CHAPTER – 10
LIGHT REFLECTION & REFRACTION

Light is a form of energy, which gives us the power of vision.

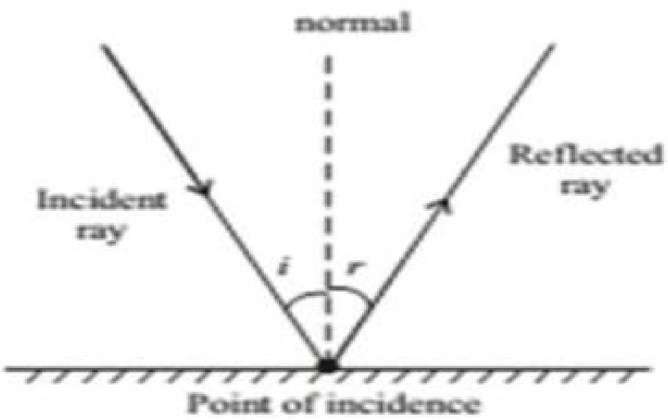
In this chapter we will study the phenomena of reflection and refraction using the property of light i.e. straight line propagation (Light wave travel from one point to another, along a straight line).

Ray of light : It is a line in the direction of movement of light.
Beam of light : It is bucnh of rays of light.
Parallel beam : All the rays are parallel.

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.
$\angle i = \angle r$



2. The incident ray, reflected ray and the normal to the reflecting surface at the point of incidence lie in the same plane.

What you have learnt

- Light seems to travel in straight lines.
- Mirrors and lenses form images of objects. Images can be either real or virtual, depending on the position of the object.
- The reflecting surfaces, of all types, obey the laws of reflection. The refracting surfaces obey the laws of refraction.
- New Cartesian Sign Conventions are followed for spherical mirrors and lenses.
- Mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ gives the relationship between the object-distance (u), image-distance (v), and focal length (f) of a spherical mirror.
- The focal length of a spherical mirror is equal to half its radius of curvature.
- The magnification produced by a spherical mirror is the ratio of the height of the image to the height of the object.
- A light ray travelling obliquely from a denser medium to a rarer medium bends away from the normal. A light ray bends towards the normal when it travels obliquely from a rarer to a denser medium.
- Light travels in vacuum with an enormous speed of 3×108 m s-1. The speed of light is different in different media.
- The refractive index of a transparent medium is the ratio of the speed of light in vacuum to that in the medium.
- In case of a rectangular glass slab, the refraction takes place at both air-glass interface and glass-air interface. The emergent ray is parallel to the direction of incident ray.
- Lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ gives the relationship between the object-distance (u),

image-distance (v), and focal length (f) of a spherical mirror.

- The focal length of a spherical mirror is equal to half its radius of curvature.
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- Power of a lens is the reciprocal of its focal length. The SI unit of power of a lens is dioptre.

Power of Lens

The degree of convergence or divergence of light ray achieved by a lensis known as power of a lens.
It is defined as the reciprocal of its focal length
Represented by P.
If F is given in meter, then

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

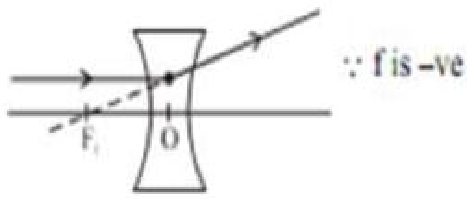
If F is given in cm , then

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

SI unit of power of a lens is "diopter" denoted by 'D'
I diopter or ID $\rightarrow$ It is the power of lens whose focal length is I m

$$\boxed{1D = \frac{1}{1m}} \quad \text{OR} \quad \boxed{1D = 1m^{-1}}$$

Power of convave lens or diverging lens is always negative



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

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

Lens formula

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

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

'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.

$$m = \frac{height\ of\ image}{height\ of\ object} = \frac{h^1}{h} = (1)\ \} \frac{h_1 - image\ height}{h - object\ height\ f}$$

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

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

From equation (1) & (2)
If magnification
m > 1,then image is magnified
m = 1 ,image is of same size
m < 1, image is diminished

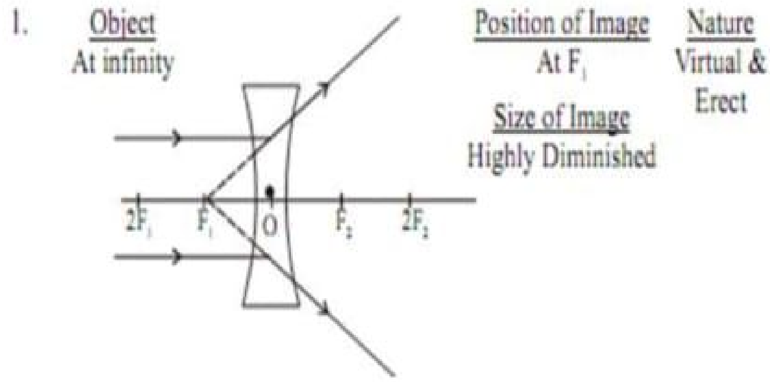
Few Tips to Remember Sign Convention for Spherical Lens

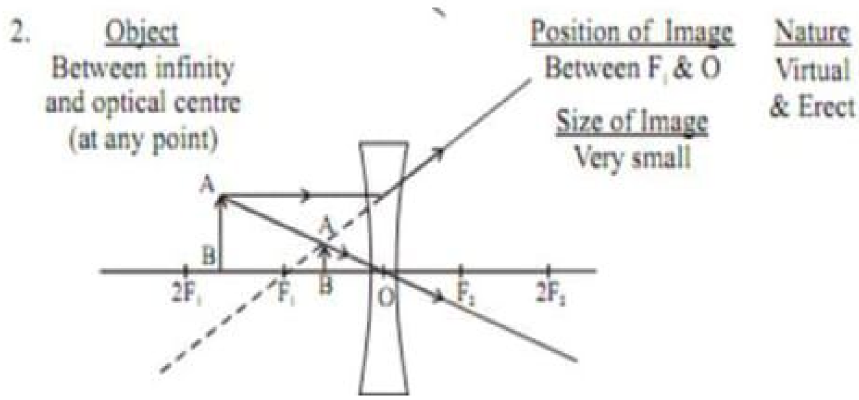
	f	u	
CONCAVE	-ve	-ve	-ve(virtual image alway
CONVEX	+ve	-ve	+ve(real) -ve(virtual)

h is always +ve
h´ −ve for Real and +ve for Virtual &Errect.

Power of Lens

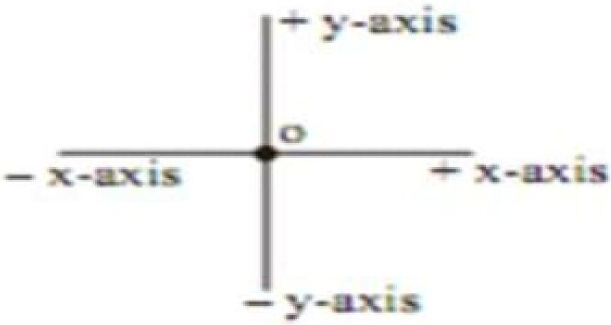
Image Formation by Concave Lens



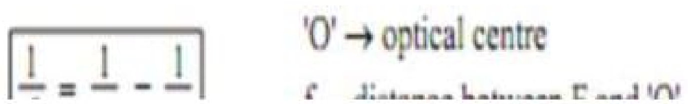


Sign Convention for Refraction by Spherical Lens

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



Lens formula



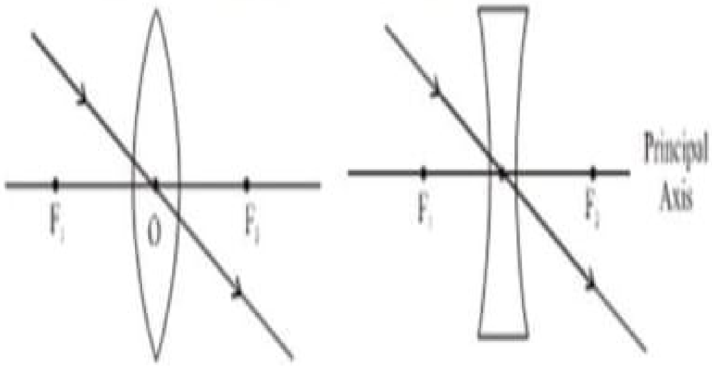
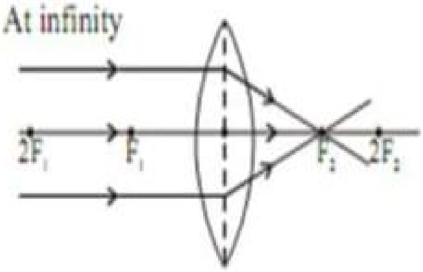


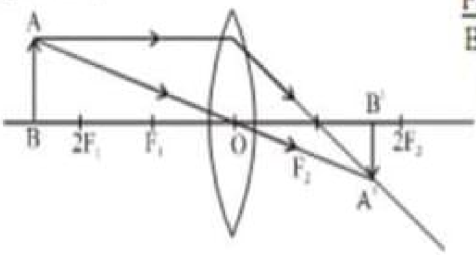
Image formation by a convex lens for various position of object

1. Object
At infinity



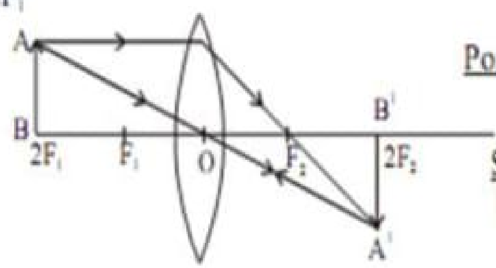
Position of Image	Nature
At focus F_2	Real & inverted
Size of Image	
Highly diminished (point size)	

2. Object
Beyond $2F_1$



Position of Image	Nature
Between F_2 & $2F_2$	Real & inverted
Size of Image	
Small	

Object
At $2F_1$



Position of Image	Nature
At $2F_2$	Real & inverted
Size of Image	
Same size of object	

Object
Between F& $2F_1$

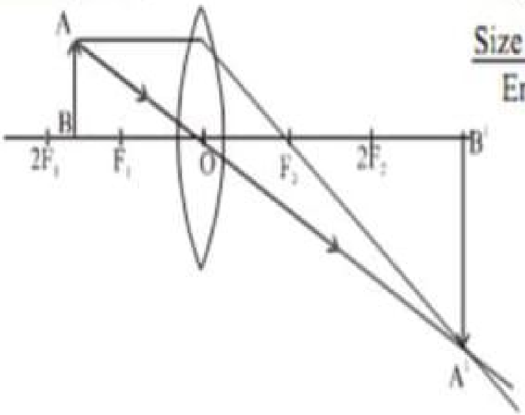
Position of Image	Nature
Beyond $2F_2$	Real & inverted
Size of Image	

Object
Between F & 2F $_1$

Position of Image
Beyond 2F $_2$

Size of Image
Enlarged

Nature
Real & inverted

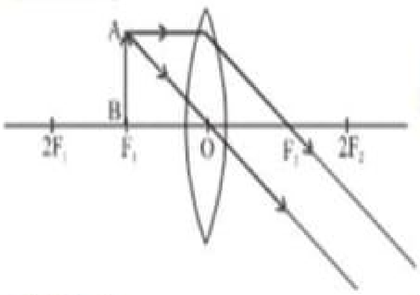


5. **Object**
At focus F $_1$

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

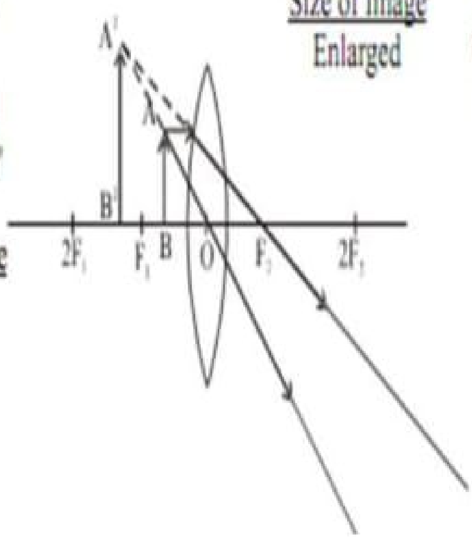


Image Formation by Concave Lens

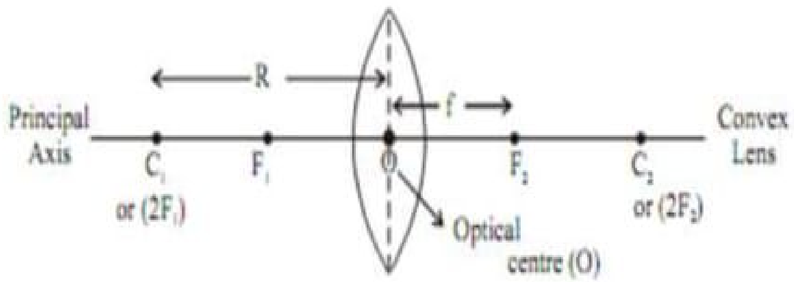
1. **Object**
At infinity

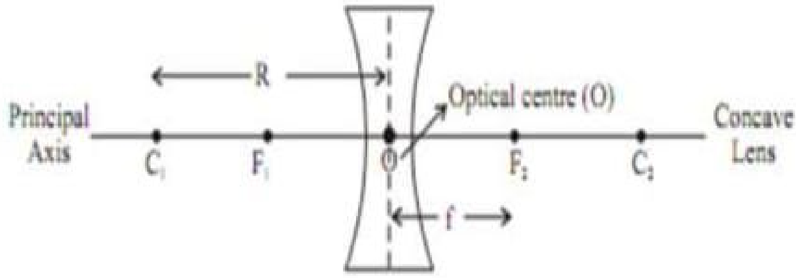
Position of Image
At F $_1$

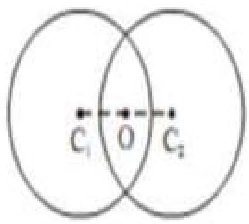
Size of Image

Nature
Virtual & Erect

Few Basic Terms Related to Spherical Lens







1. **Centre of curvature** : A lens, either a convex lens or a concave lens is combination of two spherical surfaces. Each of these surfaces forma part of sphere. The centre of these two spheres are called centre of curvature represented by C1 and C2.
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 to principal axis, after refraction from

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

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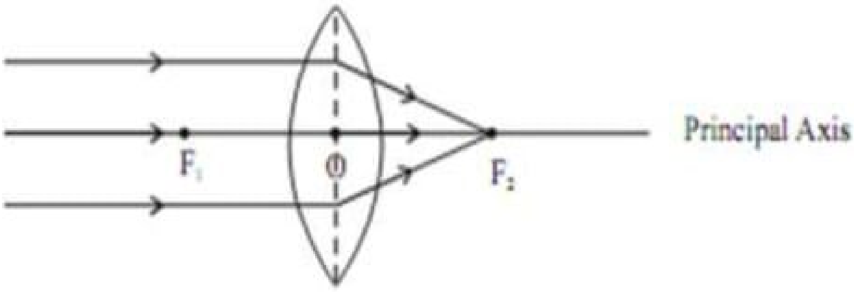
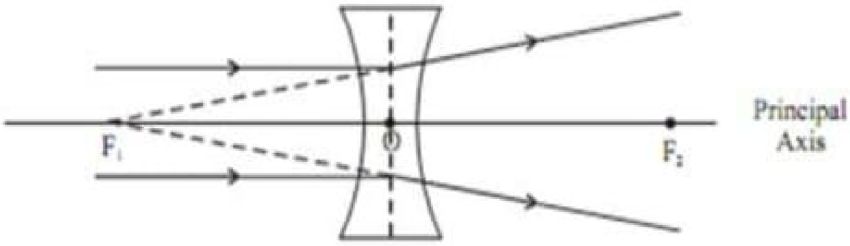


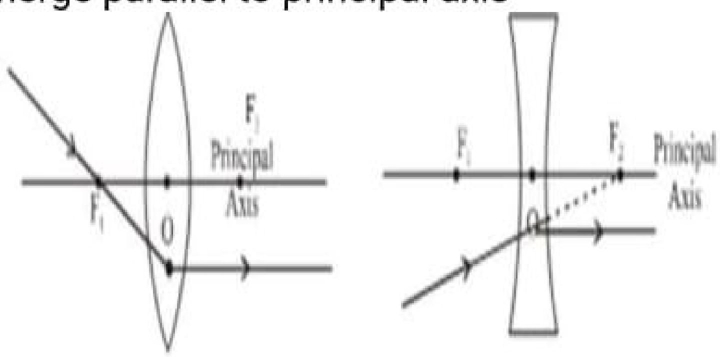
2. **Concave lens**, appear to diverge from a point on the principal axis known as principal focus.



The distance OF2 and OF1 is called as focal length

Tips for Drawaomg Ray Diagram

1. After refraction, a ray parallel to principal axis will pass through F.
2. A ray passes through F, after refraction will emerge parallel to principal axis



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

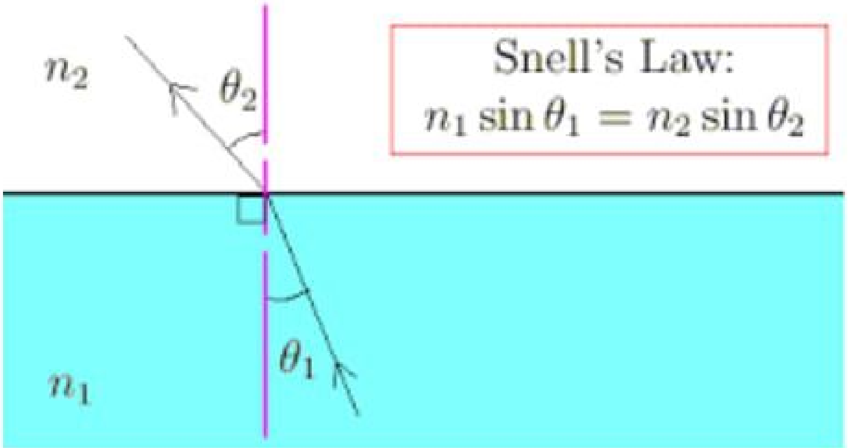
- The ratio of sine of angle of incidence to the sine of angle of refraction is a constant i.e. $\frac{Sin\ i}{Sin\ r} = cons\tan t\ (r)$

For given colour and pair of media, this law is also known as Snell's Law

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

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

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



Refractive Index

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

$$n_{ga} = \frac{speed\ of\ light\ of\ air}{speed\ oflight\ in\ glass} = \frac{c}{v}$$

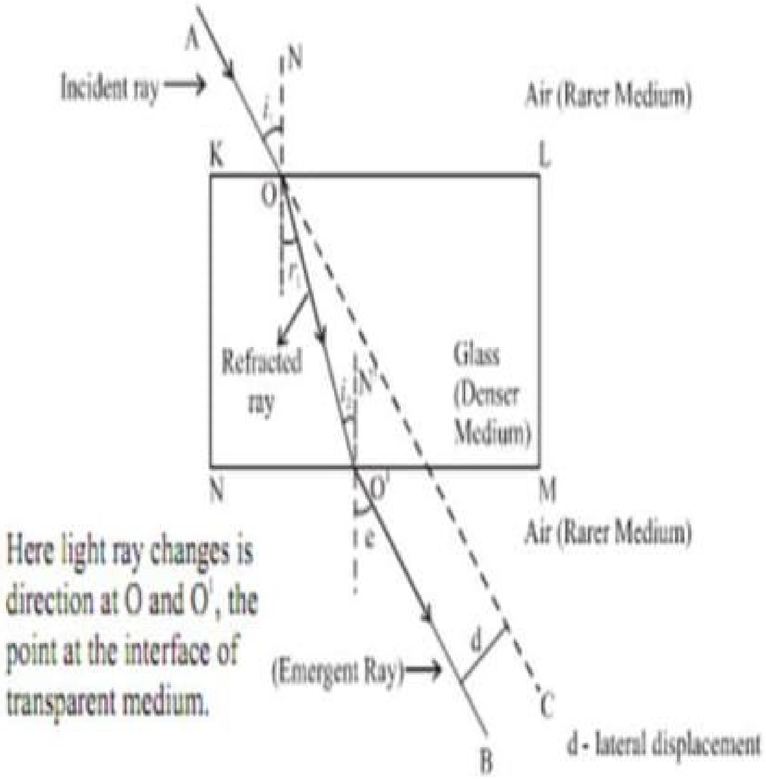
c→ Speed of light in vacuum = $3 \times 10^8\ m/s$
speed of light in air is marginally less, compared to that in vacuum.

Refractive index of air with respect to glass is given

Some Commonly observed phenomenon due to Refraction

- Your eyes.
- Rainbows.
- Light bending in a glass of water.
- Glasses.
- Camera lenses.
- Object dislocation in water.
- Binoculars..

Refraction through a Rectangular Glass Slab



When a incident ray of light AO passes from a rarer medium (air) to adenser medium (glass) at point. O on interface KL, it will bends towards the normal. At ptO1, on interface NM the light ray entered from denser medium(glass) to rarer medium (air) here the light ray will bend away from normal OO1 is a refracted ray O_1 B is an emergent ray. If the incident ray is extended to C, we will observe that emergent

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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

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.

- The ratio of sine of angle of incidence to the sine of angle of refraction is a constant i.e.
  $\frac{Sin\ i}{Sin\ r} = cons\tan t\ (r)$

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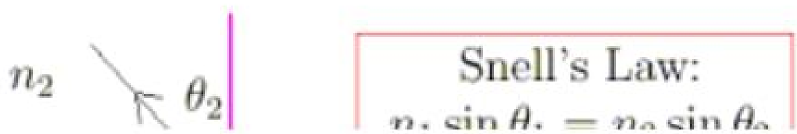


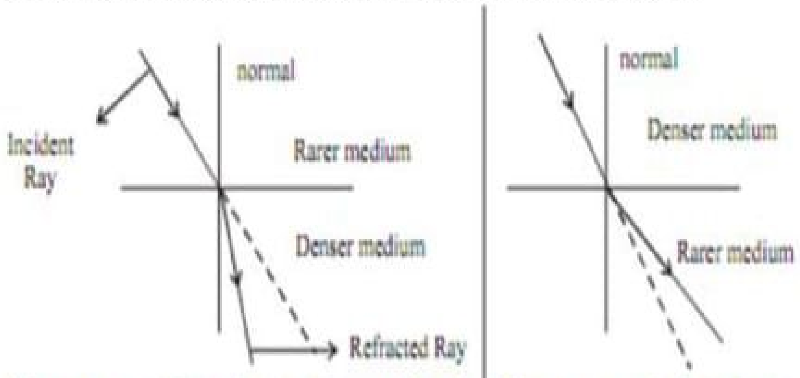
CONVEX	+ve	+ve

h – is always +ve
h´ – is +ve for virtual , –ve for Real.

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

- Your eyes.
- Rainbows.
- Light bending in a glass of water.
- Glasses.
- Camera lenses.
- Object dislocation in water.

$h^1 \rightarrow$ Object height from principle axis

If magnification	$m > 1$ _____	Image is magnified
	$m = 1$ _____	Image is of same size
	$m < 1$ _____	Image is diminished.

Few tips to remember sign convention for Spherical mirror

	f	u
CONCAVE	-ve(real)	-ve(real)
CONVEX	+ve	+ve

h – is always +ve
h´ – is +ve for virtual , −ve for Real.

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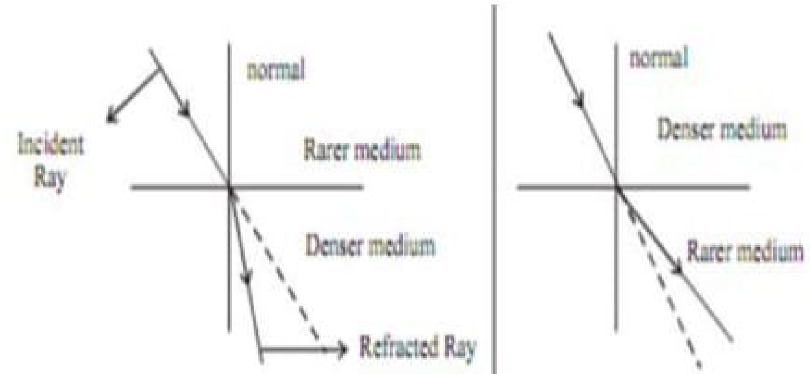
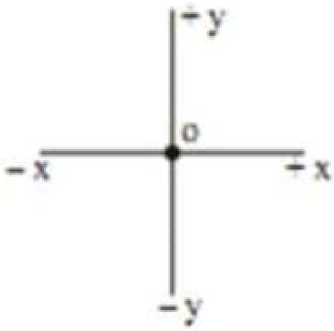


When ray travel from Rarer to Denser it bends | When ray travel from denser



(Cartesian system)

Mirror Formula

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

f $\rightarrow$ distance between F and Pole
v $\rightarrow$ distance of image from Pole
u $\rightarrow$ distance of object from Pole
R $\rightarrow$ distance between centre of curvature and pole.

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

Magnification

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

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

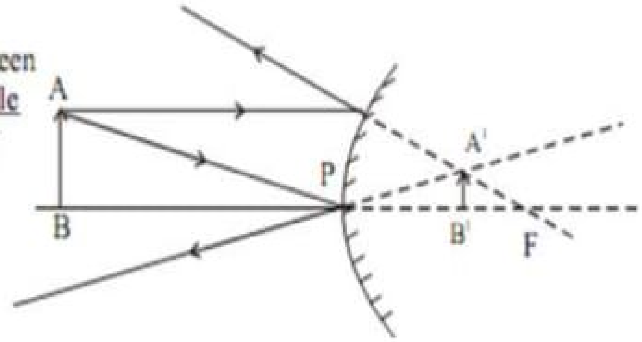
$$m = \frac{-v}{u} \quad --- \quad (2)$$

$\therefore$ From 1 and 2 equation

$m = \frac{h^1}{h} = \frac{-v}{u}$ When $h^1 \rightarrow$ image height from principle axis.

$h^1 \rightarrow$ Object height from principle axis

2. Object
Anywhere between infinity and pole of the mirror



Position of Image — *Between P & F*

Size of Image — *Very small*

Nature — *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

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

Sign Convention for Reflection by Spherical Mirror

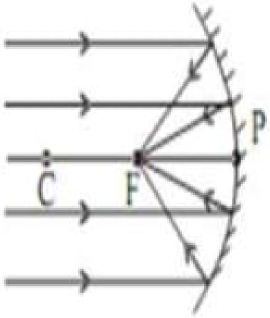
1. The object is always placed to the left side of mirror.
2. All distance should be measured from pole (P); parallel to principal axis.
3. Take 'P' as origin. Distances measured

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**

Image Formation by Concave Mirror

1. Object
At infinity

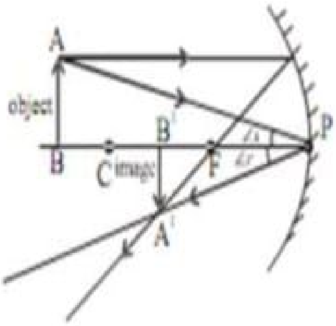


Position of Image
At focus

Nature
Real and Inverted

Size of Image
Highly diminished (point size)

2. Object
Beyond C

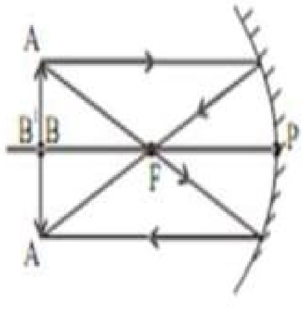


Position of Image
Between F&C

Nature
Real and Inverted

Size of Image
Small

3. Object
At C

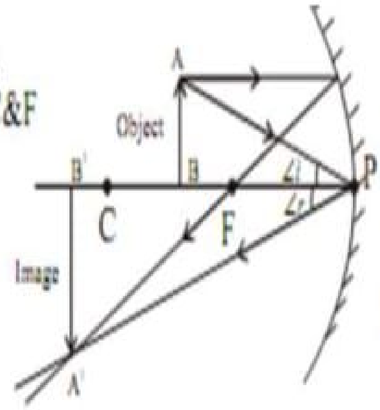


Position of Image
At C

Nature
Real and Inverted

Size of Image
Same Size of object

4. Object
Between C&F



$\angle i = \angle r$

Position of Image
Beyond C

Nature
Real and Inverted

Size of Image
Enlarged

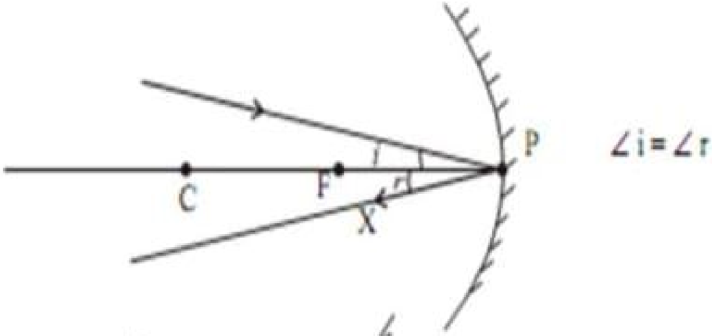
5. Object
At F

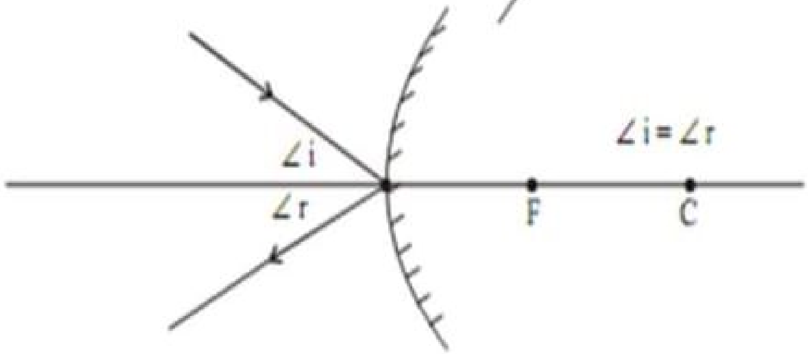
$\angle i = \angle r$

Position of

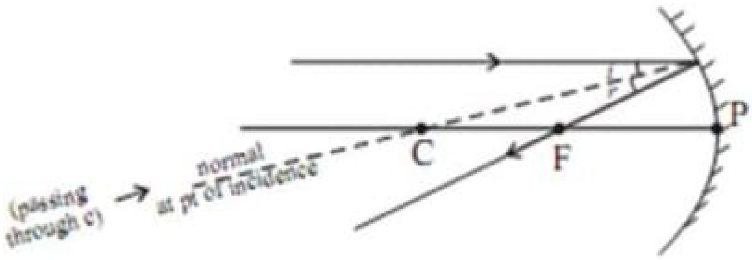
Nature

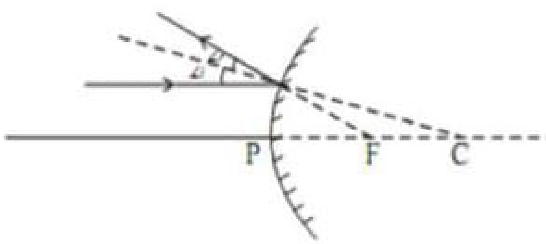
(c) A ray of light falling on pole get reflected at the same angle on the other side of principal axis.





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

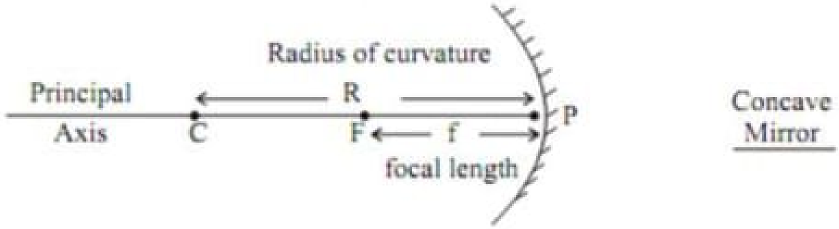


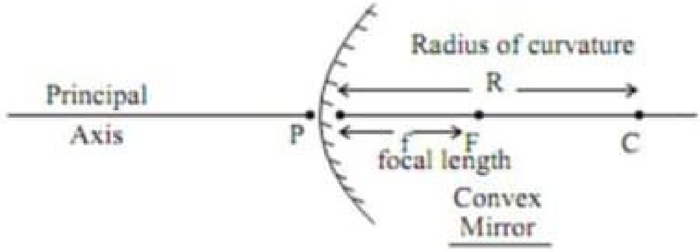


Note 1 : The image will only form when two or more rays meets at a point. Image formation by a concave

If it is curved inward →Act as concave mirror
If it is curved outward → Act as a convex mirror.

Few Basic terms related to Spherial Mirror



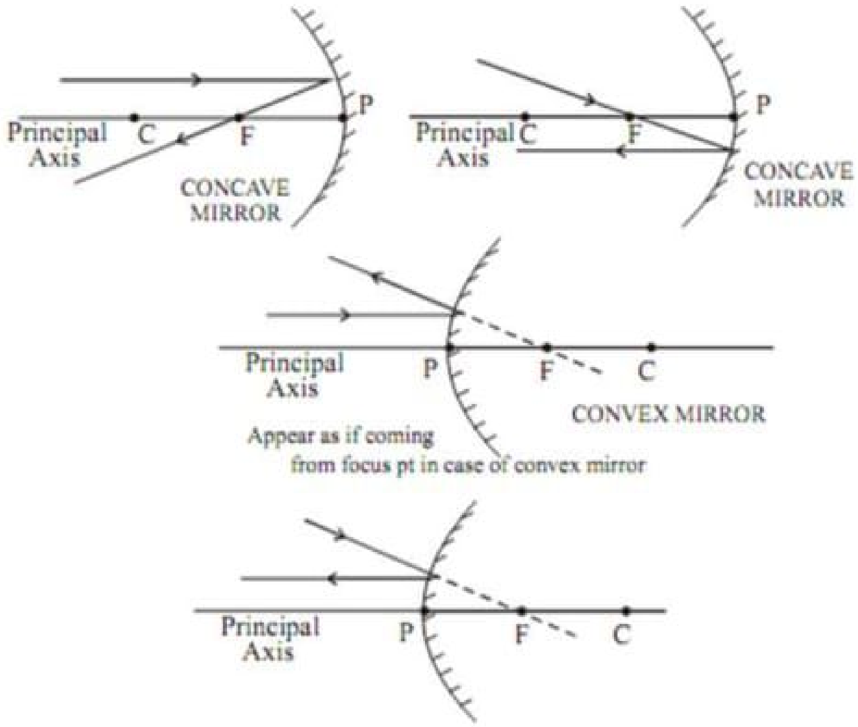


1. **Principal axis** : Line joining the pole and centre of curvature of the spherical mirror.
2. **Pole** : The geometrical central point of the reflecting spherical surface. (aperture), denoted by (P).
3. **Aperture** : The width of reflecting spherical surface.
4. **Centre of curvature** : The centre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

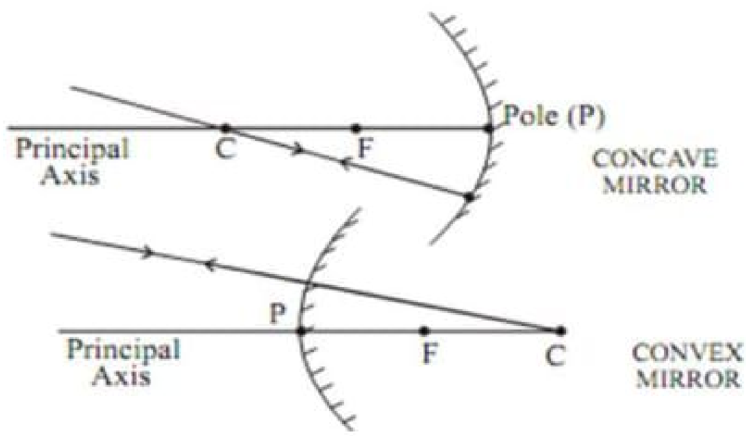
Image Formation by Spherical Mirror

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

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

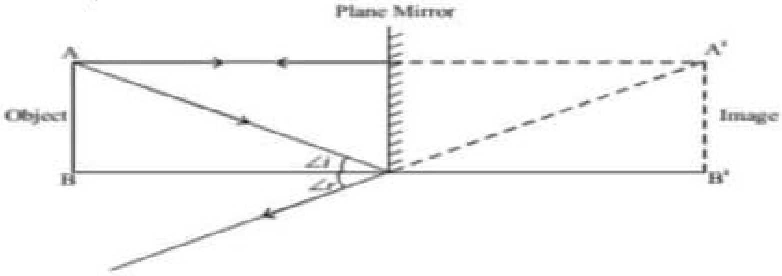


(b) A ray of light which passes through centre of curvature (it is also known as normal at the point of incidence on spherical mirror) will retrace their path after reflection.



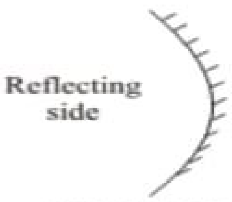
2. The incident ray, reflected ray and the normal to the reflecting surface at the point of incidence lie in the same plane.

Image formed by Plane Mirror (Plane reflecting surface)

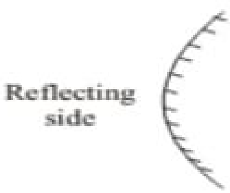


1. Virtual (imaginary) & Erect : The image that do not form on screen.
Real images can be recorded on the screen.
2. Laterally inverted (The left side of object appear on right side of image)
3. The size of image is equal to that of object.
4. The image formed is as far behind the mirror as the object 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.



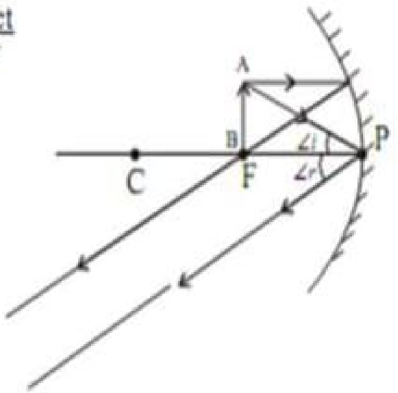
Concave Mirror
OR CONVERGING MIRROR



Convex mirror
OR DIVERGING MIRROR

If it is curved inward → Act as concave mirror

5. Object
At F



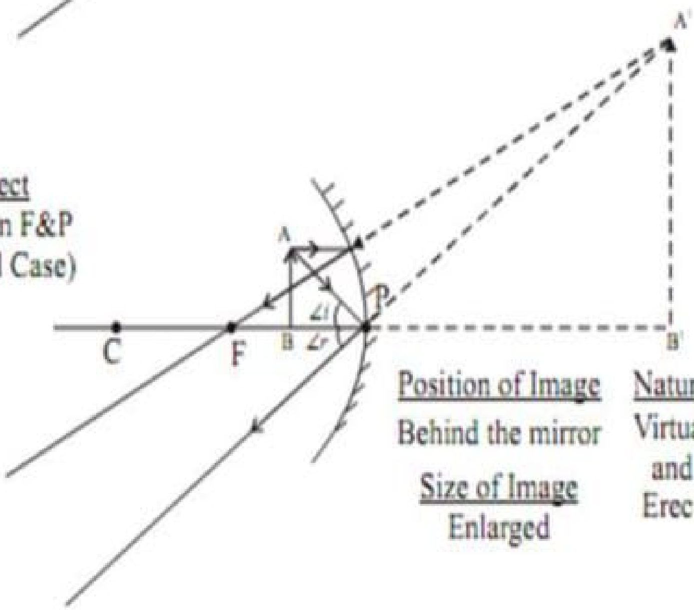
$\angle i = \angle r$

Position of Image
At (infinity)

Nature
Real and Inverted

Size of Image
Highly enlarged

6. Object
Between F&P
(Special Case)



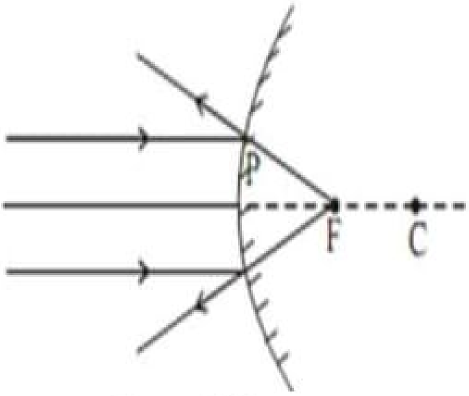
Position of Image
Behind the mirror

Nature
Virtual and Erect

Size of Image
Enlarged

Image formation by Convex Mirror

1. Object
At infinity



Position of Image
At focus

Size of Image
Highly diminished

Nature
Virtual & erect

2. Object

Refractive index of air with respect to glass is given by

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

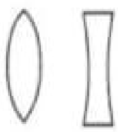
Refractive index of water $(n_w) = 1.33$

Refractive index of water $(n_g) = 1.52$

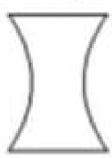
Spherical Lens

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

Convex lens Concave lens
1. Bulging outwards 1. Bulging inwards.
2. Converging lens. 2. Diverging lens.



Concave Lens
A lens bounded by two spherical surfaces, curved inwards is known asdouble 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