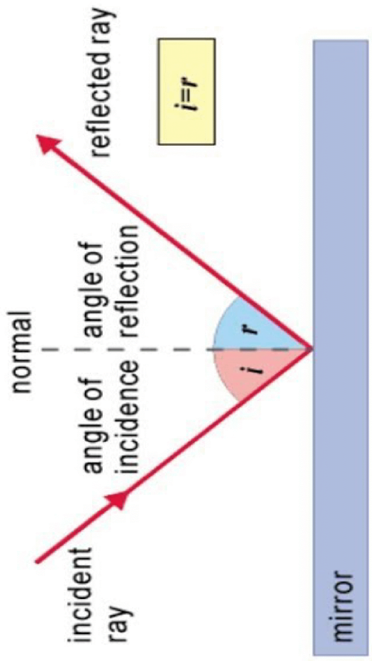
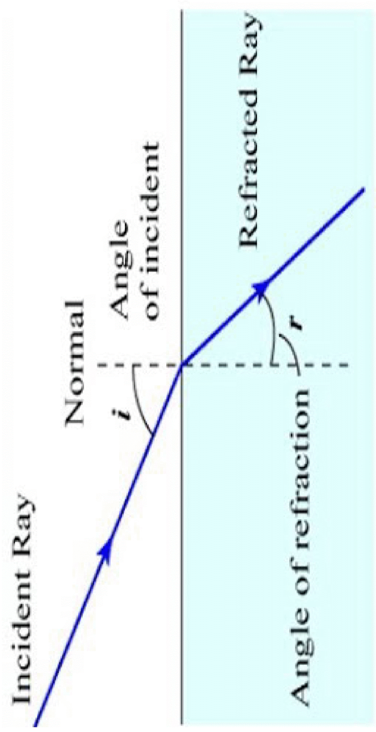
LIGHT : REFLECTION AND REFRACTION

1

Concepts





INTRODUCTION

'Seeing' is one of the most common things we do. When light from an object enters our eyes, we see the object. This light can be that emitted by the object, as in the case of an electric bulb or a red-hot iron nail. It can also be the light bouncing off an object like a book. An object that emits light is a source of light. During the day, the sun acts as a natural source of light. Candles, oil lamps and electric bulbs are sources of light made by us. Most common phenomenon involving light can be understood by thinking of light as a wave, certain phenomenon can be explained only if we think of light as being made up of particles. We now understand that light shows the characteristics of both a wave and a particle.

1. CHARACTERISTICS OF LIGHT

(i) Light has dual nature i.e. both wave and particle nature.

(ii) Light does not need a material medium to travel, i.e., it can travel through a vacuum too. The best example of this is light travelling from the sun to the earth across vast expanses of space that have no material (or matter). Compare this with sound, which is also a wave. Sound needs a material medium to travel.

(iii) Light waves travel at a tremendous speed-whose value scientists have fixed at 3×10^8 m/s. According to current scientific theories, no material particle can travel at a speed greater than that of light.

(iv) A medium in which light can travel freely over large distances is called a transparent medium. Water, glycerine, glass and clear plastics are transparent. A medium in which light cannot travel is called opaque. Wood, metals, bricks, etc., are opaque. In materials like oil, light can travel some distance, but its intensity reduces rapidly. Such materials are called translucent.

(v) The speed of light changes when it travels from one medium to another.

(vi) Light travels from one point to another in a straight line which is known as rectilinear propagation of light.

(vii) The light gets reflected when it falls on polished surfaces like mirror.

(viii) The frequency of light remains same in all mediums.

(ix) The light undergoes refraction when it travels from one transparent medium to another.

2. BASIC DEFINITION RELATED TO THE LIGHT

(A) Source of light : A body which emits light or reflect the light falling on it in all possible direction is said to be the source of light. The source can be point one or an extended one. the sources of light are of two types :

(i) Luminous Source : Any object which by itself emits light is called as a luminous source.

e.g. : Sun and stars (natural luminous sources), electric lamps, candles and lanterns (artificial luminous sources).

(ii) Non–luminous Source : Those objects which do not emit light but become visible only when light from luminous objects falls on them. They are called non–luminous sources.

e.g. : Moon, planets (natural non–luminous sources), wood, table (artificial non–luminous sources).

(B) Medium of light : Substance through which light propagates or tends to propagate is called medium of light.

(i) Transparent Object : Bodies that allow to pass light through them i.e. transmit light through them, are called transparent bodies.

e.g. : glass, water, air etc.

(ii) Translucent Object : Bodies that can transmit only a part of light through them are called translucent objects.

e.g. : Frosted or ground glass, greased paper, paraffin wax.

(iii) Opaque Object : Bodies that do not allow light to pass through them at all are said to be opaque object.

Eg. Chair, desk etc.

Focus Point

Depending on composition optical medium are divided into two type.

Homogeneous medium : An optical medium which has a uniform composition throughout is called homogeneous medium.

e.g. Vacuum, distilled water, pure alcohol, glass plastics, diamond, etc.

Heterogeneous medium : An optical medium which has different composition at different points is called heterogeneous medium.

E.g. Air, muddy water, fog, mist, etc.

(C) Ray of Light : The straight line path along which the light travels in a homogeneous medium is called a ray. It is represented by an arrow head on a straight line, the arrow head represents the direction of propagation of light.

(D) Beam of light : A bundle of rays is called a beam. It is of following three types :

(i) Convergent beam : It is a beam in which diameter of beam decreases in the direction of ray.

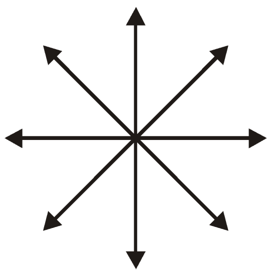
(ii) Divergent beam : It is a beam in which all the rays meet at a point when produced backward and the diameter of beam goes on increasing as the rays proceed forwards.

(iii) Parallel beam : It is a beam in which all the rays constituting the beam move parallel to each other and diameter of beam remains same.

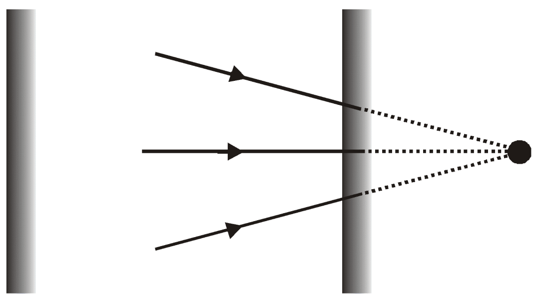
(E) Object : An optical object is decided by incident rays only. It is of two kinds :

(i) Real object : When the incident rays diverge in all the directions and the point of divergence gives the position of real object.

(ii) Virtual object : When the incident rays converge at a point and the point of convergence gives the positon of virtual object.



Real object



Virtual object

Focus Point

Virtual object cannot be seen by human eye because for an object or image to be seen by eyes, rays received by eyes must be diverging.

3. REFLECTION OF LIGHT

(A) Definitions of Reflection :

The phenomena of bouncing back of light in same medium after striking at the interface of two media is called reflection of light.

(B) General definitions about Reflection :

(i) Mirror : A smooth polished surface from which regular reflection can take place is called mirror. MM' is the mirror as shown in figure.

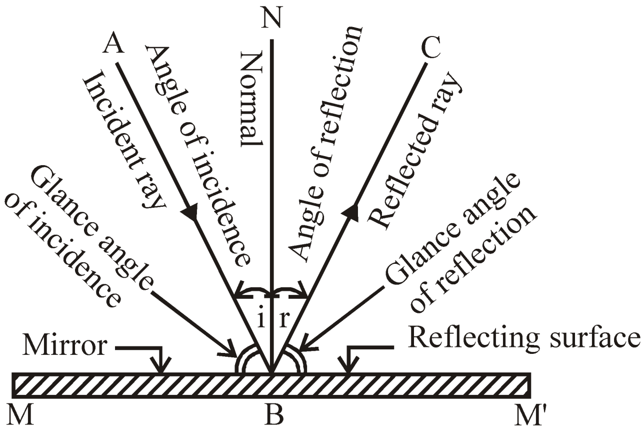


Figure : Reflection of light

(ii) Incident ray : A ray of light which travels towards the mirror is called incident ray. Ray AB is incident ray in figure.

(iii) Point of incidence : The point on the mirror, where an incident ray strikes is called point of incidence. 'B' is the point of incidence in figure.

(iv) Reflected ray : A ray of light which bounces off the surface of a mirror, is called reflected ray. BC is reflected ray in figure.

(v) Normal : the perpendicular drawn at the point of incidence, to the surface of mirror is called normal. BN is normal in figure.

(vi) Angle of incidence : The angle made by the incident ray with the normal is called angle of incidence. $\angle$ABN is the angle of incidence in figure. It is denoted by $\angle$i.

(vii) Angle of reflection : The angle made by the reflected ray with the normal is called angle of reflection. $\angle$CBN is the angle of reflection in figure. It is denoted by $\angle$r.

(viii) Glance angle of incidence : The angle which the incident ray makes with the mirror is called glance angle of incidence. $\angle$MBA is the glance angle of incidence in figure.

(ix) Glance angle of reflection : The angle which the reflected ray makes with the mirror is called glance angle of reflection. $\angle$M'BC is the glance angle of reflection in figure.

Types of Reflection :

(i) Regular reflection : The reflection of a parallel beam of light from a mirror so that the reflected rays are parallel to each other as shown in figure (a) are called regular reflection. Regular reflection takes place from the objects like looking glass, still water, oil, highly polished metals, etc.

(ii) Irregular reflection : The reflection of light from a rough irregular surface such as walls of a room, page of a book randomly in various directions not parallel to each other as shown in figure (b) are called irregular 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.

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

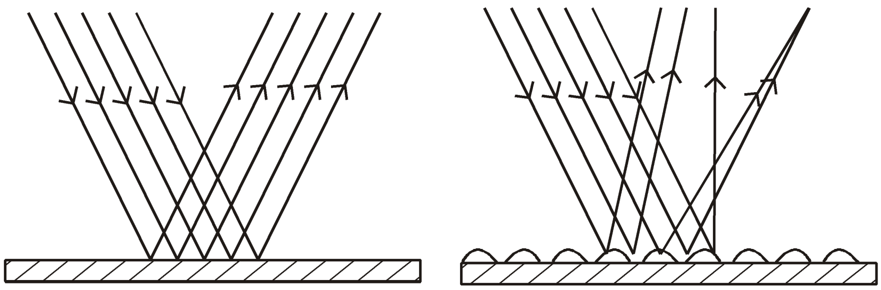


Figure : (a) Regular reflection ***(b) Irregular reflection***

Laws of reflection : The phenomenon of reflection is governed by following two laws :

(i) First law : The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence, all lie in same plane.

(ii) Second law : The angle of incidence is equal to the angle of reflection. $\angle i = \angle r$

Note : The laws of reflection are valid for any smooth reflecting surface irrespective of geometry.

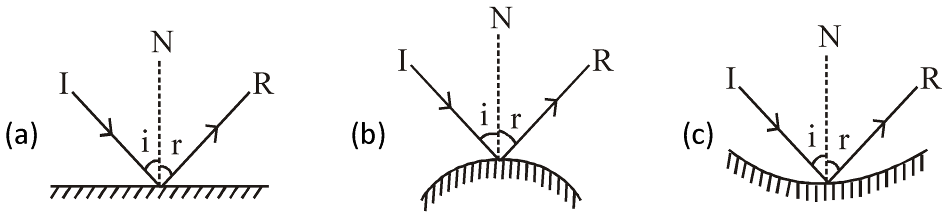
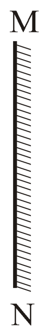


Figure : Mirrors

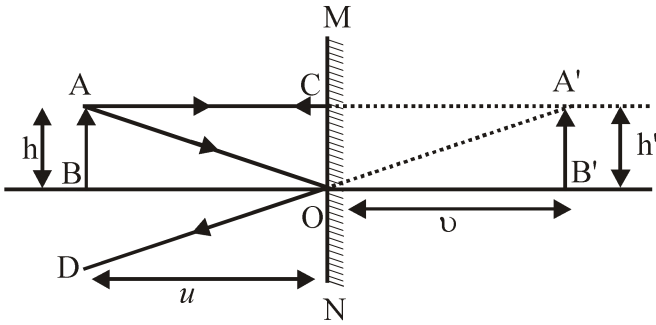
4. PLANE MIRROR

A highly polished plane (flat) surface is called a plane mirror, e.g. looking glass.
The having short, oblique lines represents the back side of the plane mirror.
The image formed by a plane mirror can be seen only by looking into the mirror.



Formation of image by plane mirror

- The image formed by the mirror is a virtual image and it is erect (up right).
- The image in a plane mirror lies as far behind the mirror as the object is in front of the mirror, i.e., object distance (u) = image distance (υ).



- The image is of the same size as the object.

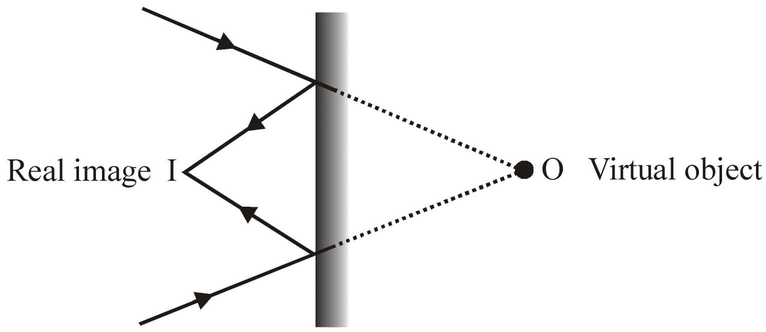


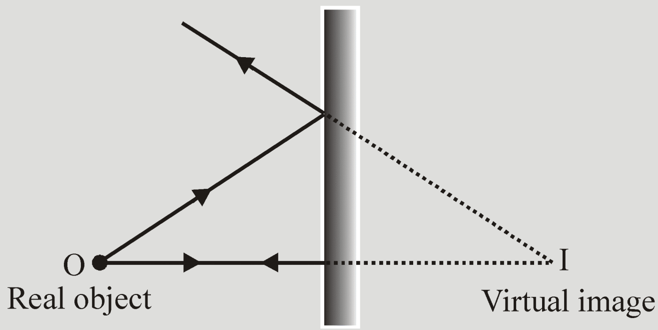
Figure : Plane miror showing real image formation of a virtual object

[∵ AB (height of the object) = A'B' (height of the image).]

Focus Point

An optical image is decided by reflected or refracted rays only. It is of two types :

(a) Real image : This is formed due to real intersection of reflected or refracted rays. Real image can be obtained on screen.



Plane mirror forming virtual image of a real object

(b) Virtual image : This is formed due to apparent intersection of reflected or refracted light rays. Virtual image can't be obtained on screen.

4.1 DIFFERENCE BETWEEN REAL AND VIRTUAL IMAGE

S.No.	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.	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.	A virtual image cannot be obtained on a screen.
3.	A real image is inverted with respect to the object.	A virtual image is erect with respect to the object.

4.2 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

When an asymmetric object is placed in front of plane mirror, then the right side of the object appears to be the left side of image and the left side of the object appears to be the right side of its image. This change of sides of an object seen in the image is called left–right inversion or lateral inverstion. The image is inverted side ways, thus, also called 'side ways inversion' (see figure).

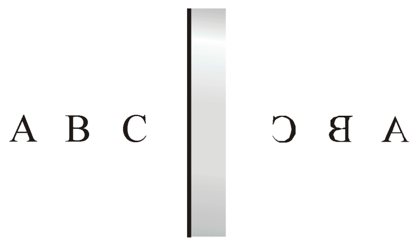
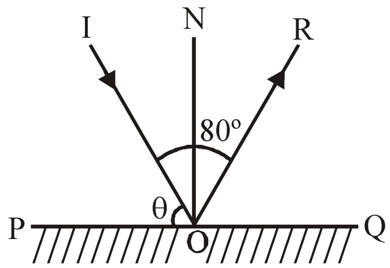


Figure : Lateral inversion of image in a Plane mirror

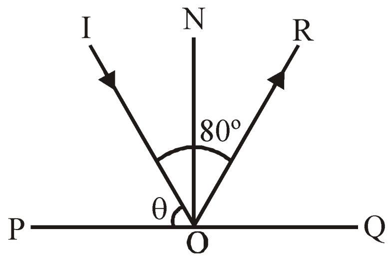
Example 1

A ray of light is incident on a plane mirror making an angle θ with it.

If the angle between the incident and reflected rays is 80º, find the value of θ.



Solution :



Because $\angle i = \angle r$ and $\angle IOR = 80^\circ = \angle i + \angle r = 2\angle i$ or $\angle i = 40^\circ$

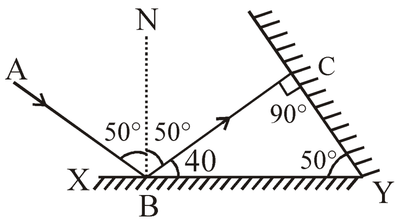
Now $\angle PON = \angle POI + \angle ION$

$90^\circ = \theta + \angle i = \theta + 40^\circ$ or $\theta = 50^\circ$

Example 2

Light ray AB incidents on a polished surface XY at an angle of 50º. The second polished surface is placed is such a way that the reflected ray BC from polished surface XY retraces its path. Find the angle of inclination of two polished surface.

Solution :



Ray BC retraces its path when A fall on second polished surface perpendicularly, so as per figure $\angle BYC$ will be equal to 50º.

Example 3

A ray falls on a plane mirror, making an angle 30° with mirror, then after reflection find the angle between inicident ray and reflected ray.

Solution :

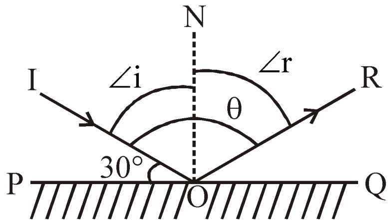
i + 30° = 90°

Angle of incidences, i = 90 – 30 = 60°

So, angle of reflection, r = 60°

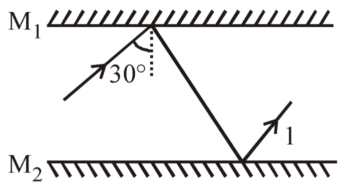
Angle between incident ray and reflected ray,

i + r = 60 + 60 = 120°



Example 4

Two mirror are placed parallel to each other according to given figure. What will be the angle made by rays-1 with mirror M_1, after third reflection in degree ?



Solution :

∠OAB = 30°

∠BAC = ∠OAB = 30° (i = r)

∠DCA = ∠BAC = 30°(alternate interiar angles)

∠DCE = ∠ACD = 30° (i = r)

∠CEF = ∠DCE = 30° (alternate interior angles)

∠DEF = 90°

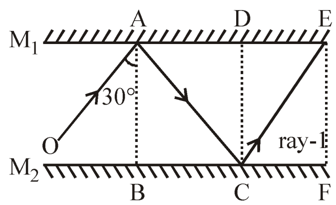
∠DEF = ∠DEC + ∠CEF

⇒ 90° = ∠DEC + ∠CEF

⇒ ∠DEC = 90° – 30°

⇒ ∠DEC = 60°

∴ The angle made by ray-1 with mirror m_1, after third reflection = ∠DEC = 60°.



5. REFLECTION FROM SPHERICAL MIRROR

Spherical Mirror :

(A) Definition :

A mirror whose reflecting surface is a part of a hollow sphere of glass is known as spherical mirror. For example, a dentist uses a curved mirror to examine the teeth closely, large curved mirrors are used in telescopes. These are of two types convex and concave. In concave mirror, reflecting surface is concave but in convex mirror, reflecting surface is convex.

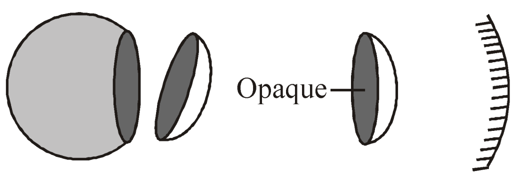


Figure : Convex mirror

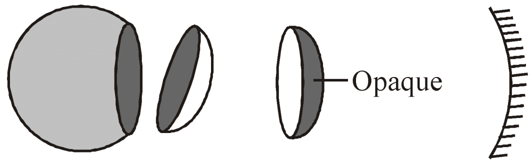
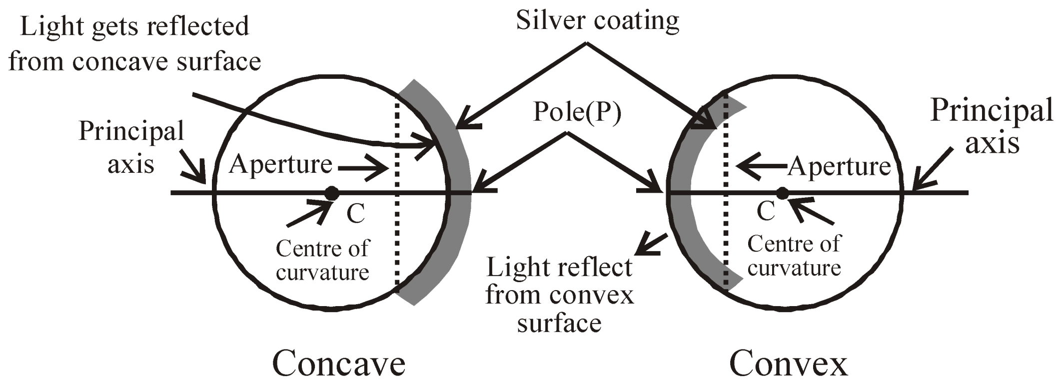


Figure : Concave mirror

(B) Concave and Convex Mirror :

Convex mirror is a spherical mirror, whose inner (cave type) surface is silvered and reflection takes place at the outer (convex) surface. Concave mirror is a spherical mirror, whose outer bulged surface is silvered and reflection takes place from the inner hollow (cave type) surface.

(C) Some terms related to spherical mirror :



(i) Pole (P) : The central point of a mirror is called its pole.

(ii) Centre of curvature (C) : The centre of the sphere of which the mirror is a part is called centre of curvature.

(iii) Radius of curvature (R) : The radius of the sphere of which the mirror is a part is called radius of curvature.

(iv) Principal axis : The straight line joining the pole and the centre of curvature is called the principal axis.

(v) Aperture : The size of the mirror is called its aperture.

(vi) Principal focus (F) :

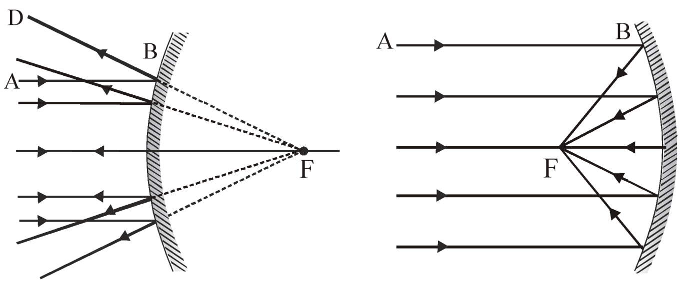


Figure : Convex mirror and Concave mirror

(vii) Focal length (f) : The distance between the pole and the focus is called the focal length. The focal length is half the radius of curvature.

(viii) Focal plane : A plane passing through the principal focus and at right angles to the principal axis of a spherical mirror is called the focal plane.

(D) Rules for the formation of images by concave and convex mirrors :

(i) A ray incident parallel to the principal axis actually passes (concave) or appears to pass (convex) through the focus.

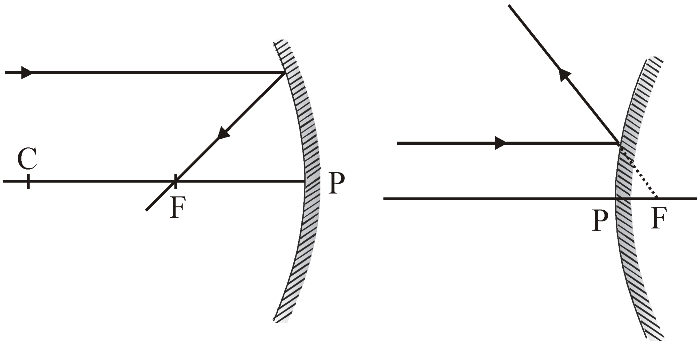


Figure : Concave mirror and Convex mirror

(ii) A ray incident through the centre of curvature (C) falls normally and is reflected back along the same path.

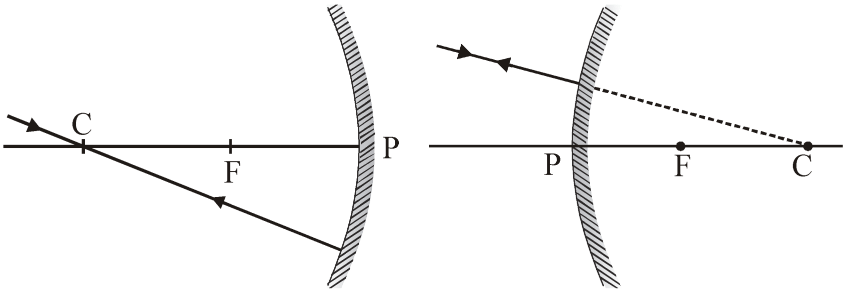


Figure : Concave mirror and Convex mirror

(iii) A ray incident through the focus is reflected parallel to the principal axis.

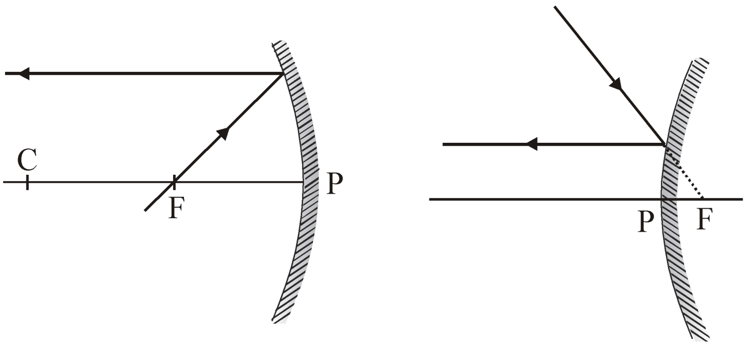


Figure : Concave mirror and Convex mirror

(E) Formation of Images by convex mirror :

(i) When the object is placed at infinity then image is formed at the focus. The image formed is virtual, erect and extremely diminished.

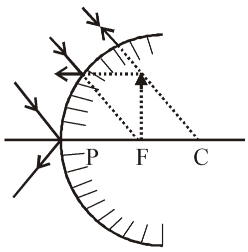


Figure : Convex mirror

(ii) When the object is placed between infinity and pole then the image is formed between the focus and the pole. The image formed is virtual, erect and diminished.

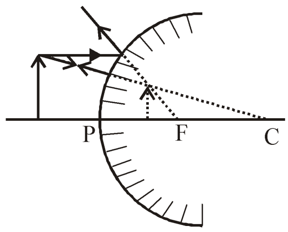


Figure : Convex mirror

Image formation by a convex mirror :

The image formed by a convex mirror is always behind the mirror, that is, it is always virtual and erect. Also, the size of image is always diminished, that is, its size is always smaller than that of the object.

Position of the object	Position of the image	Size of the image	Nature of the image
Between infinity and the pole P	Between P and F, behind the mirror	Diminished	Virtual and erect
At infinity	At the focus F, behind the mirror	Highly diminished point-sized	Virtual and erect

(F) Formation of images by concave mirror :

(i) When the object is placed between the pole and the focus, then the image formed is virtual, erect and magnified.

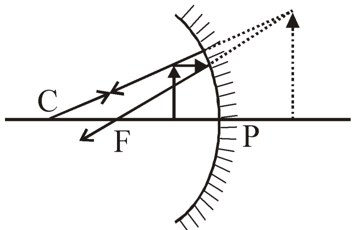


Figure : Convex mirror

(ii) When the object is placed at the focus then the image is formed at infinity. The image is extremely magnified.

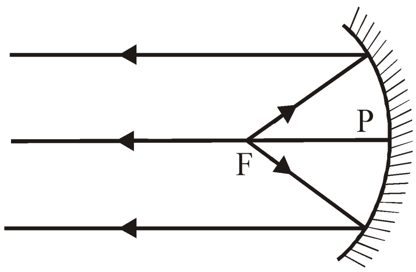


Figure : Concave mirror

(iii) When the object is placed between the focus and the centre of curvature then the image is formed beyond the centre of curvature. The image formed is real, inverted and bigger than the object.

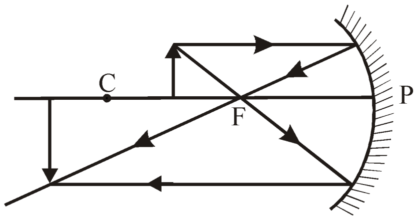


Figure : Concave mirror

(iv) When the object is placed at the centre of curvature, then the image is formed at the centre of curvature. The image formed is real, inverted and equal to the size of the object.

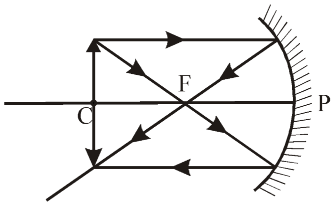


Figure : Concave mirror

(v) When the object is placed beyond the centre of curvature, then the image is formed between the focus and centre of curvature. The image formed is real, inverted and diminished.

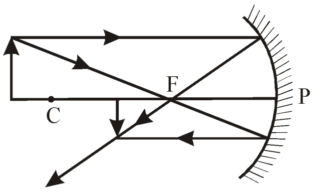


Figure : Concave mirror

(vi) When the object is placed at infinity then the image is formed at the focus. The image formed is real, inverted and extremely diminished in size.

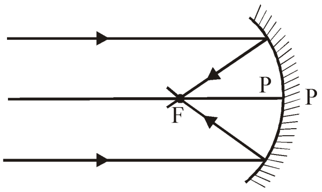


Figure : Concave mirror

Position of object	Position of image	Size of image	Nature of image
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

(G) Uses of concave mirror :

(i) They are used as shaving mirrors.

(ii) They are used as reflectors in car head-lights, search lights, torches and table lamps.

(iii) They are used by doctors to concentrate light on body parts like ears and eyes which are to be examined.

(iv) Large concave mirrors are used in the field of solar energy to focus sun-rays on the objects to be heated.

(v) **Solar cookers** : When a parallel beam of sunlight falls on a concave mirror, this beam is brought to the focus of the mirror (see figure). As a result of this, the temperature of an object (say a container containing uncooked food) placed at the focus increases considerably. Hence the food in the container is cooked.

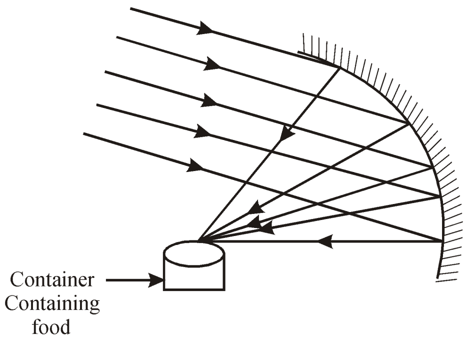


Figure : Spherical Reflector type solar cooker

(H) Uses of convex mirror : Convex mirror is used as rear view mirror in automobiles like cars, trucks and buses to see the traffic at the back side. It is also used in street lamps.

(I) Sign convention or measuring distance in concave and convex mirror :

(i) All distances are measured from the pole, of mirror

(ii) The incident ray is taken from left to right.

(iii) Distances measured in the same direction as that of the incident ray are taken to be +ve.

(iv) Distances measured in a direction opposite to the incident ray are taken to be –ve.

(v) Distances measured upwards and perpendicular to principal axis are taken +ve.

(vi) Distances measured downwards and perpendicular to principal axis are taken –ve.

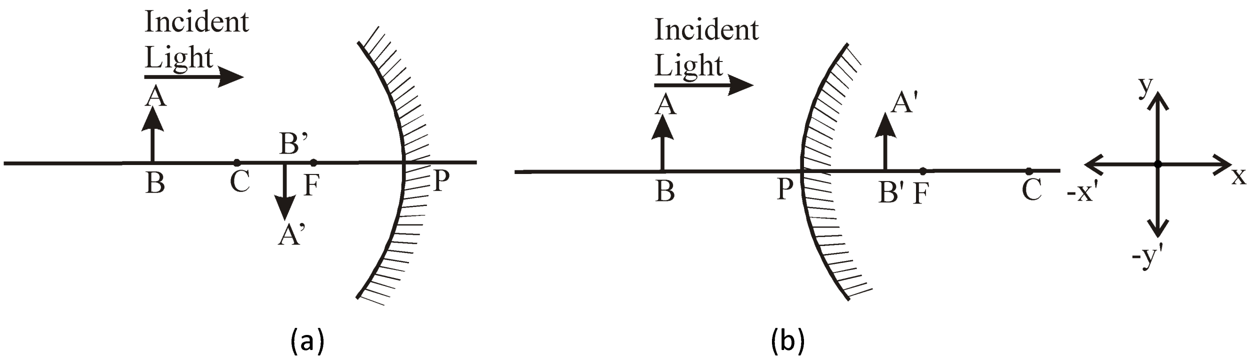


Figure : Sign convention in concave and convex mirror

$$\therefore \left\{\begin{array}{l}\text{Focal length of concave mirror is} - \text{ve} \\ \text{Focal length of convex mirror is} + \text{ve} \\ \text{For real image v is} - \text{ve} \\ \text{for virtual image v is} + \text{ve}\end{array}\right\}$$

These signs are according to the rectilinear co-ordinate system.

(J) Mirror formula :

The mirror formula is a relation relating the object distance (u), the image distance (v) and the focal length (f) of a mirror.

The **mirror formula** is : $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

Above equation is known as mirror formula and is valid for both concave and convex mirrors. However, the quantities must be substituted with proper signs.

(i) Power of mirror : Optical power of a mirror is given by :

$$P \text{ (in Diopter)} = \frac{1}{f(\text{in meter})}$$

(ii) Relation between focal length (f) and radius of curvature (R) :

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

(K) Magnification of concave mirror :

The linear magnification of a spherical mirror is the ratio of height of the image (h_2) formed by the mirror to the height of the object (h_1) i.e.

$$\text{Linear magnification, } m = \frac{\text{Height of image}}{\text{Height of object}} = \frac{h_2}{h_1}$$

The linear magnification is a number that simply tell us how much taller the images is than the object. For example, if m = 1, it means that the image and the object are of the same height.

Another formula for magnification is :

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

The arbitroty minus sign given to linear magnification has nothing to do with the relative sizes of the object and the image but we can use it to tell whether the image is erect or inverted w.r.t. object.

Focus Point

Always draw a rough ray diagram while solving a numerical problem. Otherwise we will be confused as to which distance should be taken as +ve & which –ve.

For virtual image : m is +ve [as virtual image is erect $\therefore$ h_2 is +ve as well as h_1 is +ve]

For real image : m is –ve [as real image is always inverted $\therefore$ h_2 is –ve while h_1 is +ve]

Example 5

How can we distinguish between a plane mirror, a concave mirror and a convex mirror without touching them?

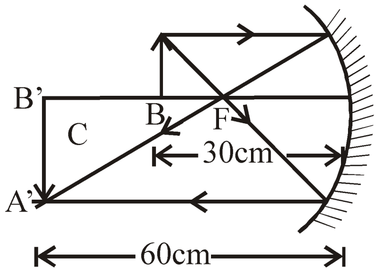
Solution :

We can distinguish between them by bringing our face close to each of them. All of them will produce different types of image of our face.

A plane mirror will produce an image of same size as our face. A concave mirror will produce a magnified image and our face will look much bigger. A convex mirror will produce a diminished image and our face will look small.

Example 6

A 2.0 cm long object is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is 30 cm and its image is formed 60 cm from the mirror on the same side of the mirror as the object. Find the height of the image formed



Solution :

u = –30 cm, v = –60 cm

$\therefore\ m = \frac{h_2}{h_1} = -\frac{v}{u} = -\frac{(-60)}{(-30)} = -2$

$\Rightarrow h_2 = -2h_1 = -2 \times 2 = -4cm$

$\therefore$ Height of the image is 4 cm. It is inverted.

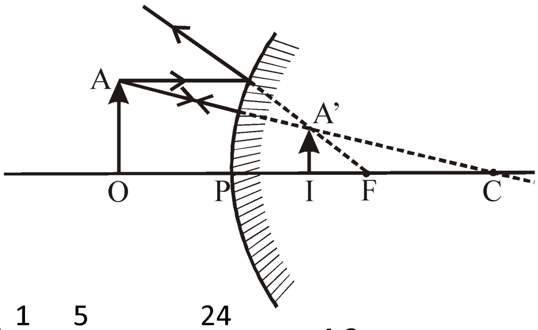
Example 7

A 1.2 cm long pin is placed perpendicular to the principal axis of a convex mirror of focal length 12 cm, at a distance of 8 cm from it.

(a) Find the location of the image.

(b) Find the height of the image.

(c) Is the image erect or inverted ?



Solution :

Here f is +ve so f = 12 cm

Also, u = –8cm.

(a) Using, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ or $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{12} - \frac{1}{(-8)} = \frac{1}{12} + \frac{1}{8} = \frac{5}{24}$ $\therefore\ v = \frac{24}{5}$ cm = 4.8 cm

(b) Given, h_1 = 1.2 cm; We know, $\frac{h_2}{h_1} = -\frac{v}{u}$ $\Rightarrow h_2 = -\frac{v}{u} \times h_1 = -\frac{4.8}{-8} \times 1.2 = \frac{4.8}{8} \times 1.2 = 0.72\,cm$

(c) Image formed is erect.

Example 8

A 2 cm high object is placed at a distance of 32 cm from a concave mirror. The image is real, inverted and 3cm in size. Find the focal length of the mirror and the position of the image.

Solution :

We have, $m = \frac{-v}{u} = \frac{h_i}{h_o}$; From the question, h_i = –3cm and h_o = 2cm.

$\therefore\ m = \frac{h_i}{h_o} = \frac{-3cm}{2cm} = -1.5$ or $-\frac{v}{u} = -1.5$ or $\frac{v}{-32cm} = 1.5$ or v = –48 cm

We have $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{-32cm} + \frac{1}{(-48cm)} = \frac{-5}{96cm}$ or $f = \frac{-96cm}{5} = -19.2$ cm.

So the focal length of the concave mirror is 19.2 cm and the image is formed 48 cm in front of it.

Example 9

A concave mirror forms an erect image of an object placed at a distance of 10 cm from it. The size of the image is double that of the object. Where is the image formed ?

Solution :

From the question, $\frac{h_i}{h_o} = +2$ (erect image) or $-\frac{v}{u} = 2$ or $v = -2u = -2(-10cm) = +20$ cm

Thus, the image is formed 20 cm behind the mirror (from the position sign of v).

Example 10

An object, 4.0 cm in size, is placed at 25.0 cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image ? Find the nature and the size of the image.

Solution :

Given, object size, $h_1 = +4$ cm; object distance, $u = -25$cm ;

Focal length, $f = -15$cm ; image distance ; v = ? ; image size, h_2 = ?

Mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \text{ or } \frac{1}{v} + \frac{1}{(-25)} = \frac{1}{(-15)} \text{ or } \frac{1}{v} - \frac{1}{25} = -\frac{1}{15}$$

$$\text{or } \frac{1}{v} = \frac{1}{25} - \frac{1}{15} = \frac{3-5}{75} = \frac{-2}{75} \text{ or } v = \frac{-75}{2} = -37.5 \text{ cm}$$

The screen should be placed at 37.5 cm from the mirror.

Now, magnification, $m = \frac{h_2}{h_1} = -\frac{v}{u}$

$$\text{or } h_2 = -\frac{v}{u} \times h_1 = -\frac{(-75/2)}{(-25)} \times (+4) = -\frac{3}{2} \times 4 = -6\text{cm}$$

The image is real, inverted and enlarged

Example 11

A 4.5 cm needle is placed 12 cm away from a convex mirror of focal length 15 cm. Give the location of the image and the magnification. Describe what happens as the needle is moved farther from the mirror.

Solution :

Given, object distance, $u = -12$ cm; focal length ; $f = +15$ cm;

object size, $h_1 = +4.5$ cm; image distance, v = ? ; magnification, m = ?

image size, h_2 = ?

Mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \text{ or } \frac{1}{v} + \frac{1}{(-12)} = \frac{1}{(+15)} \text{ or } \frac{1}{v} - \frac{1}{12} = \frac{1}{15}$$

or $\frac{1}{v} = \frac{1}{15} + \frac{1}{12} = \frac{4+5}{60} = \frac{9}{60}$ or v = +(60/9) cm = + 6.67 cm

Now, magnification, m = $-\frac{v}{u} = \frac{(+60/9)}{(-12)} = +\frac{5}{9} = +0.55$

Also, magnification, m = $\frac{h_2}{h_1}$ or $+\frac{5}{9} = \frac{h_2}{(+4.5)}$ or $h_2 = +\frac{5}{9} \times (+4.5) = +2.5$ cm

Image is virtual, erect and diminished.
If the needle (object) is moved farther from the mirror, its image moves away from the mirror i.e., from pole towards the focus. The image remains virtual and erect but it gradually decreases in size. When the object becomes infinitely far away, the image is formed at the focus and it is a point sized image. But, the image never goes beyond the focus in a convex mirror.

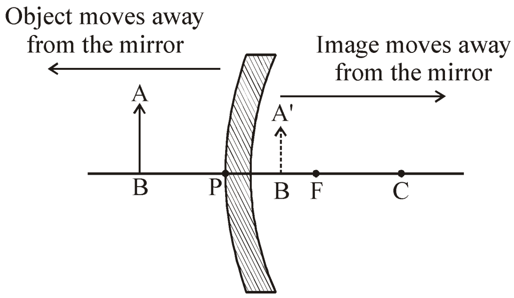


Figure : Effect on the position of the image formed when an object is moved away from a convex mirror.

6. REFRACTIVE INDEX

Light travels the fastest in vacuum with the highest speed of 3×10^8 m s^{-1}. In air, the speed of light is only marginally less, compared to that in vacuum. But for all practical purposes, we consider the speed of light in air equal to the speed of light in vacuum. However speed of light decreases in denser media like water, glass etc. It means when light goes from air to some other medium like water and glass, its speed decreases. The amount of change in the speed of light in a medium depends upon the property of the medium. This property is known as refractive index of the medium. Refractive index is a measure of how much the speed of light changes when it enters a medium from air.

Absolute Refractive index :

Absolute refractive index of a medium is defined as the ratio of the speed of light in vacuum or air to the speed of light in the medium. It is denoted by n.

Then, n = $\frac{\text{Speed of light in air}}{\text{Speed of light in medium}} = \frac{c}{v}$

It has no unit.

Relative refractive index :

When light passes from medium 1 to another medium 2, the refractive index of medium 2 with respect to medium 1 is written as $_2n_1$ and is called relative refractive index.

$_2n_1 = \dfrac{\text{Speed of light in air}}{\text{Speed of light in medium}} = \dfrac{v_1}{v_2}$ ......(i)

Multiply and divide R.H.S. of eqn. (i) by c (speed of light in air), we get

$_2n_1 = \dfrac{cv_1}{cv_2} = \left(\dfrac{c}{v_2}\right) \times \left(\dfrac{v_1}{c}\right) = \left(\dfrac{c/v_2}{c/v_1}\right)$ ......(ii)

But $\dfrac{c}{v_1} = n_1$ (absolute refractive index of medium 1) and $\dfrac{c}{v_2} = n_2$ (absolute refractive index of medium 2)

Hence, eqn. (ii) can be written as $_2n_1 = \dfrac{n_2}{n_1}$ ......(iii)

Thus, relative refractive index of medium 2 with respect to medium 1 is defined as the ratio of absolute refractive index of medium 2 to the absolute refractive index of medium 1.

We know, refractive index of medium 2 with respect to medium 1 is given by, $_2n_1 = \dfrac{v_1}{v_2}$ ......(iv)

Similarly, refractive index of medium 1 with respect to 2 is given by, $_1n_2 = \dfrac{v_2}{v_1}$ ......(v)

Multiplying eqn. (iv) and (v), we get $_2n_1 \times {_1n_2} = \dfrac{v_1}{v_2} \times \dfrac{v_2}{v_1} = 1$ or $_2n_1 = \dfrac{1}{_1n_2}$

i.e. refractive index of medium 2 with respect to medium 1 is the reciprocal of refractive index of medium 1 with respect to medium 2.

Example 12

Find the refractive index of glass with respect to water, the refractive index of glass with respect to air is 3/2 and refractive index of water with respect to air is 4/3.

Solution :

For water, $_wn_a = \dfrac{4}{3}$ or 1.33, For glass, $_gn_a = 1.5$

Refractive index of glass with respect to water, $_gn_w = \dfrac{_gn_a}{_wn_a} = \dfrac{3/2}{4/3} = \dfrac{9}{8} = 1.125$

Example 13

The speed of light in air is 3×10^8 ms^{-1} and the speed of light in water is 2.26×10^8 m s^{-1}. Find the refractive index of water.

Solution :

Given, $c = 3\times10^8$ m s^{-1}, $v = 2.26\times10^8$ m s^{-1}

Using, $n = \dfrac{c}{v}$, we have $n = \dfrac{3\times10^8 \text{ m s}^{-1}}{2.26\times10^8 \text{ m s}^{-1}} = 1.33$

Thus, refractive index of water = 1.33

7. REFRACTION OF LIGHT

(a) Definition :

When light travels in the same homogeneous medium. It travels along a straight path. However, when it passes from one transparent medium to another, the direction of its path changes at the interface of the two media. This is called refraction of light.

The phenomenon of the change in the path of the light as it passes from one transparent medium to another is called refraction of light. The path along which the light travels in the first medium is called incident ray and that in the second medium is called refracted ray. The angles which the incident ray and the refracted ray make with the normal at the surface of separation are called angle of incidence (i) and angle of refraction (r) respectively.

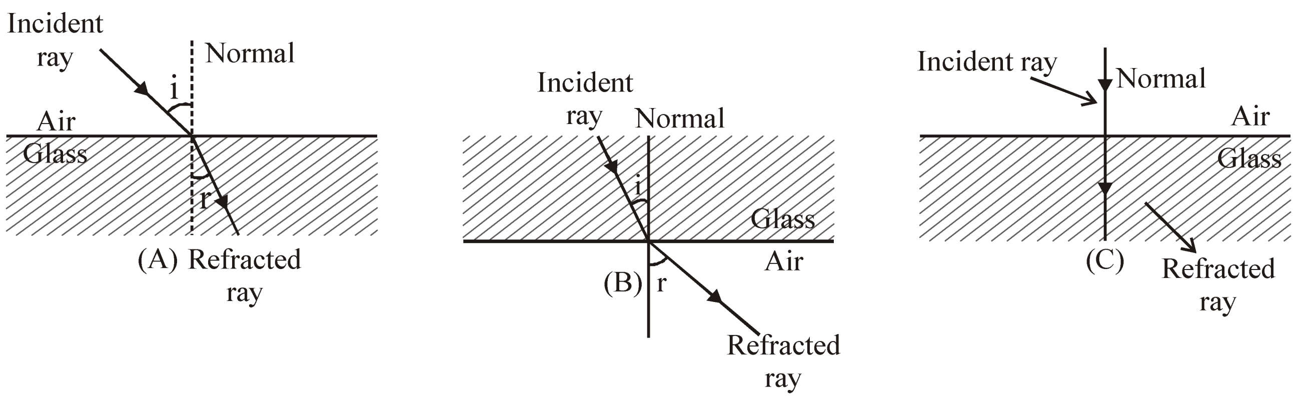


Figure : Showing different cases of refraction

It is observed that :

(i) When a ray of light passes from an optically rarer medium to a denser medium, it bends towards the normal ($\angle r < \angle i$), as shown in figure (A).

(ii) When a ray of light passes from an optically denser to a rarer medium, it bends away from the normal ($\angle r > \angle i$) as shown in figure (B).

(iii) A ray of light travelling along the normal passes undeflected, as shown in figure (C). Here $\angle i = \angle r = 0°$.

(b) Cause of refraction :

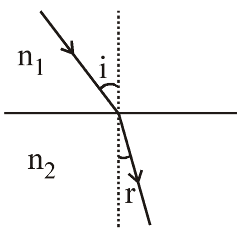
Light rays get deviated from their original path, while entering from one transparent medium to another medium of different density. This deviation (change in direction) in the path of light is due to the change in velocity of light in the different medium. The velocity of light depends on the nature of the medium in which it travels. Velocity of light in a rarer medium (low optical density) is more than in the denser medium (high optical density).

7.1 LAWS OF REFRACTION

Refraction of light follows the following two laws :

First Law : The incident ray, the normal to the transparent surface at the point of incidence and the refracted ray, all lie in the same plane.

Second Law : The ratio of sine of the incidence angle ($\angle i$) to the sine of the refracted angle ($\angle r$) is constant. It is denoted by ${}_2n_1$.



i.e., $\frac{\sin i}{\sin r} = {}_2n_1$

This constant is called refractive index of the second medium with respect to the first medium. Refractive index of second medium with respect to the first medium is denoted by $_2n_1$.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$n_1 \sin i = n_2 \sin r$

8. REFRACTION THROUGH GLASS SLAB

Consider a rectangular glass slab, as shown in figure. A ray AE is incident on the face PQ at an angle of incidence i. On entering the glass slab, it bends towards normal and travel along EF at an angle of refraction r. The refracted ray EF is incident on face SR at an anlge of incidence r'. The emergent ray FD bends away from the normal at an angle of refraction e.

Thus the emergent ray FD is parallel to the incident ray AE, but it has been laterally displaced with respect to the incident ray. There is shift in the path of light on emerging from a refracting medium with parallel faces.

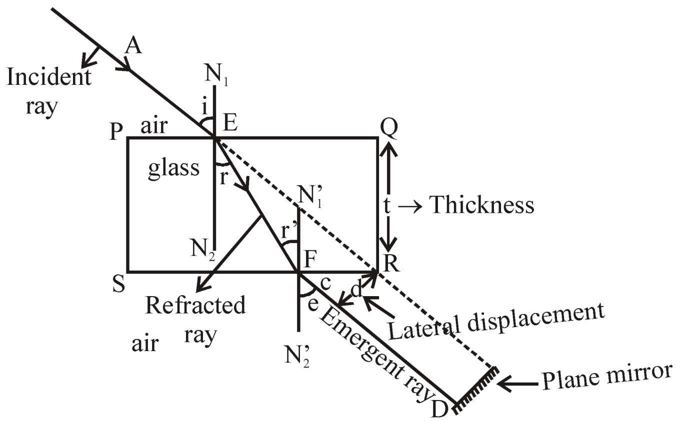


Figure : Bending of light in glass slab

If a plane mirror is placed in the path of emergent ray FD then the path of the emergent ray along FD is reversed back, it follows the same path along which it was incident i.e. the incidence ray becomes the emergent ray & emergent ray becomes the incident ray. It is known as principle of reversibility of light.

Case I : For light going from air to glass at point E.

$\angle i$ = angle of incidence, $\angle r$ = angle of refraction.

$$_a\mu_g = \frac{\sin i}{\sin r} \quad ....(1)$$

($_a\mu_g$ = absolute refractive index of glass)

Case II : For light going from glass to air at point F.

$$\Rightarrow {}_g\mu_a = \frac{\sin r'}{\sin e} \text{ where } \left\{\begin{array}{l}\angle r' = \text{angle of incidence} \\ \angle e = \text{angle of emergence}\end{array}\right\} \because \angle r = \angle r'$$

$\Rightarrow {}_g\mu_a$ = (as $\angle e = \angle i$)

$\therefore \frac{1}{{}_g\mu_a} = \frac{\sin i}{\sin r}$ ....(2)

$\therefore$ From (1) & (2) $\Rightarrow$

$\angle e = \angle i$, hence incident ray and emergent ray are parallel.

$${}_a\mu_g = \frac{1}{{}_g\mu_a} \Rightarrow {}_a\mu_g \times {}_g\mu_a = 1$$

Lateral shift : Lateral shift is the perpendicular distance between the incident and emergent rays when light is incident obliquely on a refracting slab with parallel faces. if thickness of glass slab is t then lateral shift $d = \frac{t\sin(i-r)}{\cos r}$

Factors on which lateral shift depends are :

(i) Lateral shift is directly proportional to the thickness of glass slab.

(ii) Lateral shift is directly proportional to the incident angle.

(iii) Lateral shift is directly proportional to the refractive index of glass slab.

(iv) Lateral shift is inversely proportional to the wavelength of incident light.

9. APPARENT DEPTH

When an object lying inside an optically denser medium is seen from a rarer medium, its depth appears to be less than its real depth. This depth is called 'apparent depth' (see figure). Apparent depth = AI ; real (actual) depth = OA. This happens because rays of light from denser medium (like water) when enter into rarer medium (like air), they bend away from the normal and thus, they appear to diverge from a point above the object where the image of the object is formed. Thus, we see the image of the object (not the actual object) in water which is at lesser depth than the real depth.

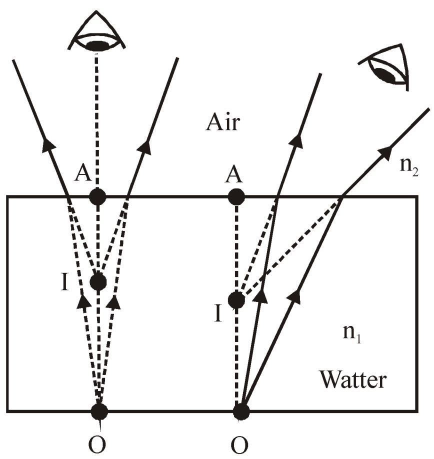


Figure : Apparent depth of an object is less than the actual depth when seen from air

9.1 EFFECT OF REFRACTION OF LIGHT

(i) A pencil appears bent and short in water :

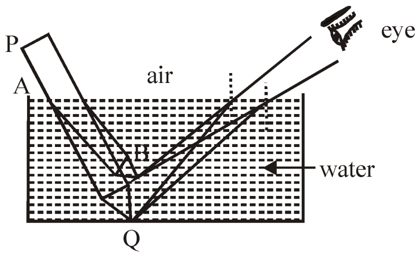


Figure : Bending of pencil in water

Consider a pencil PQ. Let AQ portion of the pencil be dipped in water as shown in figure. Rays of light from the tip (Q) of the pencil bend away from the normal as they go from water to air i.e. denser to rarer medium. These rays appear to come from a point B. Thus, the dipped portion of the pencil appears as AB. Hence a pencil appears bent and short when immersed in water.

(ii) A water tank appears shallow i.e. less deep than its actual depth :

Consider an object O say a stone lying on the bed of a water tank as shown in figure. A ray (OB) of light from the object suffers refraction at the free surface of water in the tank and bends away from the normal along BC. The refracted ray BC appears to come from point I which is above the object O. Thus, the bed of the tank appears at the level of point. In other words, water tank appears shallow.

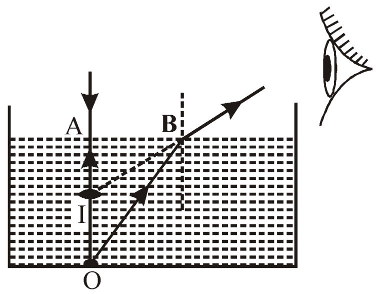


Figure : Appearance of object in watertant

10. TOTAL INTERNAL REFLECTION

The phenomenon by virtue of which a beam of light travelling from a denser medium to a rarer medium gets reflected back in the same denser medium at the interface of two media, obeying laws of reflection is called "total internal reflection".

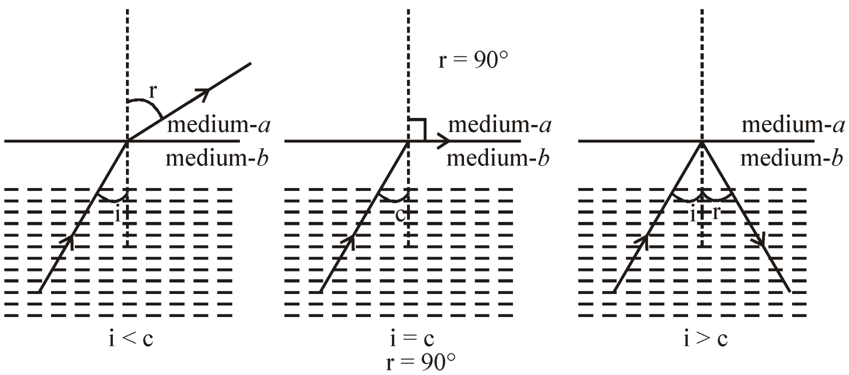


Figure : Total internal Reflection

- The critical angle for a pair of media is the angle of incidence of light in the denser medium, for which the angle of refraction in the rarer medium is 90°, i.e., when i = c then r = 90°

So by Snell's law

$$^{b}\mu_{a} = \frac{\sin c}{\sin 90^\circ} = \frac{\sin c}{1} \text{ or } ^{a}\mu_{b} = \frac{1}{\sin c}$$

For total internal reflection to take place, necessary conditions are

- The ray of light should be travelling from optically denser medium towards optically rarer medium.
- The angle of incidence should be greater than the critical angle for the given pair of media.

11. SPHERICAL LENSES

(A) Definition :

A lens is a piece of transparent refracting material bounded by two spherical surfaces or one spherical and other plane surface.

A lens is the most important optical component used in microscopes, telescopes, cameras, projectors etc.

Basically lenses are of two types :

(i) Convex lens or converging lens (ii) Concave lens or diverging lens

Convex lens and its types :

A lens which is thick at the centre and thin at the edges is called a convex lens. The most common form of a convex lens has both the surfaces bulging out at the middle. Some forms of convex lens are shown in the figure.

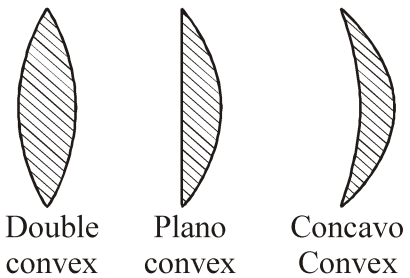


Figure : different types of convex lens

Concave lens and its types :

A lens which is thin at the middle and thick at the edges is called a concave lens. The most common form of a concave lens has both the surfaces depressed inward at the middle. Some forms of concave lenses are shown in the figure.

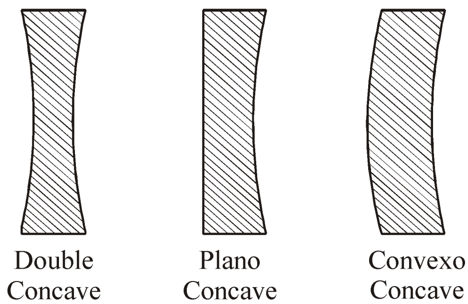


Figure : Different types of concave lens

(B) Definitions in connection with spherical lens :

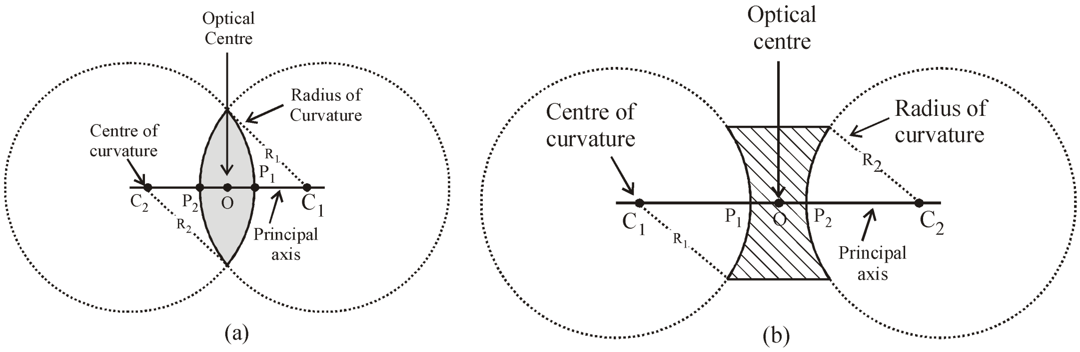


Figure : Characteristics of convex and concave lenses

(i) Optical centre : If a ray of light is incident on a lens such that after refraction through the lens the emergent ray is parallel to the incident ray, then the point at which the refracted ray intersects, the principal axis is called the optical centre of the lens. In the figure O is the optical centre of the lens. It divides the thickness of the lens in the ratio of the radii of curvature of its two surfaces.

If the radii of curvature of the two surfaces are equal then the optical centre coincides with the geometric centre of the lens.

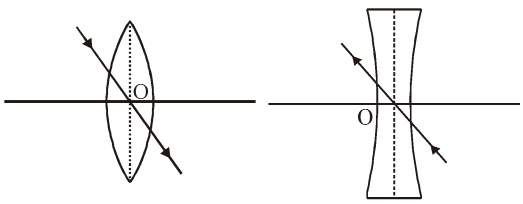


Figure : Optical centre in convex and concave len's

For a ray passing through the optical centre, the incident and emergent rays are parallel. However, the emergent ray suffers some lateral displacement relative to the incident ray. The lateral displacement decreases with the decreases in thickness of the lens. Hence a ray passing through the optical centre of a thin lens does not suffer any lateral deviation, as shown in the figure above.

(ii) Principal foci and focal length :

(a) First principal focus and first focal length : It is a fixed point on the principal axis such that rays starting from this point (in convex lens) or appearing to go towards this point (concave lens), after refraction through the lens, become parallel to the principal axis. It is represented by F_1 of f'. The plane passing through this point and perpendicular to the principal axis is called the first focal plane. The distance between first principal focus and the optical centre is called the first focal length. It is denoted by f_1 of f'.

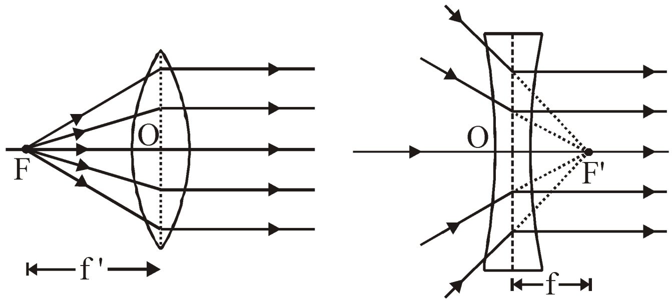


Figure : Ray diagram showing First principal focus

(b) Second principal focus and second focal length : It is a fixed point on the principal axis such that the light rays incident parallel to the principal axis, after refraction through the lens, either converge to this point (in convex lens) or appear to diverge from this point (in concave lens). The plane passing through this point and perpendicular to principal axis is called the second focal plane. The distance between the second principal focus and the optical centre is called the second focal length. It is denoted by f_2 or f.

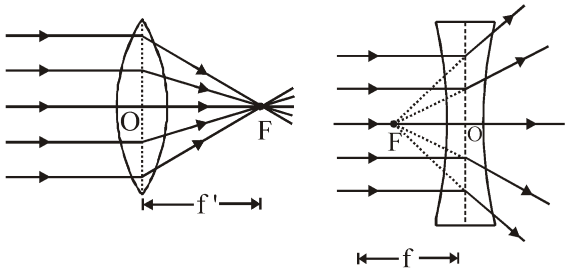


Figure : Ray diagram showing Second principal focus

Generally, the focal length of a lens refers to its second focal length. It is obvious from the above figures, that the foci of a convex lens are real and those of a concave lens are virtual. Thus the focal length of a convex lens is taken positive and the focal length of a concave lens is taken negative.

If the medium on both sides of a lens is same, then the numerical values of the first and second focal lengths are equal. Thus f = f ʹ

(C) Rules for image formation by convex lens :

The position of the image formed by a convex lens can be found by considering two of the following rays (as explained below).

(i) A ray of light coming parallel to principal axis, after refraction through the lens, passes through the principal focus (F) as shown in the figure.

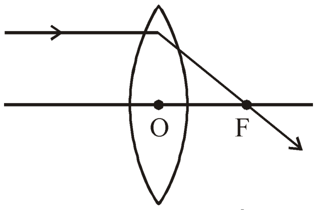


Figure : Convex lens

(ii) A ray of light passing through the optical centre O of the lens goes straight without suffering any deviation as shown in the figure.

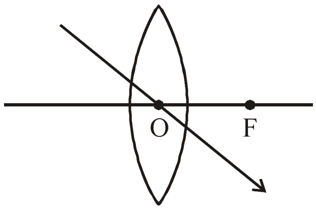


Figure : Convex lens

(iii) A ray of light coming from the object and passing through the principal focus of the lens after refraction through the lens, becomes parallel to the principal axis.

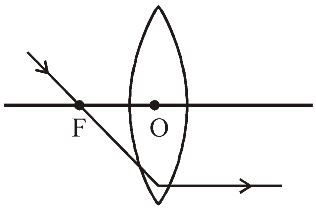


Figure : Convex lens

(D) Image formed by Convex lens :

The position, size and nature of the image formed by a convex lens depends upon the distance of the object from the optical centre of the lens. For a thin convex lens, the position and nature of image formed is summerised in the table :

(i) When object lies at infinity : When an object lies at infinity, a real, inverted and highly diminished image is formed on the other side of the lens in its focal plane.

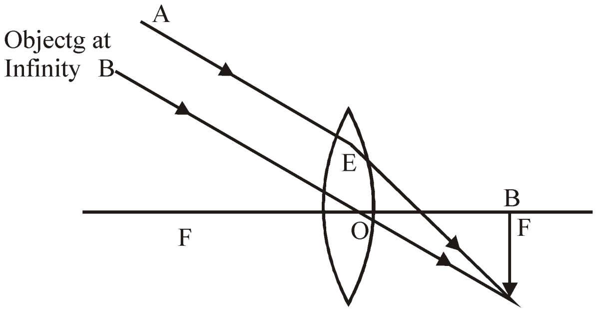


Figure : Convex lens

(ii) When object lies beyond 2F : When an object lies beyond 2F, its real, inverted and diminished image is formed between F and 2F on the other side of the lens.

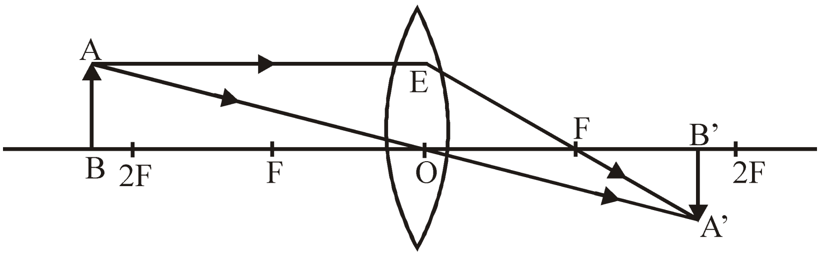


Figure : Convex lens

(iii) When object lies at 2F : When an object lies at 2F, its real inverted image having same size as that of the object is formed on the other side of the convex lens.

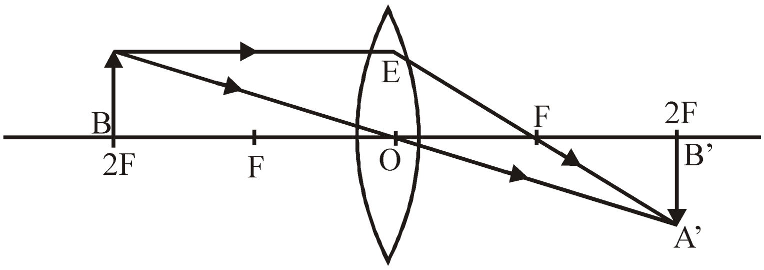


Figure : Convex lens

(iv) When object lies between F and 2F : When an object lies between F and 2F in front of a convex lens, its real, inverted and magnified image is formed beyond 2F on the other side of the lens.

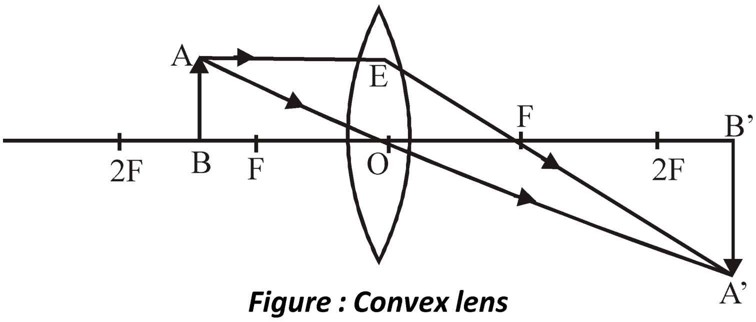


Figure : Convex lens

(v) When object lies at F : When an object lies at the principal focus F of a convex lens, then its real, inverted and highly magnified image is formed at infinity on the other side of the lens.

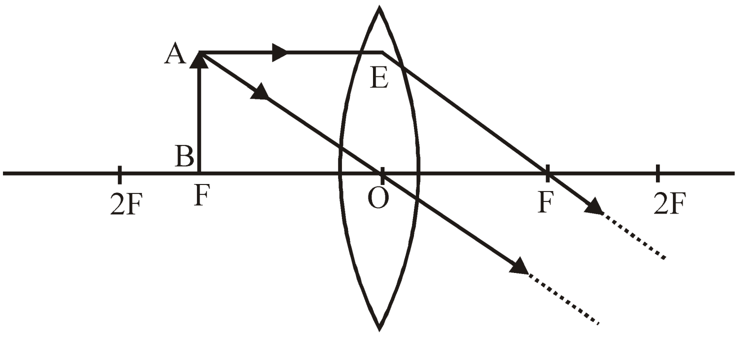


Figure : Convex lens

(vi) When object lies between O and F : When an object lies between the optical centre O and the principal focus F of a convex lens, then its virtual, erect and magnified image is formed on the same side as that of the object.

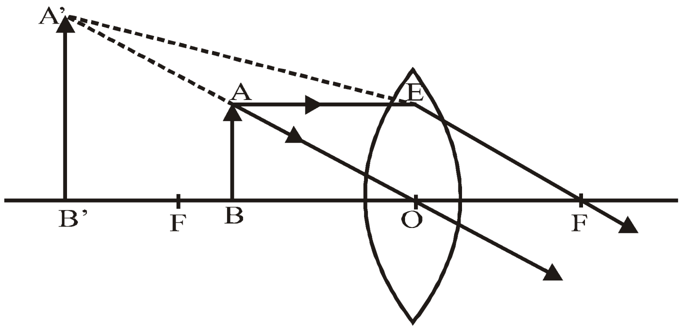


Figure : Convex lens

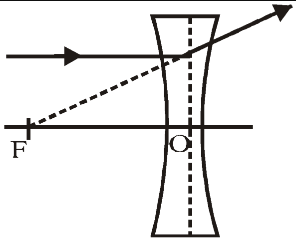
Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished	Real and inverted
Beyond 2F	Between F and 2F	Diminished	Real and inverted
At 2F	At 2F	Same size	Real and inverted
Between F and 2F	Beyond 2F	Magnified	Real and inverted
At F	At infinity	Highly Magnified	Real and inverted
Between O and F	On the side of the object	Magnified	Virtual and erect

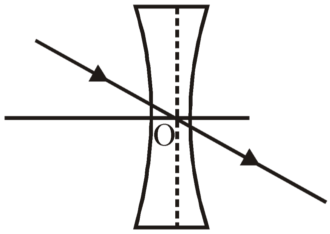
(E) Rules for image formation by Concave lens :

The position of the image formed by a concave lens can be found by considering following two rays coming from a point object (as explained below).

(i) A ray of light coming parallel to the principal axis, after refraction, appears to pass through the principal focus F of the lens, when produced backward as shown in figure (a).

(ii) A ray of light passing through the optical centre O of the lens goes straight without suffering any deviation as shown in figure (b)





(F) Image formed by Concave lens :

The image formed by a concave lens is always virtual, erect and diminished and is formed between the optical centre O and the principal focus F of the lens.

(i) When the object lies at infinity :

When object lies at infinity in front of a concave lens, a virtual, erect, highly diminished image is formed at the principal focus F.

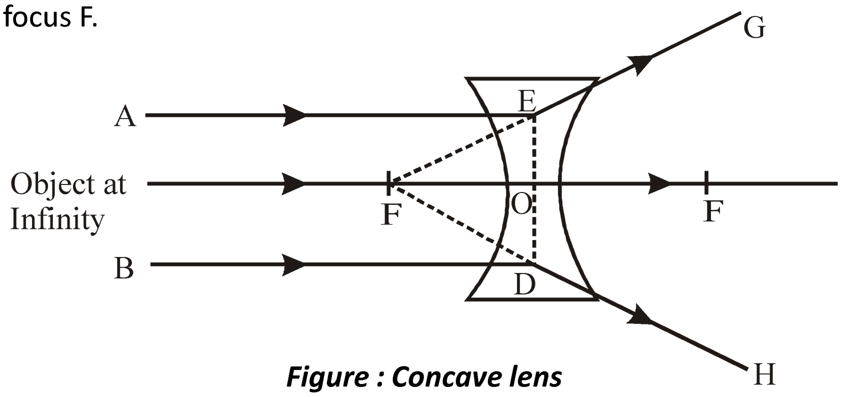


Figure : Concave lens

(ii) When the object lies between O and ∞.

When an object lies at any position between the optical centre O and infinity in front of a concave lens, the image formed is virtual, erect, diminished and is formed between the optical centre O and the principal focus F.

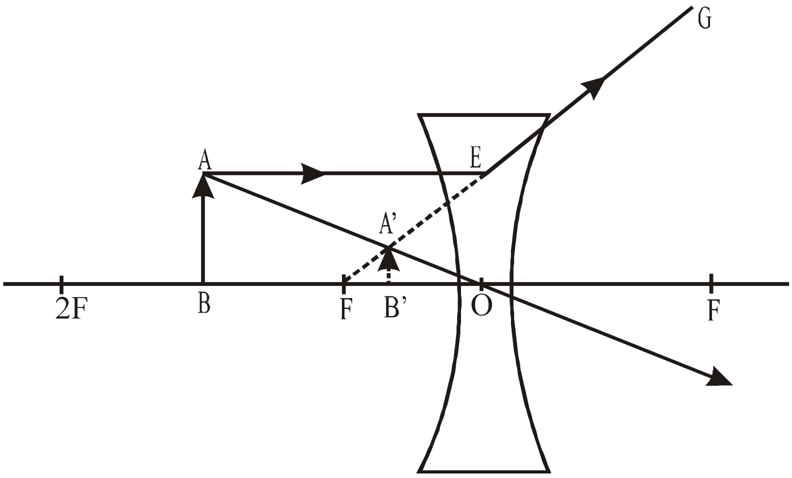


Figure : Concave lens

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished	Virtual and erect
Between O and infinity	Between O and F	Diminished	Virtual and erect

(G) Lens formula :

Relation between object distance u, image distance v and focal length f is :

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

(H) Linear magnification :

Linear magnification (m) is defined as the ratio of the size of the image to the size of the object.

$$m = \frac{A'B'}{AB} = \frac{h_2}{h_1} = \frac{\text{height of image}}{\text{height of object}}.$$

also $m = \frac{v}{u}$

$$\begin{matrix}\text{if } m \text{ is } +ve \text{ (images is virtual \& erect)} \\ \text{if } m \text{ is } -ve \text{ (images is real \& inverted)}\end{matrix} \quad \text{or} \quad \left(m = \frac{f-v}{f}\right)$$

(I) Power of lens :

It is the measure of deviation produce by a lens. It is defined as the reciprocal of its focal length in metres. Its unit is Diopter (D) (f should always be in metres).

$$\text{Power (P)} = \frac{1}{\text{focal length (f in m)}}$$

Power of a convex lens is +ve (As it has a real focus and its focal length measured is +ve)
Power of a concave lens is –ve (As it has a virtual focus and its focal length measured is –ve).

Focus Point

If two thin lenses are placed in contact, the combination has a power equal to the algebraic sum of the power of two lenses, $P = P_1 + P_2$

$$\Rightarrow \frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

Here, f_1 and f_2 are the focal length of lenses and f is focal length of combination of lenses.

Example 14

A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens ? Also, find the magnification produced by the lens.

Solution :

A concave lens always forms a virtual, erect image on the same side of the object.

Image distance v = –10cm; focal length f = –15 cm ;

object distance u = ?

Lens equation,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \text{ or } \frac{1}{(-10)}-\frac{1}{u}=\frac{1}{(-15)}$$

$$\text{or } \frac{1}{u}=\frac{1}{15}-\frac{1}{10}=\frac{2-3}{30}=\frac{-1}{30} \text{ or } u = -30 \text{ cm}$$

$$\text{Magnification, } m = \frac{v}{u}=\frac{(-10)}{(-30)}=\frac{1}{3}=+0.33$$

The positive sign shows that the image is erect and virtual. The image is one-third of the size of the object.

Example 15

A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

Solution :

Given, height of the object h_1 = 2.0 cm ; focal length f = +10 cm; object distance u = –15 cm ; image distance v = ? ; height of the image h_2 = ?

Lens equation,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \text{ or } \frac{1}{v}-\frac{1}{(-15)}=\frac{1}{(+10)}$$

$$\text{or } \frac{1}{v}=\frac{1}{10}-\frac{1}{15}=\frac{3-2}{30}=\frac{+1}{30} \text{ or } v = +30 \text{ cm}$$

$$\text{Magnification, } m = \frac{h_2}{h_1}=\frac{v}{u} \text{ or } h_2=\frac{v}{u}\times h_1=\frac{+30}{-15}\times(+2)=-4\text{cm}$$

The negative sign of h_2 shows that the image is inverted and real. A real, inverted image, 4 cm tall, is formed at a distance of 30 cm on the other side of the lens.

Example 16

What distance should an object be placed in front of a convex lens of focal length 0.4 m so that the virtual image is thrice the size of the object ?

Solution :

Given f = 0.4 m, $h_i = 3h_O$, u = ?

$$\text{We know that, } m = \frac{h_i}{h_o}=\frac{v}{u}=3 \text{ (virtual)}$$

$\frac{h_i}{h_o} = \frac{3h_o}{h_o} = \frac{v}{u} \Rightarrow v = 3u$ (virtual image)

Also from lens formula,

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ = (1/3u) – (1/u) = (2/3 u)

$f = -\frac{3u}{2} \quad \Rightarrow \; u = -\frac{2f}{3} = -\frac{2 \times 0.4}{3} = -0.267$ m

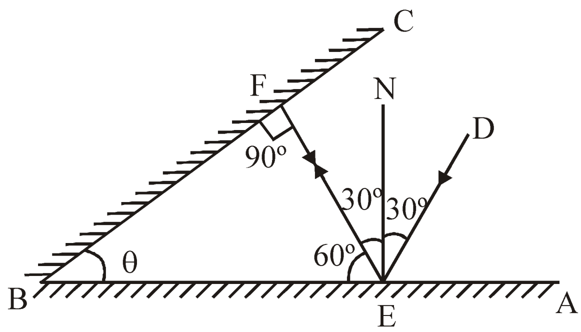
i.e. object distance, u = –0.267 m

The object must be placed at 0.267 m from the lens.

SE. 1

Two plane mirrors are inclined to each other at some angle. A ray of light is incident on one of them at an angle of 30°. The light after reflection falls on the second mirror and finally gets reversed. Find the angle between the mirrors.

Ans.



Let the mirrors AB and BC be inclined at angle θ in adjoining figure. Let DE be the incident ray which after reflection from mirror AB goes along EF. Draw NE normal on miror AB. Then according to laws of reflection,

$\angle DEN = \angle NEF = 30°$

As the ray EF gets reversed, so it must be falling normally on the second mirror BC. As NE is normal to AB, $\angle NEB = 90°$

In ΔFBE, $\angle EFB = 90°$

$\therefore \angle FEB = 90° - 30° = 60°$

As the sum of the three angles of a triangle is two right angles or 180°, so

$90° + 60° + \angle\theta = 180° \Rightarrow \angle\theta = 30°$

So, the two mirrors are inclined to each other at an angle of 30°.

SE. 2

An object 4.0 cm in size is placed at a distance of 25.0 cm in front of a convex mirror of radius of curvature 40 cm. Find (i) the position, (ii) the size and (iii) nature of the image.

Ans. Here, h = +4.0 cm

u = –25.0 cm (sign conventions)

R = +40 cm

$\therefore\ f = \frac{R}{2} = \frac{40}{2} = 20.0$ cm

(i) Determination of the position of the image

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

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{20} - \frac{1}{(-25)} = \frac{1}{20} + \frac{1}{25} = \frac{9}{100}$$

or $v = \frac{100}{9} = 11.11$ cm

Thus, the image is at 11.11 cm behind the convex mirror.

(ii) Determination of size

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

or $h' = -\frac{(100/9)(4)}{-25} = \frac{16}{9} = 1.78$ cm

Thus, size of image = 1.78 cm

(iii) Since h' is positive, so the image is erect

SE. 3

An object 3cm high is placed at a distance of 10 cm in front of a concave mirror of focal length 20 cm. Find the position, nature and size of the image formed

Ans. Here, size of object, h = 3cm

u = –10 cm (sign convention)

f = –20 cm (sign convention)

Using $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$, we have

$$-\frac{1}{10} + \frac{1}{v} = -\frac{1}{20} \text{ or } \frac{1}{v} = -\frac{1}{20} + \frac{1}{10} = \frac{1}{20}$$

$\therefore\ v = 20$ cm

Thus, image is formed at a distance of 20 cm from the concave mirror. Since v is positive, so image is formed behind the concave mirror. It means the image is virtual (nature).

Using $m = \frac{h'}{h} = -\frac{v}{u}$, we get

$$\frac{h'}{h} = -\frac{20cm}{-10cm} = 2$$

or h′ = 2×h = 2×3 cm = 6 cm

Thus, size of the image is 6 cm.

SE. 4

An object is placed at a distance of 8 cm from a concave mirror of focal length 10 cm. Find the nature of the image formed by drawing the ray diagram.

Ans. Here, (using sign convention)

Focal length, f = –10 cm

Object distance, u = –8cm

Image distance, v = ?

From mirror formula, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

Putting values, we get

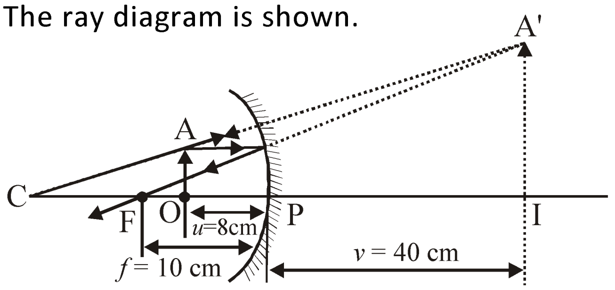
$$\frac{1}{v} = \frac{1}{-10} - \frac{1}{-8} = \frac{-4+5}{40} = \frac{1}{40}$$

v = +40 cm

The image is formed at distance 40 cm behind the mirror.

It is virtual, erect and enlarged.

The ray diagram is shown.



Incident rays taken are one parallel to principal axis and the other appearing to come from side of centre. Reflected rays appear to come from A′, forming virtual image of A. IA′ is erect, virtual image of real object OA.

SE. 5

An object 2cm high is placed at a distance of 16cm from a concave mirror which produce a real image 3 cm high. What is the focal length of the mirror and position of the image ?

Ans. Here, (using sign convention)

Object height, h_1 = +2 cm

Image height, h_2 = –3 cm

Object distance, u = –16 cm

(object on left of mirror)

Focal length, f = ?

Image distance, u = ?

From relation, $\frac{h_2}{h_1} = -\frac{v}{u}$

We have, $v = -u\frac{h_2}{h_1}$

Putting values, we get, $v = -(-16)\times\frac{-3}{2}$

v = –24 cm.

The image is formed at distance of 24 cm in front of the mirror (negative sign means on the left side).

To find focal length of mirror

From mirror formula, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

We have, $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$

Putting values, we get

$$\frac{1}{f} = \frac{1}{-16} + \frac{1}{(-24)} = \frac{-3-2}{48} = -\frac{5}{48}$$

or $f = -\frac{48}{5} = -9.6\,cm$

The focal length of the mirror is 9.6 cm (negative sign means concave mirror)

SE. 6

When an object is placed at a distance of 25 cm from a mirror, the magnification is m_1. The object is moved 15 cm farther away with respect to the earlier position and the magnification becomes m_2.

If $\frac{m_1}{m_2} = 4$, then calculate the focal length of the mirror.

Ans. We know that, $m = \frac{v}{u} = \frac{f}{f-u}$

Here $m_1 = \frac{f}{f-(-25)} = \frac{f}{f+25}$

and $m_2 = \frac{f}{f-(-25-15)} = \frac{f}{f+40}$

Since $\frac{m_1}{m_2} = 4$,

therefore, $\frac{f+40}{f+25} = 4$;

Thus f + 40 = 4f + 100 or f = –20 cm

The negative sign show that the mirror is concave.

SE. 7

How far should an object be held from a concave mirror of focal length 40 cm so as to get an image magnified three times ?

Ans. Given : Focal length (f) = –40 cm

Magnification (m) = 3

Distance of the object (u) = ?

Since the nature of the image so formed is not specified, so two cases arise here.

Formula to be used : $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Since only f and m are given, therefore, we cannot use this formula directly and instead first use the formula,

$m = -\frac{v}{u} \Rightarrow 3 = -\frac{v}{u}, v = -3u$

Case I : When image formed is real, v = +3 u cm

Substituting the given values, we get

$\frac{1}{3u} + \frac{1}{u} = \frac{1}{-40} \Rightarrow \frac{1+3}{3u} = \frac{1}{-40} \Rightarrow \frac{3u}{4} = -40$

$\therefore$ u = –53.33 cm

Case II : When image formed is virtual, v = –3u cm

Substituting the given values, we get

$-\frac{1}{3u} + \frac{1}{u} = -\frac{1}{40} \Rightarrow \frac{-1+3}{3u} = -\frac{1}{40}$

$\Rightarrow \frac{2}{3u} = -\frac{1}{40} \Rightarrow u = \frac{-80}{3}$

$\therefore$ u = –26.67 cm

Hence, if the object is held at a distance of 53.33 cm, a real image thrice in size is obtained. Also, a virtual image of thrice the size is obtained if the distance of the object is 26.67 cm.

SE. 8

Size of image of an object by a mirror having focal length of 20 cm is observed to be reduced to 1/3[rd] to its size. At what distance, the object has been placed from the mirror ? What is the nature of the image and the mirror ?

Ans. Here, considering (the case for both type of possible spherical mirrors)

For concave mirror

Focal length, f = – 20 cm

Magnification, $m = -\frac{1}{3}$

Since, magnification, $m = -\frac{v}{u}$

Magnification, $m = -\frac{1}{3} = -\frac{v}{u}$

$v = \frac{u}{3}$

Using mirror formula, we have

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{1}{u} + \frac{3}{u} = \frac{4}{u}$

$\Rightarrow$ u = 4f = 4(–20) – 80 cm

The object should be placed at a distance 80 cm from the concave mirror.

For convex mirror,

Focal lenght, f = + 20 cm

Magnification, $m = +\frac{1}{3}$

Since, magnification, $m = -\frac{v}{u}$

$\therefore$ Magnification, $m = \frac{1}{3} = -\frac{v}{u}$

$$v = -\frac{u}{3}$$

Using mirror formula, we have

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

$$\frac{1}{f}=\frac{-3}{u}+\frac{1}{u}=\frac{-2}{u}$$

$$u = -2f = -2(20) = -40 \text{ cm}$$

The object should be placed at a distance 40 cm from the convex mirror to from virtual, erect and diminished image.

SE. 9

A car is fitted with a convex mirror of focal length 20 cm. A second car 2m broad and 1.6m high is 6m away from the first car.

(a) Find position of the second car as seen in the mirror of the first and

(b) Find the breadth and height of the second car seen in the mirror of the first car, are respectively.

Ans. u = –6m = –600cm, f = +20cm

(a) $\frac{1}{v}+\frac{1}{-600}=\frac{1}{20}$ or $\frac{1}{v}=\frac{31}{600}$

or $v=\frac{600}{31}\text{cm} = 19.35\text{cm}$

(b) $m = -\frac{v}{u} = -\frac{600}{31}\times\frac{1}{-600}=\frac{1}{31}$

Breadth of image = $\frac{1}{31}\times 200$ cm = 6.45 cm

Height of image = $\frac{1}{31}\times 160$ cm = 5.16 cm

SE. 10

A dentist uses a small concave mirror of focal length 3.0 cm and holds it at a distance of 2 cm from the tooth. what is the magnification of the image.

Ans. Given

Focal length of the mirror (f) = –3.0 cm

Distance of the object (u) = –2.0 cm

Magnification (m) = ?

Formula to be used : $m = -\frac{v}{u}$

Since in this case we do not know the value of v, so first of all we will use the formula, $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$, to calculate v and then we will find out m.

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

Substituting the given values, we get

$$\frac{1}{v}=-\frac{1}{3}-\left(-\frac{1}{2}\right)=-\frac{1}{3}+\frac{1}{2}=\frac{-2+3}{6}=\frac{1}{6}$$

$\therefore$ v = 6 cm

Since v is positive, the image is virtual

Now, $m = -\frac{v}{u} = -\frac{6}{-2} = 3$

i.e., the image is three times the size of the object.

SE. 11

The refractive index of water is 4/3 and for glass it is 3/2 with respect to air. What is the refractive index of glass with respect to water ?

Ans. Here,

Refractive index of water with respect to air,

$${}_wn_a = \frac{4}{3}$$

R.I. of glass with respect to air, ${}_gn_a = \frac{3}{2}$

R.I. of glass with respect to water, ${}_gn_w$ = ?

From relation,

For successive refraction, ${}_wn_a \times {}_gn_w \times {}_an_g = 1$

$$\left(\text{As}\ \frac{n_w}{n_a}\times\frac{n_g}{n_w}\times\frac{n_a}{n_g}=1\right)$$

We have, $_gn_w = \frac{1}{_wn_a \times {_an_g}} = \frac{_gn_a}{_wn_a}$

Putting value, we get,

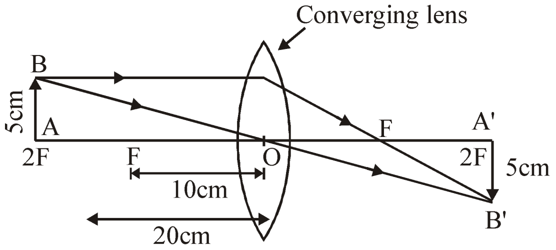
$$_gn_w = \frac{3/2}{4/3} = \frac{3}{2} \times \frac{3}{4} = \frac{9}{8} = 1.125$$

SE. 12

An object of 5cm is placed 20 cm away from a converging lens of focal length 10 cm. Draw the ray diagram to produce the image and find the position, size and the nature of the image formed.

Ans. In this case, f = +10 cm, u = –20cm, h_1 = 5cm

Here, object is placed 20 cm away from the lens of focal length 10 cm, so object is at 2F. So the image of the object will be formed at 2F on right side of the lens. The image formed will be real, inverted and of the same size as that of the object as shown in the diagram.



Step I : Using $-\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$, we have

$$-\frac{1}{(-20)} + \frac{1}{v} = \frac{1}{10} \text{ or } \frac{1}{v} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}$$

$\therefore$ v = +20 cm

Positive sign shows that a real image is formed

Step II : Using, $\frac{h_2}{h_1} = \frac{v}{u}$, we have $h_2 = \frac{v}{u}h_1$

$$= \frac{20}{-20} \times 5 = -5\text{cm}$$

Negative sign shows that the image formed is inverted.

Thus, image formed is real, inverted and of the same size as that of the object.

SE. 13

A convex lens forms a real and inverted image of a needle at a distance of 25 cm from the lens. If the image is of the same size as that of the needle, then where should the needle be placed in front of the lens. Also calculate the power of the lens.

Ans. Step 1. We know, if the size of the real and inverted image is same as that of the object, then the object is at 2F and image is also formed at 2F on the other side of the convex lens.

$\therefore$ u = –25 cm, v = 25 cm ($\because$ u = v)

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

$$\frac{1}{f} = \frac{1}{25} + \frac{1}{25} = \frac{2}{25} \text{ or } f = \frac{25}{2} = 12.5 \text{ cm}$$

In this case, 2f = 25 cm or f = 12.5 cm

Thus, needle must be placed at a distance of 25cm in front of the convex lens.

Step 2 : Now, power of lens, $P = \frac{100}{f(\text{in cm})}$

$$= \frac{100}{12.5} = +0.8 \text{ D}$$

SE. 14

A diverging lens or a concave lens of focal length, f = 15 cm forms an image 10 cm from the lens. Draw a ray diagram and prove that the object is placed 30 cm away from the lens. Use a scale of 1 : 5.

Ans. In figure, A'B' is the image AB is the real object.

Also by measurements.

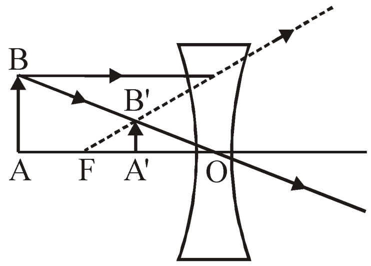


Image distance CA' = 2 cm

i.e., v = 10 cm

Focal length, CF = 3 cm i.e., f = 15 cm

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

or $\frac{1}{u}-\frac{1}{v}=\frac{1}{f} = \frac{1}{10}-\frac{1}{15}=\frac{3-2}{30}=\frac{1}{30}$

or u = 30 cm CA comes to be 6 cm.

Hence, object distance = 30 cm

SE. 15

A concave lens has focal length of 15 cm. At what distance should be object from the lens be placed so that it forms an image at 10 cm from the lens ? Also find the magnification of the image.

Ans. Here, (using sign convention)

Focal length, f = –15 cm (focus on left of the lens)

Image distance, v = –10cm (image on left of the lens)

(i) Object position

From lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

We have, $-\frac{1}{u}=\frac{1}{f}-\frac{1}{v}$

Putting values, we get, $-\frac{1}{u}=\frac{1}{-15}-\frac{1}{-10}$

$-\frac{1}{u}=\frac{-2+3}{30}=-\frac{1}{30} \quad \therefore u=-30cm$

Object must be placed at distance 30 cm on the left of the lens.

(2) Magnification

From relation, $m=\frac{h_2}{h_1}=\frac{v}{u}$

Putting value, we get, $m=\frac{-10cm}{-30cm}=\frac{1}{3}$

The virtual image has $\left(\frac{1}{3}\right)^{rd}$ size as that of the object.

SE. 16

The image of candle flame formed by a lens is obtained on a screen placed on the other side of the lens. If the image is three times the size of the flame and the distance between lens and image is 80 cm, at what distance should the candle be placed from the lens ? what is the nature of the imge at a distance of 80 cm and the lens ?

Ans. The image is real as only the real image can be taken on the screen.

Here, image distance v = + 80 cm

Magnification, m = – 3

Object distance, u = ?

Since, magnification, $m=\frac{v}{u} \Rightarrow -3=\frac{80}{u}$

$u=\frac{-80}{3}cm$

Nature of image

→ Real, inverted

→ magnified

→ formed beyond 2F

Using lens formula, we have

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

$\frac{1}{f}=\frac{1}{80}-\frac{3}{-80}=\frac{4}{80}=\frac{1}{20}$

$\Rightarrow$ f = 20 cm

Positive focal length denoted that lens is convex.

NS. 1

Define the principal focus of a concave mirror.

Ans. A point on the principal axis where the parallel rays of light after reflecting from a concave mirror meet.

NS. 2

The radius of curvature of a spherical mirror is 20 cm. What is its focal length ?

Ans. Radius of curvature, R = 20 cm

$\therefore$ Focal length, $f = \frac{R}{2} = \frac{20}{2} = 10$ cm

NS. 3

Name a mirror that can give an erect and enlarged image of an object.

Ans. A concave mirror gives an erect and enlarged image of an object between pole and principal focus of the mirror.

NS. 4

Why do we prefer a convex mirror as a rear-view mirror in vehicles ?

Ans. This is because a convex mirror forms an erect and diminished (small in size) images of the objects behind the vehicle and hence the field of view behind the vehicle is increased.

NS. 5

Find the focal length of a convex mirror whose radius of curvature is 32cm.

Ans. Given, R = +32 cm

$\therefore f = \frac{R}{2} = \frac{32}{2} = +16$ cm

Thus, the focal length of the convex mirror is 16 cm.

NS. 6

A concave mirror produces three times magnified real image of an object placed at 10 cm in front of it. Where is the image located ?

Ans. Here, linear magnification (m) = 3

(Negative sign for real image, which is inverted)

Object distance (u) = –10cm

Image distance (v) = ?

As $m = -\frac{v}{u} \Rightarrow -3 = \frac{-v}{-10} \therefore v = -30\text{cm}$

The image is located at 30 cm in front of the mirror

NS. 7

The image formed by a concave mirror is observed to be virtual, erect and larger than the object. Where should be the position of the object ?

(a) Between the focus and the centre of curvature

(b) At the centre of curvature

(c) Beyond the centre of curvature

(d) Between the pole of the mirror and its focus.

Ans. (d) For virtual, erect and larger image, the object must lie between the pole of the mirror and its focus.

NS. 8

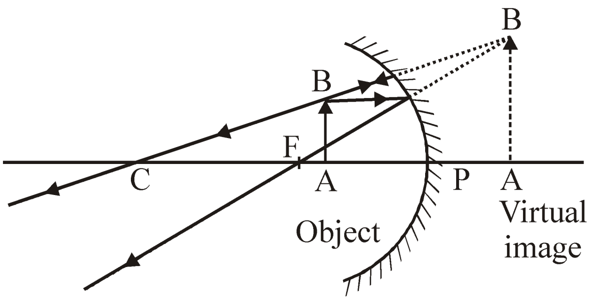
No matter how far you stand from a miror, your image appears erect. The mirror is likely to be (a) plane (b) concave (c) convex (d) either plane or convex

Ans. (d) The image is erect in a plane mirror and also in a convex mirror, for all positions of the object.

NS. 9

We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror ? What is the nature of the image ? Is the image larger or smaller than the object ? Draw a ray diagram to show the image formation in this case.

Ans. A concave mirror produces an erect image if the object is placed between the pole and the focus of the concave mirror. Thus, object may be placed at any position whose distance is less than 15cm from the concave mirror. The image is virtual and erect. The image is larger than the object. The ray diagram is shown below



NS. 10

Name the type of mirror used in the following situations.
(a) Headlights of a car
(b) Side/rear-view mirror of a vehicle
(c) Solar furnace
Support your answer with reason.

Ans. (a) For head lights of a car, we use a concave mirror. The light source is held at the focus of the mirror. On reflection, a strong parallel beam of light emerges.
(b) A convex mirror is used as side rear view mirror, because its field of view is larger and it forms virtual, erect and diminished images of objects behind.
(c) For solar furnace, we use a concave mirror. Light from the sun, on reflection from the mirror, is concentrated at the focus of the mirror, producing heat.

NS. 11

An object is placed at a distance of 10 cm from a convex mirror of focal length 15 cm. Find the position and nature of the image.

Ans. Here, object distance (u) = –10 cm,
focal length (f) = 15 cm,
image distance (v) = ?

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

$\Rightarrow \frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{15}-\frac{1}{(-10)}=\frac{1}{15}+\frac{1}{10}=\frac{5}{30}=\frac{1}{6}$

$\therefore$ v = 6 cm

Here, + sign of v indicated that image is at the back of the mirror. It must be virtual, erect and smaller in size than the object.

NS. 12

The magnification produced by a plane mirror is m =+1. What does this mean ?

Ans. As $m=\frac{h_2}{h_1}=+1$

$\Rightarrow h_2 = h_1$

i.e., size of image is equal to size of the object. Further, +sign of m indicates that the image is erect and hence virtual.

NS. 13

An object 5.0 cm in length is placed at a distance of 20 cm in front of a convex mirror of radius of curvature 30 cm. Find the positio of the image, its nature and size.

Ans. Here, object size (h_1) = 5.0 cm,
object distance (u) = –20cm
Radius of curvature (R) = 30 cm,
image distance (v) = ?

As $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}=\frac{2}{R}$

$\Rightarrow \frac{1}{v}=\frac{2}{R}-\frac{1}{u}=\frac{2}{30}+\frac{1}{20}=\frac{4+3}{60}=\frac{7}{60}$

$\therefore v=\frac{60}{7}=8.57\text{cm}$

Positive sign of v indicates that image is at the back of the mirror. It must be virtual and erect.

As $m=\frac{h_2}{h_1}=-\frac{v}{u}$

$\Rightarrow \frac{h_2}{5.0}=\frac{-60/7}{-20}=\frac{3}{7}$

$\Rightarrow h_2=\frac{3}{7}\times 5.0=\frac{15.0}{7}=2.1\text{cm} \therefore h_2=2.1\text{cm}$

This is the size of the erect image.

NS. 14

An object of size 7.0 cm is placed at 27 cm in front of a concave mirror of focal length 18 cm. At what distance from the mirror should a screen be placed, so that a sharp focussed image can be obtained ? Find the size and the nature of the image.

Ans. Here, object size (h_1) = 7.0 cm,
object distance (u) = –27cm
focal length (f) = –18cm,
image distance(v) = ?

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

$$\Rightarrow \frac{1}{v}=\frac{1}{f}-\frac{1}{u}=-\frac{1}{18}+\frac{1}{27}=\frac{-3+2}{54}=-\frac{1}{54}$$

$\therefore$ v = –54 cm

Therefore, the screen should be held in front of the mirror at a distance of 54 cm from the mirror. The image obtained on the screen will be real.

As $m=\frac{h_2}{h_1}=-\frac{v}{u} \Rightarrow \frac{h_2}{7.0}=-\frac{(-54)}{(-27)}$

$\therefore$ h_2 = –14.0 cm

Negative sign of h_2 shows that the image is inverted.

NS. 15

A ray of light travelling in air enters obliquely into water. Does the light ray bend towards the normal or away from the normal ? Why ?

Ans. When a ray of light travels from air into water obliquely, it bends towards the normal. This is because water is optically denser than air. On entering water, speed of light decreases and the light bends towards normal.

NS. 16

Light enters from air to glass having refractive index 1.5. What is the speed of light in glass ? The speed of light in vacuum is 3×10^8 m s^{-1}.

Ans. Here, refractive index, n = 1.5,
speed of light in vacuum = c = 3×10^8 m s^{-1}
speed of light in glass, v = ?

From, $n=\frac{c}{v} \Rightarrow v=\frac{c}{n}=\frac{3\times10^8}{1.5}$

= 2×10^8 ms^{-1}

NS. 17

Give the medium having highest optical density. Also, give the medium with lowest optical density.

Ans. The medium with highest optical density is diamond and its refractive index is maximum (=2.42), also, the medium with lowest optical density is air and its refractive index is minimum (=1.0003).

NS. 18

You are given kerosene, turpentine and water. In which of these does the light travel fastest ?

Ans. We know from the definition of refractive index, that the speed of light is higher in a medium with lower refractive index. So, the light travels fastest in water relative to kerosene and turpentine.

NS. 19

The refractive index of diamond is 2.42. What is the meaning of this statement ?

Ans. This statement means that the speed of light in diamond is lower by a factor of 2.42

NS. 20

Define 1 dioptre of power of a lens.

Ans. The power of a lens whose focal length is one metre (1m) is one dioptre.

NS. 21

A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object ? Also, find the power of the lens.

Ans. Distance of the image from the lens, v = 50 cm
Distance of the object from the lens, u = ?
Size of the image, I = size of the object, O
From the definition, if h is the height of the image and that of the object,

magnification = $\frac{I}{O}=\frac{-h}{h}=-1$

[$\because$ The image is inverted]

For a lens, magnification = $\frac{v}{u}$

So, $\frac{v}{u} = -1 \Rightarrow u = -v = -50cm$

So, the needle (the object) is placed at a distance of 50cm in front of the lens.

Using the lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$\Rightarrow \frac{1}{f} = \frac{1}{50cm} - \frac{1}{(-50cm)} = \frac{1}{50cm} + \frac{1}{50cm}$

$\frac{2}{50cm} = \frac{1}{25cm}$

$\therefore$ f = 25 cm

Then, power of the lens = $\frac{100}{f(cm)}D$

$= \frac{100}{25}D = 4D$

$\therefore P = 4D$

NS. 22

Find the power of a concave lens of focal length 2m.

Ans. Focal length of the concave lens = –2m

So, power of the concave lens = $\frac{1}{-2}D = -0.5\ D$

NS. 23

Which one of the following materials cannot be used to make a lens ?

(a) Water (b) Glass (c) Plastic (d) Clay

Ans. (d) because clay is opaque.

NS. 24

Which of the following lenses would you prefer to use while reading small letters found in a dictionary?

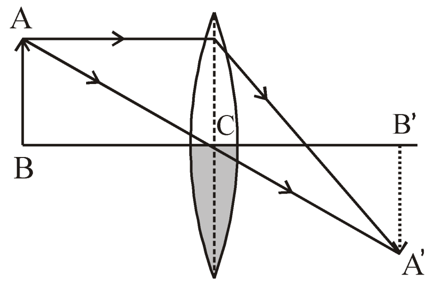
(a) Convex lens of focal length 50 cm
(b) A concave lens of focal length 50 cm
(c) A convex lens of focal length 5 cm
(d) A concave lens of focal length 5 cm

Ans. (c) For reading small letters in a dictionary, we need to use a convex lens of smaller focal length.

NS. 25

One half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object ? Varify your answer experimentally. Explain your observations.

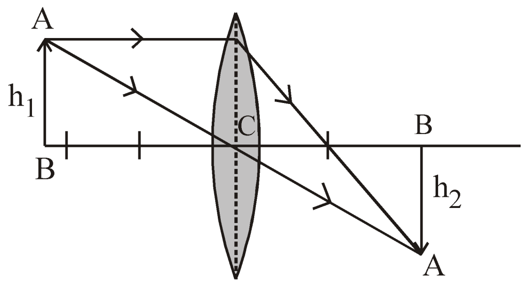
Ans. Yes, it will produce a complete image of the object, as shown in figure. This can be varified experimentally by observing the image of a distance object like tree on a screen, when lower half of the lens is covered with a black paper. However, the intensity or brightness of image will reduce.



NS. 26

An object 5cm in length is held 25 cm away from a converging lens of focal length 10cm. Draw the ray diagram and find the position, size and the nature of the image formed.

Ans. Here, object size, h_1 = 5 cm
object distance, u = –25 cm
focal length of lens, f = 10 cm
image distance, v = ?
image size, h_2 = ?



As $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ $\therefore \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{25} = \frac{5-2}{50}$

$$\Rightarrow v = \frac{50}{3} = 16.67cm$$

As v is positive, the image formed is real; on the right side of the lens, as shown in figure.

$$\text{As } m = \frac{h_2}{h_1} = \frac{v}{u}$$

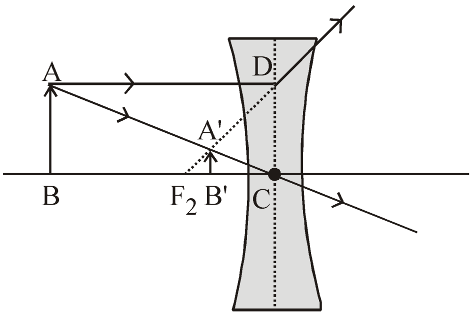
$$\therefore \frac{h_2}{5} = \frac{50/3}{-25} = \frac{-2}{3}$$

$$\Rightarrow h_2 = -\frac{10}{3} = -3.3cm$$

NS. 27

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

Ans. Here, focal length of lens, f = –15cm
image distance, v = –10cm
object distance
u = ?



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

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

$$= \frac{-3+2}{30} = \frac{-1}{30}$$

$$\therefore u = -30cm$$

NS. 28

Find the focal length of a lens of power –2.0D. What type of lens is this ?

Ans. Here, focal length, f = ?, power, P = –2.0D

$$\text{As } f = \frac{100}{P} \Rightarrow f = \frac{100}{-2.0} = -50cm$$

As power of lens is negative, the lens must be concave.

NS. 29

A doctor has prescribed a corrective lens of power +1.5D. Find the focal length of the lens. Is the prescribed lens diverging or converging ?

Ans. Power of the lens, P = +1.5D = +1.5 m^{-1}

$$\therefore \text{Focal length of the lens, } f = \frac{1}{+1.5m^{-1}}$$

= 0.667m = 66.7 cm
Thus, the focal length of the lens is 66.7 cm
Since the focal length of the lens is positive, hence the given lens is a converging lens.

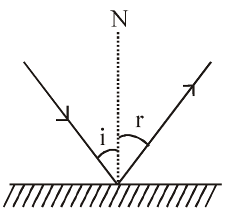
ONLY ONE CORRECT TYPE

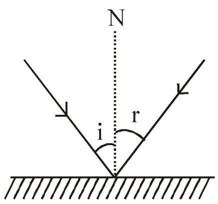
1. Which of the following is not a natural source of light ?
(A) Sun (B) Oil-lamps
(C) Moon (D) Stars

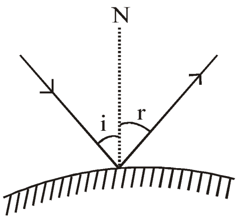
2. Air is not visible because it :
(A) is nearly a perfectly transparent substance
(B) neither absorbs nor reflects light
(C) transmits whole of light
(D) all of the above are correct

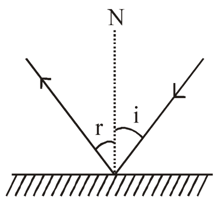
3. A light ray falls on a plane mirror and deviates by 60°, then the angle of reflection will be :
(A) 30° (B) 90° (C) 60° (D) 180°

4. Choose the wrong option :

(A)


(B)


(C)


(D)


5. A boy is standing in front of a plane mirror at a distance of 3m from it. What is the distance between the boy and his image ?
(A) 3m (B) 4.5m
(C) 6m (D) None of these

6. A mirror forms a virtual image of a real object :
(A) It must be a convex mirror
(B) It must be a concave mirror
(C) It must be a plane mirror
(D) It may be any of the mirrors mentioned above.

7. An object is placed at the centre of curvature of a concave mirror. The distance between its image and the pole is :
(A) equal to f
(B) between f and 2f
(C) equal to 2f
(D) greater than 2f

8. An object of size 2.0 cm is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror equals the radius of curvature. The size of the image will be :
(A) 0.5 cm (B) 1.0 cm
(C) 1.5 cm (D) 2.0 cm

9. The magnification m of an image formed by a spherical mirror is negative. It means, the image is :
(A) smaller than the object
(B) larger than the object
(C) erect
(D) inverted

10. A ray of light is incident on a concave mirror. If it is parallel to the principal axis, the reflected ray will :
(A) pass through the focus
(B) pass through the centre of curvature
(C) pass through the pole
(D) retrace its path

11. If an incident ray passes through the centre of curvature of a spherical mirror, the reflected ray will
(A) pass through the pole
(B) pass through the focus
(C) retrace its path
(D) be parallel to the principal axis

12. To get an image larger than the object, one can use :
(A) a convex mirror but not a concave mirror
(B) a concave mirror but not a convex mirror
(C) either a convex mirror or a concave mirror
(D) a plane mirror

13. The image is always erect in :
(A) Plane mirror (B) Concave mirror
(C) Convex mirror (D) Both (A) & (C)

14. Choose the correct relation between u, v and R for spherical mirror :
(A) $R = \frac{2uv}{u+v}$ (B) $R = \frac{2}{u+v}$
(C) $R = \frac{2(u+v)}{(uv)}$ (D) None of these

15. A dentist has a small mirror of focal length 16 mm. he views the cavity in the tooth of a patient by holding the mirror at a distance of 8 mm from the cavity. The magnification is :

(A) 1 (B) 1.5
(C) 2 (D) 3

16. The focal length of a concave mirror is f and the distance of the object from the principal focus is a. The magnitude of magnification obtained will be :

(A) (f + a)/f (B) f/a
(C) $\sqrt{f} / \sqrt{a}$ (D) f^2/a^2

17. The image formed by a concave mirror is observed to be virtual, erect and larger than the object, then the position of the object should be :

(A) between the focus and the centre of curvature
(B) at the centre of curvature
(C) beyond the centre of curvature
(D) between the pole of the mirror and the focus

18. Which of the following can make a parallel beam of light when light from a point source is incident on it ?

(A) Concave mirrr as well as convex lens
(B) Convex mirror as well as concave lens
(C) Two plane mirrors placed at 90º to each other
(D) Concave mirror as well as concave lens

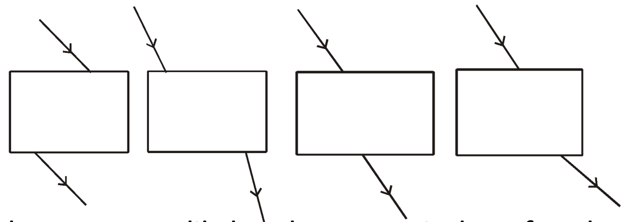
19. A ray of light travelling in air falls obliquely on the surface of a calm pond. It will :

(A) go into the water without deviating from its path
(B) deviate away from the normal
(C) deviate towards the normal
(D) turn back on its original path

20. A ray of light goes from a medium of refractive index n_1 to a medium of refractive index n_2. The angle of incidence is i and the angle of refraction is r. Then, sin i / sin r is equal to :

(A) n_1 (B) n_2
(C) n_1/n_2 (D) n_2/n_1

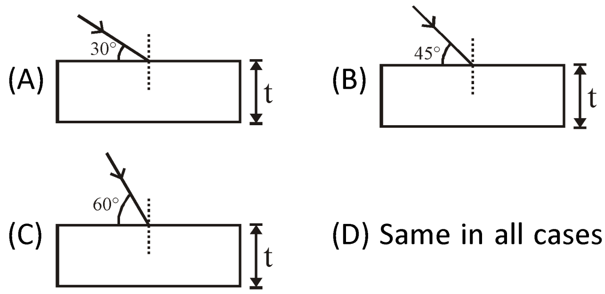
21. Four students showed the following traces of the path of a ray of light passing through a rectangular glass slab.



The trace most likely to be correct is that of student

(A) I (B) II (C) III (D) IV

22. In which figure lateral displacement will be larger if a ray of light of same wavelength



23. A convex lens forms a virtual image when an object is placed at a distance of 18 cm from it. The focal length must be :

(A) greater than 36 cm (B) greater than 18 cm
(C) less than 36 cm (D) less than 18 cm

24. An object is placed before a concave lens. The image formed :

(A) is always erect (B) may be real or virtual
(C) is always virtual (D) both (A) and (C)

PARAGRAPH TYPE

PARAGRAPH # 1

The radius of curvature of a convex mirror used on a moving automobile is 2.0 m. A truck is coming behind it at a constant distance of 3.5 m.

25. The image is at a distance of .... behind the mirror.

(A) 0.58 m (B) 0.68 m
(C) 0.78 m (D) 0.88 m

26. The nature of the image is ....

(A) Diminished and inverted
(B) Virtual and erect
(C) Virtual and inverted
(D) Real and erect

27. The size of the image relative to the size of the truck is :
(A) 22% (B) 24%
(C) 26% (D) 28%

PARAGRAPH # 2

A converging mirror forms a real image of height 4cm, of an object of height 1cm placed 20 cm away from the mirror.

28. The image distance is ....
(A) –80 cm (B) –90 cm
(C) –100 cm (D) –110 cm

29. The focal length of mirror is ....
(A) –15 cm (B) –16 cm
(C) –17 cm (D) –18 cm

30. The mirror used here is ....
(A) concave (B) convex
(C) plano convex (D) plano concave

MATCH THE COLUMN TYPE

31.

Column I	**Column II**
(a) Negative magnification	(p) Diminished image
(b) Magnification less than 1	(q) Inverted image
(c) Positive magnification	(r) Size of image is same
(d) Magnification equal to 1	(s) Erect image

(A) a-q, b-p, c-s, d-r
(B) a-r, b-s, c-q, d-p
(C) a-p, b-s, c-q, d-r
(D) a-q, b-s, c-p, d-r

32.

Column I	**Column II**
(a) Ratio speeds of light in two media	(p) Concave lens
(b) Ray passes undeviated	(q) Convex lens
(c) Divergence of rays	(r) Refractive index
(d) Convergence of rays	(s) Ray through optical centre

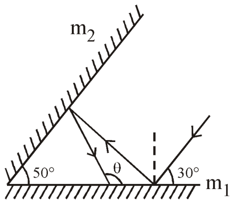
(A) a-q, b-p, c-s, d-r
(B) a-r ; b-s ; c-p ; d-q
(C) a-p, b-s, c-q, d-r
(D) a-q, b-s, c-p, d-r

Space for Notes :

EXERCISE – II

VERY SHORT ANSWER TYPE

1. What is homogeneous medium, explain.
2. What is heterogeneous medium, explain.
3. According to given figure what angle(θ) does the reflected ray from mirror m_2, make with mirror m_1 ?



4. Give differences between real image and virtual image.
5. What focal length can be assigned to a plane mirror ?
6. What are the values of the angle of incidence and the angle of reflection for normal incidence on a plane mirror ?
7. Define the principal focus of a concave mirror.
8. The radius of curvature of spherical mirror is 20 cm. What is its focal length ?
9. Name a mirror that can give an erect and enlarged image of an object.
10. The image formed by a concave mirror is observed to be virtual, erect and large than the object. State the position where the object has been placed ?

SHORT ANSWER TYPE

1. If angle of incident is 30° for a ray of light, find the angle of deviation after reflection
2. Write the two laws of reflection of light.
3. With the help of a ray diagram, state and explain the laws of reflection of light at a plane mirror. Mark the angle of incidence and reflection clearly on the diagram.
4. If magnification of an image formed by a spherical mirror comes out to be negative, what does it implies?
5. What is the difference between the virtual images produced by concave, plane and convex mirrors ?

LONG ANSWER TYPE

1. Write the sign convention used for spherical mirrors.
2. By drawing a neat ray diagram, show the formation of the image of a point object placed above the principal axis of a convex mirror. Explain the construction.
3. We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror ?
   What is the nature of the image ? Is the image larger or smaller than the object ?
   Draw a ray diagram to show the image formation in this case.
4. Name the type of mirror used in the following situations
   (a) Headlights of a car
   (b) Side/rear-view mirror of a vehicle
   (c) Solar furnace
5. Explain the principle of reversibility of light and prove that ${}_1\mu_2 = \frac{1}{{}_2\mu_1}$.

TRUE / FALSE TYPE

1. Light cannot travel in vacuum.
2. The angle of incidence is equal to the angle of reflection. This is true for reflection from plane mirrors, but is not true for reflection from spherical mirrors.
3. A spherical mirror never forms an image whose size is the same as that of the object.
4. A ray starting from the focus of a concave mirror becomes parallel to the principal axis after reflection.
5. A ray of light incident parallel to the principal axis of a spherical mirror retraces its path after reflection.

FILL IN THE BLANKS

1. Light travels the fastest in..............with the highest speed of..........m/s.
2. A light ray travelling obliquely from a denser medium to a rarer medium bends.........from the normal.
3. The ratio of sine of angle of incidence to the sine of angle of refraction is..........., for the light of a given colour and for the given pair of media.
4. The value of the refractive index for a given pair of media depends upon the..........of light in the two media.
5. In case of a rectangular glass slab, the refraction takes place at both air-glass interface and glass-air interface. The emergent ray is..........to the direction of incident ray.

NUMERICAL PROBLEMS

1. An object is placed at a distance of 12 cm from a concave mirror of radius of curvature 16 cm. Find the position of the image.
2. An object of height 2 cm is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. Draw a scale diagram to locate the image. From the diagram, find the length of the image formed.
3. An object is placed 20 cm from a convex mirror. Its image is formed 12 cm from the mirror. Find the focal length of the mirror.
4. Find the position, size and nature of the image formed by a spherical mirror from the following data :
   $f = -12$ cm, $u = -36$ cm, $h_0 = 2$cm
5. An object is placed at a distance of 12 cm from a concave mirror. The image formed is real and four times larger than the object. Calculate the distance of the image from the mirror.

Space for Notes :

Answer Key

EXERCISE–I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	D	C	B	C	D	C	D	D	A	C	B	D	A	C
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B	D	A	C	D	C	A	B	D	C	B	A	A	B	A
31	32													
A	B													

EXERCISE – II

VERY SHORT ANSWER TYPE

3. 130º   8. 10cm

SHORT ANSWER TYPE

1. 120º

TRUE / FALSE

1. F   2. F   3. F   4. T   5. F

FILL IN THE BLANKS

1. vacuum ; 3×10^8 **2.** away   **3.** constant

4. speed   **5.** parallel

NUMERICAL PROBLEMS

1. 24 cm from the mirror, on the same side as the object

2. 4 cm

3. 30 cm

4. 18 cm, 1 cm, real and inverted

5. 48 cm

SELF PROGRESS ASSESSMENT FRAMEWORK

(CHAPTER : LIGHT : REFLECTION AND REFRACTION)

CONTENT	STATUS	DATE OF COMPLETION	SELF SIGNATURE
Theory			
In-Text Examples			
Solved Examples			
NCERT Exercises			
Exercise I			
Exercise II			
Short Note-1			
Revision - 1			
Revision - 2			
Revision - 3			
Remark			

NOTES :

1. In the status, put "completed" only when you have thoroughly worked through this particular section.
2. Always remember to put down the date of completion correctly. It will help you in future at the time of revision.

Space for Notes :