Reflection of Light

Physics – X CBSE

Nature of Light

- **Ray Nature**
  Light travels from the source along a straight line/ called the ray.
  Thus, ray nature has been used to explain the phenomena of reflection and refraction which is our everyday experience.
- **Wave Nature**
  Light travels from the source along a straight line in the form of wave. Light waves are electromagnetic waves. These waves do not require any material medium for their propagation.
  The speed of these waves is 3×10^8 m/s in vacuum and slightly less in air. The speed of light is represented by the symbol c. Its actual value is, c = 299, 792, 458 m/s.
  The wavelength of visible light ranges from 4×10^{-7} m to 7×10^{-7} and is very small as compared to the size of usual objects. Due to the smallness of waves, they can be taken to travel (propagate) from one point to another in a straight line, called the ray of light.

Characteristics of Light

- The speed of light in vacuum or free space is 3×10^8 m/s, marginally less in air (≈ equals to 3×10^8 m/s). In water it is 2.25×10^8 m/s and in glass it is 2×10^8 m/s.
- The velocity of light changes when it travels from one medium to another.
- Light travels from one point to another in a straight line.
- The light gets reflected when it falls on polished surfaces like mirror.
- The frequency of light remains same in all mediums.
- The light undergoes refraction when it travels from one transparent medium to another.

Basic Definitions

- **Source**

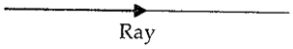
A body which emits light is called source. The source can be a point one or an extended one. It is of two kinds:

(a) Self luminous: It is a source which possess light of its own. For example the sun, electric arc, candle etc.

(b) Non-luminous : It is a sour 'e of light which does not possess light of its own but acts as source of light by reflecting from external source and light received by it. For example, the moon, objects around us, book etc.

Sources are also classified as isotropic and non isotropic. Isotropic sources give out light in all direction whereas non isotropic sources do not give out light in all direction.

- **Medium**
  Substance through which light propagates or tends to propagate is called medium. It is of following three kinds:
  (a) Transparent: It is a medium through which light can be propagated easily, e.g., glass, water etc.
  (b) Translucent: It is a medium through which light is propagated partially e.g., oil paper, ground glass etc.
  (c) Opaque: It is a medium through which light cannot be propagated e.g., wood, iron etc.
- **Ray**
  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.



Notes: A single ray cannot be isolated from a source of light.

- **Beam**

A bundle or bunch of rays is called a beam. It is of following three types:

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

(b) 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.

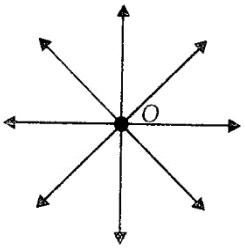
(c) Parallel beam: It is a beam in which all the rays constituting the beam move parallel to each other and diameter of beam remains same.

- **Object**

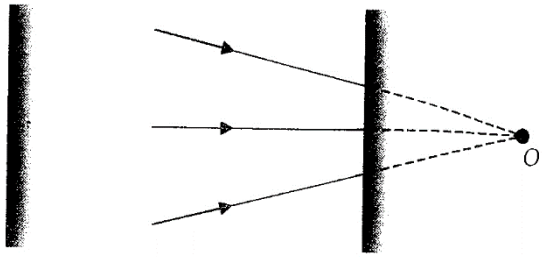
An optical object is decided by incident rays only. It is of two kinds:

(a) Real object: In this case incident rays are diverging and point of divergence is the position of real object.

(b) Virtual object: In this case incident rays are converging and point of convergence is the position of virtual object.



(a) Real object

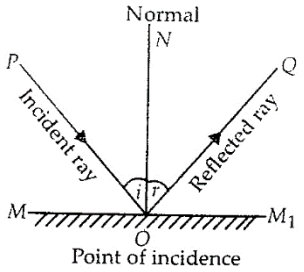


(b) Virtual object

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

Reflection of Light

When a beam of light is incident on a polished interface, is thrown back in same medium. This phenomenon is called reflection.



In reflection the frequency, speed and wavelength do not change, but a phase change may occur depending on the nature of reflecting surface.

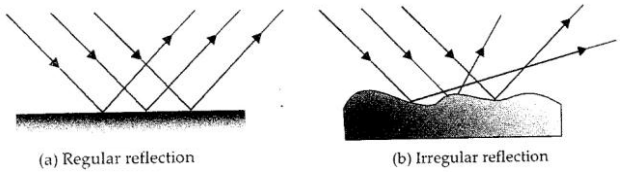
- **Associated Terms**

1. **Reflecting surface:** The surface from which the light is reflected, is called the reflecting surface.MM_1 is the reflecting surface.
2. **Point of incidence:** The point on the reflecting surface at which a ray of light strikes, is called the point of incidence.
3. **Normal:** A perpendicular drawn on the reflecting surface at the point of incidence, is called the normal. NO is the normal.
4. **Incident ray:** The ray of light which strikes the reflecting surface at the point of incidence is called the incident ray.
5. **Reflected ray:** The ray of light reflected from the reflecting surface, is called the reflected ray. OQ is the reflected ray.
6. **Angle of incidence:** The angle that the incident ray makes with the normal, is called the angle of incidence. It is represented by the symbol *i*. Angle PON is the angle of incidence.
7. Angle of reflection: The angle that the reflected ray makes with the normal, is called the angle of reflection. It is represented by the symbol r. QON is the angle of reflection.
8. **Plane of incidence:** The plane in which normal and the incident ray lie, is called the plane of incidence. The plane of the book-page, is the plane of incidence.
9. **Plane of reflection:** The plane in which the normal and the reflected ray lie, is called the plane of reflection. The plane of the book-page, is the plane of reflection.

- **Types of Reflection**

(a) 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.

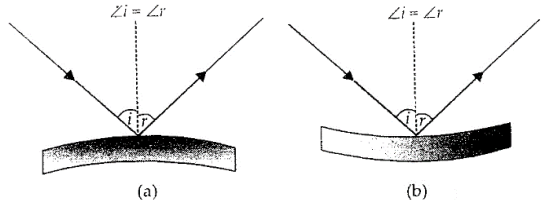
(b) Irregular reflection: The reflection of light from a rough irregular surface such as walls of a room, page of a book randomly in various directions not parallel to each other as shown in figure (b) are called irregular reflection.



Laws of Reflection

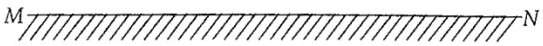
The phenomenon of reflection is governed by following two laws:

- **First law:** The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence, all lie in one plane which is perpendicular to the reflecting surface.
- **Second law:** The angle of incidence is equal to the angle of reflection. $\angle i = \angle r$.
  Note: The laws valid for any smooth reflecting surface irrespective of geometry.

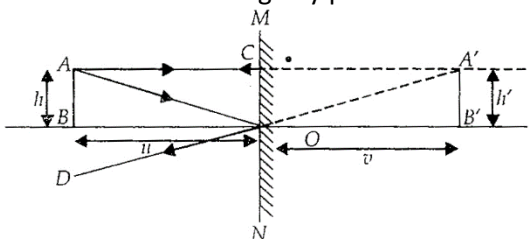


Plane Mirror

A highly polished plane (flat) surface is called a plane mirror, e.g., looking glass.



Formation of image by plane mirror:



(a) The image is a virtual image and it is erect (up right).
(b) 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 (11) = image distance (v).
(c) The image is of the same size as the object. [∵ AB (height of the object) = A'B' (height of the image).]
(d) The image is laterally inverted.
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 onscreen.

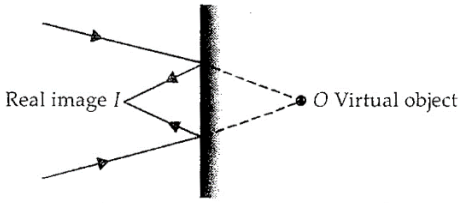


Fig.: Plane mirror showing real image formation of a virtual object

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

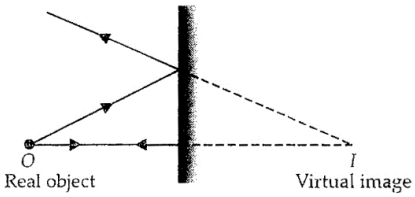


Fig. : Plane mirror showing virtual image formation of a real object.

Note: Human eye can't distinguish between real and virtual image because in both case rays are diverging.
Difference between Real and Virtual images are given in table

	Real Image	Virtual Image
1.	Real image is formed: When reflected or refracted light rays actually intersect at a point.	Virtual image is formed: When reflected or refracted light rays do not actually intersect at a point but appear to meet at a point.
2.	Real image can be obtained on a screen.	Virtual image can be obtained on a screen.
3.	Real image is inverted: (i) In case of mirror: Real image is formed in front of a mirror. (ii) In case of lens: Real image is formed on the other side of a lens.	Virtual image is erect. (i) In case of mirror: Virtual image is formed, behind (or inside) a mirror. (ii) In case of lens: Virtual image is formed on the same side of the object (in front).

Properties of image formed by plane mirror

- The image formed in a plane mirror is as far behind as the object is in front of it.
- The image formed by the plane mirror is erect, virtual laterally inverted.
- When two plane mirrors are inclined to each other at an angle θ, the number of images of a point object formed as follows:

(a) $\frac{360°}{\theta} = n$ is an even integer, then number of images formed is (n - 1) for all positions of the object.

For example: If $\theta = 90°$, $\frac{360°}{60°} = 4$ (even) and number of images is 3. If $\theta = 60°, \frac{360°}{60°} = 6$, number of images is 5.

(b) If $\frac{360°}{\theta} = n$ is an odd integer, the number of images formed is n, if the object does not lie on the plane which bisects the angle between mirrors and (*n*-1), if the object lies on the plane which bisects angle between the mirrors.

For example: If $\theta = 72°, \frac{360°}{72°} = 5$ if object lies a symmetrically, number of images is 5 and if symmetrically number of images is 4.

(c) If $\frac{360°}{\theta}$ is a fraction, the number of images formed will be equal to the integral part.

For example: If $\theta = 80°, \frac{360°}{80°} = 4.5$, number of images formed is 4. If $\theta = 70°, \frac{360}{70} = 5.14$, number of images is 5.

ACTIVITY CORNER

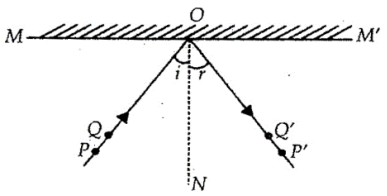
The experiment to verify laws of reflection.

For this activity you need plane mirror, four pens, scale and protractor, white paper and drawing board. Draw a straight line

MM' on a white paper fixed to the drawing board. Draw a perpendicular to MM' and name it ON.

Draw a line PO such that it makes suitable acute angle with the normal as shown is figure. Now place a plane mirror on MM'. Fix two pine P' and Q' on the line PO. FO is the incident ray. Looking from the other side of the normal observe the image of the pins P and Q.

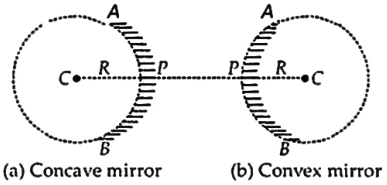
Fix two more pins P' and Q' in line with the images of the pins P and Q. Remove the plane mirror. Join P' and 0. OP' gives the reflected ray. Measure $\angle$ PON and $\angle$ P'ON. $\angle$ PON gives the angle of incidence and $\angle$ P'ON gives the angle of reflection. Repeat the experiment for different angles of incidence and tabulate the results. You can see that angle of incidence is always equal to angle of reflection.



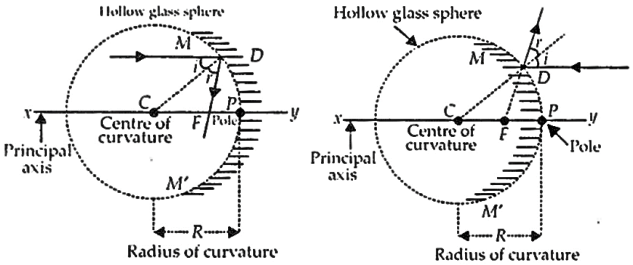
Spherical Mirrors

Spherical mirrors are part of spherical reflecting surfaces. They are made from hollow glass spheres.

If a portion of the hollow sphere is cut along a plane and silvered, it serves as a spherical mirror. If the portion APB is silvered such that the depressed surface becomes, the reflecting surface then it is called **Concave spherical mirror**. On the other hand, if the silvering is done so that the surface bulging outwards serves as the reflecting surface, then it is called Convex spherical mirror.



- **Concave mirror:** A concave mirror is one at which the reflection takes place at inner surface and whose outer surface is polished.
- **Convex mirror:** A convex mirror is one at which reflection takes place from outer surface and whose inner surface is polished.



Few Definitions:

(a) Centre of curvature: The centre of the hollow sphere of which mirror forms a part is called the center of curvature of the mirror. It is represented by point C.

(b) Radius of curvature: The radius of the sphere, of which the mirror forms a part is called the radius of curvature of the mirror. It is represented by R. The distance PC = R represents the radius of curvature of the mirror.

(c) Pole: The centre of the spherical mirror is called the pole. It is denoted by point P.

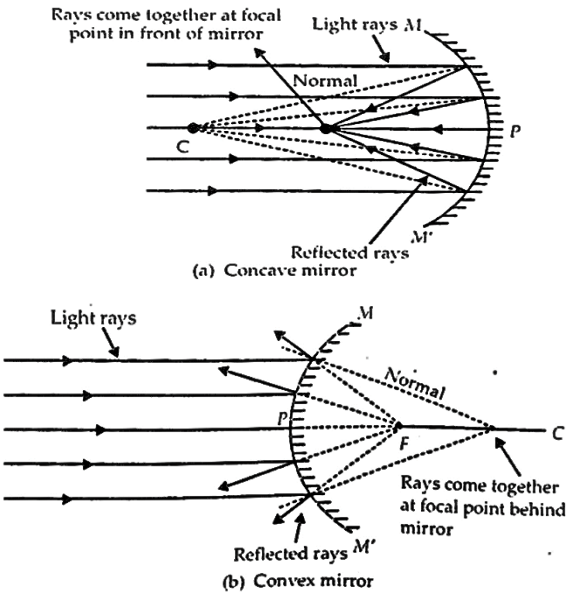
(d) Principal axis: The line joining the pole and the centre of curvature of the mirror is called the principal

axis of the mirror. The line PC extended both ways represents the principal axis of the mirror.

(e) Aperture: The diameter of the mirror is called aperture of the mirror. In figure (a) and (b) AB represents the aperture of the mirror.

(f) Principal focus: The point at which a narrow beam of light moving parallel to its principal axis, meets or appears to meet after reflection from the mirror, is called the principal focus of the mirror. It is represented by F.

In case of a concave mirror, the rays of light incident parallel to the principal axis, after reflection actually meet at point F. On the other hand, in case of a convex mirror, the rays of light incident parallel to principal axis, after reflection from the mirror do not meet at F but appear to come from it, when produced backward.



(g) Focal length: The distance between the pole and the principle focus of the mirror is called the focal length of the mirror. It is denoted by f. The distance PF= f represents the foal length of the spherical mirrors i.e., concave and convex mirrors.

Assumptions and Sign Convention

- All distances are measured from the pole of the mirror.
- Distances actually traversed in the direction of light are taken as positive and those in the opposite direction are taken as negative.

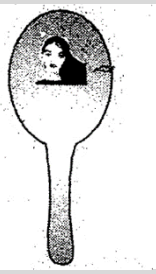
ACTIVITY CORNER

If we hold a steel spoon (polished by rubbing a fine cotton cloth it) close to our face, what do we observe?

When the highly polished spoon is held close to our face, we see the image of our face. It appears bigger, but, if we move the spoon slowly away from our face, does the image change? Yes, the image becomes smaller and smaller and it appears inverted.

We now reverse the spoon, how does the image look now? The image is erect but smaller in size.

Real, inverted and enlarged image formed by the surface of the spoon curved inwards

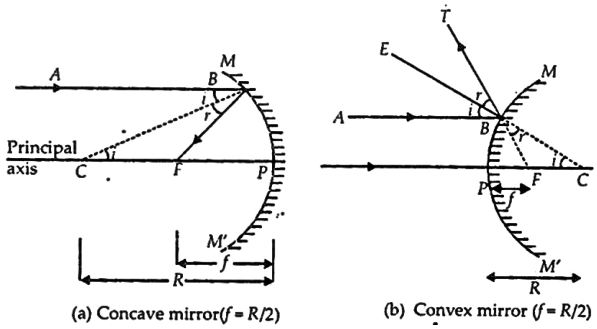


Virtual, erect and small sized image formed by the surface of the spoon bulged out word

- **Conclusion:** We may now understand that the surface or the spoon curved inwards can be approximated to a concave mirror. The image formed by the surface of the spoon curved inwards is inverted and real. When the object is near the surface, the image is enlarged but the size of the image becomes smaller and smaller as the object is moved away from the surface of the spoon. The image formed by the surface of the spoon bulged outwards can be approximated to a convex mirror. The image formed by the surface of the spoon bulged outward is erect and virtual and of smaller size.

- **Relation between Focal Length And Radius Of Curvature**

Consider a ray of light coming from infinity incident on a spherical mirror at B. If the mirror is concave, it meets at F after reflection. If the mirror is convex, it appears to come from F after reflection.



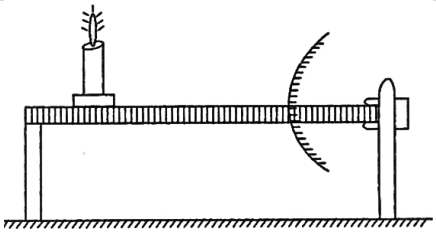
(a) Concave mirror($f = R/2$) (b) Convex mirror ($f = R/2$)

Ray diagram to drive the relation between radius of curvature and focal length of a concave mirror and convex mirror.

ACTIVITY CORNER

Based on image formation by convex mirror.

Place two trolleys on the rails of the optical bench. On one trolley fix a convex mirror such that its reflecting surface is towards the other trolley. Fix a pen on the other trolley. Place the two trolleys as close as possible. You will see a virtual and erect image of the pen when you watch the reflecting surface of the mirror. The image will appear behind the mirror. Now move the trolley (on which the pen is attached) away from the trolley on which the mirror is fixed. Simultaneously see the reflecting surface of the mirror to watch the image. You will find that the image remain virtual and erect but decreases in size and it moves away from the mirror towards the focus of the mirror.



Conclusion: When the object moves away from the convex mirror, the image also moves from the convex mirror towards its focus and simultaneously its size decreases. The image remain virtual and erect throughout.

Mirror Formula

- Mirror Formula for Concave Mirror Object distance (measured from P to A)
  PA = $-u$ (Object on the left to the mirror)
  Image distance (measured from P to A')
  PA' = $-v$ (Image on the left of the mirror)
  Focal length (measured from P to F)
  PF = $-f$ (Focus on the left of the mirror)in similar triangle A'B''F and triangle NXF

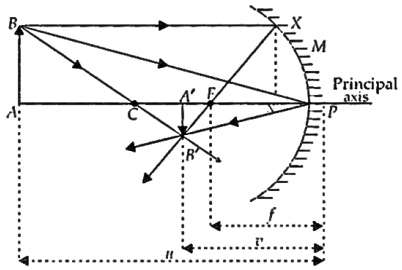


Fig. : Ray diagram for a concave mirror real image formula.

$\frac{A'B'}{NX} = \frac{FA'}{FN} = \frac{A'P - FP}{FP}$ (For mirror of small aperture N is near P, FN = FP)

Putting values, with proper sign

$$\frac{A'B'}{NX} = \frac{-v-(-f)}{-f} = \frac{v-f}{f} \quad \text{... (i)}$$

in similar triangles A'B'P and ABP ($\angle A'PB' = \angle APB$)

$$\frac{A'B'}{AB} = \frac{A'P}{AP} = \frac{-v}{-u} = \frac{v}{u} \quad \text{...(ii)}$$

But, NX = AB

Hence, from equations (i) and (ii), $\frac{v-f}{f} = \frac{v}{u}$

Cross-multiplying, $uv - uf = vf$

Transposing, $-vf - uf = -uv$

Changing sign and dividing by uvf, we get $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

ILLUSTRATION

1. An object is placed at a distance of 20.0cm from a concave mirror of focal length 15.0 cm. At what distance from the mirror, should aj screen be placed to get the sharp image?

Sol.: Here,

$f = -15.0$ cm (sign convention)

$u = -20.0$ cm

Determination of the position of image.

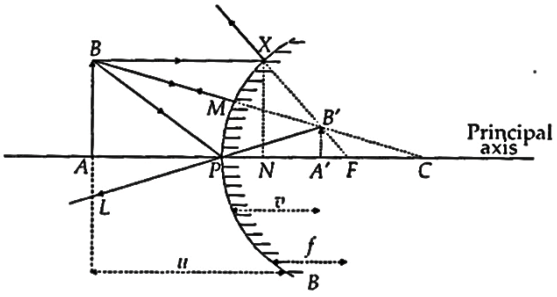
Using $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$, we get

$$\frac{1}{u} = \frac{1}{f} - \frac{1}{u} = -\frac{1}{15} - \frac{1}{(-20)}$$

Or $\frac{1}{v} = \frac{1}{15} + \frac{1}{20} = -\frac{1}{60}$ or $u = -60$ cm

So the screen must be placed at a distance of 60 cm in front of the concave mirror.

- **Mirror Formula for Convex Mirror**



Ray diagram for a convex mirror which mostly forms a virtual images

Object distance (measured from P to A)
$PA = -u$ (Object on the left of the mirror)
Image distance (Measured from P to A),
$PA' = +v$ (Image on right of the mirror)
Focal length (measured from F to F),
$PF + = f$ (Focus on right of the mirror)
In similar triangles, AW and NXF,

$$\frac{A'B'}{XN} = \frac{FA'}{FN} = \frac{PF - PA'}{FP} = \frac{f - v}{f} \quad \text{... (i)}$$

In similar triangles A'B'P and ABP
$(\angle APB = \angle APL = \angle A'PB')$

$$\frac{A'B'}{AB} = \frac{PA'}{PA} = \frac{v}{-u}$$

But NX = AB $\frac{A'B'}{NX} = \frac{A'B'}{AB}$

Hence, from equation (i) and (ii), $\frac{f - v}{f} = \frac{v}{-u}$

Cross multiplying, $-uf + uv = vf$
Transposing, $-vf - uf = -uv$

Changing sign and dividing by uvf, we get, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Notes:

- Mirror equation is valid for both type of mirrors and for any type of object irrespective of its positions
- In case of spherical mirrors if object distance (x_1) and image distance (x_2) are measured from focus instead of pole, then
  $u = f + x_1$ and $v = f + x_2$ the mirror formula reduces to
  $\frac{1}{f + x_2} + \frac{1}{f + x_1} = \frac{1}{f}$ or $x_1 x_2 = f^2$
  Which is known as Newton's formula. This formula is applicable to real objects and real images.
- In numerical problems it is convenient to use mirror equation in following form
  $v = \frac{uf}{u - f}, u = \frac{vf}{v - f}, f = \frac{uv}{u + v}$
- While using mirror equation known quantities are to be substituted with proper sign and quantities to be calculated (unknown quantities) are not be given any sign.

ILLUSTRATION

2. An object is placed at a long distance in front of a convex mirror of radius of curvature 30 cm. State the position of its image.

Sol: Here, using sign convention Object distance $u = \infty$ (infinite)
Radius of curvature, R = 30 cm (center of right of mirror)
Focal length $f = \frac{R}{2} = 15$ cm
Image distance, $v = ?$
From mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
We have, $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$
Putting values, we get, $\frac{1}{v} = \frac{1}{15} - \frac{1}{\infty} = \frac{1}{15}$
or
The image is formed at a distance 15 cm to the right of the mirror. The image lies at focus.

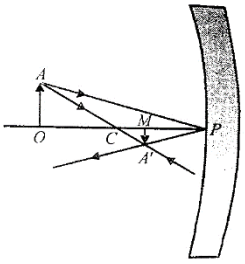
Magnification

This is defined as the ratio of size of image to the size of object.

Magnification (m) $\frac{\text{size of image(I)}}{\text{Size of object(o)}}$

Three types of magnification are produced by a spherical mirror.

- **Linear Magnification (Transverse Magnification/Lateral Magnification)**
  In this case, size of object and image is measured perpendicular to principal axis.
  $\text{m} = \frac{\text{Height of image(I)}}{\text{Height of object (o)}}$
  From similar triangles APO and ATM.
  $$\frac{AO}{A'M} = \frac{PO}{PM} \quad \text{...(i)}$$



$$\frac{O}{-I}=\frac{-u}{-v}$$

or, $\frac{I}{O}=-\frac{v}{u}$

Thus, $m=-\frac{v}{u}$

- The above formula is valid for convex as well as concave mirror and it is independent of nature of object (real or virtual) irrespective of its position.
- In terms of focal length, magnification can be expressed as: $m=\frac{f}{f-u}=\frac{f-v}{f}$
- Magnification can be either positive or negative depending on the nature of the image. If m is negative, then image is inverted with respect to object.
- Real image is not always inverted and virtual image is not always erect.

- **Superficial Magnification**

  When a small surface is placed perpendicular to the principal axis, length and breadth are magnified in the ratio $\frac{v}{u}$. The superficial magnification is:

  $$m_s=\frac{\text{Area of image}}{\text{Area of object}}=\left(\frac{-v}{u}\right)\left(\frac{-v}{u}\right)=\frac{v^2}{u^2}$$

- Axial Magnification (Longitudinal Magnification)

  In this case size of image and object is measured along principal axis

  $$m=\frac{\text{Length of image}}{\text{Length of object}}$$

  For linear object placed along the principal axis, the magnification is

  $$m_L=\frac{v_A-v_B}{u_A-u_B}$$

Notes:

- For small object $m_L=\frac{dv}{du}$

  From mirror equation, we have, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

  Differentiating both sides, we get,

  $-\frac{1}{v^2}dv-\frac{1}{u^2}du=0$ or $\frac{dv}{du}=-\frac{v^2}{u^2}$

  Thus, longitudinal magnification = (Transverse magnification)^2.

ILLUSTRATION

3. A concave mirror produces four times magnified image of an object placed at 10 cm from it. Find the position of the image.

Soln.: Here, $u=-10$ cm (sign convention)

$m=4$, but $m=-\frac{v}{u}$ or $4=-\frac{v}{u}$

$\therefore v=-4u=-(-10\,\text{cm})=40$

Thus, image of the object is at 40 cm from the pole of the mirror and behind the mirror.

4. An object 4 cm high is placed at a distance of 6 cm in front of a concave mirror of focal length 12 cm. Find the position, nature and size of the image formed.

Soln.: Here, size of object, h = 4 cm

$u=-6$ cm (sign convention)

$f=-12$ cm (sign convention)

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

$-\frac{1}{6}+\frac{1}{v}=-\frac{1}{12}$ or $\frac{1}{v}=-\frac{1}{12}+\frac{1}{6}=\frac{1}{12}$

or $v=12$ cm

Thus, image is formed at a distance of 12 cm behind the concave mirror as v is positive. Therefore, image is virtual in nature.

Step 2. Using $\frac{h'}{h}=\frac{-v}{u'}$ we get

$$h'=-\frac{v}{u}\times h=\frac{-12\,\text{cm}}{-6\,\text{cm}}\times 4\,\text{cm}=8\,\text{cm}$$

So, image is 8 cm tall. Since *h*, is positive, so image is erect.

Difference between concave and convex mirrors

	concave mirror	convex mirror
1.	Its focus is situated in front of the mirror.	Its focus is situated behind the mirror.
2.	Its radius of curvature and the focal length are negative,	Its radius of curvature and focal length are positive.
3.	The incident rays are reflected from its concave surface.	The incident rays are reflected from its convex surface.
4.	Its convex side is polished.	Its concave side is polished.
5.	The image distance for this may be positive or negative because the	The image distance is always positive.

	real image is formed in front of the mirror and virtual image is formed behind the mirror.	
6.	The image formed by it may be erect inverted magnified or smaller.	The image formed by it is erect and smaller.
7.	Its field of view is narrow.	Its field of view is broad.
8.	Concave mirrors are used as make-up mirrors, as reflectors, for medical purposes in light houses in seas, in ophthalmoscope, in torch for hunting	Convex mirrors are used in night lamps on roads and as side mirrors in cars to view the vehicles behind.

ACTIVITY CORNER

To distinguish different type of mirrors

Take a plane mirror to observe the image of a distant object, saya distant tree. The mirror does not show full length image of the distant tree. With the plane mirrors of different sizes also, we could not see the entire image of the object.

Take the concave mirror to observe the image of the same distant tree. Even the concave mirror does not show full length of the object.

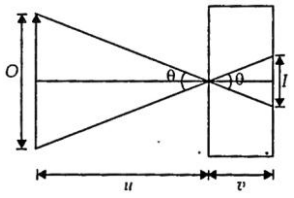
Repeat this activity using a convex mirror. We can full length of distant tree but it is very disminished in size.

- Conclusion: Only a convex mirror gives a wide field to view as it is curved outwards.

Pinhole Camera

It is based on rectilinear propagation of light and forms the so called image on the screen which is real and inverted as shown in the figure. If an object of size 0 is situated at a distance it from the pinhole and its image of size I is formed at distance;' from the pinhole:

$$\theta = \frac{O}{u} = \frac{1}{v} \text{ i.e., } \frac{1}{O} = \frac{v}{u}$$



So, in case of pinhole camera:

- If two objects of same size are placed at different distances from pinhole, greater the distance of the object from pinhole lesser will be 6 and so smaller will be the image.
- If the image of two objects is of same size.

  i.e., $\theta_1 = \theta_2 = \theta, \frac{O_1}{u_1} = \frac{O_2}{Q_2}$ or $\frac{O_1}{O_2} = \frac{u_1}{u_2}$

  i.e., if the ratio of size of objects is equal to the ratio of their distance from the pinhole, images will be of equal size.
- If the size of pinhole is reduced the increase will be reduced and image will become blurred due to diffraction effects. However, if the size of hole is increased intensity will increase and image will again become blurred but this time due to super-position of images formed by different rays passing through the hole.
- The image formed on the screen by the pinhole camera is neither a shadow nor a true image. It is not a shadow as it is not dark and is not an image as the rays of light do not intersect each other and cannot be seen as an aerial image in absence of screen. It is the illuminated region of the screen by the hole through the light from the object.

ESSENTIAL POINTS For COMPETITIVE EXAMS

- **Light:** Light is a form of energy which produces the sensation of light.
- **Ray of light:** A line drawn in the direction of propagation of light is called ray of light.
- **Beam of light:** A group of parallel rays of light emitted by a source of light is called beam of light.
- **Laws of reflection:**
  (i) The angle of incidence is equal to the angle of reflection
  (ii) The incident ray the normal to the mirror at the point of incidence and the reflected ray all lie in the same plane.
- **Plane mirror:** It always forms a virtual, erect, laterally inverted image formed behind the mirror and has the same size as the object.
- **Concave mirror:** Concave mirror is a part of a hollow sphere whose outer part is silvered and inner part is the reflecting surface.
- **Convex mirror:** Convex mirror is a part of a hollow sphere whose outer part is reflecting surface and inner part is silvered.
- **Spherical mirror:** A reflecting surface which is a part of a sphere in which inner or outer surface is reflecting.
- **Centre of curvature:** The centre of a hollow sphere of which the spherical mirror forms apart is called centre of curvature. It is denoted by C.

- **Radius of curvature:** The radius of a hollow sphere of which the spherical mirror forms apart is called radius of curvature. It is denoted by R.
- **Pole:** The midpoint of a spherical mirror is called its pole. It is denoted by P.
- **Aperture:** The part of a spherical mirror exposed to the incident light is called the aperture of the mirror.
- **Principal axis:** A line joining the centre of curvature (C) and pole (P) of a spherical mirror and extended on either side is called principal axis of a spherical mirror.
- **Principal focus:** A point on the principal axis of a spherical mirror where the rays of light parallel to the principal axis meet or appear to meet after reflection from the spherical mirror is called principal focus. It is denoted by F.
- **Focal plane:** A plane normal or perpendicular to the principal axis and passing through the principal focus (F) of the spherical mirror is called focal plane of the spherical mirror.
- **Focal length (f):** The distance between the pole (P) and the principal focus (F) of a spherical mirror is called the focal length of the spherical mirror.
  (i) $f = \frac{R}{2}$ where R is the radius of curvature of the mirror.
  (ii) Focal length and radius of curvature of a concave mirror are negative.
  (iii) Focal length and radius of curvature of a convex mirror are positive.
- **Real image:** The image which can be obtained on the screen is called real image. It is inverted with respect to the object.
- **Virtual Image:** The Image which cannot be obtained on the screen is called a virtual image. It is erect with respect to the object.
- **Mirror Formula:** The relation between u, v and focal length (f) of a spherical mirror is known as mirror formula. That is, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$
- **Magnification:** m = Height of the image (h')Height of the object and also, m = – image distance (v)/object distance (u) So we can get $m=\frac{h'}{h}=-\frac{\upsilon}{u}$

SOLVED EXAMPLES

1. The radius of curvature of a spherical mirror is 30 cm. Find the focal length of this mirror.

Sol. Here $R = 30cm$

Using, $f = \frac{R}{2}$, we have

$$f = \frac{30cm}{2} = 15cm.$$

Thus, focal length of the spherical mirror $= 15\ cm$

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.

Sol. Here, $h = +4.0\ cm$

$u = -25.0\ cm$ (sign conventions)

$R = +40\ cm$

$$\therefore \quad f = \frac{R}{2} = \frac{40}{2} = 20.2cm$$

Step 1. Determination of the position of the image.

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

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

$$\upsilon = \frac{100}{9} = 11.11cm$$

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

Step 2. Determination of size and nature of image.

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

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

Thus, size of image $= -1.78\ cm.$

Since h' is negative, so the image is inverted.

3. A convex mirror used in a bus has radius of curvature 3.5 m. If the driver of the bus locates a car at 10.0 m behind the bus, find the position, nature and size of the image of the car.

Sol. Here, $R = 3.5m$

$$f = \frac{R}{2} = \frac{3.5}{2} = 1.75m$$

$u = -10.0m$

Step 1. Determination of the position of the car.

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

$$\frac{1}{\upsilon}=\frac{1}{f}-\frac{1}{u}=\frac{1}{1.75}-\frac{1}{(-10)}=\frac{1}{1.75}+\frac{1}{10}=\frac{47}{70}$$

$$\text{Or } \upsilon = \frac{70}{47} = 1.5m$$

Thus, the car appears to be at 1.5 m from the convex mirror.

Step 2. Determination of the size and nature of the image.

Using, $m = -\frac{\upsilon}{u}$, we get

$$m = \frac{-1.5}{(-10)} = 0.15$$

Thus, the size of the image of the car is 0.15 times the actual size of the car.

Since m is positive, so image of the car is erect (i.e., upright)

4. 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 distance of 3.5 m. Calculate (i) the position, and (ii) the size of the image relative to the size of the truck. What will be the nature of the image?

Sol. Here, $R = 2.0m$

$$\therefore \quad f = \frac{R}{2} = \frac{2.0}{2} = 1.0m$$

$$u = -3.5m$$

Step 1. Determination of position of truck

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

$$\frac{1}{\upsilon} = \frac{1}{f} - \frac{1}{u} = \frac{1}{1} + \frac{1}{3.5} = \frac{4.5}{3.5} \text{ or } \upsilon = \frac{3.5}{4.5} = .078m$$

Thus, the truck appears to be at 0.78 m from the convex mirror.

Step 2. Determination of size and nature of the image

Using, $m = -\frac{\upsilon}{u} = \frac{-3.5/4.5}{-3.5} = \frac{1}{4.5} = \frac{2}{9}$

Thus, size of the image of the truck is $\frac{2}{9}$ times the actual size of the truck.

Since m is positive, so image of the truck is erect and. virtual.

5. An object is placed at a distance of 20 cm from a convex mirror of focal length 10 cm. Find the position and nature of the image.

Sol. Here, $f = 10cm$ (sign convention)

$u = -20\ cm$ (sign convention)

Step 1. Using, $\frac{1}{f} = \frac{1}{u} + \frac{1}{\upsilon}$ we have

$$\frac{1}{10} = -\frac{1}{20} + \frac{1}{\upsilon}$$

$$\text{or } \frac{1}{\upsilon} = \frac{1}{10} + \frac{1}{20} = \frac{2+1}{20} = \frac{3}{20} \therefore \upsilon = \frac{20}{3} 6.67cm$$

Step 1. $m = -\frac{\upsilon}{u} \therefore = \frac{-(20/3)}{(-20)} = \frac{1}{3}$

Since magnification is positive, so image formed is virtual.

6. An object 3 cm 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.

Sol. Here size of object, $h = 3\ cm$

$u = 10\ cm$ (sign convention)

$f = -20\ cm$ (sign convention)

Step 1. Using $\frac{1}{u} + \frac{1}{\upsilon} = \frac{1}{f}$, we have

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

$$\therefore \upsilon = 20cm$$

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

Step 2. Using, $m = \frac{h'}{h} = \frac{\upsilon}{u}$, we get

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

or $h' = 2 \times h = 2 \times 3cm = 6cm$

Thus, size of the image is 6 cm.

7. The radius of curvature of a concave mirror is 36 cm. What is the focal length of this mirror?

Sol. Here,

Radius of curvature, $R = 36\ cm$

Focal length, $f = ?$

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

$$f = \frac{36}{2} = 18$$

$$f = 18cm$$

8. 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.

Sol. Here, (using sign convention)

Focal length, $f = -10\ cm$ (focus on left of mirror)

Object distance, $u = -8cm$ (object on left of mirror)

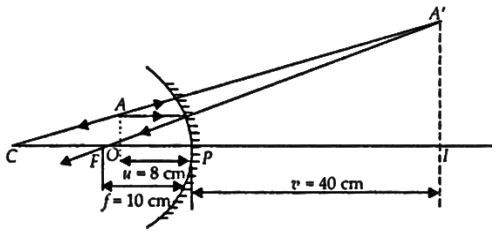
Image distance, $v = ?$ (to be calculated)

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

Putting values, we get

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

$$\upsilon = +40\ cm$$



The image is formed at distance40 cm behind the mirror, (on the positive side).

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.

9. An object 4.0 cm in size is placed 25.0 cm in front of 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 size of the image.

Sol. Here, using sign convention

Focal length, $f = -15\ cm$ (focus on left of mirror)

Object distance, $u = -25\ cm$ (object on left of mirror)

Object size, $h_1 = +4\ cm$ (erect object)

Image distance, $v = ?$

(i) Position of screen for image

From mirror formula. $\frac{1}{u} + \frac{1}{\upsilon} = \frac{1}{f}$

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

Putting values, we get,

$$\frac{1}{u} = \frac{1}{-15} - \frac{1}{-25} = \frac{-5+3}{75} = \frac{-2}{75}$$

Image distance, $\upsilon = \frac{-75}{2} = -37.5cm$

Screen must be placed at distance 37.5 cm from the mirror and in front of it.

(ii) Nature of image. Since the image is formed on the screen on the left, its nature, is real inverted.

(iii) Size of image:

From relation, in $m = \frac{h_2}{h_1} = -\frac{\upsilon}{u}$

We have, $h_2 = (-h_1)\frac{\upsilon}{u}$

Putting values, we get $h_2 = -4 \times \frac{-37.5}{-25} = -6$

The image formed has size 6 cm (negative sign means inverted and real).

10. Find the size, nature and position of image formed when an object of size 1 cm is placed at a distance of 15 cm from a concave mirror of focal length 10 cm.

Sol. Here, using sign convention

Object distance, $u = -15\ cm$ (object on left of mirror)

Focal length, $f = -10\ cm$ (focus on left of mirror)

Object size, $h_1 = 1cm$ (erect object)

Image distance, $\upsilon = ?$

Image size, $h_2 = ?$

(i) Position of image

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

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

Putting values, we get

$$\frac{1}{\upsilon} = \frac{1}{-10} - \frac{1}{-15} = \frac{-3-(-2)}{30} = -\frac{1}{30}$$

$\upsilon = -30cm.$

The image is formed at distance 30 cm on the left side (negative sign means on the left).

(ii) Nature of image. Since the image is formed on left of the mirror, its nature is real-inverted.

(iii) Size of image

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

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

Putting values, we get $h_2 = -1 \times \frac{-30}{-15} = -2$

Image size, $h_2 = -2cm.$

The image formed has size 2 cm (negative sign means inverted, and real)

11. An object 2 cm high is placed at a distance of 16 cm from a concave mirror which produces a real image 3 cm high.

(i) What is the focal length of the mirror?

(ii) Find the position of the image.

Sol. Here, (using sign convention)

Object height, $h_1 = +2cm$ (erect upward)

Image height, $h_2 = -3cm$ (real downward)

Object distance, $u = -16cm$ (object on left of mirror)

Focal length, $f = ?$

Image distance, $u = ?$

(i) Position of image

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

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

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

$$\upsilon = -24\ cm.$$

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

(ii) Focal length of mirror

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

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

Putting values, we get $\frac{1}{f} = \frac{1}{-16} + \frac{1}{-24} = \frac{-3-2}{48} = -\frac{5}{48}$

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

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

12. An object 5 cm high is placed at a distance of 10 cm from a convex mirror of radius of curvature 30 cm. Find the nature, position and size of the image.

Sol. Here, using sign convention

Object height, $h_1 = +5cm$ (erect upward)

Object distance, $u = -10\ cm$ (object on left of mirror)

Radius of curvature, $R = +30\ cm$ (centre of right of mirror)

Focal length, $f = \frac{R}{2} = 15cm$

Image distance, $u = ?$

(i) Position of image

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

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

Putting values, we get $\frac{1}{\upsilon} = \frac{1}{15} - \left(\frac{1}{-10}\right) = \frac{2+3}{30} = \frac{5}{30}$

or $\upsilon = 6\ cm.$

The image is formed at a distance of 6 cm behind the mirror. ($\therefore$ u is positive)

It is a virtual image.

(ii) Size of image

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

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

Putting values, we get $h_2 = -\frac{5 \times 6}{-10} = 3cm$

The image is 3 cm high. It is virtual erect, because h_2 is positive.

13. A convex mirror used on an automobile has 3.00 m radius of curvature. If a bus is located at5.00 m from the mirror; find the position, nature and size of the image.

Sol. Here, (using sign convention)

Radius of curvature, $R = +3\ m$ (centre of the right of mirror)

Focal length, $f = \frac{R}{2} = +1.5m$

Object distance, $u = -5m$ (object on the left of mirror)

Image distance, $u = ?$

Image size, $h_2 = ?$

(i) Image Position

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

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

Putting values, we get, $\frac{1}{\upsilon} = \frac{1}{1.5} - \frac{1}{-5} = \frac{10+3}{15} = \frac{13}{15}$

Image distance, $\upsilon = \frac{15}{13} = 1.15m$

Image is formed at distance 1.15 m behind the mirror.

(ii) Size of image

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

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

Putting values, we get, $h_2 = h_1\frac{15/13}{-5} = \frac{3}{13}h_1 = 0.23h_1$

Image size is (0.23) of the object size.

(Positive means erect virtual image)

14. 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.

Sol. We know that, $m = -\frac{\upsilon}{u} = \frac{f}{f-u}$

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

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

Since $\dfrac{m_1}{m_2} = 4$, therefore, $\dfrac{f+40}{f+25} = 4$; Thus

$f + 40 = 4f + 100$ or $f = -20cm$

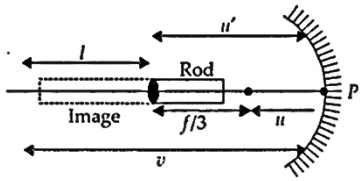
The negative sign shows that the mirror is concave.

15. A thin rod of length $f/3$ is placed along the optical axis of a concave mirror of focal length f such that its image which is real and elongated just touches the rod. Calculate the magnification.

Sol. Let l be the length of the image, then

$m = \dfrac{l}{f/3} \Rightarrow l = \dfrac{mf}{3}$

Also image of one end coincides with the object $u' = 2f$



$u' = u + \dfrac{f}{2} \Rightarrow u = 2f - \dfrac{f}{3} = \dfrac{5f}{3}$

$\upsilon = -\left(u + \dfrac{f}{3} + \dfrac{mf}{3}\right)$

Putting in mirror formula,

$\dfrac{1}{u + (f/3) + (mf/3)} + \dfrac{1}{u} = \dfrac{1}{f}$

$\Rightarrow \dfrac{3}{5f + f + mf} + \dfrac{3}{5f} = \dfrac{1}{f}$

$\Rightarrow \dfrac{1}{m+6} = \dfrac{2}{15} \Rightarrow m = \dfrac{3}{2}.$

16. An object 1 cm high is placed at 10 cm in front of a concave mirror of focal length 15 cm. Find the position, height and nature of the image.

Sol. Mirror formula, $\dfrac{1}{\upsilon} + \dfrac{1}{u} = \dfrac{1}{f}$

Here $u = -10\ cm;\ f = -15\ cm$

or $\dfrac{1}{\upsilon} = \dfrac{1}{10} - \dfrac{1}{15} = \dfrac{15-10}{150} = \dfrac{1}{30} \Rightarrow \upsilon = 30cm$

The positive sign indicates that the images are virtual and erect and it is formed behind the mirror.

The magnification,

$m = \dfrac{-\upsilon}{u} = \dfrac{h_1}{h_O} \Rightarrow h_1 = h_O\left(-\dfrac{\upsilon}{u}\right) = 1\left(-\dfrac{30}{-10}\right) = 3cm$

17. 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?

Sol. 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: $\dfrac{1}{\upsilon} + \dfrac{1}{u} = \dfrac{1}{f}$

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

$m = \dfrac{\upsilon}{u} \Rightarrow 3 = \dfrac{\upsilon}{u} \Rightarrow \upsilon = 3u$

Case I: When image formed is real, $\upsilon = +3u\ cm$

Substituting the given values, we get

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

$\therefore u = -53.33cm$

Case II: When image formed is virtual, $\upsilon = -3u\ cm$

Substituting the given values, we get

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

$\Rightarrow \dfrac{2}{3u} = -\dfrac{1}{40} \Rightarrow u = \dfrac{-80}{3}\ \therefore u = -26.67cm$

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.

18. A concave mirror of focal length 10 cm is kept in front of an object at a distance of 50 cm from it. If the object is 1.0 cm high, what will be the size of the image?

Sol. Given: Focal length $(f) = -10cm$

Distance of the object $(u) = -50cm$

Size of the object $(O) = +1cm$

Formula to be used: $m = \dfrac{-I}{O}$ ... (i)

$\Rightarrow$ But to calculate I, we will have to find out m and to calculate m, we must know υ.

We know that, $\dfrac{1}{u} + \dfrac{1}{\upsilon} = \dfrac{1}{f}$ or $\dfrac{1}{\upsilon} = \dfrac{1}{f} - \dfrac{1}{u}$

Substituting the value of f and u, we get

$$\frac{1}{\upsilon}=-\frac{1}{10}-\left(-\frac{1}{50}\right)=-\frac{1}{10}+\frac{1}{50}\Rightarrow$$

$$\frac{1}{\upsilon}=\frac{-5+1}{50}\Rightarrow \upsilon=-\frac{50}{4}\therefore \upsilon=-12.5cm$$

Now, $m=-\frac{\upsilon}{u}$

Substituting the value of υ and u, we have

$$m=-\frac{-12.54}{-50}=-\frac{1}{4}$$

Now, putting the value of m and O in eq. (i), we get

$$-\frac{1}{4}=-\frac{I}{1.0}\Rightarrow I=0.25cm$$

i.e., the size of the image is 0.25 cm

19. How far from a lamp must a concave mirror of focal length 3.0 m be placed in order to throw its image on the screen 8.0 m from the lamp?

Sol. Given: Focal length $(f)=-3.0m$

Distance of the image $(\upsilon)=-8.0m$

Formula to be used: $\frac{1}{f}=\frac{1}{\upsilon}+\frac{1}{u}\Rightarrow\frac{1}{u}=\frac{1}{f}-\frac{1}{\upsilon}$

Substituting the given values in the mirror formula, we get

$$\frac{1}{u}=\frac{-1}{3.0}-\left(-\frac{1}{8.0}\right)=-\frac{1}{3.0}+\frac{1}{8.0}=\frac{-8+3}{24}=\frac{-5}{24}$$

$$\Rightarrow u=-\frac{24}{5}=-4.8m \qquad \therefore u=-4.8m$$

20. Using the mirror formula obtain relations between m and f .

Sol. Mirror formula can be written as

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

or $1+\frac{\upsilon}{u}=\frac{\upsilon}{f}$ [By multiplying v on both sides]

or $\frac{\upsilon}{u}=\frac{\upsilon}{f}-1=\frac{\upsilon-f}{f}$ or $m=-\frac{\upsilon}{u}=\frac{f-\upsilon}{f}$

$$\therefore m=\frac{f-\upsilon}{f}$$

Also, $\frac{u}{\upsilon}+1=\frac{u}{f}$ [By multiplying u on both sides]

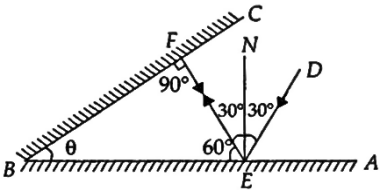
or $\frac{u}{\upsilon}=\frac{u}{f}-1=\frac{u-f}{f}$ or $-\frac{u}{\upsilon}=\frac{f}{f-u}=m$

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

21. 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.

Sol. 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 mirror 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°.

22. A car is fitted with a convex mirror of focal length 20 cm. A second car 2 m broad and1.6 m high is 6 m 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.

Sol. (a) $\frac{1}{\upsilon}+\frac{1}{-600}=\frac{1}{20}$ or $\frac{1}{\upsilon}=\frac{1}{600}$ or

$$\upsilon=\frac{600}{31}cm=19.35cm$$

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

Breadth of image

$$=\frac{1}{31}\times 200\ cm=5.16\ cm$$

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

23. 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?

Sol. **Given:**

Focal length of the mirror $(f)=-3.0\ cm$

Distance of the object $(u)=-2.0\ cm$

Magnification $(m)=?$

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

Since in this case we do not know the value of υ, so first of all we will use the formula,

$\frac{1}{f}=\frac{1}{\upsilon}+\frac{1}{u}$, to calculate v and then we will find out m.

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

Substituting the given values, we get

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

$\therefore \upsilon=6cm$

Since υ is positive, the image is virtual

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

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

24. A concave mirror produces a real image of height 2 cm of an object from 0.5 cm placed10 cm away from the mirror. Find the position of the image and focal length of the mirror?

Sol. Given,

Distance of the object $(u)=-10cm$

Size of the image $(I)=-2cm$

Size of the object $(O)=0.5cm$

Formula to be used:

(i) $m=\frac{I}{O}$

(ii) $m=-\frac{\upsilon}{u}$

and (iii) $\frac{1}{\upsilon}+\frac{1}{u}=\frac{1}{f}$

Since we are given I and O, we will first find m and then from formula (ii) we will find out υ.

From first formula, $m=\frac{I}{O}\Rightarrow m=\frac{-2}{0.5}=-4$

Putting the value of m in formula (ii), we get

$-4=-\frac{\upsilon}{-10}\Rightarrow \upsilon=-40cm$

Now, to find / we will use formula (iii)

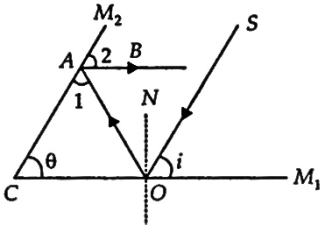
$\frac{1}{f}=\frac{1}{\upsilon}+\frac{1}{u}$

$\Rightarrow \frac{1}{f}=-\frac{1}{40}+\left(-\frac{1}{10}\right)=-\frac{1}{40}-\frac{1}{10}=\frac{-5}{40}$

$\therefore f=-8cm$

Thus, $f=-8cm$ and $\upsilon=-40\ cm$

25. Two plane mirrors are inclined to each other at an angle $\theta=70°$ as shown in following figure. A ray SO of light falls at some angle i on the mirror M_1, falls after reflection from it, on the other mirror M_2 from which it gets reflected along a direction parallel to the plane mirror Mi. Find the value of $\angle$ i.



Sol. As ray reflected from M_2 is parallel to M_1 (From figure)

$\therefore \angle 2=\angle\theta=70°$ (Corresponding $\angle$ S)

Also, $\angle 1=\angle 2=70°$

In $\Delta\ OAC, \theta+\angle 1+\angle AOC=180°$

$70°+70°+\angle AOC=180°$

$\angle\ AOC=180°-140°=40°$

According to the laws of reflection,

$\angle\ i=\angle\ AOC=40°$

26. The image of a real object in a convex mirror is 4 cm from the mirror. If the mirror has a radius of curvature of 24 cm, find the position of object and magnification.

Sol. Mirror formula $\frac{1}{\upsilon}+\frac{1}{u}=\frac{1}{f}$

Here $\upsilon=+4cm;\ f=+\frac{R}{2}=+\frac{24}{2}=+12cm$

Now $u=\frac{\upsilon f}{\upsilon-f}=\frac{(4)(12)}{4-12}=-6cm$

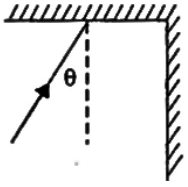
The negative sign shows that the object is real and it is placed in front of the mirror.

The magnification.

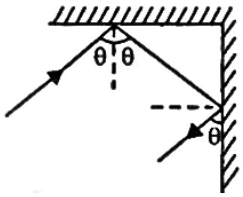
$m=-\frac{u}{\upsilon}=\frac{-(+4)}{-6}=\frac{2}{3}$

Thus, the image is two-third as high as the object.

27. Two plane mirrors are arranged at right angles to each other as shown in the figure. A ray of light is incident on the horizontal mirror at an angle θ. For what value of θ the ray emerges parallel to the incoming ray after reflection from the vertical mirror.



Sol.



The incident and the second reflected ray make the same angle θ with vertical. Therefore, they are parallel for any value of θ

NCERT SECTION

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.

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, $f = \frac{R}{2} = \frac{20}{2} = 10\,\text{cm}$

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 held between pole and principal focus of the mirror.

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.

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

Ans. Given, R = + 32 cm

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

Thus, the focal length of the convex mirror = + 16 cm.

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 $(u) = -10\ \text{cm}$

Image distance $(\upsilon) = ?$

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

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

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.

8. No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be

(a) plane

(b) concave

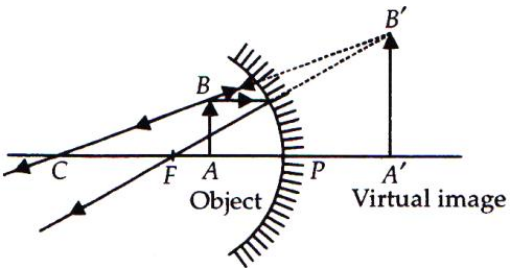
(c) convex

(d) either plane or convex

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

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 15 cm from the concave mirror. The image is virtual and erect. The image is larger than the object. The ray diagram is shown below.



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.

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 $(\upsilon) = ?$

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

$\Rightarrow \quad \frac{1}{\upsilon}=\frac{1}{f}-\frac{1}{u}=\frac{1}{15}+\frac{1}{10}=\frac{5}{30}=\frac{1}{6}$

$\therefore \quad \upsilon = 6\ cm$

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

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.

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 m. Find the position of the image, its nature and size.

Ans.: Here, object size $(h_1)=5.0\ cm$, object distance $(u)=-20\ cm$ radius of curvature (R) = 30 cm, image distance $(\upsilon) = ?$

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

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

$\therefore \quad \upsilon=\frac{60}{7}=8.57\ cm$

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

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

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

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

This is the size of the erect image.

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 $(u)=-27\ cm$ focal length $(f)=-18\ cm$, image distance $(\upsilon) = ?$

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

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

$\therefore \quad \upsilon=-54\ cm$

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

$m=\frac{h_2}{h_1}=-\frac{\upsilon}{u} \Rightarrow \frac{h_2}{7.0}=-\frac{-54}{-27}$

$\therefore$

Negative sign of h_2 shows that the image is inverted.

EXERCISE

Multiple Choice Questions

1. The number of images observable between two parallel mirrors is

(a) 6 (b) infinite

(c) 2 (d) 4

2. The number of images formed by two plane mirrors inclined at an angle 60° of an object placed symmetrically between mirrors is

(a) 5 (b) infinite

(c) 6 (d) 7

3. How many images of himself does an observer see if two adjacent walls and the ceiling of a rectangular room are mirror surfaced?

(a) 6 (b) 7

(c) 3 (d) 5

4. A thick plane mirror shows a number of images of the filament of an electric bulb. of these, the brightest image is the

(a) last (b) fourth

(c) first (d) second

5. A light bulb is placed midway between two plane mirrors inclined at an angle of 40°. The number of images formed are

(a) 5 (b) 4

(c) 6 (d) 8

6. Choose the wrong statement.

(a) A concave mirror can form a magnified real image.

(b) A concave mirror can form a magnified virtual image.
(c) A convex mirror can form a diminished virtual image.
(d) A convex mirror can form a diminished real image.

7. A man 180 cm high stands in front of a plane mirror. His eyes are at a height of 172 cm from the floor. Then to see his full image for minimum length of mirror, the lower end of the mirror should be placed at a height of
(a) 86 cm from the floor
(b) 94 cm from the floor
(c) 4 cm from the floor
(d) 8 cm from the floor

8. A man standing on the road in front of a large window glass pane sees his image bigger than himself. The glass pane is
(a) convex outside (b) cylindrical outside
(c) Plane (d) concave outside

9. It is desired to photograph the image of an object placed at a distance of 3 m from a plane mirror. The camera, which is at a distance of 4.5 m from the mirror should be focused for a distance of
(a) 6m (b) 7.5 m
(c) 3m (d) 4.5m

10. An object 5 cm long and a pencil 10 cm long are placed in front of a pin hole camera such that their images have the same length. The ratio of the distance of the object from the pin hole to that of the pencil is
(a) 5 : 2 (b) 1: 4
(c) 3:2 (d) 1:2

11. A plane mirror reflecting a ray of incident light is rotated through an angle 9 about an axis through the point of incidence in the plane of the mirror perpendicular to the plane of incidence. Then
(1) the reflected ray does not rotate
(2) the reflected ray rotates through an angle θ
(3) the reflected ray rotates through an angle 2θ
(4) the incident ray is fixed Of the above statements
(a) (3) and (4) are correct
(b) and (4) are correct
(c) Only (1) is correct
(d) and (3) are correct

12. Given a point source of light, which of the following can produce a parallel beam of light?
(a) Concave lens
(b) Two plane mirrors inclined at 90° to each other
(c) Convex mirror (d) Concave mirror

13. A ray of light is incident on a plane mirror at an angle of incidence of 30°. The deviation produced by the mirror is
(a) 90° (b) 120°
(c) 30° (d) 60°

14. An object is photographed when placed at a distance of 2 m from the camera. If the same object be placed at a distance of 4 m from the camera, how will the time of exposure be affected?
(a) It will be increased four times.
(b) It will be decreased four times.
(c) It will be decreased two times.
(d) It will be increased two times.

15. A convex mirror is used to form an image of a real object. Then the incorrect statement is
(a) the image is erect
(b) the image is real
(c) the image lies between the pole and the focus.
(d) the image is diminished in size

16. A plane mirror is approaching you at $10\,\mathrm{cm\,s^{-1}}$. You can see your image in it. At what speed will your image approach you
(a) $20\,\mathrm{cm\,s^{-1}}$ (b) $15\,\mathrm{cm\,s^{-1}}$
(c) $10\,\mathrm{cm\,s^{-1}}$ (d) $5\,\mathrm{cm\,s^{-1}}$

17. A virtual image, larger than the object can be produced by
(a) plane mirror (b) concave lens
(c) convex mirror (d) concave mirror

18. For a real object, a convex mirror always forms an image which is
(a) virtual and erect
(b) real and magnified
(c) real and inverted
(d) virtual and inverted

19. The image formed by a pin hole camera is sharpest when the
(a) camera is used in a dark room
(b) hole is very small
(c) object is brightly illuminated
(d) distance from the pin hole to the object is small

20. The image of an object placed on the principal axis of a concave mirror of focal length 12 cm is formed at a point which is 10 cm more distant from the mirror than the object. The magnification of the image is
(a) 2 (b) 1.5
(c) $\frac{8}{3}$ (d) 2.5

21. It is necessary to illuminate the bottom of a well by reflected solar beam when the light is incident at an angle of $\alpha = 40^o$ to the vertical. At what angle β to the horizontal should a plane mirror be placed?
(a) 50° (b) 40°
(c) 70° (d) 20°

22. A concave spherical mirror forms a 40 cm high real image of an object whose height is 10 cm. The radius of the mirror is 60 cm. Find the distance from the object to its image.
(a) 90 cm (b) 112.5 cm
(c) 97.5 cm (d) 75 cm

23. A short linear object of length *b* lies along the axis of a concave mirror of focal length f at a "distance u from the pole of the mirror. The size of the image approximately is equal to
(a) $b\left(\frac{u-f}{f}\right)$ (b) $b\left(\frac{f}{u-f}\right)^2$
(c) $b\left(\frac{u-f}{f}\right)^{\frac{1}{2}}$ (d) $b\left(\frac{f}{u-f}\right)^{\frac{1}{2}}$

24. When a plane mirror is placed horizontally on level ground at a distance of 60 m from the foot of a tower, the top of the tower and its image in the mirror subtend an angle of 90° at the eye. The height of the tower is
(a) 90 m (b) 120 m
(c) 30 m (d) 60 m

25. A clock hung on a wall has marks instead of numbers on its dial. On the opposite wall there is a mirror and the image of the clock in the mirror when read gives time as 3:25. Then the time on the clock is
(a) 6 : 55 (b) 3 : 25
(c) 7:35 (d) 8 :35

26. In a concave mirror an object is placed at a distance *x* from the focus, and the image is formed at a distance *y* from the focus. The focal length of the mirror is
(a) $\frac{x+y}{2}$ (b) $\sqrt{\frac{x}{y}}$
(c) xy (d) $\sqrt{xy}$

27. An object 20 cm from a spherical mirror give rise to a virtual image 15 cm behind the mirror. The type of the mirror and its focal length is
(a) concave, 8.5 cm (b) convex, 30 cm
(c) concave, 60 cm (d) convex, 60 cm

28. A candle flame 3 cm high is placed at a distance of 3 m from a wall. How far from the wall must a concave mirror be placed in order that it may form an image of the flame 9 cm high on the wall?
(a) 450 cm (b) 150 cm
(c) 225 cm (d) 300 cm

29. In the above question, the radius of curvature of the mirror is
(a) 125 cm (b) 150 cm
(c) 450 cm (d) 225 cm

30. An object 4 cm high is placed at a distance of 15 cm in front of a convex mirror having a radius of curvature of 10 cm. Then the image formed is at a distance of
(a) 7.5 cm behind the mirror
(b) 3.75 cm in front of the mirror
(c) 7.5 cm in front of mirror
(d) 3.75 cm behind the mirror

31. At what distance from a concave mirror of focal length 10 cm must an object be placed in order that an image double its size may be obtained?
(a) Either 5 cm or 15 cm (b) At 10 cm
(c) 5cm (d) 15 cm only

32. A convex mirror has a focal length 15 cm. A real object placed at a distance 15 cm in front of it from the pole, produces an image at
(a) 7.5 cm (b) 30 cm
(c) infinity (d) 15cm

33. When a convergent beam of light falls incident on a plane mirror, the image formed is
(a) inverted and real
(b) inverted and virtual
(c) erect and real
(d) erect and virtual

34. A man stands in the centre of a room. A plane mirror is fixed on the wall in front of him. What should be the smallest length of the mirror so as to enable him to see full image of the back wall?
(a) One half of the height of the wall.
(b) One sixth of the height of the wall.
(c) One fourth of the height of the wall.
(d) One third of the height of the wall.

35. A person standing in front of a mirror finds his image thinner but with normal height. This implies that the mirror is
(a) convex and cylindrical with axis vertical
(b) convex and cylindrical with axis horizontal
(c) convex and spherical
(d) concave and spherical

36. A person standing in front of a mirror finds his image larger than himself. This implies that the mirror is
(a) concave
(b) cylindrical with bulging side outwards

(c) plane (d) convex

37. A man 180 cm tall stands 4.5 metre in front of a large vertical plane mirror. Then the angle subtended at the eye by his image in the plane mirror is
(a) 0.2 radians (b) 0.4 radians
(c) 0.2 degrees (d) 0.4 degrees

38. A ray reflected successively from two plane mirrors inclined at a certain angle undergoes a deviation of 240°. Then the number of images observable is
(a) 7 (b) 9
(c) 3 (d) 5

39. In a pinhole camera, the effect of doubling the diameter of the hole from 0.5 mm to 1.0 mm is to
(a) increase the blurring of the image caused by diffraction
(b) cut the necessary exposure time to one fourth of its previous value
(c) double the magnification of the image
(d) worsen the chromatic aberration of the image

40. The sun subtends an angle of half a degree at the pole of a concave mirror which has a radius of curvature of 15 m. Then the size (diameter) of the image of the sun formed by the concave mirror is
(a) 3.5cm (b) 13.1cm
(c) 7.5cm (d) 6.55cm

41. A convex and a concave mirror of radii 10 cm each are facing each other and 15 cm apart. A point object is placed midway between them. Then the position of the final image if the reflection first takes place at the concave mirror and then in the convex mirror is
(a) coincident with the object itself.
(b) 5 cm behind the convex mirror.
(c) at the pole of the concave mirror.
(d) at the pole of the convex mirror.

42. An object is placed 18 cm away from a concave mirror whose focal length is 10 cm. Then the size of area of the image if the object be 4 mm broad and 12 mm long is
(a) $0.75cm^2$ (b) $2cm^2$
(c) $1.5cm^2$ (d) $0.5\ cm^2$

43. An object is at a distance of 10 cm from a mirror and the image of the object is at a distance of 30 cms from the mirror on the same side as the object. Then the nature of the mirror and its focal length is
(a) convex, 15 cm (b) concave 1.5 cm
(c) convex, 7.5 cm (d) concave, 7.5 cm

44. At what distance will the image of an object be obtained in a convex spherical mirror with radius of curvature 40 cm if the object is placed at 30 cm from the mirror?
(a) 12 cm (b) 9 cm
(c) 6 cm (d) 18 cm

45. A real image of half the size is obtained in a concave spherical mirror with a radius of curvature of 40 cm. The distance of the object and that of its image will be
(a) 5 15 cm, 30 cm (b) 30 cm, 15 cm
(c) 30 cm, 60 cm (d) 60 cm, 30 cm

46. The image of an object in a concave spherical mirror is twice the size of the object. The distance between the object and image is 15 cm. Then the focal length of the mirror is
(a) 15 cm (b) 20 cm
(c) 5cm (d) 10cm

47. A ray of light makes an angle of 10° with the horizontal and strikes a plane mirror which is inclined at an angle to the horizontal. The angle *r* for which reflected ray becomes vertical, is
(a) 80° (b) 100°
(c) 40° (d) 50°

48. Rays of light strike a horizontal plane mirror at an angle of 45°. A second plane mirror is arranged at an angle 6 with it. If the ray after reflection from the second mirror goes horizontally parallel to the first mirror, then 6 is
(a) 67.5° (b) 135°
(c) 45° (d) 60°

49. Two vertical plane mirrors are inclined at an angle of 60°, with each other. A ray of light travelling-horizontally is reflected first from one mirror and then from the other mirror. Then the resultant deviation is
(a) 180° (b) 240°
(c) 60° (d) 120°

50. Two planes mirrors are inclined to each other at an angle of 70°. A ray is incident on one mirror at an angle 9. The ray reflected from this mirror falls on the second mirror from where it is reflected parallel to the first mirror. The value of e is
(a) 50° (b) 40°
(c) 70° (d) 60°

51. Two plane mirrors are inclined to each other at an angle 9. A ray of light is reflected first at one mirror and then at the other. The total deviation of the ray is
(a) $360^o - 2\theta$ (b) $180^o - \theta$
(c) 2θ (d) $240^o - 2\theta$

52. A motorcar is fitted with a convex driving mirror of focal length 20 cm. A second

motorcar 2 m broad and 1.6 m high is 6 m away from the first car. Then the position of the second car as seen in the mirror of the first car is

(a) 21.4 cm (b) 15.4 cm
(c) 19.4 cm (d) 17.4 cm

53. In the above question, the breadth and height of the second car seen in the mirror of first car, are respectively

(a) 2.5 cm, 4.6 cm (b) 1 m, 0.8 m
(c) 5.2 cm, 6.4 cm (d) 6.4 cm, 5.2 cm

54. An object is placed in front of a convex mirror at a distance of 50 cm. A plane mirror is introduced covering the lower half of the convex mirror. If the distance between the object and the plane mirror is 30 cm, it is found that there is no parallax between the images formed by the two mirrors. The radius of the curvature of the convex mirror is

(a) 12.5 cm (b) 25 cm
(c) 50 cm (d) 37.5 cm

55. The focal length of a concave mirror is f and the distance from the object to the principal focus is *x.* Then the ratio of size of the image to the size of the object is

(a) $\frac{f^2}{x^2}$ (b) $1+\frac{x}{f}$
(c) $\sqrt{\frac{f}{x}}$ (d) $\frac{f}{x}$

56. A person standing midway between the-two walls of a room 15 m high looks into a plane mirror fixed on the wall. The minimum length of the plane mirror required for him to see the full length image of the wall behind him is equal to

(a) 5m (b) 7.5 m
(c) 15 m (d) 10 m

57. A concave mirror of focal length 200 cm is used to obtain the image of the sun which subtends an angle of 30', then diameter of the image of the sun is

(a) 0.435 cm (b) 174 cm
(c) 0.87 cm (d) 1.74 cm

58. A convex mirror of focal length f produces an image $\frac{1}{\mathrm{n}}\mathrm{th}$ of the size of the object. The distance of the object from the mirror is

(a) $\frac{n+1}{n}f$ (b) $(n+1)f$
(c) $(n-1)f$ (d) $\left(\frac{n-1}{n}\right)f$

59. A small piece of wire bent into an L shape with upright and horizontal portions of equal lengths, is placed with the horizontal portion along the axis of the concave mirror whose radius of curvature is 10 cm. If the bend is 20 cms from the pole of the mirror, then the ratio of the lengths of the images of the upright and horizontal portions of the wire is

(a) 1:3 (b) 2 :1
(c) 1:2 (d) 3:1

60. An object is at a distance *d* = 20 cm from a plane mirror. Then it is displaced by $\Delta d_1 = 10$ cm from the mirror in the normal direction and by $\Delta d_2 = 50$ in the direction parallel to the mirror surface. What is the initial and final distance between the object and its image?

(a) 40 cm, 10 cm (b) 20 cm, 80 cm
(c) 40 cm, 100 cm (d) 40 cm, 60 cm

61. A perfectly reflecting mirror has an area or cm^2. Light energy is allowed to fall on it for one hour at the rate of 10 W cm^{-2}. The force that acts on the mirror is

(a) $3.35\times10^{-7}\,\mathrm{N}$ (b) $6.7\times10^{-7}\,\mathrm{N}$
(c) $3.35\times10^{-8}\,\mathrm{N}$ (d) $6.7\times10^{-8}\,\mathrm{N}$

62. Ray optics is valid, when characteristic dimensions are

(a) of the order of one millimeter
(b) much larger than the wavelength of light
(c) of the same order as the wavelength of light
(d) much smaller than the wavelength of light

63. A short linear object, of length l, lies along parallel to the axis of a concave mirror, of focal length f, at a distance *d* from the pole of the mirror. The size of the image is then (nearly)

(a) $\frac{lf^2}{(d+f)^2}$ (b) $\frac{(d+f)^2}{f_2}l$
(c) $\frac{lf}{d+f}$ (d) $\frac{d+l}{lf}$

64. All of the following statements are correct except

(a) a virtual, erect, magnified image can be formed using a concave mirror
(b) a real, inverted, same sized image can be formed using a convex mirror
(c) the magnification produced by a convex mirror is always less than one
(d) a virtual, erect, same sized image can be obtained by using a plane mirror

65. The maximum deviation produced by a prism in a monochromatic light ray

(a) depends upon refractive index of prism
(b) depends upon the angle of incidence

(c) depends upon the refracting angle of the prism
(d) depends upon incident angle

66. A ray of light is incident on a plane mirror at an angle of incidence 30° The ray, after reflection, is deviated through
(a) 30° (b) 60°
(c) 90° (d) 120°

67. A man runs towards the plane mirror at $2ms^{-1}$. The relative speed of his image with respect to him will be
(a) $2ms^{-1}$ (b) $4ms^{-1}$
(c) $8ms^{-1}$ (d) $10ms^{-1}$

68. Which of the following can produce a virtual image?
(a) Plane mirror (b) Concave mirror
(c) Convex lens (d) All of the above

69. A virtual image three times the size of the object is obtained with a concave mirror of radius of curvature 36 cm. The distance of the object from the mirror is
(a) 20 cm (b) 10 cm
(c) 12 cm (d) 5 cm

70. The image formed by a convex mirror of focal length 30 cm is a quarter of the size of object. The distance of the object from the mirror is
(a) 60 cm (b) 120 cm
(c) 90 cm (d) 30 cm

71. 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/and $2f$
(c) equal to $2f$ (d) greater than $2f$

72. 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 centre of curvature
(c) retrace its path
(d) be parallel to the principal axis

73. For a concave mirror, whenever the distance of the object is less than the focal length, the image is virtual. That is called virtual image, because
(a) the image is formed behind the mirror
(b) the image is not inverted
(c) the image cannot be obtained on screen
(d) the image can be located by virtue of parallax

74. In case of concave mirror, the minimum distance between a real object and its real image is
(a) f (b) $2f$
(c) $4f$ (d) zero

75. If the magnification of a body of size 1 m is 2, what is the size of the image?
(a) 2m (b) 2 m
(c) 3m (d) 4 m

76. A plane mirror is moved towards a stationary observer with a speed of $4ms^{-1}$. The speed with which his image will move towards him?
(a) $2ms^{-1}$
(b) $4ms^{-1}$
(c) $8ms^{-1}$
(d) the image will stay at rest

77. Choose the only wrong statement from the following
(a) a convex mirror forms virtual images for all positions of the object.
(b) a concave mirror forms real images for all positions of the object.
(c) a concave mirror, if suitably placed in front of an object, can form a unity.
(d) the magnification produced by a convex mirror is always less than unity.

78. A concave mirror gives an image three times as large as the object placed at a distance of 20 cm from it. For the image to the real, the focal length should be
(a) 10 cm (b) 15 cm
(c) 20 cm (d) 30 cm

FILL IN THE BLANKS

1. A concave mirror gives real, inverted and same size image if the object is placed at.....

2. A concave mirror gives virtual, erect and enlarged image if the object is placed.....

3. Focal length of combination of two thin lenses of power + 6 D and - 2 D is .....

4. The radius of curvature of a mirror is 20 cm, its focal length is .....

5. An incident ray makes 60° angle with the surface of the plane mirror the angle of reflection is .....

6. If the linear magnification in case of spherical mirror is greater than one, then the image formed is .....

7. The magnification of image in case if an object is placed 10 cm in front of a concave mirror of radius of curvature 15 cm is .....

8. A ray of light falling normally on a mirror reflect by ..... angle.

9. If an object is placed between two plane mirrors inclined at 30° to each other then the number of images formed is .....

10. If distance of a surface from a source is made twice, the luminance of the surface becomes

11. If the object is placed at focus of a concave mirror, the image is formed at .....

TRUE OR FALSE

1. Light is an electromagnetic radiation.

2. Light always behaves like a wave.

3. The effective width of a spherical mirror from which reflection can take place is called its aperture.

4. A convex mirror produces a virtual, erect and magnified image.

5. Laws of reflection are applicable to all types of reflecting surfaces.

6. According to sign conventions, the distance measured in the direction of incident light is takes as negative.

7. The pole of a spherical mirror is the centre of the mirror.

8. When an object is at the centre of curvature a concave mirror, the image formed will be virtual and erect.

9. If an object of height 1 cm is placed near *a* concave mirror of magnification 10, then the height of the image will be 10 cm.

10. A convex mirror is used in the ophthalmoscope.

11. Irregular reflection of light gives a sharp image

12. Spherical mirrors can also be used as trick mirrors.

13. Focal length of a plane mirror is infinity.

14. Concave mirror forms a full size image of a far- off large object.

15. A virtual image cannot be photographed.

16. Linear magnification of a convex mirror is always negative.

17. A ray incident along normal to the mirror retraces its path.

Matrix Match Type

In this section each question contains statements given in two columns which have to be matched. Statements (A, *B, C, D) in Column-I have to be matched with statements (p, q, r, s) in Column-II*

1.

Column - I	Column - II
(A) f (focal length)	(p) $\frac{1}{f}=\frac{1}{u}+\frac{1}{\upsilon}$
(B) Plane mirror	(q) $\frac{R}{2}$
(C) Mirror equation	(r) $-\frac{\upsilon}{u}$
(D) Magnification	(s) m = + 1

2.

Column - I	Column - II
(A) Car head lights	(p) Plane mirror
(B) Looking glass	(q) Convex mirror
(C) Make-up mirror	(r) Concave mirror
(D) Vigilance mirror	(s) Diverging mirror

3.

Column - I	Column - II
(A) Power of convex mirror	(p) Positive power
(B) Power of concave mirror	(q) Negative power
(C) Power of plane mirror	(r) Zero power
(D) Power of convex lens	(s) Infinite power

4.

Column - I	Column - II
(A) Regular reflection	(p) Paper
(B) Concave mirror	(q) Virtual focus
(C) Convex mirror	(r) Mirror
(D) Irregular reflection	(s) Real focus

5.

Column - I	Column - II
(A) Reflector	(p) Plane mirror
(B)Lateral inversion	(q) Sun
(C)Translucent	(r) Silver
(D)Luminous object	(s) Waxed paper

ASSERTION & REASON QUESTIONS

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a responding statement of Reason (R) just below it. Of the statements, mark the correct answer as

(a) *If both assertion and reason are true and reason is the correct explanation of assertion.*

(b) *If both assertion and reason are true but reason is not the correct explanation of assertion.*

(c) *If assertion is true but reason is false*
(d) *If assertion is false but reason is true.*

1. **Assertion:** If a plane glass slab is placed on the letters of different colours all the letters appear to be raised up to the same height.
Reason: Different colours have different wavelengths.

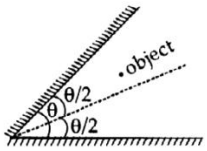
2. **Assertion:** The mirrors used in search lights are parabolic and not concave spherical.
Reason: In a concave spherical mirror the image formed is always virtual.

3. **Assertion:** The twinkling of star is due to reflection of light.
Reason: The velocity of light does not change while going from one medium to the other.

4. **Assertion**: A ray incident along normal to the mirror retraces its path.
Reason: In reflection, angle of incidence is always equal to angle of reflection.

5. **Assertion:** For the observing traffic at our back, we prefer use a convex mirror.
Reason: A convex mirror has a much larger field of view than a plane mirror or a concave mirror.

6. **Assertion:** If the angle between the two plane mirror is 72° and the object is asymmetrically placed between the two mirrors, then 5 images of the object will be formed.



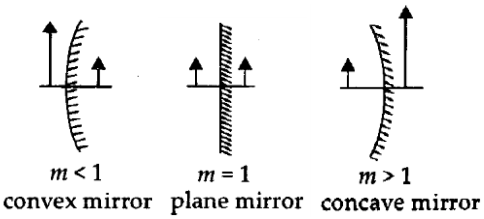
Reason: For given system of mirror the total number of images formed due to successive reflection is equal to eithe $\frac{360^o}{\theta}$ or $\frac{360^o}{\theta}-1$ accordingly as $\frac{360^o}{\theta}$ is odd or even respectively.

7. **Assertion:** When a concave mirror is held under water, its focal length will increase.
Reason: The focal length of a concave mirror is independent of the medium in which it is placed.

8. **Assertion:** A convex mirror is used as a driver's mirror.
Reason: Because convex mirror's field of view is large and images formed are virtual, erect and diminished.

9. **Assertion:** Keeping a point object fixed, if a plane mirror is moved, the image will also move.
Reason: In case of a plane mirror, distance of object and its image is equal from any point on the mirror.

10. **Assertion:** We can decide the nature of a mirror by observing the size of erect image in the mirror



Reason: The minimum distance between a real object and its real image in a concave mirror is zero.

11. **Assertion:** The fluorescent tube is considered better than an electric bulb.
Reason: Efficiency of fluorescent tube is more than the efficiency of electric bulb.

12. **Assertion:** When the object moves with a velocity $\vec{\upsilon}$, its image in the plane mirror moves with a velocity of $-2\vec{\upsilon}$
Reason: The minimum height of the mirror to be required to see the full image of man of height h is

13. **Assertion:** Reflection of light is the phenomenon of bouncing back of light in the same medium on striking the surface of any object.
Reason: Light particle possess, elastic property.

14. **Assertion:** ENT specialist use a concave mirror as a head mirror to concentrate light on the body parts like eye, ear, nose etc.
Reason: A concave mirror is more cost effective and easily available.

15. **Assertion:** Large convex mirrors are used to concentrate sunlight to produce heat is solar cookers.
Reason: Convex mirror converges the light rays falling on it to a point.

PASSAGE

PASSAGE 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 3.5m.

1 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

2 The nature of the image is .....
(a) Diminished and inverted
(b) Virtual and erect

(c) Virtual and inverted
(d) Real and erect

3 The size of the image relative to the size of the truck is
(a) 22 % (b) 24 %
(c) 26 % (d) 28 %

PASSAGE 2: A converging mirror forms a real mage of height 4 cm, of an object of height 1 cm placed 20 cm away from the mirror.

1 The image distance is .....
(a) - 80 cm (b) - 90 cm
(c) - 100 cm (d) - 110 cm

2 L The focal length of mirror is .....
(a) 15 cm (b) 16 cm
(c) 17 cm (d) 18 cm

3 The mirror used here is .....
(a) concave (b) convex
(c) piano convex (d) piano concave

SUBJECTIVE PROBLEMS

VERY SHORT ANSWER TYPE QUESTIONS

1 Radius of curvature of a concave mirror is 25 cm. What is its focal length?

2 An object 1 cm high is held near a concave mirror of magnification 10. How tall will be the image?

3 Name the various types of beams of light.

4 In which mirror would you be able to see a full size image of a far off large object.

5 Can a concave mirror form a virtual image of same size as the object?

6 State the expression for lateral magnification or a concave mirror in terms of object distance and image distance.

7 According to the sign convention, which mirror has negative focal length?

8 Where should an object be placed in order to use a convex lens as a magnifying glass?

9 What is a spherical mirror?

10 M does not show lateral inversion whereas P does. Explain.

11 Give two difference between real image and virtual image.

12 Why does a convex mirror has a virtual principal focus?

13 We have seen a plane mirror forming a virtual image. Can we get a real image by a plane mirror?

14 The image of a distant object is formed at 30 cm from a concave mirror. What is the focal length of the mirror?

15 Define Aperture of a mirror.

SHORT ANSWER TYPE QUESTIONS

1 An object is placed 90 cm away from a concave mirror of focal length 30 cm. Find the position and the nature of the image formed.

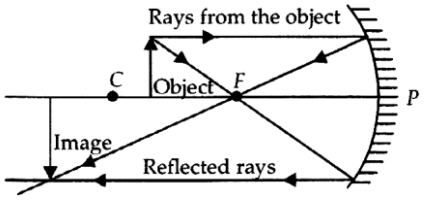
2 A concave mirror produces three times magnified real image of an object placed at 10 cm in front of it. Where is the image located?

3 Use the mirror formula to show that for an object lying between the pole and focus of a concave mirror, the image formed is always virtual in nature.

4 Find the position, nature and size of the image of an object 3 cm high placed at a distance 6 cm from a concave mirror of focal length 12 cm.

5 Show that the mirror formula for spherical mirrors holds good for a plane mirror too.

6 Describe the image formation shown in the diagram.



7 Give one example each of (a) parallel 'b) converging (c) diverging beams of light.

8 A concave mirror produces three times enlarged image of an object placed at 10 cm in front of it. Calculate the radius of curvature of the mirror.

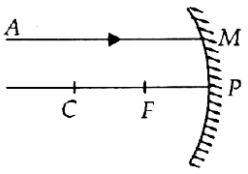
9 An object 4 cm high is placed at a distance of cm in front of a concave mirror of focal length 12 cm. Find the position, nature and size of the an age formed.

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

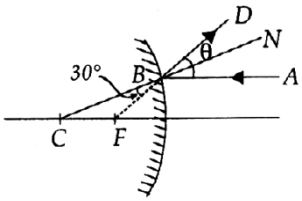
11 A 2 cm high object is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is 30 cm, and its image is formed 60 cm from the mirror, on the same side of the mirror as the object. Find the height of the image formed.

12 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?

13 A ray of light AM is incident on a spherical mirror as shown in the diagram. Redraw the diagram and show the path of reflected ray. Also indicate and mark the angle of reflection in the diagram.



14 From the ray diagram find θ.



15 An object is placed at a distance of 20 cm in front of a convex mirror of radius of curvature 30 cm. Find the position and nature of the image.

LONG ANSWER TYPE QUESTIONS

1 Find the position, nature and size of the image of an object 3 cm high placed at a distance of 9 cm from a concave mirror of focal length 18 cm.

2 An object 5 cm in height is placed at a distance of 20 cm in front of a convex mirror of radius of curvature 30 cm. Find the image, its nature and size.

3 Discuss the nature of image formed, when the object moves from infinity towards the concave mirror.

4 An object of size 7 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 focused linage can be obtained? Find the size and nature of the image.

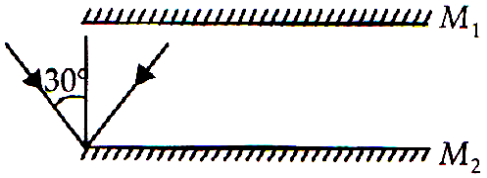
5 When an object is placed at a distance of 60 cm from a diverging spherical mirror, the magnification produced is 0.5. Where should the object be placed to get a magnification of $\frac{1}{3}$.

6 (a) State the relation between object distance, image distance and focal length of a spherical mirror.

(b) A concave mirror of focal length 15 cm form an image of an object kept at a distance of 10 cm from the mirror. Find the position nature and size of the image formed by it.

(c) Draw a ray diagram to show the image formed by a concave mirror when an object is placed between pole and focus of the mirror.

7 Two plane mirrors M_1 and M_2 have a length of 20 m each and are 10 cm apart. A ray of light is incident on one end of the mirror M_2 at an angle of 30°. Find the number of reflections the ray undergoes before reaching the other end.



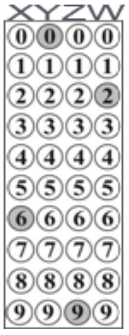
8 A convex mirror used in a bus has radius of curvature 3.5 m. If the driver of the bus locates a car at 10 m behind the bus, find the position, nature and size of the image of the car.

9 An object 3 cm 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.

10 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 distance of 3.5 m. Calculate the position and (ii) the size of the image relative to the size of the truck. What will be the nature of the image?

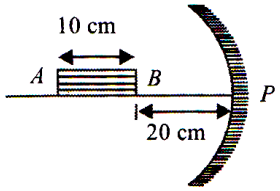
INTEGER ANSWER TYPE

This section contains 5 questions. The answer to each of the questions is *a single digit integer, ranging from 0 to 9.*
If the correct answers to question numbers X, Y, Z and W (say) are 6, 0, 9 and 2 respectively, then the correct darkening of bubbles will look like the following.



1 A rod *AB* of length 10 cm is placed along the principal axis of a concave mirror having focal length equal to 10 cm as shown in figure. The

distance *PB* = 20 cm. What is the length of the image of the rod *AB?*



2 A square wire of side 3.0 is placed 25 cm away from a concave mirror of focal length 10 cm. What is the area enclosed by the image of the wire? The centre of the wire is on the axis of the mirror, with its two sides normal to the axis.

3 A candle is held 3 cm away from a concave mirror of radius of curvature 24 cm. Where 15 the image formed?

4 A person stands straight in front of a convex mirror at a distance of 30 m away from it. He sees his erect image whose height is $\frac{1}{6}$th of his real height. Find the focal length of the convex mirror.

5 Find the size of the image formed by a spherical mirror from the following data : $u = -20, f = -15cm, h_0 = 1.0cm$

ANSWER – KEY

Multiple Choice Questions

1. B	**2.** A	**3.** A	**4.** D	**5.** D
6. D	**7.** A	**8.** D	**9.** B	**10.** D
11. A	**12.** D	**13.** B	**14.** A	**15.** B
16. A	**17.** D	**18.** A	**19.** B	**20.** B
21. C	**22.** B	**23.** B	**24.** D	**25.** D
26. D	**27.** D	**28.** A	**29.** D	**30.** D
31. A	**32.** A	**33.** C	**34.** D	**35.** A
36. A	**37.** A	**38.** D	**39.** B	**40.** D
41. D	**42.** D	**43.** D	**44.** A	**45.** D
46. D	**47.** D	**48.** A	**49.** B	**50.** B
51. A	**52.** C	**53.** D	**54.** B	**55.** D
56. A	**57.** D	**58.** C	**59.** D	**60.** D
61. D	**62.** B	**63.** A	**64.** B	**65.** AC
66. D	**67.** B	**68.** D	**69.** C	**70.** C
71. C	**72.** C	**73.** C	**74.** D	**75.** B
76. C	**77.** B	**78.** B		

Fill in the Blanks

1. At the centre of curvature	**2.** Between F and O
3. 25 cm	**4.** 10 cm
5. 60^o	**6.** Enlarged
7. 3	**8.** Zero degree
9. 11	**10.** One fourth
11. Infinity	

True and False

1. True	**2.** False	**3.** True	**4.** False
5. True	**6.** False	**7.** True	**8.** False
9. True	**10.** False	**11.** False	**12.** True
13. True	**14.** False	**15.** False	**16.** True
17. True			

Matrix Match Type

1.	A → q; B → s; C → p; D → r
2.	A → s; r; B → p; C → r, s; D → q
3.	A → p; B → q; C → r; D → p
4.	A → r; B → s; C → q; D → p
5.	A → r; B → p; C → s; D → q

Assertion & Reason

1. C	**2.** D	**3.** A	**4.** A	**5.** A
6. D	**7.** A	**8.** A	**9.** B	**10.** A
11. D	**12.** C	**13.** C	**14.** A	

Passage Comprehension

Passage: 1

1. C	**2.** B	**3.** A

Passage: 2

1. A	**2.** B	**3.** A

Integer Answer Type

1. 5	**2.** 4	**3.** 4	**4.** 6	**5.** 3