CBSE

CLASS - X

Light-Reflection & Refraction

Study Modules

PHYSICS

CHAPTER - 10

LIGHT – REFLECTION AND REFRACTION

LIGHT

An object reflects light that falls on it. This reflected light when received by our eyes, enables us to see things.

Reflection of light

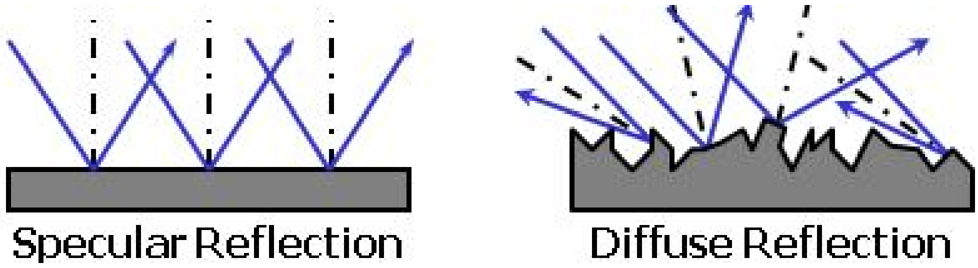
Reflection of light is the phenomenon of bouncing back of light in the same medium on striking the surface of any object.

There are two types of reflection:

1. Regular reflection or Specular Reflection
2. Irregular reflection or Diffuse Reflection

Regular Reflection: When the reflecting surface is smooth and well polished, the parallel rays falling on it are reflected parallel to one another, the reflected light goes in one particular direction. This is Regular reflection or Specular reflection see below figure.

Irregular reflection: When the reflecting surface is rough, the parallel rays falling on it reflected in different direction, as shown in below fig. Such a reflection is known as diffuse reflection or irregular reflection.

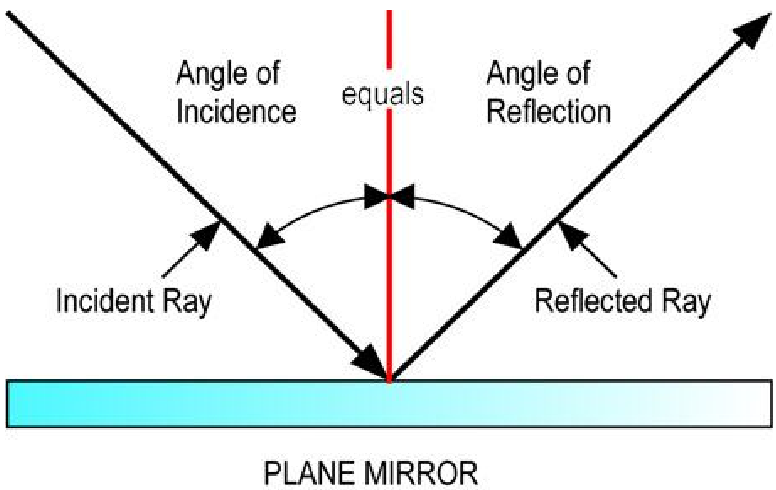


LAWS OF REFLECTION OF LIGHT

According to the laws of Reflection of light,

(i) The angle of incidence is equal to the angle of reflection, and

(ii) The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.



These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.

OBJECTS

Anything which gives out light rays either its own or reflected by it is called an object.

LUMINOUS OBJECTS: The objects like the sun, other stars, electric bulb, tube-light etc. which emit their own light are called luminous objects.

NON – LUMINOUS OBJECTS: The objects which do not emit light themselves but only reflect or scatter the light which falls on them, are called non-luminous objects. A flower, chair table, book, trees, etc are all non-luminous objects.

IMAGES

Image is an optical appearance produced when light rays coming from an object are reflected from a mirror (or refracted through lens).

REAL IMAGE

The image which can be obtained on a screen is called a real image. In a cinema hall, we see the images of actors and actress on the screen. So, the images formed on a cinema screen is an example of real images.

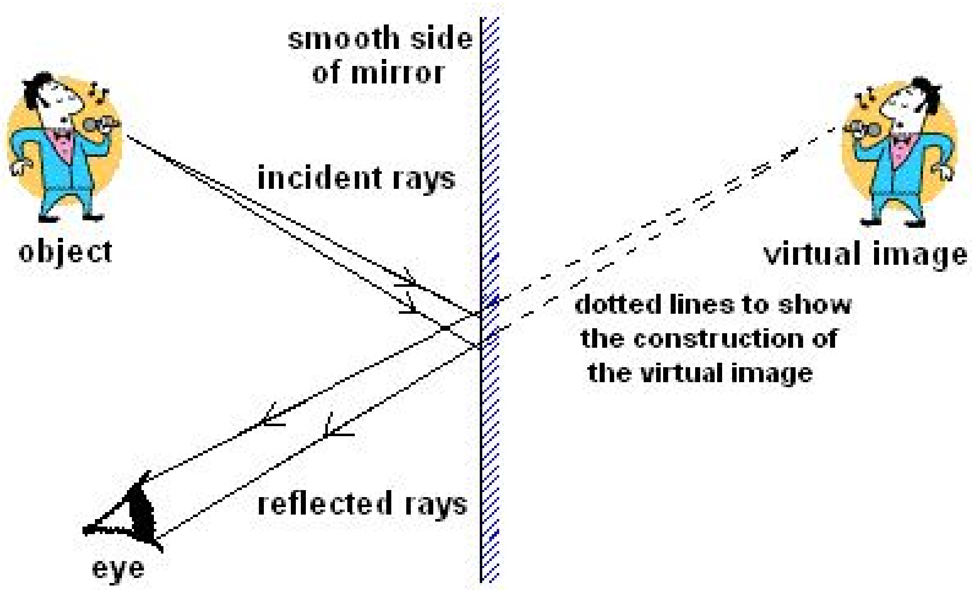
VIRTUAL IMAGE

The image which cannot be obtained on a screen is called a virtual image. A virtual image can be seen only by looking into a mirror. The image of our face in a plane mirror is an example of virtual image.

LATERAL INVERSION

When an object is placed in front of a plane mirror, then the right side of object appears to become the left side of image; and the left side of object appears to become the right side of image. This change of sides of an object and its mirror image is called lateral inversion.

The phenomenon of lateral inversion is due to the reflection of light.



CHARACTERISTICS OF IMAGES FORMED BY PLANE

The characteristics of images formed by plane mirrors are:

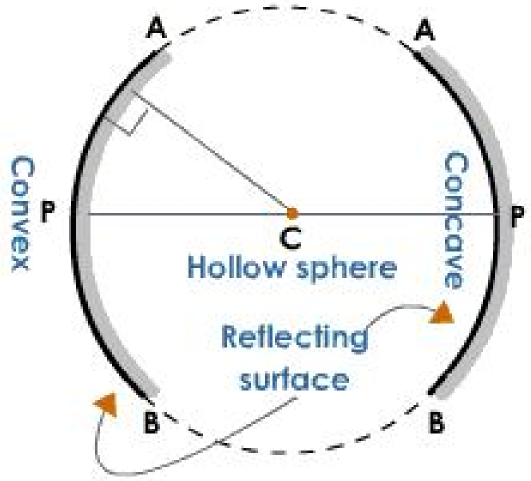
1. The image of real object is always virtual. Such image cannot be taken on a screen.
2. The image formed in a plane mirror is always erect.
3. The size of the image in a plane mirror is always the same as the size of the object.
4. The image formed in a plane mirror is as far behind the mirror, as the object is in front of the mirror.
5. The image formed in a plane mirror is laterally inverted i.e. the left side of the objects becomes the right side of the image and vice-versa.

SPHERICAL MIRROR

A spherical mirror is that mirror whose reflecting surface is the part of a hollow sphere of glass. The spherical mirrors are of two types: Concave mirror and Convex mirror.

CONCAVE MIRROR: A concave mirror is that spherical mirror in which the reflection of light takes place at the concave surface (or bent-in surface).

CONVEX MIRROR: A convex mirror is that spherical mirror in which the reflection of light takes place at the convex surface (or bulging –out surface).

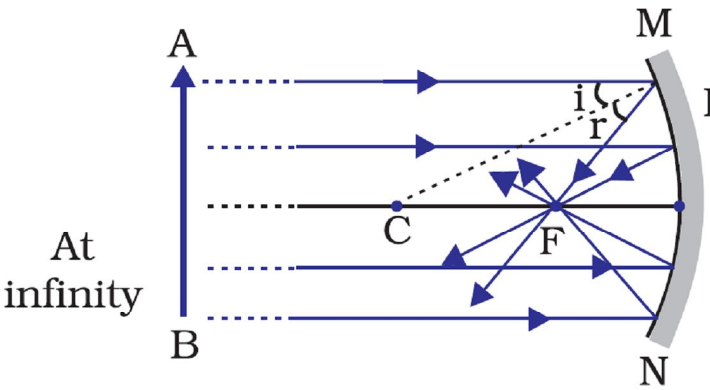


TERMS RELATED TO SPHERICAL MIRRORS

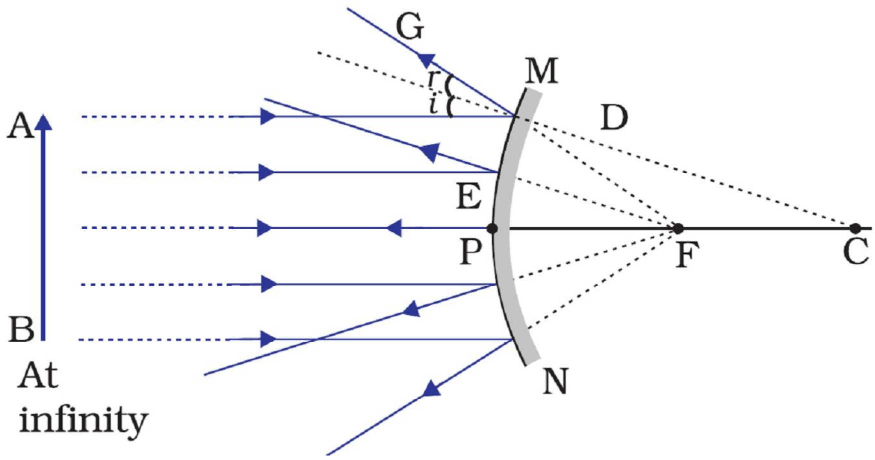
Centre of Curvature(C): The centre of curvature of a spherical mirror is the centre of the hollow sphere of glass of which the spherical mirror is a part. It is represented by letter ‘C’.
Pole(P): The pole of a spherical mirror is the centre of the mirror. It is represented by letter ‘P’.
Radius of Curvature(R): The radius of curvature of a spherical mirror is the radius of the hollow sphere of glass of which the spherical is a part. It is represented by the letter ‘R’.
Principal axis: The principal axis of a spherical mirror is the straight line passing through the centre of curvature C and pole P of the spherical mirror, produced on both sides.
Aperture: The aperture of a spherical mirror is the diameter of the reflecting surface of the mirror.

PRINCIPAL FOCUS OF A SPHERICAL MIRROR

The principal focus of a concave mirror is a point on its principal axis to which all the light rays which are parallel and close to the axis, converge after reflection from the concave mirror. A concave mirror has a real focus. The focus of a concave mirror is in front of the mirror. Since a concave mirror converges a parallel beams of light rays, it is also called converging mirror.



The principal focus of a convex mirror is a point on its principal axis from which a beam of light rays, initially parallel to the axis, appears to diverge after being reflected from the convex mirror. A convex mirror has a virtual focus. The focus of a convex mirror is situated behind the mirror. Since a convex mirror diverges a parallel beams of light rays, it is also called diverging mirror.



Focal Length: The focal length of a spherical mirror is the distance between its pole and principal focus. It is denoted by the letter '*f*'.

Relation between Radius of curvature and focal length of a spherical mirror
The focal length of a spherical mirror is equal to half of its radius of curvature.

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

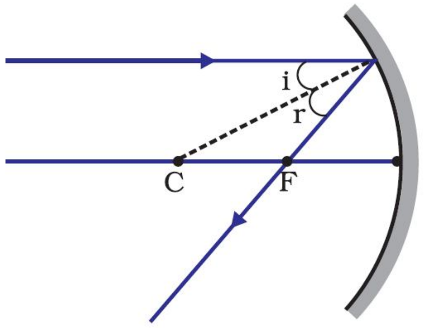
In other words, for spherical mirrors of small apertures, the radius of curvature is found to be equal to twice the focal length.

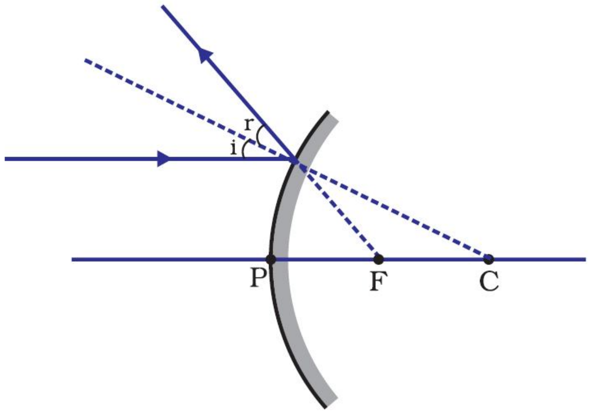
$$R = 2f$$

RULES FOR OBTAINING IMAGES FORMED BY SHPERICAL MIRRORS

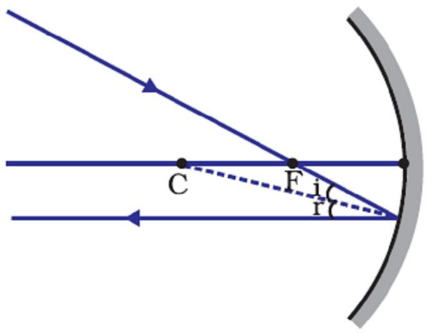
The intersection of at least two reflected rays give the position of image of the point object. Any two of the following rays can be considered for locating the image.

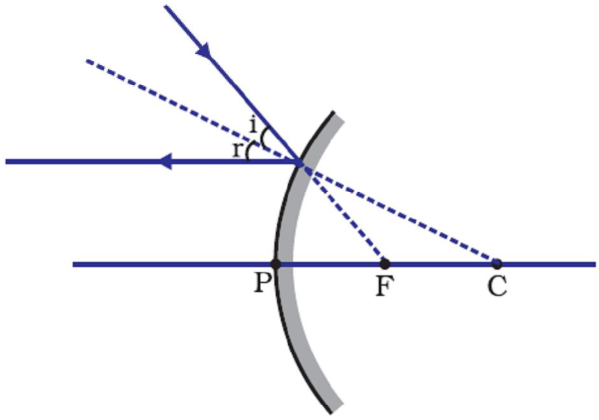
1. *A ray parallel to the principal axis,* after reflection, will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror.



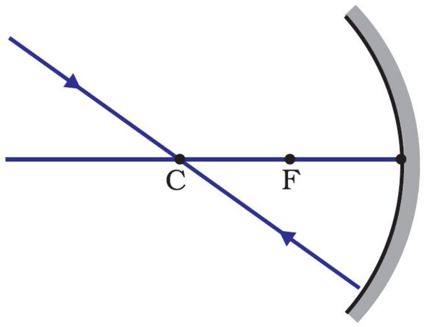


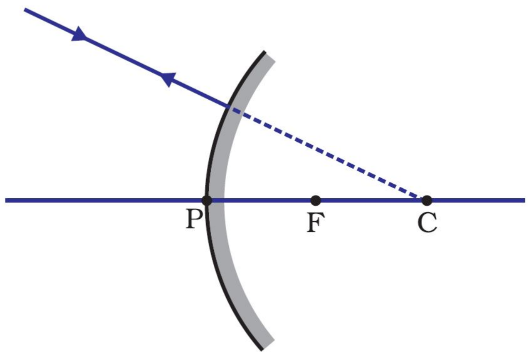
2. *A ray passing through the principal focus* of a concave mirror or *a ray which is directed towards the principal focus of* a convex mirror, after reflection, will emerge parallel to the principal axis.



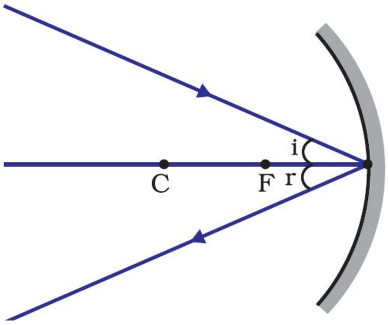


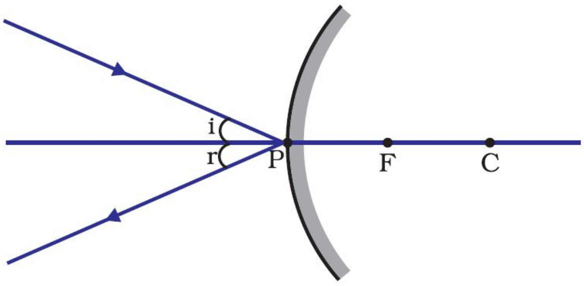
3. *A ray passing through the centre of curvature* of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path. The light rays come back along the same path because the incident rays fall on the mirror along the normal to the reflecting surface.





4. *A ray incident obliquely to the principal axis*, towards a point P (pole of the mirror), on the concave mirror or a convex mirror , is reflected obliquely. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis.





FORMATION OF DIFFERENT TYPES OF IMAGES BY A CONCAVE MIRROR

The type of image formed by a concave mirror depends on the position of object in front of the mirror. There are six positions of the object:

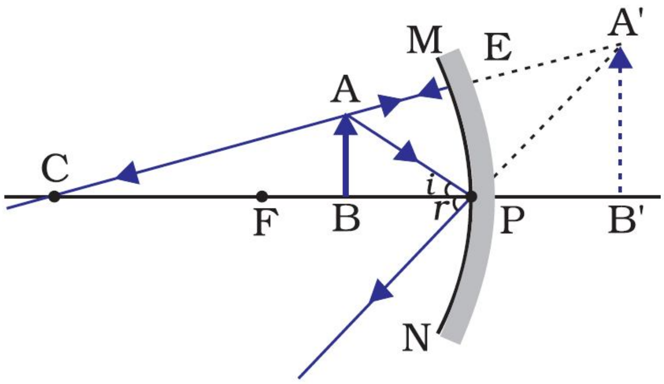
Case–1: Object is in between P and F

When an object is placed between the pole(P) and focus(F) of a concave mirror, the image formed is

(i) behind the mirror

(ii) virtual and erect and

(iii) larger than the object (or magnified)



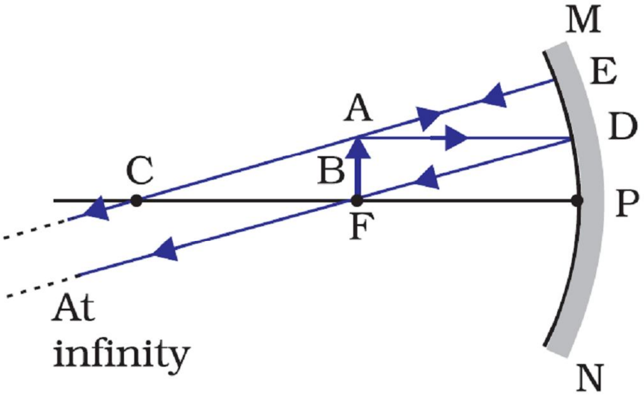
Case–2: Object is at the focus(F).

When an object is placed at the focus of a concave mirror, the image formed is

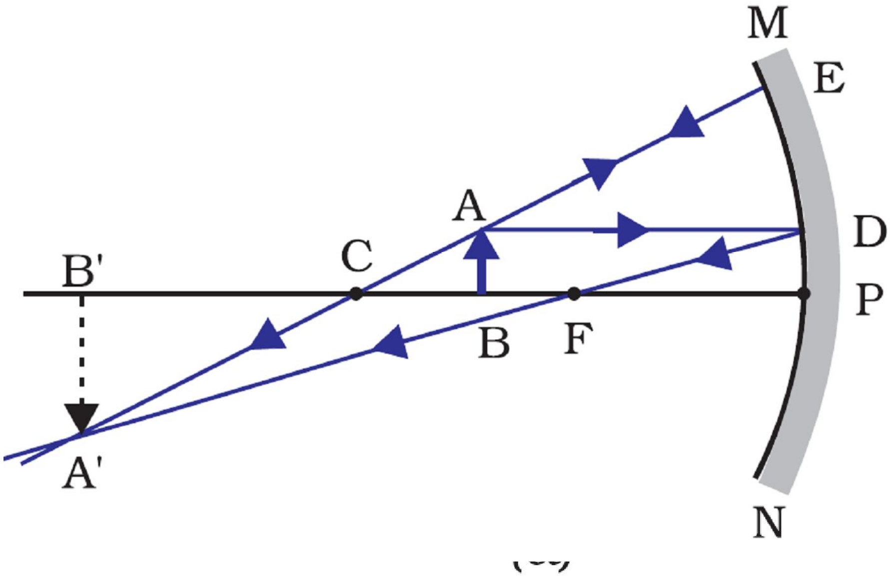
(i) at infinity

(ii) real and inverted, and

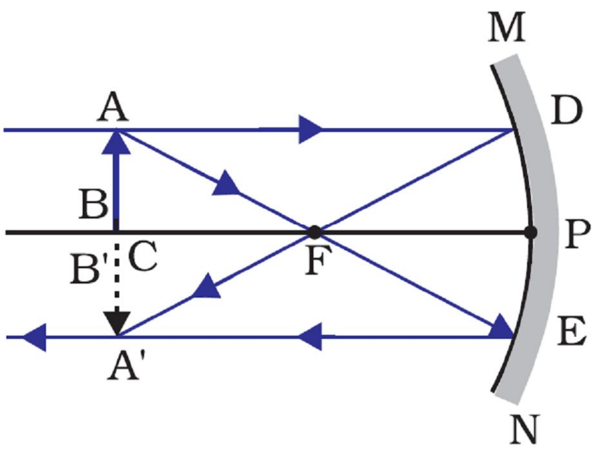
(iii) highly magnified (or highly enlarged)



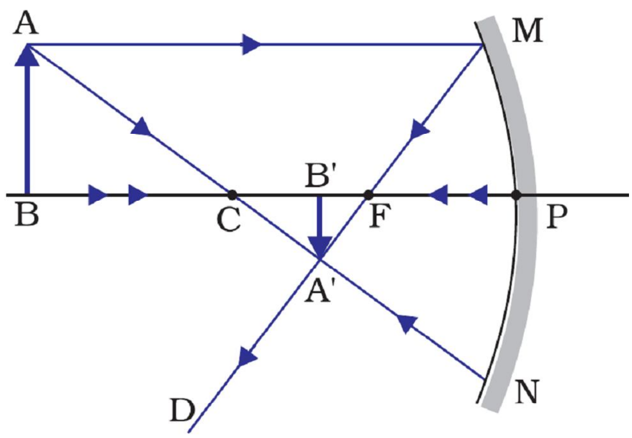
Case–3: Object is in between focus(F) and centre of curvature(C)
When an object is placed between the focus(F) and centre of curvature(C) of a concave mirror, the image formed is
(i) beyond the centre of curvature
(ii) real and inverted, and
(iii) larger than the object (or magnified)



Case–4: Object is at the centre of curvature(C)
When an object is placed at the centre of curvature of a concave mirror, the image formed is
(i) at the centre of curvature
(ii) real and inverted, and
(iii) same size as the object

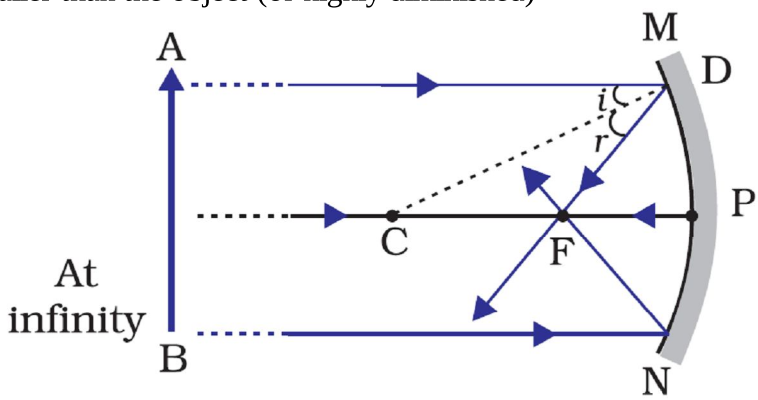


Case–5: Object is beyond the centre of curvature(C)
When an object is placed beyond the centre of curvature of a concave mirror, the image formed is
(i) between the focus and centre of curvature
(ii) real and inverted, and
(iii) smaller than the object (or diminished)



Case–6: Object is at infinity.

When an object is placed at infinity of a concave mirror, the image formed is
(i) between the focus and centre of curvature
(ii) real and inverted, and
(iii) much smaller than the object (or highly diminished)



USES OF CONCAVE MIRRORS

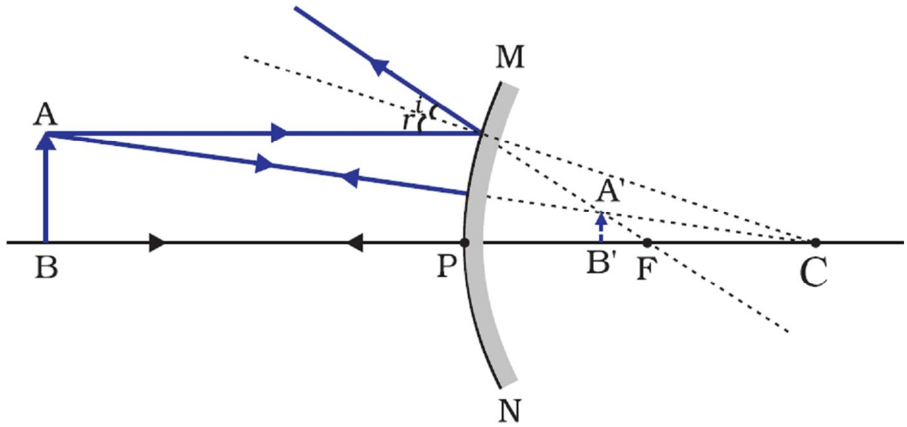
1. Concave mirrors are commonly used in torches, search-lights and vehicles headlights to get powerful parallel beams of light.
2. Concave mirrors are used as shaving mirrors to see a larger image of the face.
3. The dentists use concave mirrors to see large images of the teeth of patients.
4. Concave mirrors are used as doctor’s head mirrors to focus light coming from a lamp on to the body parts of a patient to be examined by the doctor.
5. Concave dishes are used in TV dish antennas to receive TV signals from the distant communications satellite.
6. Large concave mirrors are used to concentrate sunlight to produce heat in solar furnaces.

FORMATION OF DIFFERENT TYPES OF IMAGES BY A CONVEX MIRROR

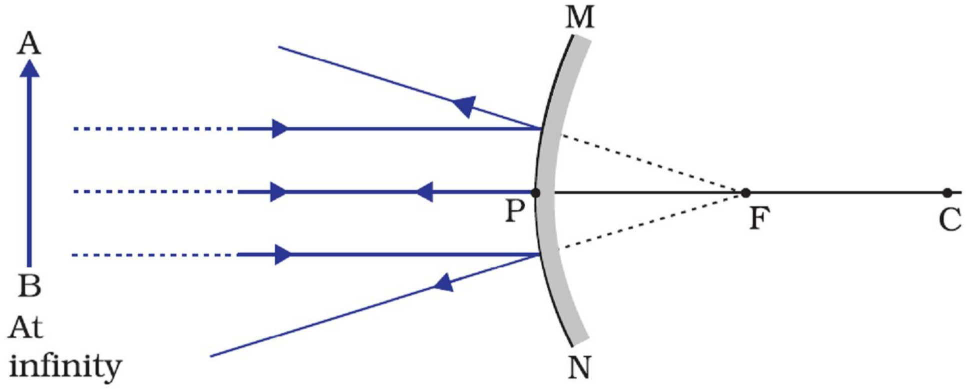
The type of image formed by a convex mirror depends on the position of object in front of the mirror. There are six positions of the object:

Case–1: Object is placed between P and infinity

When an object is placed between pole and infinity in front of a convex mirror, the image formed is
(i) between the pole and focus
(ii) virtual and erect, and
(iii) smaller than the object (or diminished)



<u>Case–2: Object is at infinity.</u>
When an object is placed at infinity of a convex mirror, the image formed is
(i) behind the mirror at focus
(ii) virtual and erect, and
(iii) much smaller than the object (or highly diminished)



USES OF CONVEX MIRRORS

Convex mirrors are commonly used as rear-view (wing) mirrors in vehicles. These mirrors are fitted on the sides of the vehicle, enabling the driver to see traffic behind him/her to facilitate safe driving. Convex mirrors are preferred because they always give an erect, though diminished, image. Also, they have a wider field of view as they are curved outwards. Thus, convex mirrors enable the driver to view much larger area than would be possible with a plane mirror.

<u>INTEXT QUESTIONS PAGE NO. 168</u>

1. Define the principal focus of a concave mirror.
Ans. Light rays that are parallel to the principal axis of a concave mirror converge at a specific point on its principal axis after reflecting from the mirror. This point is known as the principal focus of the concave mirror.

2. The radius of curvature of a spherical mirror is 20 cm. What is its focal length?
Ans. Here R = 20 cm
We know that $f = \frac{R}{2} \Rightarrow f = \frac{20}{2} = 10cm$

3. Name a mirror that can give an erect and enlarged image of an object.
Ans. When an object is placed between the pole and the principal focus of a concave mirror, the image formed is virtual, erect, and enlarged.

4. Why do we prefer a convex mirror as a rear-view mirror in vehicles?
Ans. Convex mirrors give a virtual, erect, and diminished image of the objects placed in front of them. They are preferred as a rear-view mirror in vehicles because they give a wider field of view, which allows the driver to see most of the traffic behind him.

MIRROR FORMULA

In a spherical mirror, the distance of the object from its pole is called the object distance (u). The distance of the image from the pole of the mirror is called the image distance (v). The distance of the principal focus from the pole is called the focal length (f). There is a relationship between these three quantities given by the *mirror formula* which is expressed as

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

MAGNIFICATION

Magnification produced by a spherical mirror gives the relative extent to which the image of an object is magnified with respect to the object size. It is expressed as the ratio of the height of the image to the height of the object. It is usually represented by the letter m. If h_1 is the height of the object and h_2 is the height of the image, then the magnification m produced by a spherical mirror is given by

$$m = \frac{height\ \ of\ \ the\ \ image}{height\ \ of\ \ the\ \ object} \Rightarrow m = \frac{h_2}{h_1}$$

The magnification m is also related to the object distance (u) and image distance (v). It can be expressed as:

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

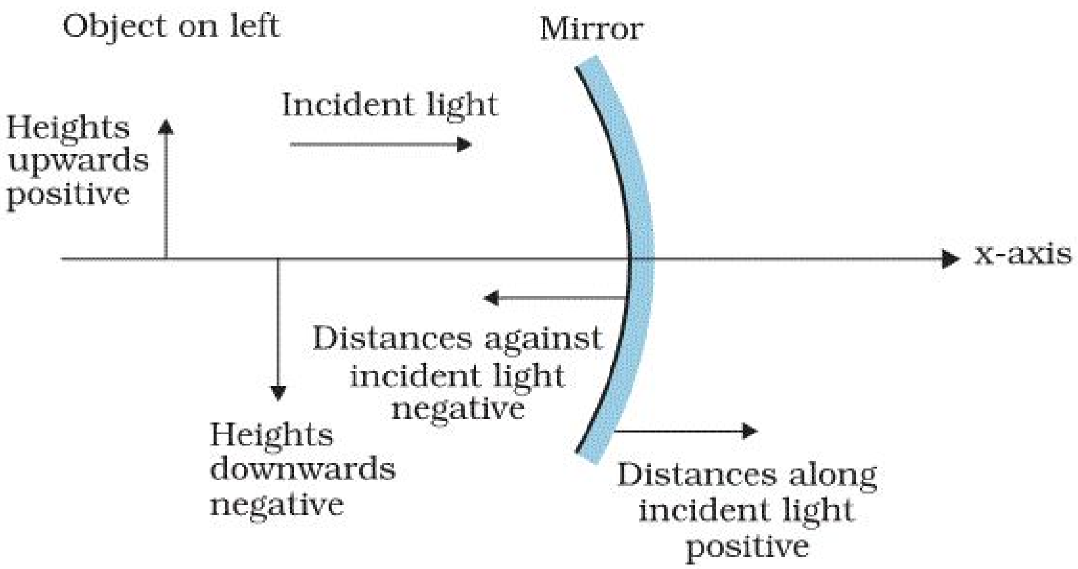
<u>Points to be remembered:</u>

- The height of the object is taken to be positive as the object is usually placed above the principal axis.
- The height of the image should be taken as positive for virtual images. However, it is to be taken as negative for real images.
- When the image is real, it is inverted so h_2 is negative which results m is –ve. A negative sign in the value of the magnification indicates that the image is real.
- When the image is virtual, it is erect so h_2 is positive which results m is +ve. A positive sign in the value of the magnification indicates that the image is virtual.

SIGN CONVENTION FOR SPHERICAL MIRRORS

The following sign convention is used for measuring various distances in the ray diagrams of spherical mirrors:

1. Object is always placed to the left of mirror
2. All distances are measured from the pole of the mirror.
3. Distances measured in the direction of the incident ray are positive and the distances measured in the direction opposite to that of the incident rays are negative.
4. Distances measured above the principal axis are positive and that measured below the principal axis are negative.



INTEXT QUESTIONS PAGE NO. 171

1. Find the focal length of a convex mirror whose radius of curvature is 32 cm.
Ans.
Ans. Here R = 32 cm

We know that $f = \frac{R}{2} \Rightarrow f = \frac{32}{2} = 16cm$

Hence, the focal length of the given convex mirror is 16 cm.

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

Ans. Here, magnification, m = –3,
object distance, u = –10 cm and
image distance, v = ?
Putting these values in the magnification formula for a mirror, we get

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

NUMERICALS BASED ON CONVEX AND CONCAVE MIRROR

1. Find the focal length of a convex mirror of radius of curvature 1m.
2. Focal length of a convex mirror is 50 cm. What is its radius of curvature?
3. Radius of curvature of a concave mirror is 25 cm. What is its focal length?
4. A concave mirror produces 10 cm long image of an object of height of 2cm. What is the magnification produced?
5. An object 1 cm high is held near a concave mirror of magnification 10. How tall will be the image?
6. An object 4 cm in size is placed at a distance of 25 cm from a concave mirror of focal length 15 cm. Find the position, nature and height of the image.
7. A converging mirror forms a real image of height 4 cm, of an object of height 1 cm placed 20 cm away from the mirror. Calculate the image distance. What is the focal length of the mirror?
8. 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.
9. An arrow 2.5 cm high is placed at a distance of 25 cm from a diverging mirror of focal length 20 cm., Find the nature, position and size of the image formed.
10. The image formed by a convex mirror of focal length 20cm is a quarter of the object. What is the distance of the object from the mirror?
11. Find the size, nature and position of image formed by a concave mirror, when an object of size 1cm is placed at a distance of 15cm. Given focal length of mirror is 10cm.
12. An object 2cm high is placed at a distance of 16cm from a concave mirror, which produces 3cm high inverted image. What is the focal length of the mirror? Also, find the position of the image.
13. An erect image 3 times the size of the object is obtained with a concave mirror of radius of curvature 36cm. What is the position of the object?
14. A 2.5cm candle is placed 12 cm away from a convex mirror of focal length 30cm. Give the location of the image and the magnification.
15. An object is placed in front of a concave mirror of focal length 20cm. The image formed is 3 times the size of the object. Calculate two possible distances of the object from the mirror.
16. The image formed by a convex mirror is virtual, erect and smaller in size. Illustrate with figure.

17. A concave mirror produces a real image 10mm tall, of an object 2.5mm tall placed at 5cm from the mirror. Calculate focal length of the mirror and the position of the image.

18. An object is placed at a large distance in front of a convex mirror of radius of curvature 40cm. How far is the image behind the mirror?

19. An object is placed 15cm from a convex mirror of radius of curvature 90cm. Calculate position of the image and its magnification.

20. The image formed by a convex mirror of focal length 30cm is a quarter of the object. What is the distance of the object from the mirror?

21. When an object is placed at a distance of 60cm from a convex mirror, the magnification produced is 1/2. Where should the object be place to get a magnification of 1/3?

22. An object is placed 18cm front of a mirror. If the image is formed at 4cm to the right of the mirror. Calculate its focal length. Is the mirror convex or concave? What is the nature of the image? What is the radius of curvature of the mirror?

23. A convex mirror used for rear view on an automobile has a radius of curvature of 3m. If a bus is located at 5m from this mirror, find the position, nature and magnification of the image.

24. An object 3cm high is held at a distance of 50cm from a diverging mirror of focal length 25cm. Find the nature, position and size of the image formed.

25. An converging mirror of focal length 20cm forms an image which is two times the size of the object. Calculate two possible distances of the object from the mirror.

26. The linear magnification of a convex mirror of focal length 15cm is 1/3. What is the distance of the object from the focus of the mirror?

27. The focal length of a convex mirror is 12.5 cm. How far is its centre of curvature (i) from the pole (ii) from the focus.

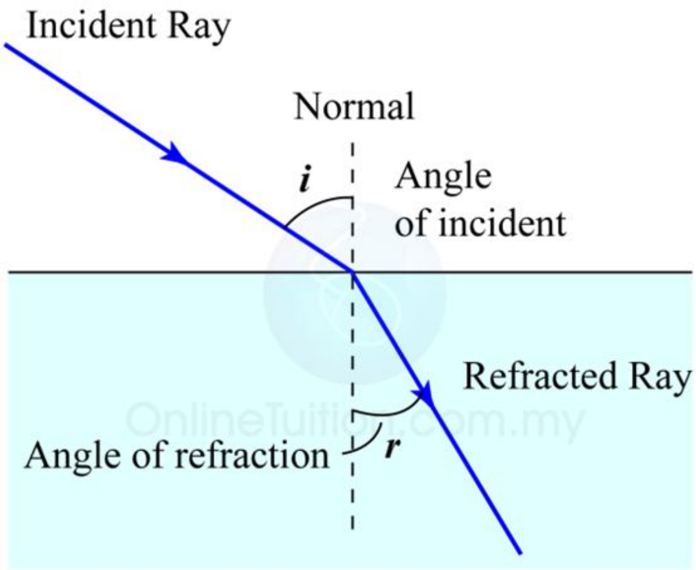
28. Find the focal length of a concave mirror that produces four times larger real image of an object held at 5cm from the mirror.

29. An object is held at 30cm in front of a convex mirror of focal length 15cm. At what distance from the convex mirror should a plane mirror be held so that images in the two images coincide with each other?

30. Draw any three ray diagrams to show how the size and nature of image of an object change when it move from centre of curvature of concave mirror towards the pole of the mirror.

REFRACTION OF LIGHT

The change in direction of light when it passes from one medium to another obliquely, is called refraction of light. In other words, the bending of light when it goes from one medium to another obliquely is called refraction of light. The refraction takes place when light enters from air to water (see below figure).



The speed of light is different in different substances. The refraction of light is due to the change in the speed of light on going from one medium to another. Thus, when light goes from one medium to another, its speed changes. And this change in speed of light causes the refraction of light.

MEDIUM

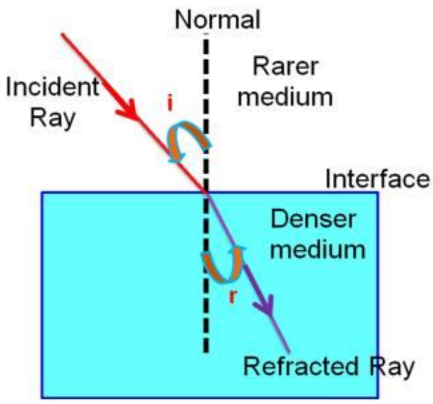
A transparent substance in which light travels is known as a medium. Medium can be divided into two types:

1. **Optically rarer medium:** A medium in which the speed of light is more is known as optically rarer medium (or less dense medium)
2. **Optically denser medium:** A medium in which the speed of light is less is known as optically rarer medium (or more dense medium)

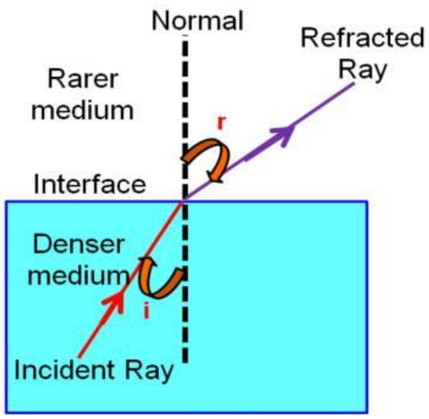
Glass is an optically denser medium than air and water.

RULES OF REFRACTION :

Rule-1 : When a light ray travels from a rarer medium to a denser medium, the light ray bends towards the normal.



Rule-2 : When a light ray travels from a denser medium to a rarer medium, the light ray bends away from the normal



LAWS OF REFRACTION

According to laws of refraction of light.

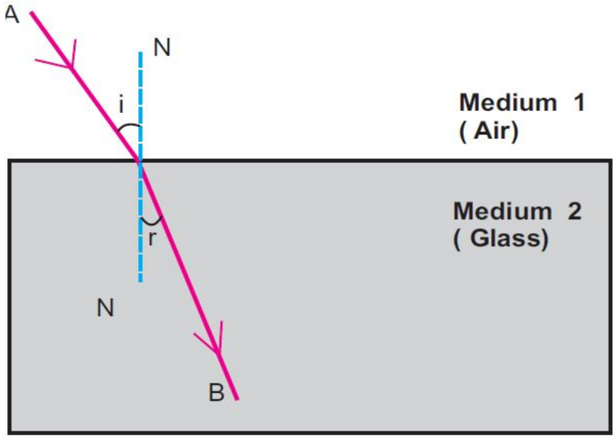
(i) *The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.*

(ii) *The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media.* This law is also known as Snell's law of refraction.

If i is the angle of incidence and r is the angle of refraction, then, $\frac{\sin i}{\sin r} = \text{constant}$. This constant value is called the refractive index of the second medium with respect to the first.

REFRACTIVE INDEX

The refractive index of a medium is defined as the ratio of speed of light in vacuum to the speed of light in the medium. It is represented by n.



- Refractive index of a medium, $n = \frac{speed\ of\ light\ in\ vacuum/air}{speed\ of\ light\ in\ medium} = \frac{c}{v}$

  Both c and v are in m/s
- Relative refractive index of medium 2 w.r.t. medium 1 is ${}^1n_2 = \frac{n_2}{n_1} = \frac{v_1}{v_2}$
- Both v_1, v_2 are in m/s, n_2, n_1 have no units
- ${}^1n_2 = \frac{1}{{}^2n_1}$

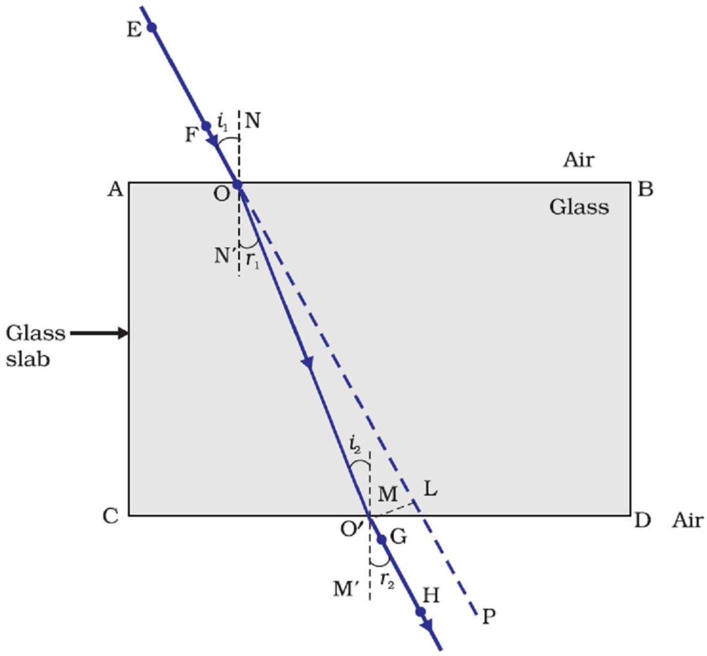
- Snell's law of refraction: When light travels from medium 1 to medium 2, then $^1n_2 = \frac{n_2}{n_1} = \frac{\sin i}{\sin r}$
- $^an_w = \frac{real\ depth(x)}{apparent\ depth(a)}$

  Both x and y are in metre or in cm.
- Velocity of light in vacuum/air is c = 3 x 10^8 m/s.

TWO REFRACTIONS THROUGH A RECTANGULAR GLASS SLAB

On passing through a rectangular glass slab, a ray of light suffers two refractions, one while going from air to glass and the other while going from glass to air. Light emerges from rectangular slab in a direction parallel to that in which it entered the glass slab. However the final emergent ray is slightly shifted sideways from the direction of original incident ray by a distance x called lateral shift.

The perpendicular distance between the original path of incident ray and the emergent ray coming out of the glass slab is called lateral displacement of the emergent ray of light. Lateral displacement depends mainly on three factors: angle of incidence, thickness of glass slab and refractive index of glass slab. Actually lateral displacement is directly proportional to (i) angle of incidence (ii) thickness of glass slab (iii) refractive index of glass slab. Higher the values of these factors, greater will be the lateral displacement. The angle which the emergent ray makes with the normal is called the angle of emergence.



CONDITION FOR NO REFRACTION

Refraction will not take place under the following two conditions:

1. *When light is incident normally on a boundary.*

A ray of light traveling in medium 1 falls normally. Therefore angle of incidence, I = 0^0.

According to Snell's law.

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

$$or \quad \sin r = \frac{n_1}{n_2}\sin i = \frac{n_1}{n_2}\sin 0^0 = \frac{n_1}{n_2}\times 0 = 0$$

$$or \quad r = 0$$

Thus, there is not deviation in the ray at the boundary. Hence, no refraction occurs when light is incident normally on a boundary of two media.

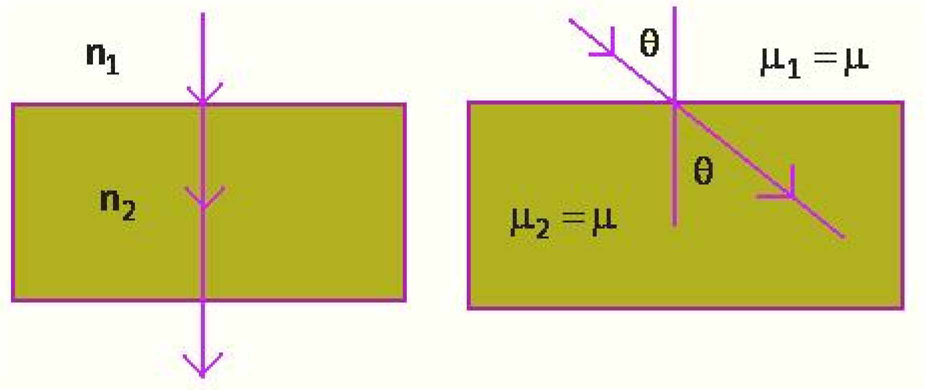
2. *When the refractive indices of two media are equal.*
When refractive index of medium 1 is equal to refractive index of medium 2 i.e. $n_1 = n_2$, then according to Snell's law

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = 1$$

$$or \quad \sin i = \sin r$$

$$or \quad i = r$$

Hence no refraction occurs at the boundary that separates two media of equal refractive indices.



INTEXT QUESTIONS – PAGE No. 176

1. **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?**
The light ray bends towards the normal. When a ray of light travels from an optically rarer medium to an optically denser medium, it gets bent towards the normal. Since water is optically denser than air, a ray of light travelling from air into the water will bend towards the normal.
2. **Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass? The speed of light in vacuum is 3×10^8 m/s.**
Refractive index of a medium n_m is given by,

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

Speed of light in vacuum, $c = 3 \times 10^8$ m/s
Refractive index of glass, $n_g = 1.50$

Speed of light in the glass, $v = \frac{c}{n_g} = \frac{3\times 10^8}{1.50} = 2\times 10^8 m$

3. **Find out, from Table 10.3, the medium having highest optical density. Also find the medium with lowest optical density.**
Highest optical density = Diamond
Lowest optical density = Air
Optical density of a medium is directly related with the refractive index of that medium. A medium which has the highest refractive index will have the highest optical density and vice-versa.
It can be observed from table 10.3 that diamond and air respectively have the highest and lowest refractive index. Therefore, diamond has the highest optical density and air has the lowest optical density.

4. **You are given kerosene, turpentine and water. In which of these does the light travel fastest? Use the information given in Table 10.3.**
Speed of light in a medium is given by the relation for refractive index (n_m). The relation is given as
$$n_m = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the medium}} = \frac{c}{v}$$
$$v = \frac{c}{n_m} \Rightarrow v \propto \frac{1}{n_m}$$
It can be inferred from the relation that light will travel the slowest in the material which has the highest refractive index and travel the fastest in the material which has the lowest refractive index.
It can be observed from table 10.3 that the refractive indices of kerosene, turpentine, and water are 1.44, 1.47, and 1.33 respectively. Therefore, light travels the fastest in water.
5. **The refractive index of diamond is 2.42. What is the meaning of this statement?**
Refractive index of a medium n_m is related to the speed of light in that medium v by the relation:
$$n_m = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the medium}} = \frac{c}{v}$$
Where, c is the speed of light in vacuum/air
The refractive index of diamond is 2.42. This suggests that the speed of light in diamond will reduce by a factor 2.42 compared to its speed in air.

<u>NUMERICALS</u>

1. Light travels through water with a speed of 2.25 x 10^8 m/s. What is the refractive index of water?
2. Light travels from rarer medium 1 to a denser medium 2. The angle of incident and refraction are respectively 45^0 and 30^0. Calculate the (i) refractive index of second medium with respect to the first medium and (ii) refractive index of medium 1 with respect to the medium 2.
3. A pond of depth 20cm is filled with water of refractive index 4/3. Calculate apparent depth of the tank when viewed normally.
4. How much time will light take to cross 2mm thick glass pane if refractive index of glasses is 3/2?

5. Calculate speed of light in water of refractive index 4/3.
6. A ray of light passes from air to glass (n = 1.5) at an angle of 30^0. Calculate the angle of refraction.
7. A ray of light is incident on a glass slab at an angle of 45^0. If refractive index of glass be 1.6, what is the angle of refraction?
8. The refractive index of diamond is 2.47 and that of glass is 1.51. How much faster does light travel in glass than in diamond?
9. The refractive index of glycerine is 1.46. What is the speed of light in air in air if its speed in glecerine is 2.05×10^8 m/s?
10. The refractive index of glass is 1.6 and that of diamond is 2.4. Calculate (i) refractive index of diamond with respect to glass and (ii) refractive index of glass with respect to diamond.
11. A ray of light is travelling from glass to air. The angle of incidence in glass is 30^0 and angle of refraction in air is 60^0. What is the refractive index of glass w.r.t air?
12. A ray of light is travelling from air to water. What is the angle of incidence in air, if angle of refraction in water is 45^0? Take refractive index of water = 1.32
13. A water tank appears to be 4 m deep when viewed from the top. If refractive index of water is 4/3, what is the actual depth of the tank?
14. What is the real depth of a swimming pool when its bottom appears to be raised by 1m? Given refractive index of water is 4/3.
15. A jar 15 cm long is filled with a transparent liquid. When viewed from the top, its bottom appears to be 12cm below. What is the refractive index of the liquid?

SPHERICAL LENSES

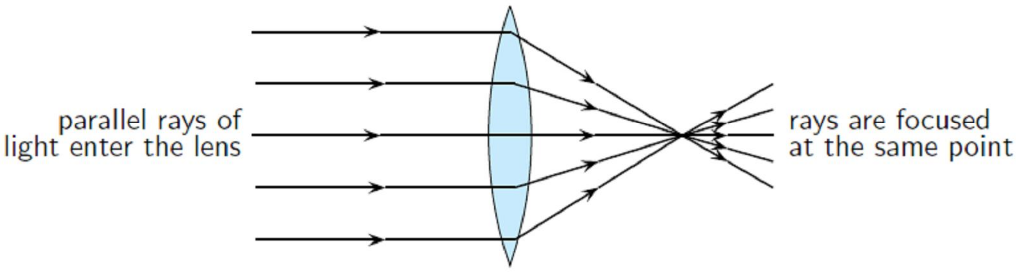
A lens is any transparent material (e.g. glass) of an appropriate shape that can take parallel rays of incident light and either converge the rays to a point or diverge the rays from a point.

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

Some lenses will focus light rays to a single point. These lenses are called converging or concave lenses. Other lenses spread out the light rays so that it looks like they all come from the same point. These lenses are called diverging or convex lenses. Lenses change the direction of light rays by refraction. They are designed so that the image appears in a certain place or as a certain size. Lenses are used in eyeglasses, cameras, microscopes, and telescopes.

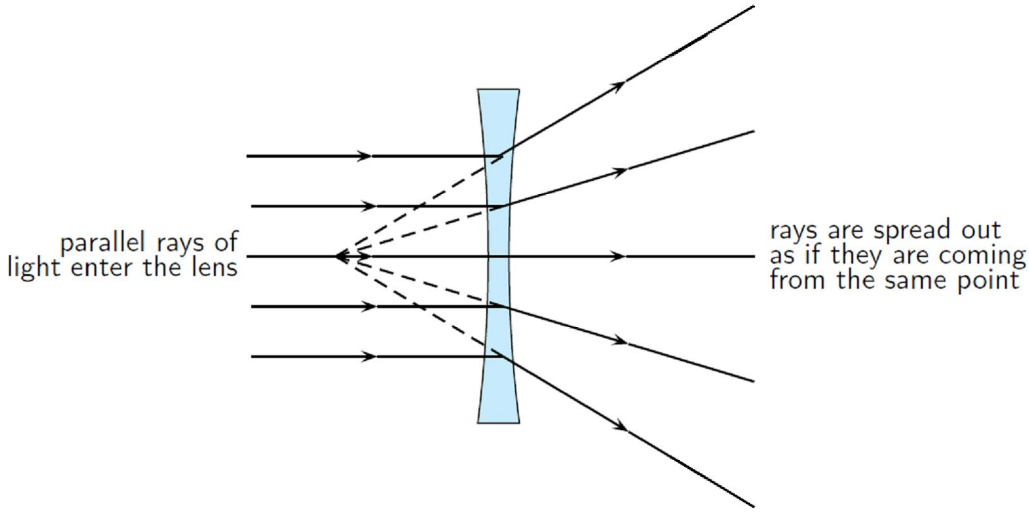
CONVEX LENS

A lens may have two spherical surfaces, bulging outwards. Such a lens is called a double convex lens. It is simply called a convex lens. It is thicker at the middle as compared to the edges. Convex lens converges light rays. Hence it is called converging lens.



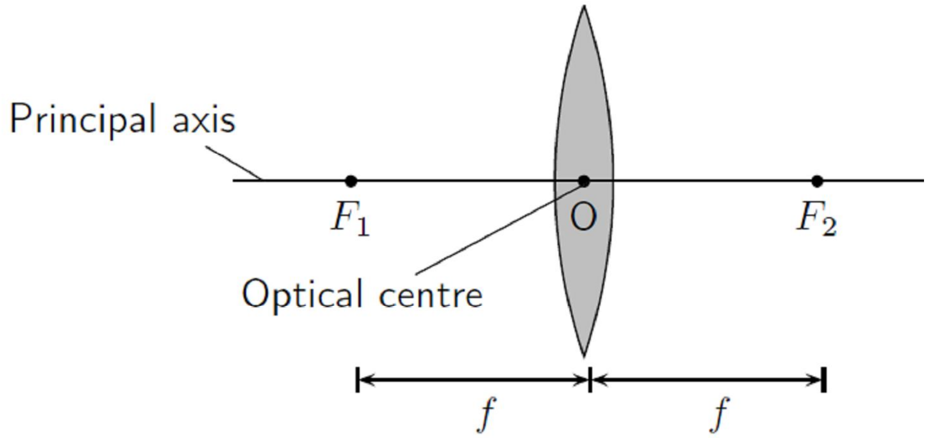
CONCAVE LENS

A double concave lens is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays and are called diverging lenses. A double concave lens is simply called a concave lens.



TERMS RELATED TO SPHERICAL LENS

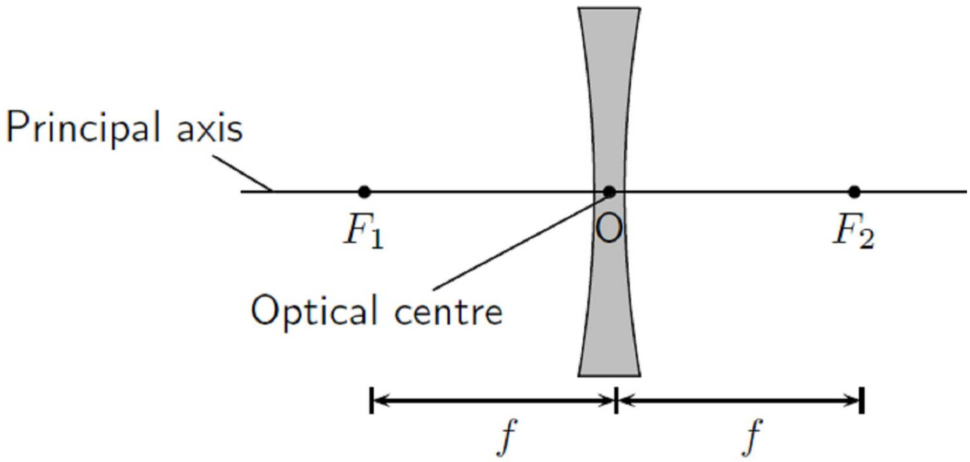
Principal Axis: The principal axis is the line which runs horizontally straight through the optical centre of the lens. It is also sometimes called the optic axis. In other words, an imaginary straight line passing through the two centres of the curvature of a lens is called its ***principal axis.***



Optical Centre: The optical centre (O) of a convex lens is usually the centre point of the lens. The direction of all light rays which pass through the optical centre, remains unchanged.

Centre of Curvature: A lens has two spherical surfaces. Each of these surfaces forms a part of a sphere. The centers of these spheres are called ***centres of curvature***

of the lens. The centre of curvature of a lens is usually represented by the letter C. Since there are two centre's of curvature, we may represent them as C_1 and C_2.



Aperture: The effective diameter of the circular outline of a spherical lens is called its ***aperture***. Lenses whose aperture is much less than its radius of curvature are called thin lenses with small aperture.

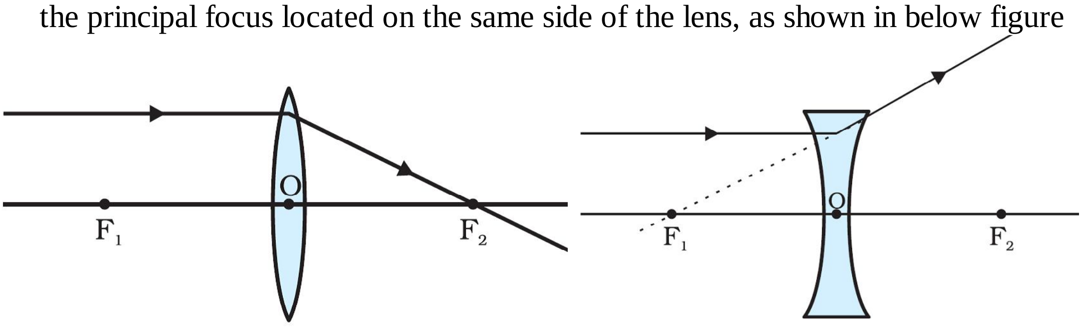
Focus: The focus or focal point of the lens is the position on the principal axis where all light rays that run parallel to the principal axis through the lens converge (come together) at a point. Since light can pass through the lens either from right to left or left to right, there is a focal point on each side of the lens (F_1 and F_2), at the same distance from the optical centre in each direction. (Note: the plural form of the word focus is foci.)

Focal Length: The focal length (f) is the distance between the optical centre and the focal point.

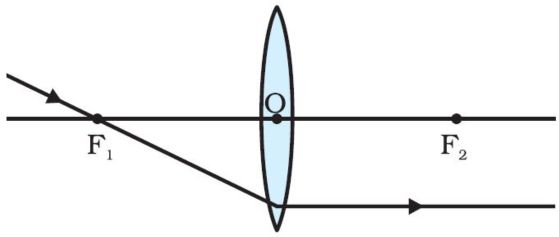
RULES FOR OBTAINING IMAGES FORMED BY SHPERICAL LENSES

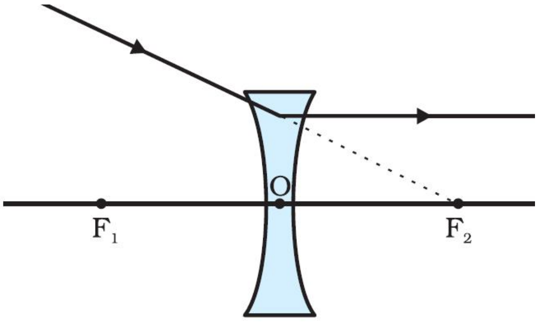
The intersection of at least two reflected rays give the position of image of the point object. Any two of the following rays can be considered for locating the image.

1. A ray of light from the object, parallel to the principal axis, after refraction from a convex lens, passes through the principal focus on the other side of the lens, as shown in below figure. In case of a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens, as shown in below figure

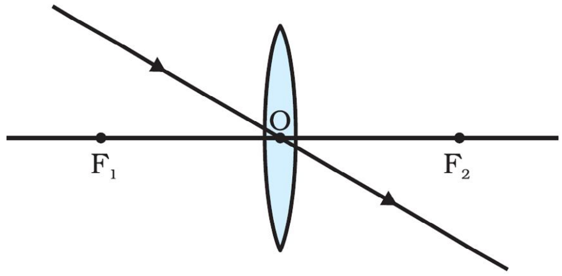


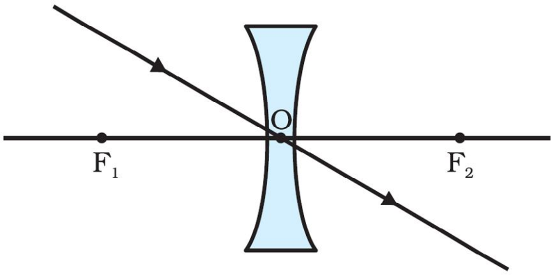
2. A ray of light passing through a principal focus, after refraction from a convex lens, will emerge parallel to the principal axis. This is shown in below figure. A ray of light appearing to meet at the principal focus of a concave lens, after refraction, will emerge parallel to the principal axis. This is shown in below figure.





3. A ray of light passing through the optical centre of a lens will emerge without any deviation. This is illustrated in below figure.



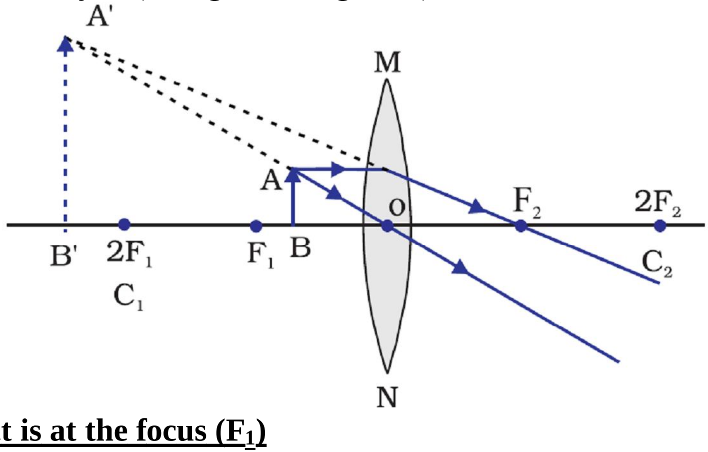


FORMATION OF DIFFERENT TYPES OF IMAGES BY A CONVEX LENS

The type of image formed by a convex lens depends on the position of object in front of the lens. There are six positions of the object:

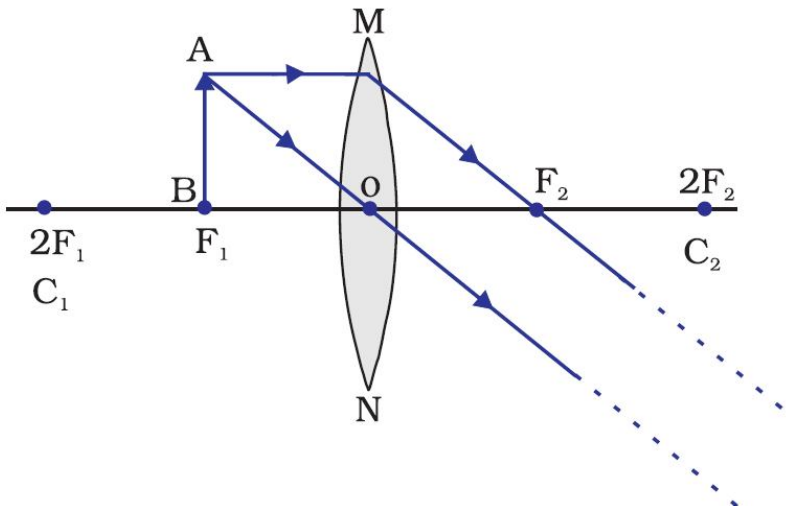
Case–1: Object is in between optical centre(O) and focus (F_1)

When the object is placed between optical centre(O) and focus(F_1), the image formed is (i) behind the object (on th left side of lens)
(ii) virtual and erect, and
(iii) larger than the object (enlarged or magnified)



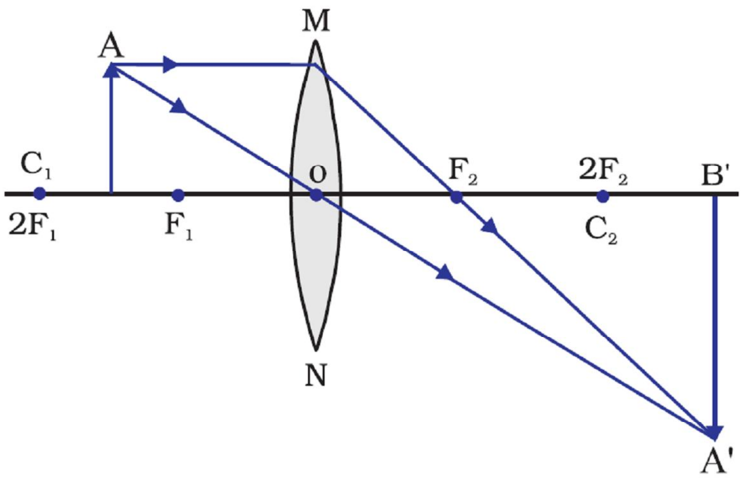
Case–2: Object is at the focus (F_1)

When the object is placed at the focus(F_1), the image formed is
(i) at infinity
(ii) real and inverted, and
(iii) highly enlarged

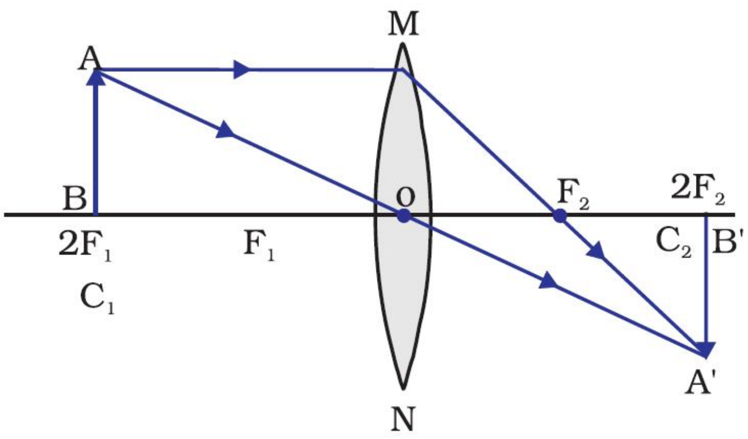


Case–3: Object is in between F_1 and $2F_2$

When the object is placed between F_1 and $2F_1$ in front of a convex lens, the image formed is
(i) beyond $2F_2$,
(ii) real and inverted, and
(iii) larger than the object (or magnified).



Case–4: Object is at $2F_1$
When the object is placed at a distance $2f$ in front of convex lens, the image formed is
(i) at $2F_2$ on the other side of the lens,
(ii) real and inverted, and
(iii) of the same size as the object.



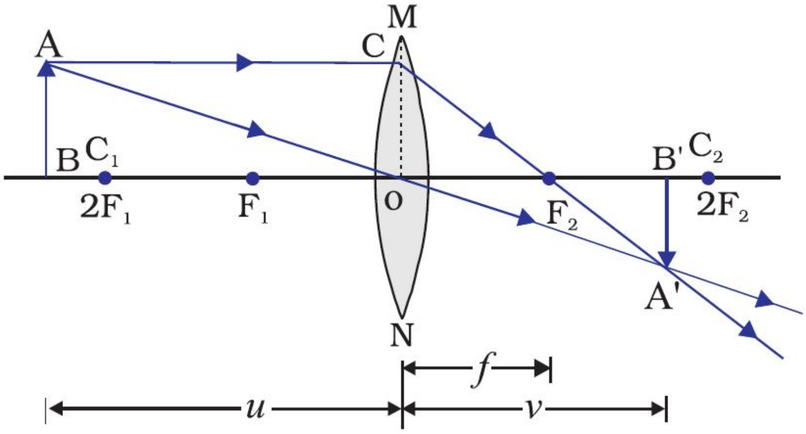
Case–5: Object is at beyond $2F_1$

When the object is placed beyond $2F_1$ in front of the convex lens, the image formed is

(i) between F_2 and $2F_2$ on the other side of the lens,

(ii) real and inverted, and

(iii) smaller than the object (or diminished)



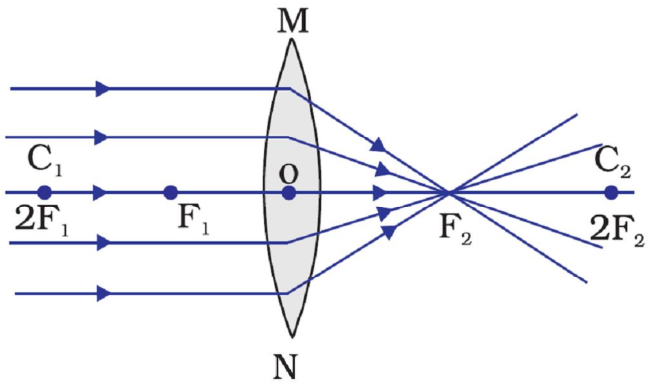
Case–6: Object is at infinity

When the object is placed at the infinity, the image formed is

(i) at the focus F_2.

(ii) real and inverted, and

(iii) much smaller than the object (or highly diminished or point sized)



FORMATION OF DIFFERENT TYPES OF IMAGES BY A CONCAVE LENS

The type of image formed by a concave lens depends on the position of object in front of the lens. There are two positions of the object:

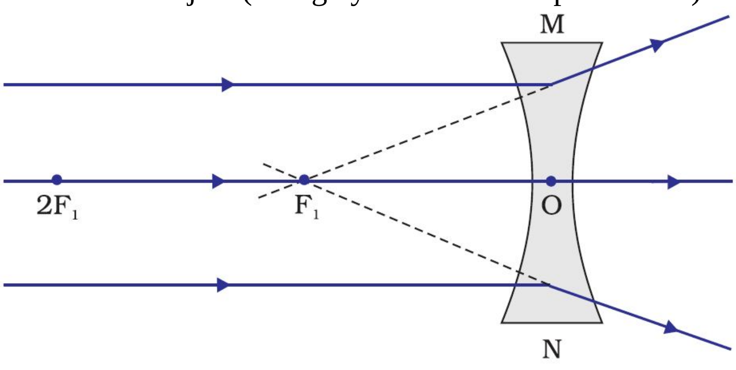
Case–1: Object is at infinity

When the object is placed at the infinity, the image formed is

(i) at the focus F_1.

(ii) virtual and erect, and

(iii) much smaller than the object (or highly diminished or point sized)

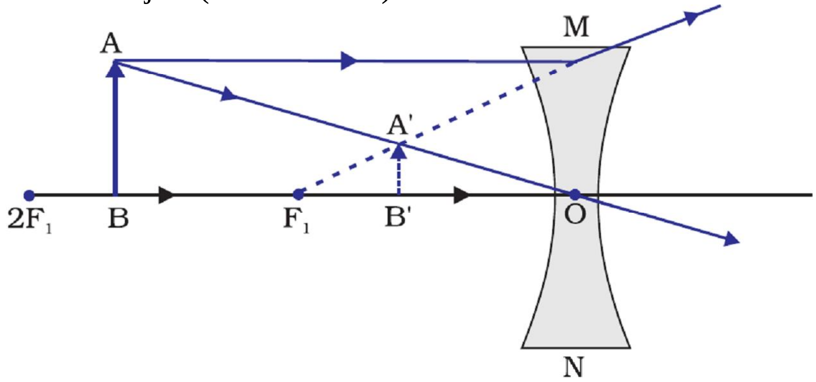


Case–2: Object is in between optical centre(O) and infinity

When the object is placed in between optical centre(O) and infinity, the image formed is (i) between optical centre(O) and focus F_1.

(ii) virtual and erect, and

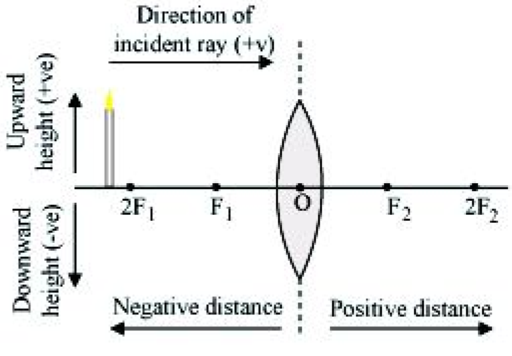
(iii) smaller than the object (or diminished)



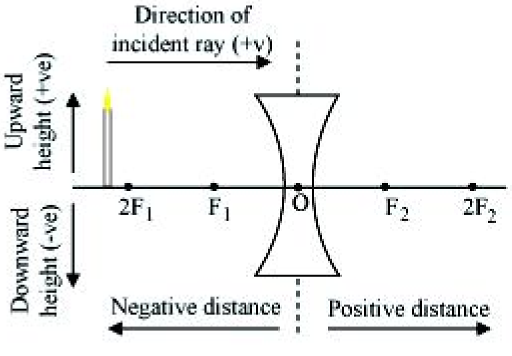
SIGN CONVENTION FOR SPHERICAL LENSES

While using the lens formula we must make use of proper sign convention while taking the values of object (u), image distance (v), focal length (f), object height (h) and image height (h'). The sign conventions are as follows:

1. All distances are measured from the optical centre of the lens.
2. The distances measured in the same direction as the incident light are taken positive.
3. The distances measured in the direction opposite to the direction of incident light are taken negative.
4. Heights measured upwards and perpendicular to the principal axis are taken positive.
5. Heights measured downwards and perpendicular to the principal axis are taken negative.



Convex mirror



Concave mirror

Consequences of new Cartesian sign convention:

- The focal length of a convex lens is positive and that of a concave lens is negative.
- Object distance u is always negative.
- The distance of real image is positive and that of virtual image is negative.
- The object height h is always positive. Height h' of virtual erect image is positive and that of real inverted image is negative.
- The linear magnification, m = h'/h is positive for a virtual image and negative for a real image.

LENS FORMULA

Lens formula gives the relationship between object distance (*u*), image-distance (*v*) and the focal length (*f*). The lens formula is expressed as

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

where 'u' is the distance of the object from the optical centre (O), 'v' is the distance of the image from the optical centre (O) and 'f' is the distance of the principal focus from the optical centre (O).

MAGNIFICATION

The magnification produced by a lens, similar to that for spherical mirrors, is defined as the ratio of the height of the image and the height of the object. It is represented by the letter *m*. If *h* is the height of the object and h' is the height of the image given by a lens, then the magnification produced by the lens is given by,

$$m=\frac{\text{Height of the Image}}{\text{Height of the object}}=\frac{h'}{h}$$

Magnification produced by a lens is also related to the object-distance *u*, and the image-distance *v*. This relationship is given by

$$\text{Magnification (m)}=\frac{h'}{h}=\frac{v}{u}$$

Points to be remembered

- If the magnification 'm' has a positive value, the image is virtual and erect. And if the magnification 'm' has a negative value, the image will real and inverted.
- A convex lens can form virtual images as well as real images, therefore, the magnification produced by a convex lens can be either positive or negative.
- A convex can form images which are smaller than the object, equal to the object or bigger than the object, therefore magnification 'm' produced by a convex lens can be less than 1, equal to 1 or more than 1.
- A concave lens, however, forms only virtual images, so the magnification produced by a concave lens is always positive.
- A concave lens forms image which are always smaller than the object, so the magnification 'm' produced by a concave lens is always less than 1.

NUMERICALS BASED ON CONVEX LENS

1. A convex lens of focal length 10cm is placed at a distance of 12cm from a wall. How far from the lens should an object be placed so as to form its real image on the wall?

2. If an object of 7cm height is placed at a distance of 12cm from a convex lens of focal length 8cm, find the position, nature and height of the image.

3. An object 4 cm high is placed at a distance of 10cm from a convex lens of focal length 20cm. Find the position, nature and size of the image.
4. A small object is so placed in front of a convex lens of 5 cm focal length that a virtual image is formed at a distance of 25cm. Find the magnification.
5. Find the position and nature of the image of an object 5cm high and 10cm in front of a convex lens of focal length 6cm.
6. Calculate the focal length of a convex lens, which produces a virtual image at a distance of 50cm of an object placed 20cm in front of it.
7. An object is placed at a distance of 100 cm from a converging lens of focal length 40cm. What is the nature and position of the image?
8. A convex lens produces an inverted image magnified three times of an object at a distance of 15 cm from it. Calculate focal length of the lens.
9. An object placed 4cm in front of a converging lens produces a real image 12cm from the lens. What is the magnification of the image? What is the focal length of the lens? Also draw the ray diagram to show the formation of the image.
10. A lens of focal length 20cm is used to produce a ten times magnified image of a film slide on a screen. How far must the slide be placed from the lens?
11. Determine how far an object must be placed in front of a converging lens of focal length 10cm in order to produce an erect image of linear magnification 4.
12. A convex lens of focal length 6cm is held 4cm from a newspaper, which has print 0.5cm high. By calculation, determine the size and nature of the image produced.
13. A convex lens of focal length 0.10m is used to form a magnified image of an object of height 5mm placed at a distance of 0.08m from the lens. Find the position, nature and size of the image.
14. An erect image 2cm high is formed 12cm from a lens, the object being 0.5cm high. Find the focal length of the lens.
15. The filament of a lamp is 80 cm from a screen and a converging lens forms an image of it on a screen, magnified three times. Find the distance of the lens from the filament and the focal length of the lens.
16. An object 2cm tall is placed on the axis of a convex lens of focal length 5cm at a distance of 10cm from the optical centre of the lens. Find the nature, position and size of the image formed. Which case of image formation by convex lenses is illustrated by this example?

17. A converging lens of focal length 5cm is placed at a distance of 20cm from a screen. How far from the lens should an object be placed so as to form its real image on the screen?
18. An object 5cm high is held 25cm away from a converging lens of focal length 10cm. Find the position, size and nature of the image formed. Also draw the ray diagram.
19. At what distance should an object be placed from a convex lens of focal length 18cm to obtain an image at 24cm from it on the other side? What will be the magnification produced in this case?
20. The magnification produced by a spherical lens is +2.5. What is the nature of image and lens?
21. What is the nature of the image formed by a convex lens if the magnification produced by a convex lens is +3?
22. What is the nature of the image formed by a convex lens if the magnification produced by a convex lens is –0.5?
23. What is the position of image when an object is placed at a distance of 10cm from a convex lens of focal length 10cm?
24. Describe the nature of the image formed when an object is placed at a distance of 30cm from a convex lens of focal length 15cm.
25. At what distance from a converging lens of focal length 12cm must an object be placed in order that an image of magnification 1 will be produced?

NUMERICALS BASED ON CONCAVE LENS

1. A concave lens produces an image 20cm from the lens of an object placed 30cm from the lens. Calculate the focal length of the lens.
2. The magnification of a spherical lens is +0.5. What is the nature of lens and image?
3. If an object is placed at a distance of 50cm from a concave lens of focal length 20cm, find the position, nature and height of the image.
4. An object is placed at a distance of 4 cm from a concave lens of focal length 12cm. Find the position and nature of the image.
5. An object is placed at a distance of 50cm from a concave lens produces a virtual image at a distance of 10 cm in front of the lens. Draw a diagram to show the formation of image. Calculate focal length of the lens and magnification produced.

6. A 50 cm tall object is at a very large distance from a diverging lens. A virtual, erect and diminished image of the object is formed at a distance of 20 cm in front of the lens. How much is the focal length of the lens?

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

8. An object 60cm from a lens gives a virtual image at a distance of 20cm in front of the lens. What is the focal length of the lens? Is the lens converging or diverging? Give reasons for your answer.

9. A concave lens of 20 cm focal length forms an image 15cm from the lens. Compute the object distance.

10. A concave lens has focal length 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.

11. Calculate the image distance for an object of height 12 mm at a distance of 0.20 m from a concave lens of focal length 0.30m and state the nature and size of the image.

12. A concave lens has focal length of 20cm. At what distance from the lens a 5cm tall object be placed so that it forms an image at 15cm from the lens? Also calculate the size of the image formed.

13. An object is placed 20cm from (a) a converging lens and (b) a diverging lens of focal length 15cm. Calculate the image position and magnification in each case.

14. A 2.0 cm tall object is placed 40cm from a diverging lens of focal length 15 cm. Find the position and size of the image.

15. Find the position and size of the virtual image formed when an object 2 cm tall is placed 20cm from (a) diverging lens of focal length 40cm and (b) converging lens of focal length 40 cm.

16. The magnification produced by a spherical lens is +0.75. What is the nature of image and lens?

17. The magnification produced by a spherical lens and a spherical mirror is +0.8. What is the nature of lens and mirror?

18. The magnification produced by a spherical lens and a spherical mirror is +2.0. What is the nature of lens and mirror?

19. The lens A produces a magnification of –0.6 whereas lens b produces magnification of +0.6. What is the nature of lens A and B.

20. An object is 2m from a lens which forms an erect image one-fourth (exactly) the size of the object. Determine the focal length of the lens. What type of the lens is this?

POWER OF A LENS

The power of a lens is defined as the reciprocal of its focal length. It is represented by the letter *P*. The power *P* of a lens of focal length *f* is given by

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

The SI unit of power of a lens is 'dioptre'. It is denoted by the letter D. If *f* is expressed in metres, then, power is expressed in dioptres. Thus, 1 dioptre is the power of a lens whose focal length is 1 metre. $1D = 1m^{-1}$. The *power of a convex lens is positive and that of a concave lens is negative.*

Many optical instruments consist of a number of lenses. They are combined to increase the magnification and sharpness of the image. The net power (*P*) of the lenses placed in contact is given by the algebraic sum of the individual powers P_1, P_2, P_3, … as $P = P_1 + P_2 + P_3 + \dots$

NUMERICALS ON POWER OF LENS

1. A concave lens produces an image 20cm from the lens of an object placed 30cm from the lens. Calculate the power of the lens.
2. A convex lens is of focal length 10 cm. What is its power?
3. A person having a myopia eye uses a concave lens of focal length 50cm. What is the power of the lens?
4. A thin lens has a focal length of –25cm. What is the power of the lens and what is its nature?
5. A lens has a power of –2.5 D. What is the focal length and nature of the lens?
6. Find the power of a concave lens of focal length 2 m.
7. A convex lens forms a real and inverted image of needle at a distance of 50cm from the lens. If the image is of the same size as the needle, where is the needle placed in front of the lens? Also, find the power of the lens.
8. Two thin lenses of power +3.5 D and –2.5 D are placed in contact. Find the power and focal length of the lens combination.
9. A doctor has prescribed a corrective lens of power –1.5 D. Find the focal length of the lens. Is the prescribed lens is diverging or converging?
10. A concave lens of focal length 25 cm and a convex lens of focal length 20 cm are placed in contact with each other. What is the power of this combination? Also, calculate focal length of the combination.

11. A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 10cm. What is the focal length and power of the combination?

12. An object is placed at a distance of 50cm from a concave lens of focal length 30cm. Find the nature and position of the image.

13. An object of height 2 cm is placed at a distance of 15cm in front of a concave lens of power –10D. Find the size of the image.

14. A convergent lens of power 8D is combined with a divergent lens of power –10D. Calculate focal length of the combination.

15. A concave lens is kept in contact with a convex lens of focal length 20cm. The combination works as a converging lens of focal length 100cm. Calculate power of concave lens.

16. Find the focal length and nature of lens which should be placed in contact with a lens of focal length 10 cm so that the power of the combination becomes 5D.

17. A convex lens of power 3D is held in contact with a concave lens of power – 1 D. A parallel beam of light is made to fall on the combination. At what distance from the combination will the bean ge5t focussed?

18. A convex lens of focal length 25cm and a concave lens of focal length 10cm are placed in close contact with one another.

a). What is the power of the combination?
b). What is the focal length of the combination?
c). Is this combination converging or diverging?

19. The power of a combination of two lenses X and Y is 5D. If the focal length of lens X be 15 cm, then

a). calculate the focal length of lens Y.
b). State the nature of the lens Y.

20. Two lenses A and B have focal lengths of +20cm and – 10 cm, respectively.

a). What is the nature of lens A and lens B?
b). What is the power of lens A and lens B?
What is the power of the combination if lenses A and B are held close together?

<u>INTEXT QUESTIONS PAGE No. 184</u>

1. Define 1 dioptre of power of a lens.

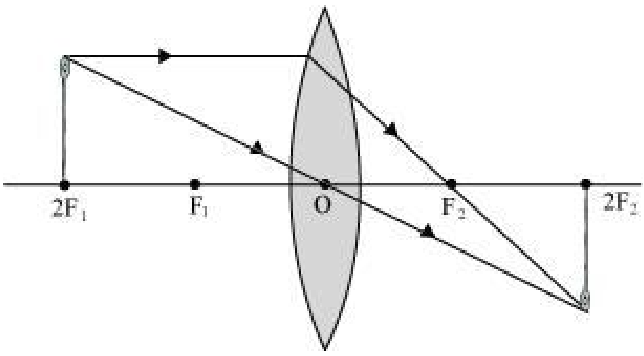
Power of lens is defined as the reciprocal of its focal length. If P is the power of a lens of focal length F in metres, then
The S.I. unit of power of a lens is Dioptre. It is denoted by D.

$$P = \frac{1}{f\,(in\ \ metres)}$$

1 dioptre is defined as the power of a lens of focal length 1 metre.
Hence, 1 D = 1 m−1

2. **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.**

When an object is placed at the centre of curvature, $2F_1$, of a convex lens, its image is formed at the centre of curvature, $2F_2$, on the other side of the lens. The image formed is inverted and of the same size as the object, as shown in the given figure.



It is given that the image of the needle is formed at a distance of 50 cm from the convex lens. Hence, the needle is placed in front of the lens at a distance of 50cm.

Object distance, u = −50 cm

Image distance, v = 50 cm

Focal length = f

According to the lens formula,

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

$$\frac{1}{f}=\frac{1}{50}-\frac{1}{-50}=\frac{1}{50}+\frac{1}{50}=\frac{1}{25}$$

$$f=25cm=0.25m$$

Power of the lens, $P=\frac{1}{f\,(in\ \ metres)}=\frac{1}{0.25}=+4D$

Hence, the power of the given lens is +4 D.

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

Focal length of concave lens, f = 2 m

Power of the lens, $P=\frac{1}{f\,(in\ \ metres)}=\frac{1}{-2}=-0.5D$

Here, negative sign arises due to the divergent nature of concave lens.

Hence, the power of the given concave lens is −0.5 D.

EXERCISE QUESTIONS PAGE No. 185 and 186

1. Which one of the following materials cannot be used to make a lens?
(a) Water (b) Glass (c) Plastic (d) Clay
Ans:
(d) A lens allows light to pass through it. Since clay does not show such property, it cannot be used to make a lens.

2. 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 principal 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 principal focus.
Ans:
(d) When an object is placed between the pole and principal focus of a concave mirror, the image formed is virtual, erect, and larger than the object.

3. Where should an object be placed in front of a convex lens to get a real image of the size of the object?
(a) At the principal focus of the lens (b) At twice the focal length (c) At infinity (d) Between the optical centre of the lens and its principal focus.
Ans:
(b) When an object is placed at the centre of curvature in front of a convex lens, its image is formed at the centre of curvature on the other side of the lens. The image formed is real, inverted, and of the same size as the object.

4. A spherical mirror and a thin spherical lens have each a focal length of −15 cm. The mirror and the lens are likely to be
(a) both concave (b) both convex (c) the mirror is concave and the lens is convex (d) the mirror is convex, but the lens is concave
Ans:
(a) By convention, the focal length of a concave mirror and a concave lens are taken as negative. Hence, both the spherical mirror and the thin spherical lens are concave in nature.

5. No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be (a) plane (b) concave (c) convex (d) either plane or convex
Ans:
(d) A convex mirror always gives a virtual and erect image of smaller size of the object placed in front of it. Similarly, a plane mirror will always give a virtual and erect image of same size as that of the object placed in front of it. Therefore, the given mirror could be either plane or convex.

6. Which of the following lenses would you prefer to use while reading small letters found in a dictionary?
(a) 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) A convex lens gives a magnified image of an object when it is placed between the radius of curvature and focal length. Also, magnification is more for convex

lenses having shorter focal length. Therefore, for reading small letters, a convex lens of focal length 5 cm should be used.

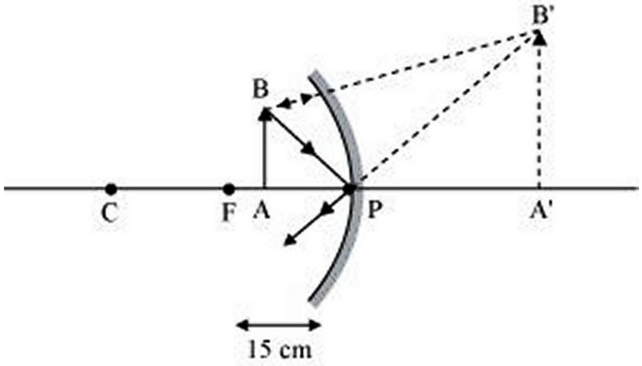
7. We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror? What is the nature of the image? Is the image larger or smaller than the object? Draw a ray diagram to show the image formation in this case.

Ans:

Range of object distance = 0 cm to15 cm

A concave mirror gives an erect image when an object is placed between its pole (P) and the principal focus (F).

Hence, to obtain an erect image of an object from a concave mirror of focal length 15 cm, the object must be placed anywhere between the pole and the focus. The image formed will be virtual, erect, and magnified in nature, as shown in the given figure.



8. 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) Concave (b) Convex (c) Concave

Explanation:

(a) Concave mirror is used in the headlights of a car. This is because concave mirrors can produce powerful parallel beam of light when the light source is placed at their principal focus.

(b) Convex mirror is used in side/rear view mirror of a vehicle. Convex mirrors give a virtual, erect, and diminished image of the objects placed in front of it. Because of this, they have a wide field of view. It enables the driver to see most of the traffic behind him/her.

(c) Concave mirrors are convergent mirrors. That is why they are used to construct solar furnaces. Concave mirrors converge the light incident on them at a single point known as principal focus. Hence, they can be used to produce a large amount of heat at that point.

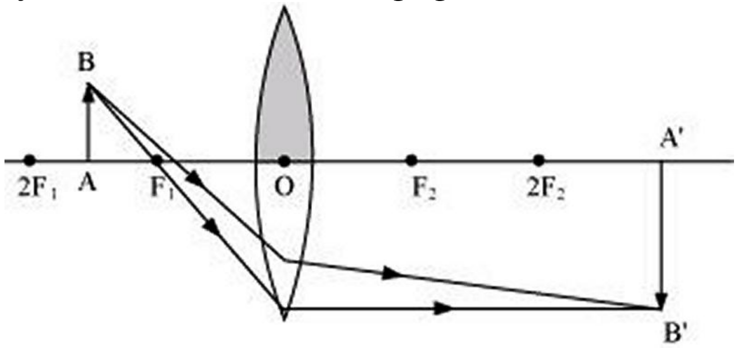
9. One-half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object? Verify your answer experimentally. Explain your observations.

Ans:

The convex lens will form complete image of an object, even if its one half is covered with black paper. It can be understood by the following two cases.

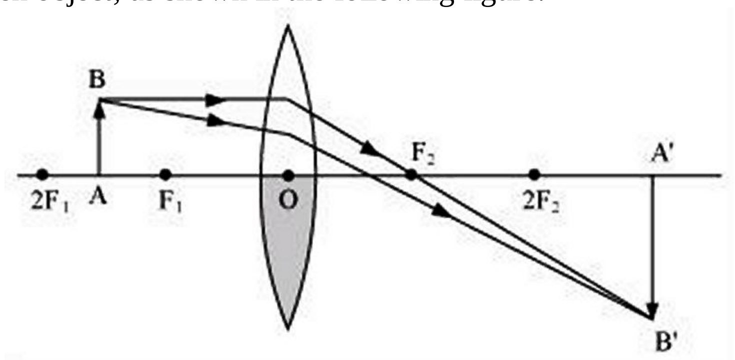
Case I: When the upper half of the lens is covered

In this case, a ray of light coming from the object will be refracted by the lower half of the lens. These rays meet at the other side of the lens to form the image of the given object, as shown in the following figure.



Case II: When the lower half of the lens is covered

In this case, a ray of light coming from the object is refracted by the upper half of the lens. These rays meet at the other side of the lens to form the image of the given object, as shown in the following figure.



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

Ans:

Object distance, u = −25 cm

Object height, ho = 5 cm

Focal length, f = +10 cm

According to the lens formula,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}=\frac{1}{f}+\frac{1}{u}=\frac{1}{10}-\frac{1}{25}=\frac{5-2}{50}=\frac{3}{50}$$

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

The positive value of v shows that the image is formed at the other side of the lens.

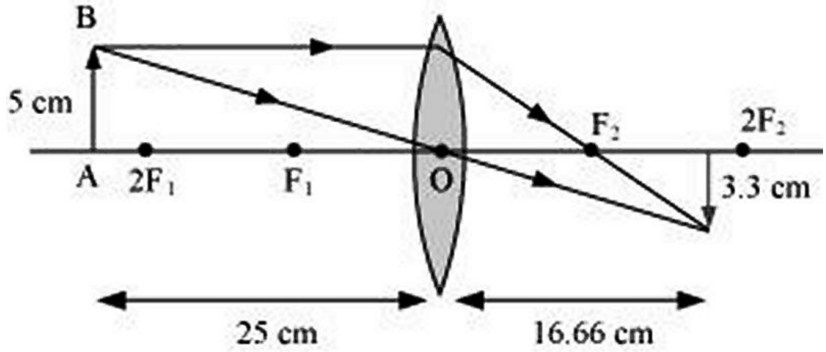
$$Magnification, m=\frac{\text{Height of the Image}}{\text{Height of the object}}=\frac{v}{u}=\frac{16.67}{-25}=-0.67$$

The negative sign shows that the image is real and formed behind the lens.

$$Magnification, m=\frac{h'}{h}=\frac{h'}{5}=\frac{v}{u}=-0.67\Rightarrow h'=-5\times 0.67=-3.3cm$$

The negative value of image height indicates that the image formed is inverted.

The position, size, and nature of image are shown in the following ray diagram.



11. 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:

Focal length of concave lens (OF1), f = −15 cm

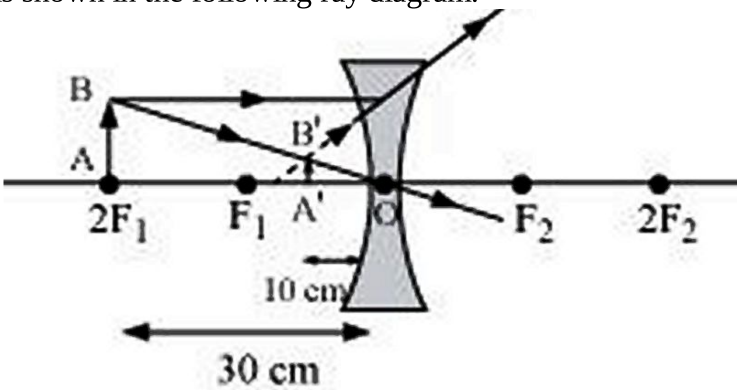
Image distance, v = −10 cm

According to the lens formula,

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

$\Rightarrow u=-30cm$

The negative value of u indicates that the object is placed 30 cm in front of the lens. This is shown in the following ray diagram.



12. 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:

Focal length of convex mirror, f = +15 cm

Object distance, u = −10 cm

According to the mirror formula,

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

$$\Rightarrow\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{15}+\frac{1}{10}=\frac{2+3}{30}=\frac{5}{30}=\frac{1}{6}$$

$\Rightarrow v=6cm$

The positive value of v indicates that the image is formed behind the mirror.

$$Magnification, m=-\frac{\text{Image distance}}{\text{Object distance}}=-\frac{v}{u}=-\frac{6}{-10}=+0.6$$

The positive value of magnification indicates that the image formed is virtual and erect.

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

Ans:

Magnification produced by a mirror is given by the relation

$$Magnification, m = -\frac{\text{Image distance}}{\text{Object distance}} = \frac{h_2}{h_1}$$

The magnification produced by a plane mirror is +1. It shows that the image formed by the plane mirror is of the same size as that of the object. The positive sign shows that the image formed is virtual and erect.

14. 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 position of the image, its nature and size.

Ans:

Object distance, u = −20 cm

Object height, h = 5 cm

Radius of curvature, R = 30 cm

Radius of curvature = 2 × Focal length

R = 2f

f = 15 cm

According to the mirror formula,

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

$$\Rightarrow \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{15} + \frac{1}{20} = \frac{4+3}{60} = \frac{7}{60}$$

$$\Rightarrow v = \frac{60}{7} = 8.57cm$$

The positive value of v indicates that the image is formed behind the mirror.

$$Magnification, m = -\frac{\text{Image distance}}{\text{Object distance}} = -\frac{v}{u} = -\frac{8.57}{-20} = +0.428$$

The positive value of magnification indicates that the image formed is virtual and erect.

$$Magnification, m = -\frac{\text{Image distance}}{\text{Object distance}} = \frac{h_2}{h_1} = \frac{h_2}{5} = +0.428$$

$$\Rightarrow h_2 = 0.428 \times 5 = +2.14cm$$

The positive value of image height indicates that the image formed is erect.

Therefore, the image formed is virtual, erect, and smaller in size.

15. 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:

Object distance, u = −27 cm

Object height, h = 7 cm

Focal length, f = −18 cm

According to the mirror formula,

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

$$\Rightarrow v = -54cm$$

The screen should be placed at a distance of 54 cm in front of the given mirror.

$$Magnification, m = -\frac{\text{Image distance}}{\text{Object distance}} = -\frac{v}{u} = -\frac{-54}{-27} = -2$$

The negative value of magnification indicates that the image formed is real.

$$Magnification, m = -\frac{\text{Image distance}}{\text{Object distance}} = \frac{h_2}{h_1} = \frac{h_2}{7} = -2$$

The negative value of image height indicates that the image formed is inverted.

$$\Rightarrow h_2 = -2 \times 7 = -14cm$$

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

Ans:

Power of the lens, $P = \frac{1}{f\,(in\ \ metres)} = -2D$

$$\Rightarrow f = \frac{-1}{2} = -0.5m$$

A concave lens has a negative focal length. Hence, it is a concave lens.

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

Ans:

Power of the lens, $P = \frac{1}{f\,(in\ \ metres)} = 1.5D$

$$\Rightarrow f = \frac{1}{1.5} = \frac{10}{15} = 0.66m$$

A convex lens has a positive focal length. Hence, it is a convex lens or a converging lens.