Light-Reflection and Refraction

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 ($\approx$ 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

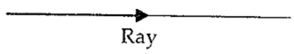
- **Source**

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.

Do You Know

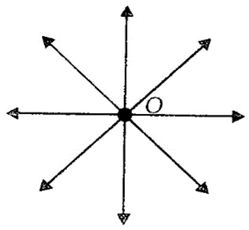
Sources are also classified as isotropic and non-isotropic. Isotropic sources give out light in all direction whereas non-isotropic sources do not give out light in all direction.

- **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.

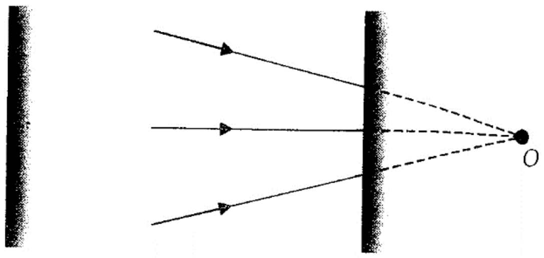


  Notes: A single ray cannot be isolated from a source of light.
- **Beam**
  A bundle or bunch of rays is called a beam. It is of following three types:
  (a) Convergent beam: It is a beam in which diameter of beam decreases in the direction of ray.
  (b) Divergent beam: It is a beam in which all the 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

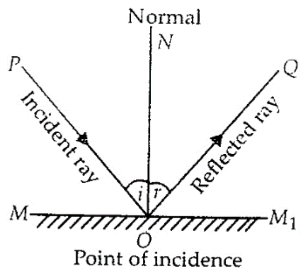


(b) Virtual object

Note: Virtual object cannot be seen by human eye because for an object or image to be seen by eyes, 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.

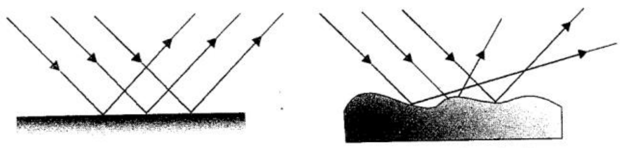
- **Associated Terms**

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.



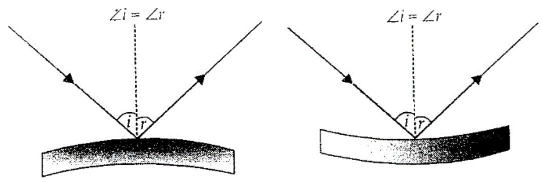
(a) Regular reflection (b) Irregular reflection

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. $\angle i = \angle r$.

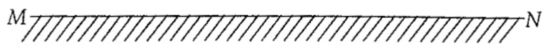
  Note: The laws valid for any smooth reflecting surface irrespective of geometry.



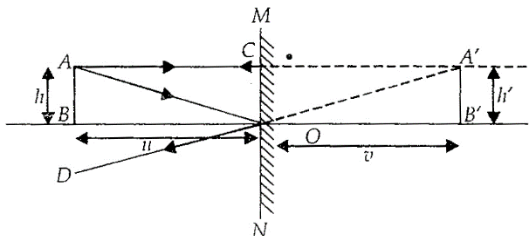
(a) (b)

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.

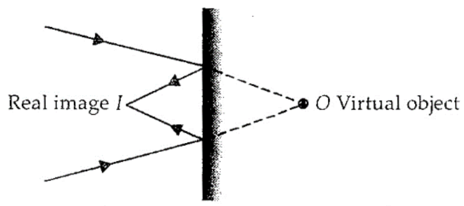


Fig.: Plane mirror showing real image formation of a virtual object

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

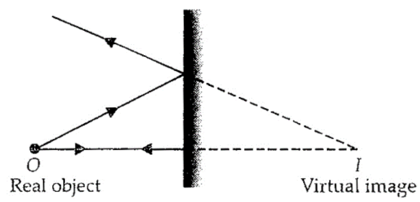


Fig. : Plane mirror showing virtual image formation of a real object.

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.

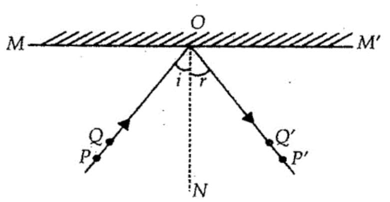
(c) If $\frac{360°}{\theta}$ is a fraction, the number of images formed will be equal to the integral part.

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

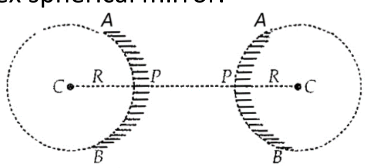
The experiment to verify laws of reflection.

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 ∠ PON and ∠ P'ON. ∠ PON gives the angle of incidence and ∠ 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.



(a) Concave mirror (b) Convex 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.

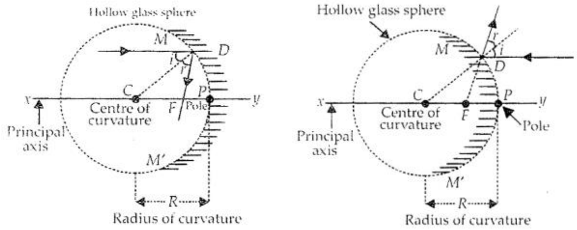
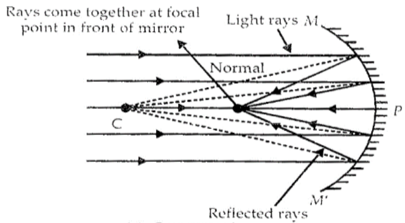


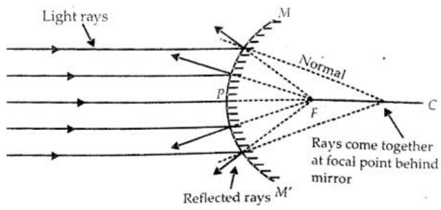
Fig. : Concave mirror Fig. : Convex mirror

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.



(a) Concave mirror



(b) Convex mirror

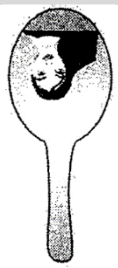
(g) Focal length: The distance between the pole and the principle focus of the mirror is called the focal length of the mirror. It is denoted by f. The distance PF= f represents the foal length of the spherical mirrors i.e., concave and convex mirrors.

Assumptions and Sign Convention

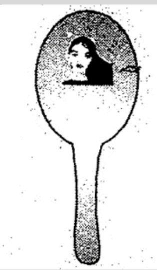
- All distances are measured from the pole of the mirror.
- Distances actually traversed in the direction of light are taken as positive and those in the opposite direction are taken as negative.

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

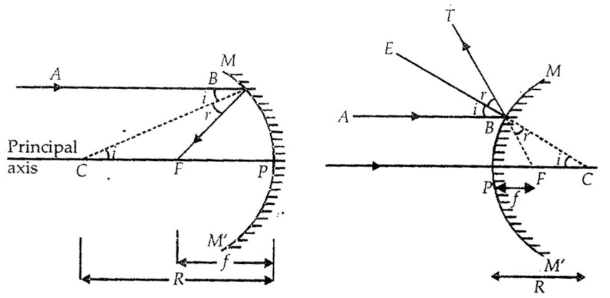


Virtual, erect and small sized image formed by the surface of the spoon bulged out word

- **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.



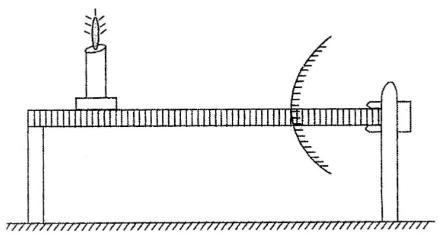
(a) Concave mirror($f = R/2$) (b) Convex mirror ($f = R/2$)

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

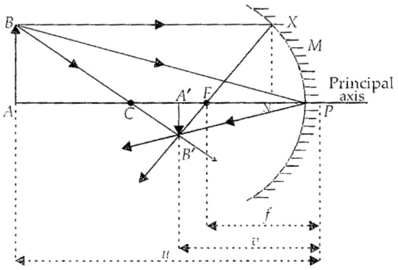


Fig. : Ray diagram for a concave mirror real image formula.

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

Putting values, with proper sign

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

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

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

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.

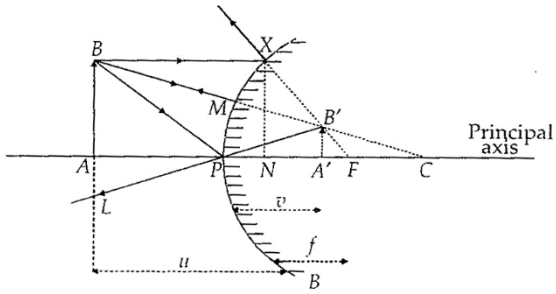
Using $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$, we get

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

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,

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

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
$$\frac{1}{f+x_2} + \frac{1}{f+x_1} = \frac{1}{f} \text{ or } x_1 x_2 = f^2$$
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 $f = \frac{R}{2} = 15\,\text{cm}$

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

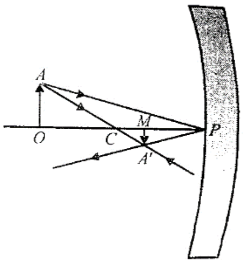
This is defined as the ratio of size of image to the size of object.

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.
$$\frac{AO}{A'M} = \frac{PO}{PM} \qquad \text{...(i)}$$



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

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:
$$\text{m}_\text{s} = \frac{\text{Area of image}}{\text{Area of object}} = \left(\frac{\text{-v}}{\text{u}}\right)\left(\frac{\text{-v}}{\text{u}}\right) = \frac{\text{v}^2}{\text{u}^2}$$
- 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 real image is formed in front of the mirror and virtual image is formed behind the mirror.	The image distance is always positive.
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.

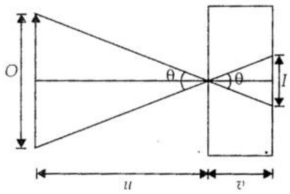
Repeat this activity using a convex mirror. We can full length of distant tree but it is very disminished in size.

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

CONCEPT MAP