LIGHT : REFLECTION

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THE NATURE OF LIGHT

Light is a form of energy (optical energy) which helps us in seeing objects by its presence.

(A) THEORIES ABOUT NATURE OF LIGHT :

(i) Particle nature of light (Newton's corpuscular theory) :

According to Newton light travels in space with a great speed as a stream of very small particles called corpuscles.

This theory was failed to explain interference of light and diffraction of light. So wave theory of light was discovered.

(ii) Wave nature of light :

Light waves are electromagnetic waves so there is no need of medium for the propagation of these waves. They can travel in vacuum also. The speed of these waves in air or in vacuum is maximum i.e., 3×10^8 m/s.

Photoelectric effect was not explained with the help of wave theory, so Plank gave a new theory which was known as quantum theory of light.

(iii) Quantum theory of light :

When light falls on the surface of metals like caesium, potassium etc., electrons are given out. These electrons are called 'photo-electrons' and phenomenon is called 'photo-electric effect'.

This was explained by Einstein. According to plank light consisted of packets or quanta's of energy called photons. The rest mass of photon is zero. Each quanta carries energy $E = h\nu$.

$h \rightarrow$ Planck's constant = 6.6×10^{-34} J-s.

$\nu \rightarrow$ Frequency of light

Some phenomenons like interference of light, diffraction of light are explained with the help of wave theory but wave theory was failed to explain the photo electric effect of light. It was explained with the help of quantum theory. So, light has dual nature.

(i) Wave nature (ii) Particle nature

(B) SOURCES OF LIGHT.

◆ The objects which emit (give) light are called **luminous objects**. It may be natural or man-made. Sun is a natural source of light and electric lamp, and oil lamp, etc. are man-made source of light.

◆ The **Non-luminous objects** do not emit light. However, such objects become visible due to the reflection of the light falling on them. Moon does not emit light. It becomes visible due to the reflection of the sunlight falling on it.

(C) PROPAGATION OF LIGHT

Light travels along straight lines in a medium or in vacuum. The path of light changes only when there is an object in its path or where the medium changes. Apart from vacuum and gases, light can travel through some liquids and solids as well.

- **Transparent medium :** A medium in which light can travel freely over large distances is called a transparent medium.

  Examples: Water, glycerin, glass and clear plastics are transparent.
- **Opaque :** A medium in which light cannot travel is called opaque.

  Examples : Wood, metals, bricks, etc., are opaque.
- **Translucent :** A medium in which light can travel some distance, but its intensity reduces rapidly. Such materials are called **translucent**.

  Examples : Oil

(D) THE CHARACTERISTICS OF LIGHT

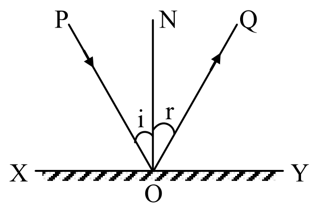
- Light is an electromagnetic wave.
- Light travels in a straight line.
- Light is a transverse wave, and does not need any medium to travel. Light can travel through vaccum. Its speed through vaccum is 3×10^8 m/s.
- The velocity of light changes when it travels from one medium to another.
- The wavelength (λ) of light changes when it goes from one medium to another.
- The frequency (f) of the light wave remains the same in all media.
- Light gets reflected back from polished surfaces, such as mirrors, polished metal surfaces, etc.
- Light undergoes refraction (bending) when it travels from one transparent medium to another.
- Light does not need a material medium to travel, that is, it can travel through a vacuum too. Scientists have assigned a value of 299, 792, 458 m/s to the speed of light in vacuum.
- According to current scientific theories, no material particle can travel at a speed greater than that of light in vacuum.

➢ REFLECTION OF LIGHT

- **Definition.** When light rays are incident on an opaque polished surface (medium), these are returned back in the same medium.

  This phenomenon of returning of ray of light in the same medium, is called reflection of light.

Definition of some associated terms :



- **Reflecting surface :** The surface from which the light is reflected, is called the reflecting surface. In diagram, XY is the reflecting surface.
- **Point of incidence :** The point on the reflecting surface at which a ray of light strikes, is called the point of incidence. In diagram, O is the point of incidence.
- **Normal :** A perpendicular drawn on the reflecting surface at the point of incidence, is called the normal. In diagram, ON is the normal.
- **Incident ray :** The ray of light which strikes the reflecting surface at the point of incidence is called the incident ray. In diagram, PO is the incident ray.
- **Reflected ray :** The ray of light reflected from the reflecting surface from the point of

incidence, is called the reflected ray. In diagram, OQ is the reflected ray.

- **Angle of incidence :** The angle that the incident ray makes with the normal, is called the angle of incidence. It is represented by the symbol i. In diagram, angle PON is the angle of incidence.
- **Angle of reflection :** The angle that the reflected ray makes with the normal, is called the angle of reflection. It is represented by the symbol r. In diagram, ∠QON is the angle of reflection.
- **Plane of incidence :** The plane in which the normal and the incident ray lie, is called the plane of incidence. In diagram, the plane of the bookpage, is the plane of incidence.
- **Plane of reflection :** The plane in which the normal and the reflected ray lie, is called the plane of reflection. In diagram, the plane of the book page, is the plane of reflection.

➢ LAWS OF REFLECTION OF LIGHT

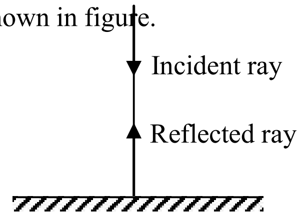
- **First law :** The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.
- **Second law :** The angle of reflection (∠r) is always equal to the angle of incidence (∠i).

i.e., ∠r = ∠i

(For normal incidence, i = 0, r = 0. The ray is reflected back along normal).

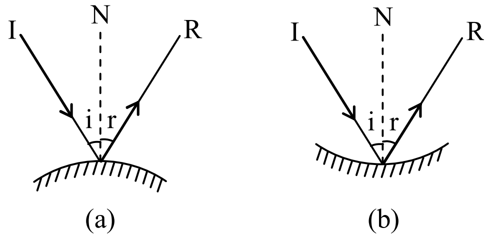
(i) A ray of light striking the surface normally retraces its path.

When a ray of light strikes a surface normally, then angle of incidence is zero i.e., ∠i = 0. According to the law of reflection, ∠r = ∠i, ∴ ∠r = 0 i.e. the reflected ray is also perpendicular to the surface. Thus, an incident ray normal to the surface (i.e. perpendicular to the surface) retraces its path as shown in figure.



Normal Incidence

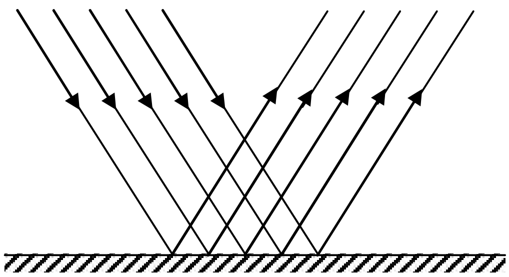
(ii) Laws of reflection are also obeyed when light is reflected from the spherical or curved surfaces as shown in figure (a) and (b)



Reflection from curved surface

(iii) Regular and Irregular Reflection :

- **Regular Reflection** – The phenomenon due to which a parallel beam of light travelling through a certain medium, on striking some smooth polished surface, bounces off from it, as parallel beam, in some other fixed direction is called Regular reflection.

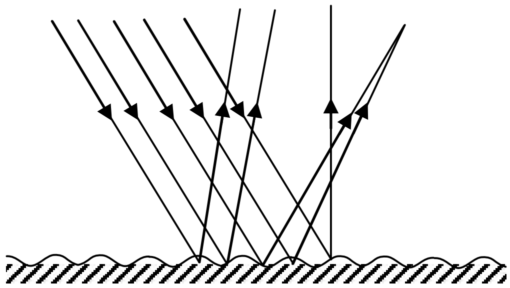


Regular reflection

Regular reflection takes place from the objects like looking glass, still water, oil, highly polished metals, etc.

Regular reflection is useful in the formation of images, e.g., we can see our face in a mirror only on account of regular reflection. However, it causes a very strong glare in our eyes.

◆ **Irregular reflection or Diffused reflection :**



Irregular or diffused reflection

The phenomenon due to which a parallel beam of light, travelling through some medium, gets reflected in various possible directions, on striking some rough surface is called irregular reflection or diffused reflection.

The reflection which takes places from ground, walls, trees, suspended particles in air, and a variety of other objects, which are not very smooth, is irregular reflection.

Irregular reflection helps in spreading light energy over a vast region and also decreases its intensity. Thus, it helps in the general illumination of places and helps us to see things around us.

◆ **Note :** Laws of reflection are always valid no matter whether reflection is regular or irregular.

➢ NATURE OF IMAGE

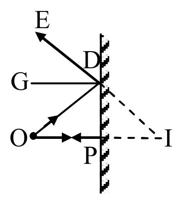
◆ **Definition :** Incident rays starting from a point object, and reflected from a mirror, either actually meet at or appear to come from a point. The other point is called the **image** of the point object.

Real Image	Virtual Image
1. A real image is formed when two or more reflected rays meet at a point in front of the mirror.	1. A virtual image is formed when two or more rays appear to be coming from a point behind the mirror.
2. A real image can be obtained on a screen.	2. A virtual image cannot be obtained on a screen.
3. A real image is inverted with respect to the object.	3. A virtual image is erect with respect to the object.

➢ REFLECTION FROM THE PLANE MIRROR

Relation between the distances of the object and the image from the plane mirror is that they are equal.

To verify this, consider the geometrical construction shown in figure. Rays OP and OD, starting from the object O, fall on the mirror. The ray OP is perpendicular to the mirror and hence, reflects back along PO. The incident ray OD and the reflected ray DE make equal angles with the normal DG. The two reflected rays when produced backwards meet at I, producing a virtual image there.



Now, $\angle EDG = \angle DIO$ (DG || IO),

$\angle EDG = \angle GDO$ (law of reflection),

and

$\angle GDO = \angle DOI$ (DG || IO).

Hence, $\angle DIO = \angle DOI$

$\therefore$ OD = DI

Now $OP^2 = OD^2 - DP^2$, and

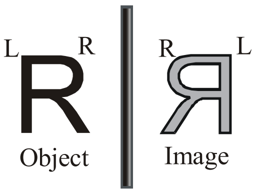
$PI^2 = DI^2 - DP^2$

From (i), since OD = DI, $OP^2 = PI^2$ or OP = PI.

So, in the case of a plane mirror, the image is formed as far behind the mirror at the same distance as the object is in front of it.

◈ SOME IMPORTANT RESULTS ABOUT REFLECTION FROM PLANE SURFACES

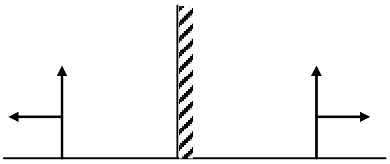
◆ **Lateral inversion :** When you see your image in a vertical plane mirror such as that fixed to an almirah, the head in the image is up and the feet are down, the same way as you actually stand on the floor. Such an image is called an erect image. However, if you move your right hand, it will appear as if the left hand of your image is moving. If you keep a printed page in front of a plane mirror, the image of the letters appear erect but inverted laterally, or sideways. Such an inversion is called lateral inversion.



◆ **Relative motion of object and image :**

Case I :

If an object moves towards (or away from) a plane mirror at speed v



The image will also approach (or recede) at speed v

The speed of image relative to object will be v – (–v) = 2v.

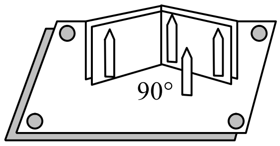
Case II :

If the mirror is moved towards or (away from) the object with speed 'v'

The image will move towards (or away from) the object with a speed '2v'.

◆ **Multiple Reflection**

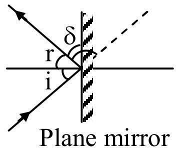
Number of images formed by combination of plane mirrors depends upon angle between mirrors.



If there are two plane mirrors inclined to each other at an angle 90° , the number of images of a point object formed are 3.

◆ **Deviation :** δ is defined as the angle between directions of incident ray and emergent ray. So if light is incident at an angle of incidence i,

$\delta = 180^\circ - (\angle i + \angle r) = \mathbf{(180^\circ - 2i)}$ [as $\angle i = \angle r$]



So if light is incident at angle of 30º,

$\delta = (180^\circ - 2 \times 30^\circ) = 120^\circ$ and for normal incidence $\angle i = 0^\circ$, $\delta = 180^\circ$

Characteristics of the image formed by a plane mirror :

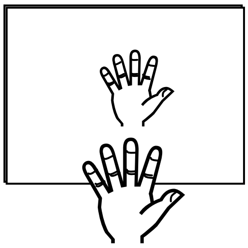
(i) The image formed by a plane mirror is virtual.

(ii) The image formed by a plane mirror is erect.

(iii) The size of the image formed by a plane mirror is same as that of the size of the object. If object is 10 cm high, then the image of this object will also be 10 cm high.

(iv) The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of it. Suppose, an object is placed at 5 cm in front of a plane mirror then its image will be at 5 cm behind the plane mirror.

(v) The image formed by a plane mirror is laterally inverted, i.e., the right side of the object appears as the left side of its image and vice-versa.

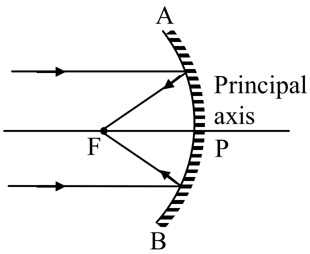


Lateral Inversion

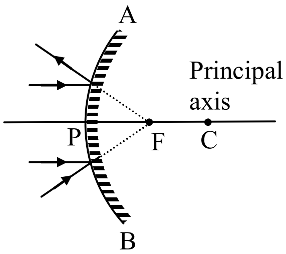
➤ REFLECTION FROM SPHERICAL MIRROR

◈ **INTRODUCTION :** There are two types of spherical mirrors:

(i) Concave mirror :



(ii) Convex mirror :



◈ **SOME TERMS ASSOCIATED WITH SPHERICAL MIRRORS.**

◆ **Aperture.** The diameter of the circular rim of the mirror. In diagram AB is the aperture of the mirror.

◆ **Pole :** The centre of the spherical surface of the mirror is called the pole of the mirror. It lies on the surface. In diagram, P is the pole of the mirror.

◆ **Centre of curvature :** The centre of the spherical shell, of which the mirror is a section, is called centre of curvature of the mirror. It lies outside the surface. Every point on mirror surface lies at same distance from it. In diagram, C is the centre of curvature of the mirror.

◆ **Principal axis :** The straight line passing through the pole and the centre of curvature of the mirror, is called principal axis of the mirror.

◆ **Principal focus :** It is a point on the principal axis of the mirror, such that the rays incident on the mirror parallel to the principal axis after reflection, actually meet at this point (in case of a concave mirror) or appear to come from it (in case of a convex mirror). In diagram, F is the principal focus of the mirror.

◆ **Radius of curvature :** The distance between the pole and the centre of curvature of the mirror, is called the radius of curvature of the mirror. It is equal to the radius of the spherical shell of which the mirror is a section. In diagram, PC is the radius of curvature of the mirror. It is represented by the symbol R.

◆ **Focal length :** The distance between the pole and principal focus of the mirror, is called the focal length of the mirror. In diagram, PF is the focal length of the mirror. It is represented by the symbol f.

$$f = +\frac{R}{2} \text{ for convex}$$

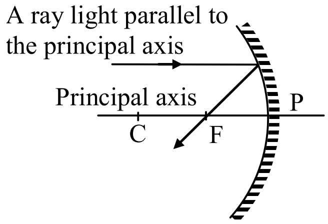
$$f = -\frac{R}{2} \text{ for concave}$$

◆ **Principal section :** A section of the spherical mirror cut by a plane passing through its centre of curvature and the pole of the mirror, is called a principal section of the mirror. It contains the principal axis. In diagram, APB is the principal section of the mirror cut by the plane of the book page.

➤ RULES FOR IMAGE FORMATION BY RAY DIAGRAM METHOD

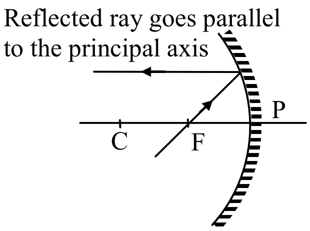
◈ **RULES FOR IMAGE FORMATION FROM CONCAVE MIRROR**

(a) *When the light ray incident parallel to the principal axis.*

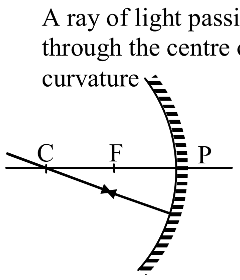


OR

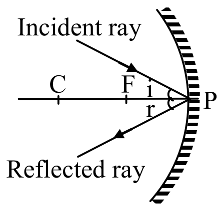
When the light ray incident towards focus**.**



(b) *When the light ray incident towards centre of curvature.*

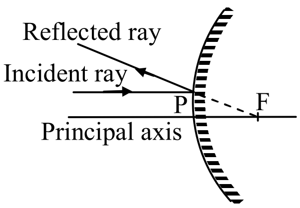


(c) *When the light ray incident on the pole of the mirror.*



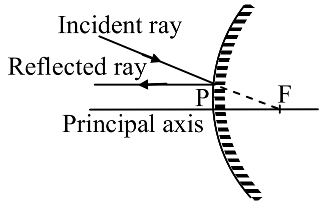
◈ RULES FOR IMAGE FORMATION FROM CONVEX MIRROR

(a) *When the light ray incident parallel to the principal axis.*

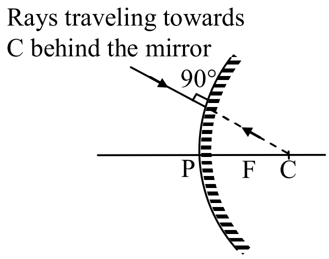


OR

When the light ray incident parallel to the principal axis.



(b) *When the light ray incident on the mirror directing towards centre of curvature.*



◈ SIGN CONVENTION

(a) **Description :** It is a convention which fixes the signs of different distances measured. The sign c**onvention** to be followed is the **New Cartesian** sign convention. It gives the following rules :

1. All distances are measured from the **pole** of the mirror.
2. The distances measured in the **same** direction as the direction of incident light from pole are taken as **positive.**
3. The distances measured in the direction **opposite** to the direction on incident light from pole are taken as **negative.**
4. Distances measured **upward** and perpendicular to the principal axis, are taken as **positive.**
5. Distances measured **downward** and perpendicular to the principal axis, are taken as **negative.**

➤ IMAGE FORMATION BY SPHERICAL MIRROR IN DIFFERENT CASES

Introduction : From mirror formula, we find that for a mirror of a fixed focal length f, as object distance u changes, image distance v also changes.

(A) BY CONCAVE MIRROR :

(1) Object at Infinity

A point object lying on the principal axis. Rays come parallel to the principal axis and after reflection from the mirror actually meet at the focus F.

The image is formed at F. It is real and point sized (fig.)

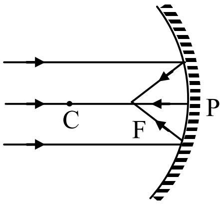
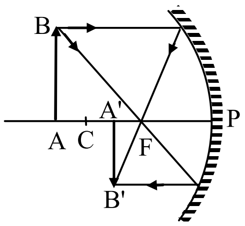


Fig. Concave mirror : point object at infinity, image at focus.

(2) Object Beyond Centre of Curvature

Real object AB has its image A′B′ formed between focus and centre of curvature. The image is real-inverted and diminished.

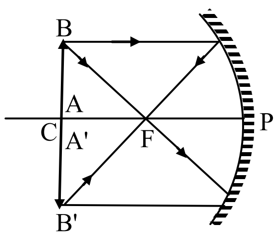


Concave mirror : object beyond centre of curvature, image between focus and centre of curvature.

(3) Object at Centre of Curvature

Real object AB, has its image A′B′ formed at centre of curvature.

The image is real-inverted and has same size as the object. (fig.).

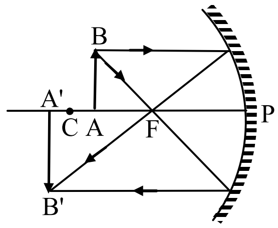


Concave mirror : object at centre of curvature, image at centre of curvature

(4) Object between Centre of Curvature and Focus

Real object AB has its image A′B′ formed beyond centre of curvature.

The image is real-inverted and enlarged (bigger in size than the object). (Fig.)

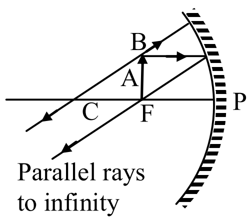


Concave mirror : object between centre of curvature and focus, image beyond centre of curvature.

(5) Object at Focus

Real object AB has its image formed at infinity.

The image is imaginary inverted (reflected rays go downward) and must have very large size.



Concave mirror : object at focus image at infinity.

(6) Object between Focus and Pole

Real object AB has its image A′B′ formed behind the mirror. The image is virtual-erect and enlarged.

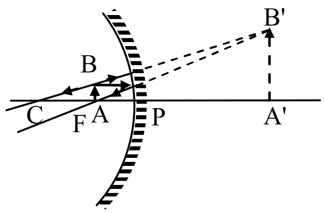


Fig. Concave mirror : Object between pole and focus, image behind the mirror.

(B) BY CONVEX MIRROR :

(1) Object at infinity

A point object lying on the principal axis.

Rays come parallel to the principal axis and after reflection from the mirror, appear to diverge from focus F behind the mirror.

The image is formed at F.

The image is virtual and point sized. [fig.]

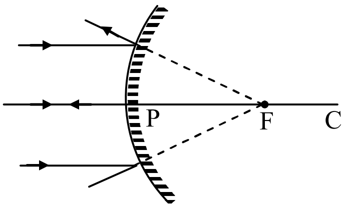


Fig. Convex mirror : point object at infinity, virtual image at focus.

(2) Object at anywhere on principle axis

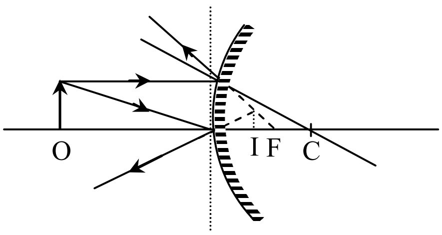


Image is virtual & point sized

➤ NUMERICAL METHOD IN SPHERICAL MIRROR

(A) Mirror formula

- **Definition :** The equation relating the object distance (u) the image distance (v) and the mirror focal length (f) is called the mirror formula.

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

- **Assumptions made :**

(i) The mirror has a small aperture.

(ii) The object lies close to principal axis of the mirror.

(iii) The incident rays make small angles with the mirror surface or the principal axis.

(B) linear magnification For spherical mirrors

- **Definition :** The ratio of the size of the image, as formed by reflection from the mirror to the size of the object, is called linear magnification produced by the mirror. It is represented by the symbol m.

$$m=-\frac{v}{u}=\frac{\text{height of image}}{\text{height of object}}$$

(C) Power of mirror

Power of a mirror *[in Diopters]* = $\frac{1}{\text{f (in metre)}}$

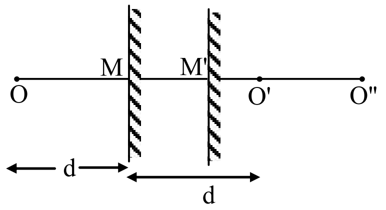
➤ SUMMARY OF IMAGES BY SPHERICAL MIRROR

	Position of object	Position of Image	Size of Image	Nature of Image
Concave mirror	At infinity	At focus F	Highly diminished	Real and inverted
	Beyond C	Between F and C	Diminished	Real and inverted
	At C	At C	Same size	Real and inverted
	Between F and C	Beyond C	Enlarged	Real and inverted
	At F	At infinity	Highly enlarged	Real and inverted
	Between P and F	Behind the mirror	Enlarged	Virtual and erect
convex mirror	at infinite	at focus	highly diminished	virtual point size
	anywhere on principal axis	between pole & focus	diminished	virtual erect

✦ SOLVED EXAMPLES ✦

Ex.1 An object is placed in front of a plane mirror. If the mirror is moved away from the object through a distance x, by how much distance will the image move?

Sol. Suppose the object O was initially at a distance d from the plane mirror M as shown in fig. The image formed at O' is at a distance d behind the mirror. Now, the mirror is shifted by a distance x to M' such that the distance of the object from M' becomes d + x. The image now formed at O" which is also at a distance d + x from M'.



So, OM = MO' = d

OM' = M'O" = d + x

Thus, OO" = OM' + M'O" = 2(d + x) ...(1)

when OO' = OM + MO' = 2d ...(2)

∴ O'O" = OO" – OO'

= 2(d + x) – 2d

= 2x

Thus, the image is shifted from O' to O" by a distance 2x.

Ex.2 An insect is at a distance of 1.5m from a plane mirror. Calculate the following?

(i) Distance at which the image of the insect is formed.

(ii) distance between the insect and its image.

Sol. (i) The distance of insect from the mirror = 1.5 m

∴ The distance of insect from the mirror is also equal to 1.5 m. The image is formed at 1.5 m behind the mirror.

(ii) The distance between the insect and image

= 1.5 + 1.5 = 3m

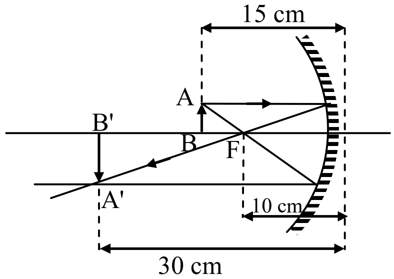
Ex.3 A concave mirror is made up by cutting a portion of a hollow glass sphere of radius 30 cm. Calculate the focal length of the mirror.

Sol. The radius of curvature of the mirror = 30 cm

Thus, the focal length of the mirror

$= \frac{30\text{cm}}{2} = 15\text{cm}$

Ex.4 An object is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. Find the position of the image.



Sol. We have u = –15 cm and f = –10 cm

Using the relation,, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ we get

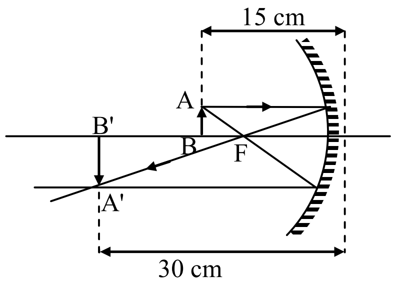
$$\frac{1}{v} + \frac{1}{-15} = \frac{1}{-10}$$

or $\frac{1}{v} = \frac{1}{15} - \frac{1}{10} = -\frac{1}{30}$

or v = –30 cm

So the image will be formed 30 cm from the mirror. Since ν has a negative sign, the image is formed to the left of the mirror, i.e. in front of the mirror as shown in fig.

Ex.5 A 3 cm long object is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is 15 cm, and its image is formed 30 cm from the mirror on the same side of the mirror as the object . Calculate the height of the image formed.



Sol. Here u = –15 cm and ν = –30 cm

Size of the object, h = 2 cm

Magnification, $m = m = \frac{h'}{h} = -\frac{v}{u}$

or $\frac{h'}{h} = -\frac{(-30)}{(-15)} = 2$

or h' = – 2 × h = – 2 × 3

= – 6 cm

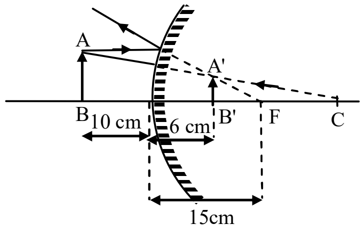
So the height of the image is 6 cm. The minus sign shows that it is on the lower side of the principal axis, i.e. the image is inverted.

Ex.6 A 1.4 cm long object is placed perpendicular to the principal axis of a convex mirror of focal length 15 cm at a distance of 10 cm from it. Calculate the following :

(i) location of the image

(ii) height of the image

(iii) nature of the image



Sol. (i) For a convex mirror, focal length is positive.

Therefore, f = +15 cm and u = –10 cm

Using the relation, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$, we get

$$\frac{1}{v}+\frac{1}{-10}=\frac{1}{15}$$

or $$\frac{1}{v}=\frac{1}{15}+\frac{1}{10}=\frac{5}{30}=\frac{1}{6}$$

or $v = 6$ cm

Since v is positive, the image is formed to the right of the mirror at a distance 6 cm from it.

(ii) Magnification,

or $$m=\frac{h'}{h}=--\frac{v}{u}$$

$$\frac{h'}{h}=\frac{-6}{-10}=+0.6$$

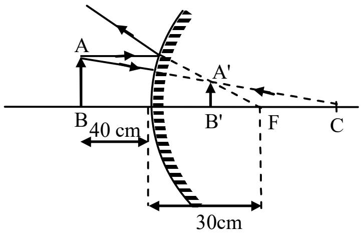
or $h' = +0.6 \times h_0 = 0.6 \times 1.4$
$= 0.84$ cm.

Thus, the height of the image is 0.84 cm.

(iii) Since h' is positive, the image will be on the same side of the principal axis as the object.

Hence, the image is virtual, erect and diminished.

Ex.7 An object is placed at a distance of 40 cm from a convex mirror of focal length 30 cm. Find the position of image and its nature.



Sol. Here, object distance, u = –40 cm

Focal length of convex mirror, f = +30 cm

Now, using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ we get

$$\frac{1}{v}+\frac{1}{-40}=\frac{1}{30}$$

or $$\frac{1}{v}=\frac{1}{40}+\frac{1}{30}=\frac{7}{120}$$

or $$v=\frac{120}{7}$$

The positive sign shows that the image is formed on the right, i.e. behind the mirror.

Now, magnification,

$$\Rightarrow m=-\frac{v}{u}=-\frac{120}{7\times(-40)}=+\frac{3}{7}$$

Since, the magnification is positive, the image is erect. Thus, the image is formed 17.1 cm behind the mirror. The image is virtual, erect and diminished.

Ex.8 A 3 cm high object is placed at a distance of 30 cm from a concave mirror. A real image is formed 60 cm from the mirror. Calculate the focal length of the mirror and the size of the image.

Sol. Object distance, u = –30

Image distance, v = –60

(real image is formed on the same side)

Now, using the mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

we get

$$\frac{1}{-60}+\frac{1}{-30}=\frac{1}{f}$$

or $$\frac{1}{f}=-\frac{3}{60}=-\frac{1}{20}$$

or f = – 20 cm

∴ Focal length of the mirror = 20 cm

Magnification $m=\frac{h'}{h}=-\frac{v}{u}$

or $\frac{h'}{3} = -\frac{(-60)}{(-30)}$

or h' = 3 × (–2) = –6 cm

The height of the image is 6 cm. The negative sign shows that the image is inverted.

Ex.9 A 1 cm high object is placed at 20 cm in front of a concave mirror of focal length 15 cm. Find the position and nature of the image.

Sol. u = –20 cm, f = –15 cm, h_0 = 1 cm

Using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ we get

$$\frac{1}{v} + \frac{1}{-20} = \frac{1}{-15}$$

or $\frac{1}{v} = -\frac{1}{15} + \frac{1}{2v} = -\frac{1}{60}$

∴ ν = – 60 cm

The image is formed 60 cm from the mirror. Since, the signs of u and ν are the same, the object and image are formed on the same side of the mirror. Therefore, the image is real.

Now magnification,

$$m = \frac{h'}{h} = \frac{v}{u} = \frac{-60\,cm}{-20\,cm} = -3$$

∴ h' = –3h = – 3 × 1 cm = – 3cm

The negative sign shows that the image is inverted. Thus, the image is real, inverted and of size 3 cm and formed 60 cm in front of the mirror.

Ex.10 An object 4 cm high is placed 25 cm in front of a concave mirror of focal length 15 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Find the nature and size of image.

Sol. Here, u = –25 cm, f = –15 cm, h = + 4 cm

Using the mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$, we get

or $\frac{1}{v} + \frac{1}{-25} = \frac{1}{-15}$

or $\frac{1}{v} = \frac{1}{-15} - \frac{1}{-25} = -\frac{1}{15} + \frac{1}{25} = -\frac{2}{75}$

or $\nu = \frac{-75}{2} = -37.5$ cm

Thus, the screen must be placed 37.5 cm from the mirror on the same side as the object.

Now, magnification, $m = \frac{h'}{h} = -\frac{v}{u}$

$$\frac{h'}{4.0\,cm} = -\frac{(-37.5)}{(-25)} = -1.5$$

or h' = – 1.5 × 4 = –6 cm

Negative sign shows that the image is inverted. Hence, the image is real, inverted and of size 6 cm.

Ex.11 An object 5 cm high is placed at a distance of 20 cm from a convex mirror of radius of curvature 30 cm. Find the position, nature and size of image.

Sol. Here, u = –20 cm, h = 5 cm

Radius of curvature, r = +30 cm

∴ Focal length, $f = \frac{r}{2} = +\frac{30}{2} = +15$ cm

Using the mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$, we get

$$\frac{1}{v} + \frac{1}{-20} = \frac{1}{+15}$$

or $\frac{1}{v} = \frac{1}{15} + \frac{1}{20} = \frac{7}{60}$

or $\nu = \frac{60}{7}$ cm

The image is formed 8.5 cm from the mirror. The positive sign shows that the image is formed on the other side or behind the mirror. So the image is virtual.

Magnification, $m = \frac{h'}{h} = -\frac{v}{u}$

or $\frac{h'}{5} = -\frac{60/7}{(-20)} = +\frac{60}{7 \times 20} = \frac{3}{7}$

or $h' = 5 \times \frac{3}{7} = \frac{15}{7}$ cm

The height of the image is 2.1 cm. Positive sign shows that the image is erect.

Ex.12 A convex mirror used on a automobile has 3 m radius of curvature. If a bus is located 5 m from this mirror, find the position, nature and size of image.

Sol. Here, u = –5 m, r = +3m

$\therefore \qquad f = \frac{r}{2} = +\frac{3}{7}\ 1.5\ m$

Using the relation, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, we get

or $\qquad \frac{1}{v} + \frac{1}{-5} = \frac{1}{1.5}$

or $\qquad \frac{1}{v} = \frac{1}{1.5} + \frac{1}{5} = +1.15\ m$

The image is 1.15 m behind the mirror.

Magnification, $m = \frac{h'}{h} = -\frac{v}{u} = -\frac{1.15}{(-5)} = +0.23$

Thus, the image is virtual, erect and smaller in size than the object.

◈ IMPORTANT POINTS TO BE REMEMBER

◆ **Laws of reflection :**

(a) Angle of incidence is equal to the angle of reflection .

(b) The incident ray, the reflected ray and the normal all lie in the same plane.

◆ **Mirror :** A smooth, highly polished reflecting surface is called a mirror. There are two types of mirrors : (a) plane mirror (b) curved mirrors

Curved mirrors are classified as spherical mirrors or parabolic mirrors depending upon the curvature of the mirror.

◆ **Concave mirror :** A spherical mirror whose inner hollow surface is the reflecting surface is called concave mirror. A concave mirror forms a real, inverted image of an object if the object is placed at any place outside F. However, when the object lies between F and P, the image formed is erect and virtual.

◆ **Convex mirror :** A spherical mirror whose outer bulging at surface is the reflecting surface is called convex mirror. The image formed by a convex mirror is always erect, virtual and smaller than the object whatever may be the position of the object. A convex mirror is used as a side-mirror (driver's mirror) on automobiles.

◆ **Aperture of a mirror :** The effective width of a spherical mirror from which reflection can take place is called its aperture.

◆ **Pole :** The centre of a curved mirror is called its pole.

◆ **Centre of curvature :** The centre of the hollow sphere of which the spherical mirror is a part is called its centre of curvature. The centre of curvature of a concave mirror is in front of it, while that of a convex mirror is behind it.

◆ **Radius of curvature :** Radius of the hollow sphere of which the mirror is a part is called its radius of curvature.

◆ **Principal axis :** A straight line passing through the centre of curvature and pole of a spherical mirror is called its principal axis.

◆ **Focus :** A point on the principal axis of a mirror at which the rays coming from infinity meet or appear to meet is called its focus. Focus is denoted by F.

◆ **Focal length :** The distance between the pole of a spherical mirror and the focus is called the focal of a spherical mirror.

◆ **Real image :** The image which can be obtained on a screen is called a real image. A real image is formed only when the reflected or refracted rays actually meet at a point.

◆ **Virtual image :** The image which can be seen into a mirror but cannot be obtained on a screen is called a virtual image. A virtual image is formed only when the reflected or the refracted rays appear to come from a point.

◆ **Sign convention for spherical mirrors :**

According to the sign convention for mirror, the focal length of a concave mirror is negative and that of a convex mirror is positive.

◆ **Mirrors formula :** The relationship, $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ is called the mirror formula.

- **Magnification :** The ratio of the size of the image to that of the object is called magnification. For a mirror, magnification (M) is given by,

$$M = -\frac{v}{u} = \frac{h_i}{h_o}$$

$$\text{power (in diopters)} = \frac{1}{f\,(\text{metre})}$$

◈ CONCLUSIONS FROM THE SIGN CONVENTION

- **For spherical mirror :**

Distance of the object,	u is negative
Distance of the real image,	v is negative
Distance of the virtual image	v is positive
Focal length,	f is negative for concave & f is + ve for convex
Radius of curvature,	R is negative for concave & R is + ve for convex
Height of the object,	O is positive
Height of the inverted (real) image,	I is negative
Height of the erect (virtual) image,	I is positive