diverges the light.

Few Basic Terms related to spherical lens.







1. **Centre of curvature -** A lens, either a convex lens or a concave lens has two spherical surfaces. Each of these surfaces form a part of sphere. The centre of these two spheres are called centre of curvature represented by C_1 and C_2.

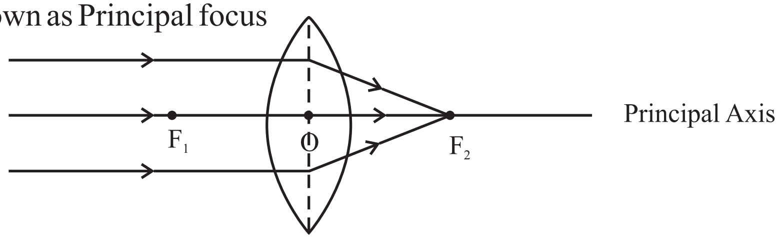
2. **Principal axis -** Imaginary straight line passing through the two centres of curvature

3. **Optical Centre -** The central point of lens is its optical centre (O). A ray of light, when passes through 'O' it remains undeviated i.e. it goes straight.

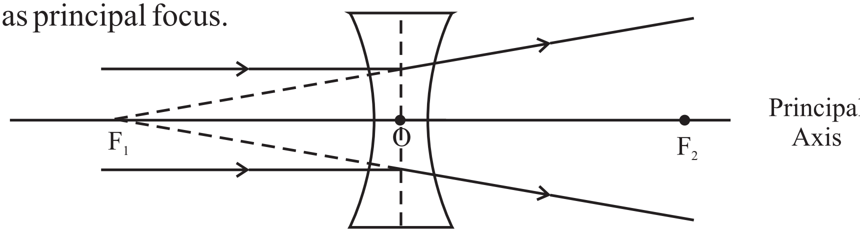
4. **Aperture -** The effective diameter of the circular outline of a spherical lens.

5. Focus of lens - Beam of light parallel is principal axis, after refraction from

    1) **Convex lens,** converge to the point on principal axis, denoted by F, known as Principal focus



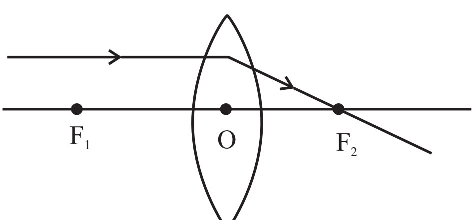
    2) Concave lens, appear to diverge from a point on the principal axis, known as principal focus.



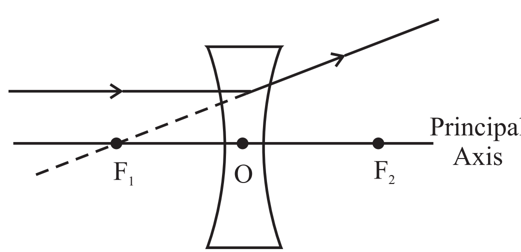
The distance OF_2 and OF_1 is called as focal length

Tips for drawing Ray diagram

a) After refraction, a ray parallel to principal axis will pass through F.

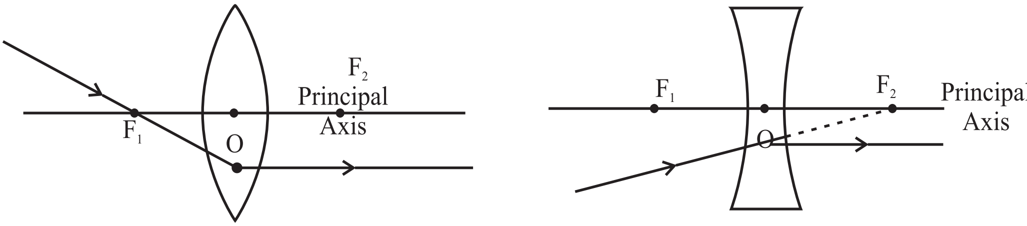


(Converge)



(Diverge)

b) A ray passes through F, after refraction will emerge parallel to principal axis.



c) A ray passes through optical centre 'O', paeses without any deviation.

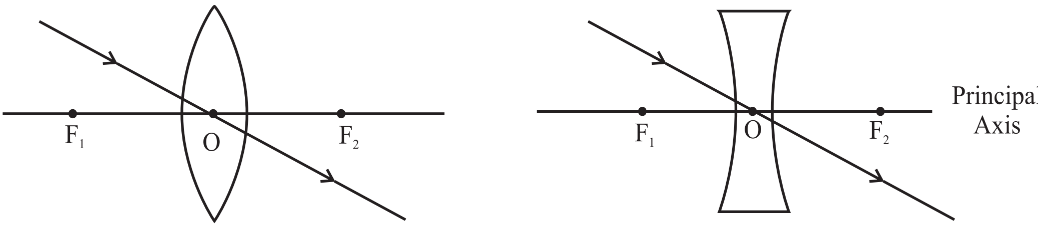
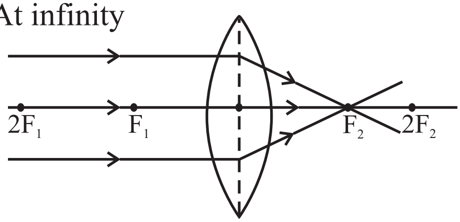


Image formation by a convex lens for various position of object

1. Object
At infinity

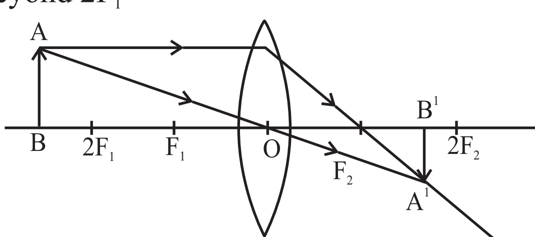


Position of Image
At focus F_2

Size of Image
Highly diminished (point size)

Nature
Real & inverted

2. Object
Beyond $2F_1$

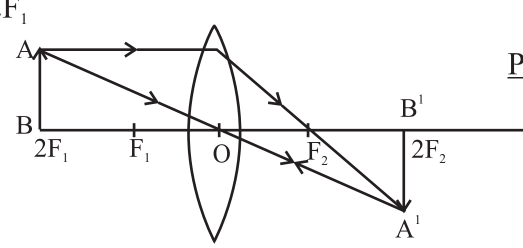


Position of Image
Between F_2 & $2F_2$

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

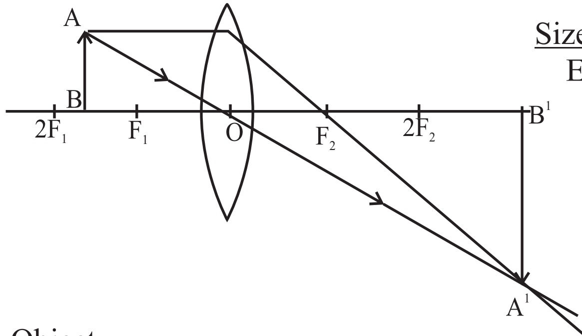
Nature
Real & inverted

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

Position of Image
Beyond $2F_2$

Size of Image
Enlarged

Nature
Real & inverted

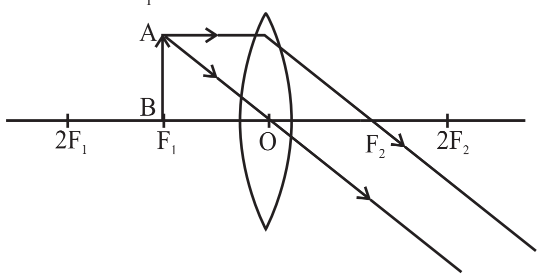


5. **Object**
At focus F_1

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

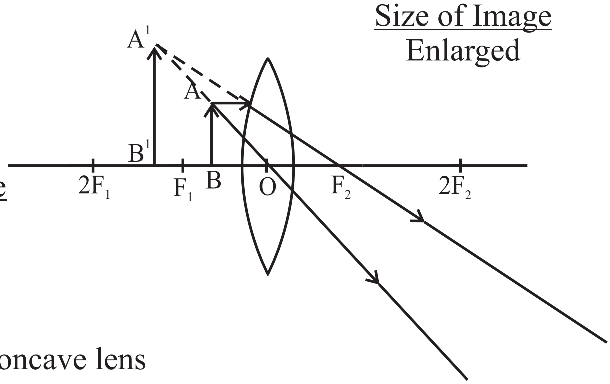


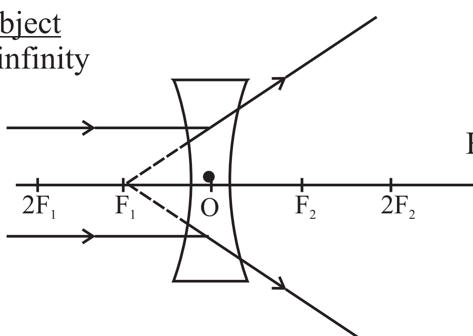
Image formation by concave lens

1. **Object**
Alt infinity

Position of Image
At F_1

Size of Image
Highly Diminished

Nature
Virtual & Erect

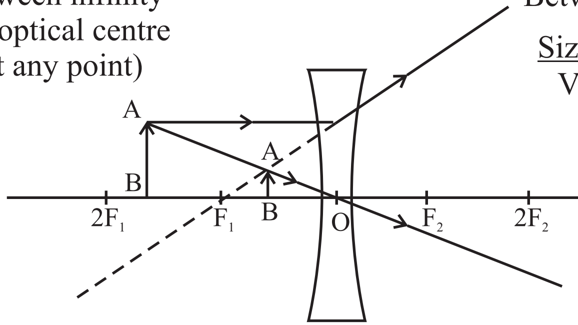


2. **Object**: Between infinity and optical centre (at any point)

Position of Image: Between F_1 & O

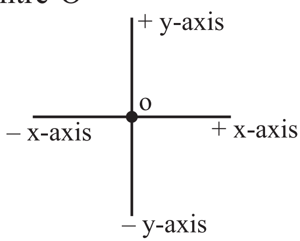
Size of Image: Very small

Nature: Virtual & Erect



Sign Convention for Refraction by spherical lens

Similar to that of spherical mirror, only the difference is that all the measurement are made from optical centre 'O'



LENS FORMULA

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

$$\boxed{f = \frac{R}{2}}$$

'O' optical centre

f - distance between F and 'O'

u - distance of object from 'O'

v - distance of image from 'O'

r - distance between centre of curvature & 'O'

MAGNIFICATION

It is defined as the ratio of the height of image to the height of object.

$$m = \frac{\text{height of image}}{\text{height of object}} = \frac{h^1}{h} = ①$$

h^1 – image height from principal axis

h – object height from principal axis

It is also related to 'u' & 'v'

$$\boxed{m = \frac{v}{u}} \text{ — ②}$$

From equation ① & ②

$$m = \frac{h^1}{h} = \frac{v}{u}$$

If magnitude of	m > |	Image is magnified
	m = 1	Image is of same size
	m < |	Image is deminished

Few tips to remember sign convention for spherical lens

Object height (h) is always **positive**

Image height (h^1) Real is always **negative**
Virtual is always **positive**

Object distance from optical centre (u) is **always negative**

Image distance from optical centre (v) { Real **positive**
virtual **negative**

Focal length (v) { Convex lens is always **positive**
Concave lens is always **negative**

Power of Lens

The degree of convergence or divergence of light ray achieved by a lens is known as **power of a lens**.

It is difined as the **reciprocal of its focal length Represented by P**

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

It f is given in meter, then

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

It f is given in cm, then

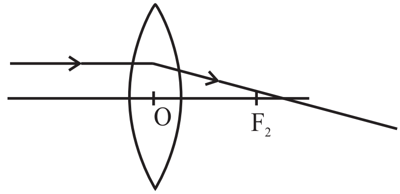
$$P = \frac{100}{f}$$

SI unit of power of a lens is "dioptre" denoted by 'D'

I dioptre or ID It is the power of lens whose focal length is 1m

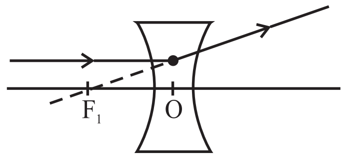
$$ID = \frac{1}{1m}$$ OR $$ID = 1m^{-1}$$

Power convex lens or converging lens is always positive



$\because$ f is +ve

Power of concave lens or diverging lens is always negative



$\because$ f is –ve

If any optical instrument have many lens, then **net power** will be

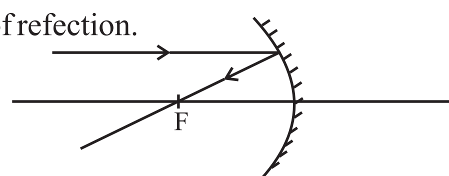
$$\boxed{P = P_1 + P_2 + P_3....}$$

EXERCISE

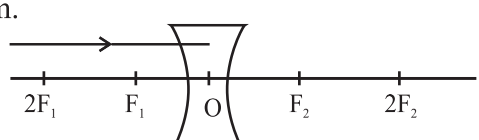
(Question Bank)

Very Short Answers Type Questions (1 Mark)

1. If the angle of incidence is O°, what is the angle of reflection?
2. What is the nature of image formed by concave mirror if the magnification produced by the mirror is +3?
3. Give two uses of concave mirror?
4. Find the focal length of a convex mirror, whose radius of curvature is 30 cm?
5. What do you understand by magnification of a spherical mirror?
6. An object is held at the principal focus of a concave lens of focal length f. Where the image will form?
7. Show the angle of incidence and angle of refection.



8. Complete the ray diagram.



9. Define the SI unit of power of lens.

10. When light undergoes refraction at the surface of seperation of two media, what happens to speed of light.

Short Answer Type Questions (2-3 Marks)

1. What do you understand by refraction of light. Draw the labelled ray diagram, when ray passes through glass slab.

2. The refractive index of glass is 1.54 and the speed of light in air is $3x10^8$ m/s. Calculate the speed of light in water?

3. A convex mirror used on an automobile has a focal length of 6m. If vehicle behind is at a distance of 12m. Find the nature and location of image.

   (4m, virtual erect small)

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

5. Two thin lens of power +3.5D and - 2.5D are placed in contact. Find the power and focal length, if the lens are in combination. (p=+10, f=1m)

6. What are the law of refraction. Define refractive index of a medium.

Very Long Answer Type Questions (5 Marks)

1. Draw the ray diagram, showing the image formed by concave mirror, when object is placed at

   a) at infinity
   b) between F22F
   c) At 2F
   d) At F
   e) between F&P

2. Draw the ray diagram, showing the image formed by convex lens, when object is placed at.

   a) At infinity
   b) between F_1 & $2F_1$
   c) At $2F_1$
   d) Beyond $2F_1$
   e) between F_1 & optical centre 'O'