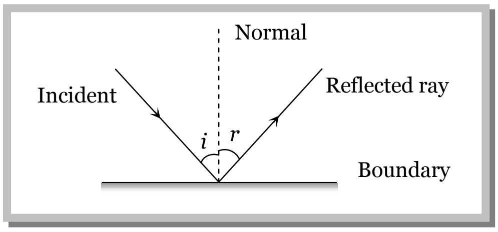
Reflection of Light

When a ray of light after incidenting on a boundary separating two media comes back into the same media, then this phenomenon, is called reflection of light.

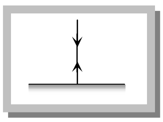


⇒ $\angle i = \angle r$

⇒ After reflection, velocity, wave length and frequency of light remains same but intensity decreases

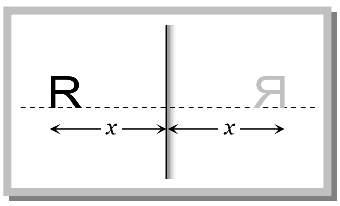
⇒ There is a phase change of π if reflection takes place from denser medium

Note : ❑ If light ray incident normally on a surface, after reflection it retraces the path.

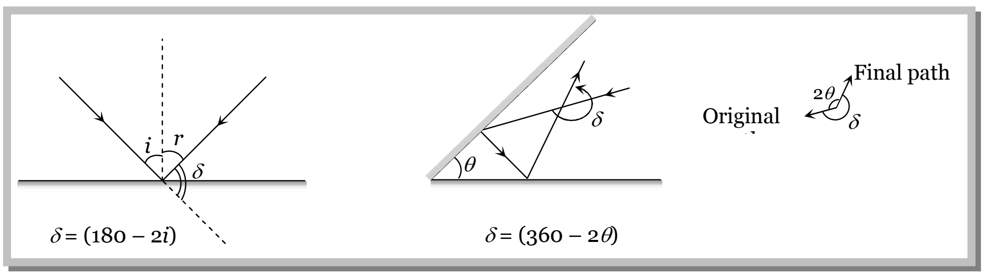


Plane Mirror

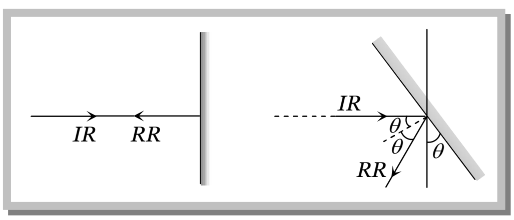
(1) The image formed by a plane mirror is virtual, erect, laterally inverted, equal in size that of the object and at a distance equal to the distance of the object in front of the mirror.



(2) **Deviation :** Deviation produced by a plane mirror and by two inclined plane mirrors.



(3) **Rotation :** If a plane mirror is rotated in the plane of incidence through angle θ, by keeping the incident ray fixed, the reflected ray turned through an angle 2θ.

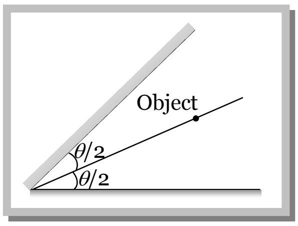


(4) **Images by two inclined plane mirrors :** When two plane mirrors inclined to each other at an angle θ, then number of images (n) of an object which is kept between them.

(i) $n = \left(\frac{360}{\theta} - 1\right)$; If $\frac{360}{\theta}$ = even integer

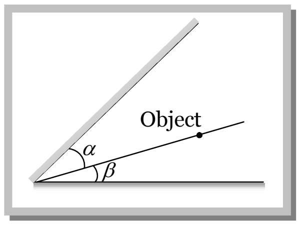
(ii) If $\frac{360}{\theta}$ = odd integer then there are two possibilities

(a) Object is placed symmetrically



$n = \left(\frac{360}{\theta} - 1\right)$

(b) Objects is placed asymmetrically



$n = \frac{360}{\theta}$

Note : ❑ If $\theta = 0^o$ *i.e.* mirrors are parallel to each other so $n = \infty$ *i.e.* infinite images will be formed.

❑ If $\theta = 90^o$, $n = \frac{360}{90} - 1 = 3$

❑ If $\theta = 72^o$, $n = \frac{360}{72} - 1 = 4$ (If nothing is said object is supposed to be symmetrically placed)

(5) **Other important informations**

(i) We observe number of images in a thick plane mirror, out of them only second is brightest.

(ii) When the object moves with speed u towards (or away) from the plane mirror then image also moves toward (or away) with speed u. But relative speed of image *w.r.t.* object is $2u$.

(iii) When mirror moves towards the stationary object with speed u, the image will also moves with speed $2u$.

(iv) Focal length of a plane mirror is infinity and it's power is zero.

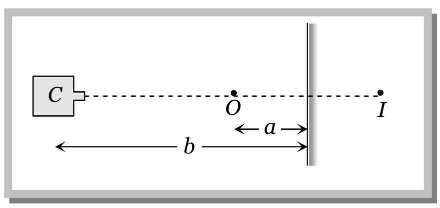
(v) A large mirror gives more bright image than smaller one.

(vi) A man of height h requires a mirror of length at least equal to $\frac{h}{2}$, to see his own complete image.

(vii) To see complete wall behind himself a person requires a plane mirror of at least one third the height of wall. It should be noted that person is standing in the middle of the room.

(6) **Some standard examples**

(i) An object O and camera C are at a distance a and b respectively from a plane mirror then.

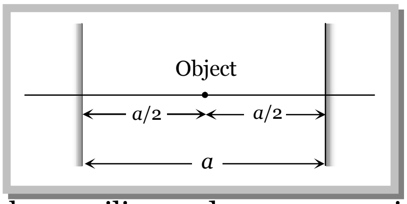


(a) To see the object, camera is focussed for distance = $(b - a)$

(b) To see the image, camera is focussed for distance = $(b + a)$

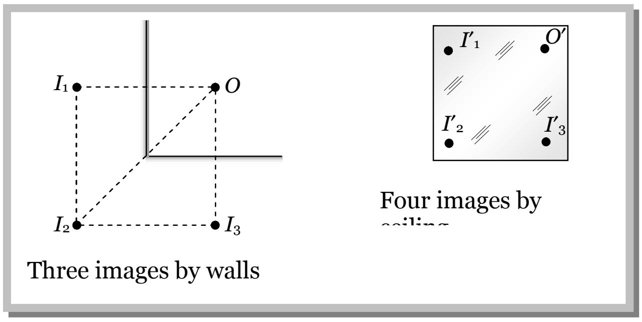
(ii) Two plane mirrors kept parallel to each other as shown in following figure. Distance (x) between the n^{th} images of given object formed by two mirrors

$x = 2na$



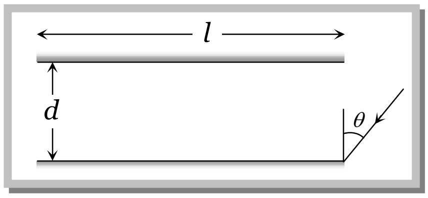
(iii) A person is standing in a room, whose ceiling and two consecutive walls are plane mirrors.

(a) Total number of images of him = 7 (b) Total number of images, he can see himself = 6



(iv) A watch shows time $\overset{hr.}{x} : \overset{min.}{y}$ when seen through a plane mirror, then actual time will be $11 : 60 - x : y$

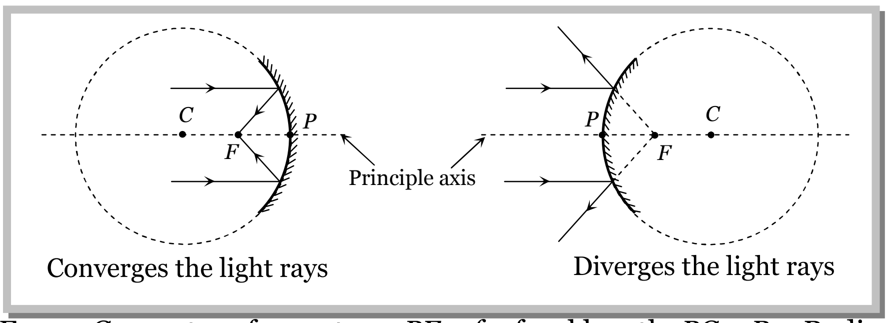
(v) Two plane mirrors are aligned parallel to each other as shown in figure. A light ray is incident at an angle θ, at one mirror. The maximum number of times the ray undergoes reflection before it emerges out is



Maximum number of reflection $n = \dfrac{l}{d \tan\theta}$

Curved Mirror

It is a part of a transparent hollow sphere whose one surface is polished.



P – pole , F – Focus, C – centre of curvature, $PF = f$ = focal length, $PC = R$ = Radius of curvature

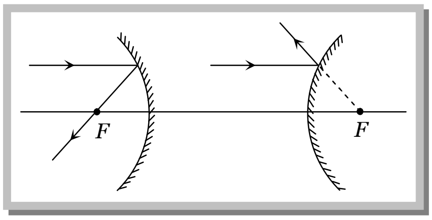
Note : ❑ $f = \dfrac{R}{2}$

❑ Effective diameter of light reflecting area of the mirror is called aperture and

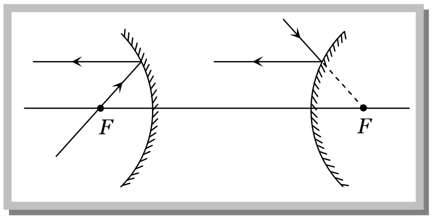
Intensity of image ∝ $(\text{Aperture})^2$

(1) **Rules of image formation and sign convention** :

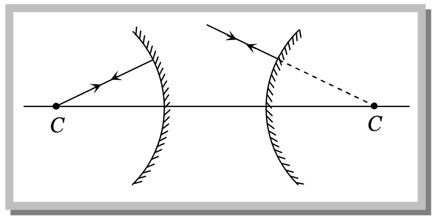
Rule (i)



Rule (ii)



Rule (iii)

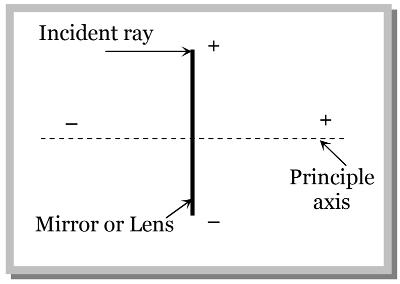


(2) **Sign conventions :**

(i) All distances are measured from the pole.

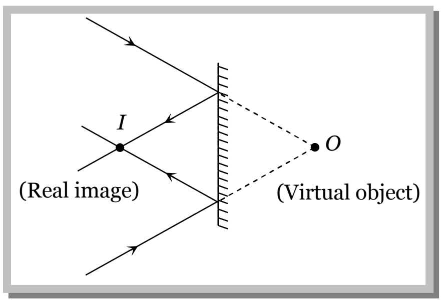
(ii) Distances measured in the direction of incident rays are taken as positive while in the direction opposite of incident rays are taken negative.

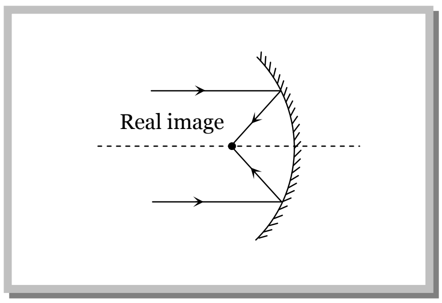
(iii) Distances above the principle axis are taken positive and below the principle axis are taken negative.

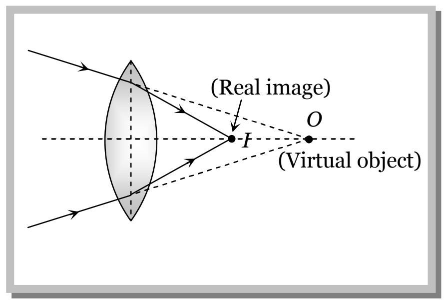


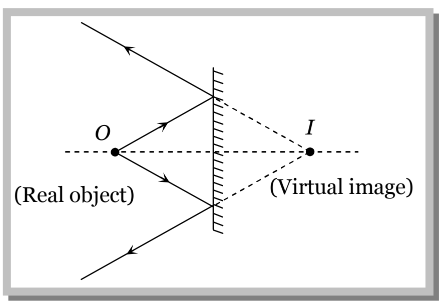
Note : ❑ Same sign convention are also valid for lenses.

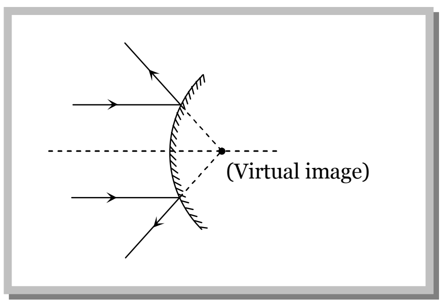
(3) **Real and virtual images :** If light rays, after reflection or refraction, actually meets at a point then real image is formed and if they appears to meet virtual image is formed.

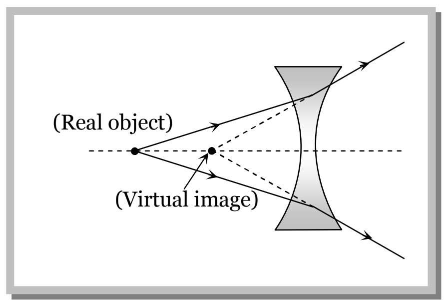




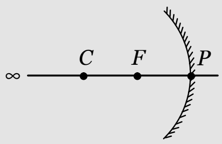
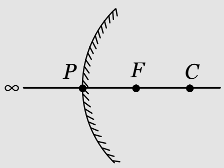








(4) **Position, size and nature of image formed by the spherical mirror**

Mirror	Location of the object	Location of the image	Magnification, Size of the image	Nature	
				Real / virtual	Erect / inverted
(a) Concave	At infinity *i.e.* $u = \infty$	At focus *i.e.* $v = f$	$m < 1$, diminished	Real	inverted
	Away from centre of curvature ($u > 2f$)	Between f and $2f$ *i.e.* $f < v < 2f$	$m < 1$, diminished	Real	inverted
	At centre of curvature $u = 2f$	At centre of curvature *i.e.* $v = 2f$	$m = 1$, same size as that of the object	Real	inverted
	Between centre of curvature and focus : $F < u < 2f$	Away from the centre of curvature $v > 2f$	$m > 1$, magnified	Real	inverted
	At focus *i.e.* $u = f$	At infinity *i.e.* $v = \infty$	$m = \infty$, magnified	Real	inverted
	Between pole and focus $u < f$	$v > u$	$m > 1$ magnified	Virtual	erect
(b) Convex	At infinity *i.e.* $u = \infty$	At focus *i.e.*, $v = f$	$m < 1$, diminished	Virtual	erect
	Anywhere between infinity and pole	Between pole and focus	$m < 1$, diminished	Virtual	erect

Note : ❑ In case of convex mirrors, as the object moves away from the mirror, the image becomes smaller and moves closer to the focus.

❑ Images formed by mirrors do not show chromatic aberration.

❑ For convex mirror maximum image distance is it's focal length

(5) **Mirror formula and magnification :** For a spherical mirror if u = Distance of object from pole, v = distance of image from pole, f = Focal length, R = Radius of curvature, o = Size of object, I = size of image, m = magnification (or linear magnification), m_s = Areal magnification, A_o = Area of object, A_i = Area of image

(i) **Mirror formula :** $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$; use sign convention while solving the problems.

(ii) **Magnification :** Magnification = $\frac{\text{Size of image}}{\text{Size of object}}$

Linear magnification $m = \frac{I}{o} = -\frac{v}{u} = \frac{f}{f-u} = \frac{f-v}{f}$

Areal magnification $m_s = \frac{A_i}{A_o} = m^2$ (use sign convention while solving problems.)

Note : ❑ For real and inverted image m is negative and for virtual and erect image m is positive.

(6) **Newton's formula :** If object distance (x_1) and image distance (x_2) are measured from focus instead of pole then $f^2 = x_1 x_2$

(7) **Use following sign while solving the problem :**

Concave mirror		Convex mirror
Real image	**Virtual image**	
$u \rightarrow -$	$u \rightarrow -$	$u \rightarrow -$
$v \rightarrow -$	$v \rightarrow +$	$v \rightarrow +$
$f \rightarrow -$	$f \rightarrow -$	$f \rightarrow +$
$O \rightarrow +$	$O \rightarrow +$	$O \rightarrow +$
$I \rightarrow -$	$I \rightarrow +$	$I \rightarrow +$
$R \rightarrow -$	$R \rightarrow -$	$R \rightarrow +$
$m \rightarrow -$	$m \rightarrow +$	$m \rightarrow +$

(8) **Use of mirrors :**

(i) **Concave mirror :** Used as a shaving mirror, In search light, in cinema projector, in telescope, by E.N.T. specialists etc.

(ii) **Convex mirror :** In road lamps, side mirror in vehicles *etc.*

Note : ❑ Field of view of convex mirror is more than that of concave mirror.

Other Important Informations

(1) Focal length of a mirror is independent of material of mirror, medium in which it is placed, wavelength of incident light

(2) Divergence or Convergence power of a mirror does not change with the change in medium.

(3) When a small object of length l_o lies along the principle axis of a spherical mirror then it's image length (l_i) is given by $l_i = l_o \left(\frac{v}{u}\right)^2 = l_o \left(\frac{f}{u-f}\right)^2$ (use sign convention)

(4) If an object is moving at a speed v_o towards a spherical mirror along it's axis then speed of image away from mirror is $v_i = -\left(\frac{f}{u-f}\right)^2 .v_o$ (use sign convention)

(5) If a spherical mirror produces an image 'm' times the size of the object (m = magnification) then u, v and f are given by the followings

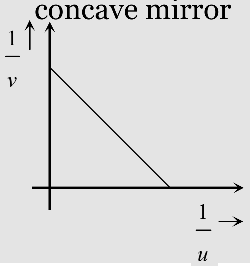
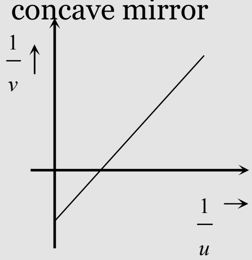
$$u = \left(\frac{m-1}{m}\right)f, \quad v = -(m-1)f \quad \text{and} \quad f = \left(\frac{m}{m-1)}\right)u$$ (use sign convention)

(6) When object is moved from focus to infinity at constant speed, the image will move faster in the beginning and slower later on, towards the mirror.

(7) In concave mirror, minimum distance between a real object and it's real image is zero. (*i.e.* when $u = v = 2f$)

(8) A concave mirror of focal length f is used to obtain the image of the sun which subtends an angle of θ at pole. The diameter of the image of the sun will be $f\,\theta$.

(9) Different graphs

Graph between $\frac{1}{v}$ and $\frac{1}{u}$			**Graph between u and v for any mirror**
(a) Real image formed by concave mirror 	(b) Virtual image formed by concave mirror 	(c) Virtual image formed by convex mirror