CHAPTER / 11

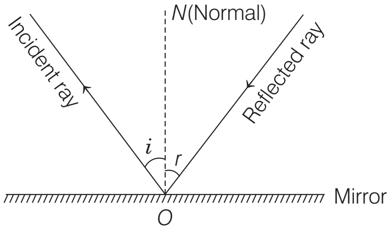
Reflection and Spherical Mirror

Topics Covered

- Reflection of Light
- Reflection by Spherical Mirror
- Mirror Formula
- Linear Magnification
- Uses of Spherical Mirrors
- Identification of Mirror

Reflection of Light

Reflection is the phenomenon of changing the path of light after incidenting on a smooth surface without any change in the medium.



The returning back of light in the same medium from which it has come after striking a smooth surface is called reflection of light.

Laws of Reflection

The laws of reflection are as follows:

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

(ii) The angle of reflection r is equal to the angle of incidence i, i.e. $\angle i = \angle r$.

Reflection by Spherical Mirror

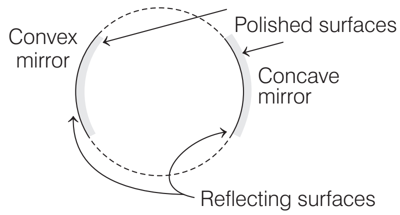
Spherical mirror is a mirror, whose reflecting surface is a part of hollow sphere.
Spherical mirrors are of two types:

(i) Concave Spherical Mirror

A spherical mirror, whose reflecting surface is towards the centre of the sphere is called concave spherical mirror.

(ii) Convex Spherical Mirror

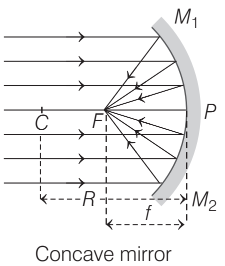
A spherical mirror, whose reflecting surface is away from the centre of the sphere is called convex spherical mirror.



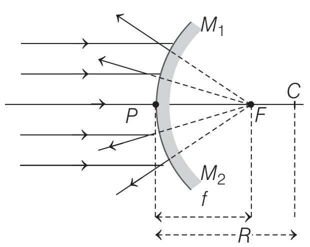
Terms Related to Spherical Mirrors

There are some terms related to spherical mirrors as given below:

- **Pole** (P) Central point of reflecting surface of mirror.
- **Centre of curvature** (C) Centre of sphere, of which the mirror forms a part.
- **Radius of curvature** (R) Radius of sphere, of which the mirror forms a part.
- **Principal axis** Straight line joining pole and centre of curvature.
- **Secondary axis** It is any other direction containing centre of curvature and any point, other than the pole, of the mirror.
- **Aperture** (M_1M_2) Diameter of the periphery of the mirror.
- **Real image** When the reflected (or refracted) rays of a point actually converge (i.e. intersect) at a second point.
- **Virtual image** When the reflected (or refracted) rays of a point appear to diverge from a second point.
- **Principal focus** (F) Point on the principal axis at which light rays parallel to the principal axis, after reflection from the mirror, actually meet or appear to come from.



Concave mirror



Convex mirror

Thus, concave mirror has real focus, while convex mirror has virtual focus.

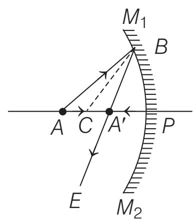
- **Focal length** (f) Distance between principal focus and pole.
- **Focal plane** A plane passing through focus and perpendicular to principal axis.

Image Formation in Spherical Mirror

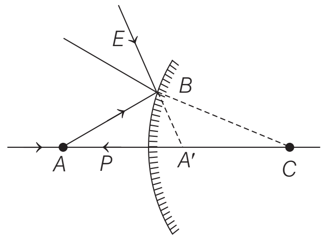
A minimum of two rays are needed to obtain the image of an object. The image formation for some types of object are given as below:

(i) For a point object

A ray starting from point object A and passing through C, after reflection, will retrace its path due to normal incidence along principal axis.



Concave mirror
(A' = Real image)

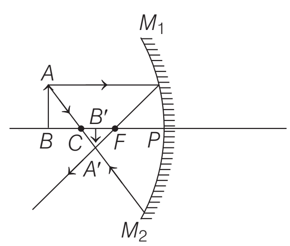


Convex mirror
(A' = Virtual image)

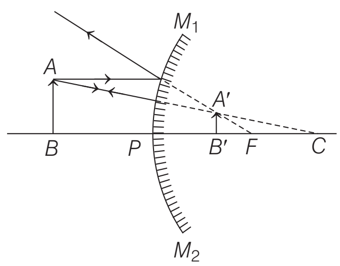
Another ray AB after reflection, will move along BE. In case of concave mirror, BE will intersect the principal axis at A. The two reflected rays BE and PA meet at A'. In image of A is formed at A'. In case of convex mirror, BE appears to intersect principal axis at A'. Reflected rays BE and PA appear to meet at A'. So image of A is formed at A'.

(ii) For an extended object

Consider two rays starting from point A of an extended object AB, one ray passing through C and another ray going parallel to principal axis. After reflection from the mirror, the image of A is obtained at A' and B at B'. Thus, image of object AB is obtained as $A' B'$.



Concave mirror



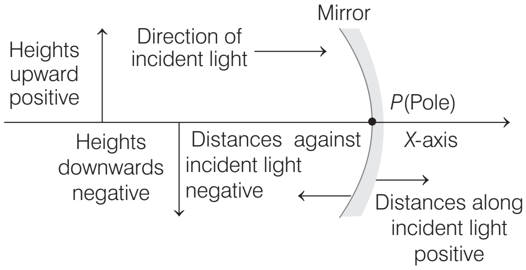
Convex mirror

In concave mirror, $A' B'$ is a real image while in case of convex mirror, $A' B'$ is virtual.

Sign Convention

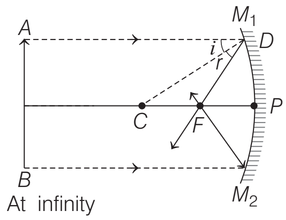
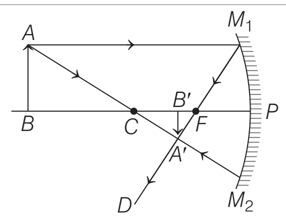
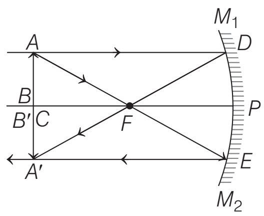
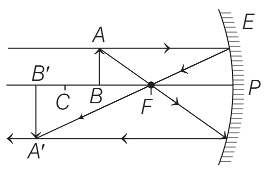
All measurements should be taken from pole of mirror.

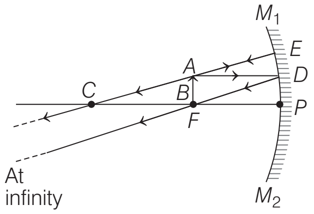
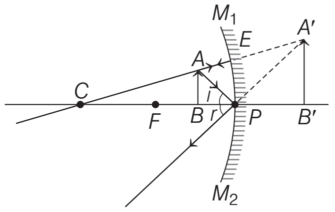
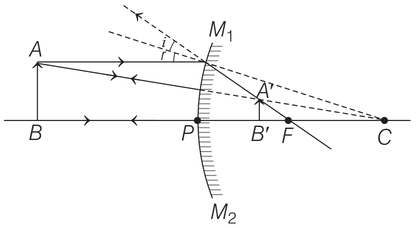
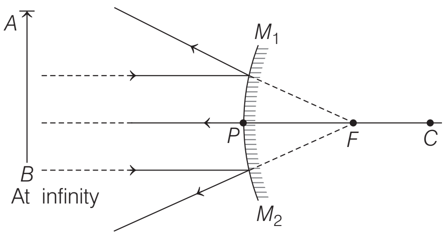
- All measurements along the direction of incident ray will be positive and opposite to incident ray are negative.
- All the measurements for the distances above the principal axis are taken as positive and below the principal axis are taken as negative.
- For a real object, u is negative whereas v is negative for real image and positive for virtual image.



Nature, Position and Size of Image Formed by Spherical Mirrors (For different positions of the object)

The characteristics of images are given in the table as follows:

Mirror	Position of object	Position of image	Ray diagram	Nature and size of image
Concave	At infinity	At F (point image)		Real, inverted and diminished
	Between infinity and C	Between F and C		Real, inverted and diminished
	At C	At C		Real, inverted and same size
	Between C and F	Beyond C		Real, inverted and enlarged

Mirror	Position of object	Position of image	Ray diagram	Nature and size of image
	At F	At infinity		Real, inverted and enlarged
	Between F and P	Behind the mirror		Virtual, erect and enlarged
Convex	Between infinity and P	Between F and P		Virtual, erect and diminished
Convex	At infinity	At F		Virtual, erect and diminished

Mirror Formula

Mirror formula is a relation between focal length of the mirror, distances of object and image from the mirror.

$$1/v + 1/u = 1/f$$

where, $f =$ focal length, $u =$ distance of the object from mirror, $v =$ distance of the image from mirror.

Focal length of mirror

$$(f) = \text{Radius of curvature } (R)/2 \Rightarrow \quad f = R/2$$

Linear Magnification

The ratio of the size of the image formed by a spherical mirror I to the size of the object O is called the **linear magnification** produced by the spherical mirror.

$$m = I/O = -v/u = f/f - u = f - v/f$$

where, $I =$ height of image and $O =$ height of object

It is negative for real image and positive for virtual image.

The expression for magnification is same for both the concave and convex mirrors.

(i) When $m > 1$, image formed is enlarged.

(ii) When $m < 1$, image formed is diminished.

(iii) When $m = 1$, image and object have same size.

(iv) When m is positive, image must be erect, i.e. virtual.

(v) When m is negative, image must be inverted, i.e. real.

(vi) In case of concave mirror, m can be positive or negative but in case of convex mirror, m is positive only.

It is of two types:

(i) **Lateral (transverse) magnification** (m) It is the ratio of the size of image to the size of object in a direction normal or transverse to the principal axis.

2. **Longitudinal magnification** (m') It is the ratio of the size of image to the size of object in a direction along the principal axis.

Also, longitudinal magnification
$= -$ (transverse magnification)^2

i.e. $m' = -m^2$

Uses of Spherical Mirrors

Convex Mirror

(i) This mirror is used as a reflector in street lamps to diverge the light over a large area.

(ii) This mirror is used as rear view mirror (or driver's mirror) in vehicles, because it has a wider field of view.

Concave Mirror

(i) This mirror is used as a reflector in search light, head lights of vehicles, etc.

(ii) This mirror is also used as face looking mirror because it forms erect and magnified image.

Identification of Mirror

A mirror (concave /convex/plane) can be identified by image formed by it.

Consider the following table:

Type of mirror		Nature of image	
(i)	Plane mirror	(i)	Erect, same size as object
(ii)	Concave miror	(ii)	Erect, magnified (when object is held near to the mirror)
(iii)	Convex mirror	(iii)	Erect, diminished (whereever the position of the object may be)

PRACTICE QUESTIONS

Exam', Textbook's & Other Imp. Questions

1 MARK *Questions*

Exams' Questions

Q.1 A convex mirror is placed inside water. Will its focal length change? (Write 'Yes' or 'No') **[2019]**

Sol No, when a convex mirror is placed inside the water, there will be no change in the focal length of the mirror because the focal length of mirror does not depend on the refractive index of external medium. **(1)**

Q.2 A convex mirror has a focal length f. An object is placed at a distance $f/2$ infront of it from the pole. The mirror produces an image at

(a) infinity (b) f (c) $2f$ (d) $f/3$ **[2013]**

Sol (*d*) Given, object distance, $u = \frac{-f}{2}$, focal length $= f$

Hence, applying mirror formula,

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

$$\therefore \quad \frac{1}{v} = \frac{3}{f} \Rightarrow v = \frac{f}{3}$$ **(1)**

Q.3 An object is placed at a distance of 10 cm infront of a concave mirror of focal length 20 cm. The size of the image is <u>greater</u> than that of the object. (Correct the underlined part, if necessary). **[2013 Instant]**

Sol Given, object distance, $u = 10$ cm

and focal length, $f = -20$ cm

Hence, applying mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} + \frac{1}{10} = \frac{1}{-20} \Rightarrow v = 20 \text{ cm}$$

Hence, magnification, $m = \frac{\text{size of image}}{\text{size of object}} = \frac{-v}{u}$

$$m = \frac{h_i}{h_o} = -\frac{20}{-10} = 2$$

$$h_i = 2 \times h_o \text{ (greater than object)}$$

Since, $u < f$, image formed is virtual and magnified, i.e. size of image is greater than object. **(1)**

Q.4 What type of image is formed in a plane mirror? (Write the answer only.) **[2012 Instant]**

Sol Virtual and same sized image. **(1)**

Q.5 A real image of an object is formed in a concave mirror. The size of the image is greater than the size of the object. Which of the following statements is correct? **[2010 Instant]**

(a) The object is situated on the centre of curvature
(b) The object is situated within the focal length
(c) The object is situated between the centre of curvature and the focus
(d) The object is situated between the centre of curvature and infinity

Sol (*c*) The object is situated between the centre of curvature and the focus. **(1)**

Q.6 What is the radius of curvature of plane mirror? (Give the answer only.) **[2009, Textbook]**

Sol Infinite **(1)**

Q.7 A small concave mirror has a focal length of 15 cm. What is the magnification of the image formed by it, when the object is placed at a distance of 30 cm infront of it? **[2008]**

Sol Since, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-15}+\frac{1}{30}$

$\therefore \quad \frac{1}{v}=-\frac{1}{30} \Rightarrow v=-30$ cm

So, the magnification, $m=-\frac{v}{u}=\frac{-(-30)}{(-30)}=-1$ **(1)**

Important Questions

Q.8 An object 5 cm tall is placed 1 m from a concave spherical mirror which has a radius of curvature of 20 cm. The size of the image is **[Textbook]**

(a) 0.11 cm (b) 0.50 cm (c) 0.55 cm (d) 0.60 cm

Sol (*c*) According to mirror formula,

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

Given, $u=-1$ m $=-100$ cm, $R=-20$ cm, $f=-10$ cm [for concave mirror]

Height of object, $h_o=5$ cm

Thus, $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=-\frac{1}{10}+\frac{1}{100} \Rightarrow v=-\frac{100}{9}$

Hence, size of image, $h_i=-\frac{v}{u}\times h_o$

$$=-\frac{100}{9\times 100}\times 5=-\frac{5}{9}=-0.55 \text{ cm}$$ **(1)**

Q.9 A dice is placed with its one edge parallel to the principal axis between the principal focus and the centre of curvature. Then, the image has the shape of **[Textbook]**

(a) cube
(b) rectangular parallelopiped
(c) barrel shaped
(d) spherical

Sol (*b*) The final image will have the edges perpendicular to principal axes larger than that of the dice. Thus, the shape of dice will be like a rectangular parallelopiped. **(1)**

Q.10 A boy stands straight infront of a mirror at a distance of 30 cm away from it. He sees his erect image whose height is $\frac{1}{5}$th of his real height. The mirror he is using is **[Textbook]**

(a) plane mirror
(b) convex mirror
(c) concave mirror
(d) plane-concave mirror

Sol (*b*) As the size of the image is diminished but erect, hence the mirror must be convex mirror. **(1)**

Q.11 The relation between linear magnification m, the object distance u and focal length f of a spherical mirror is **[Textbook]**

(a) $m=\frac{f}{f-u}$ (b) $m=\frac{f-u}{f}$
(c) $m=\frac{f+u}{f}$ (d) $m=\frac{f}{f+u}$

Sol (*a*) We know that, $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$

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

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

$\Rightarrow \quad \frac{v}{u}=\frac{f}{u-f} \Rightarrow m=\frac{-v}{u}=\frac{f}{f-u}$ **(1)**

Q.12 An object of length 4 cm is kept on the principal axis of a convex mirror at a distance of f. The size of the image formed is **[Textbook]**

(a) 2 cm (b) 8 cm (c) 6 cm (d) 4 cm

Sol (*a*) Given, object distance, $u=-f$, $h_o=4$ cm

Applying mirror formula, $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{f}-\frac{1}{-f}$

$$\frac{1}{v}=\frac{2}{f} \Rightarrow v=\frac{f}{2}$$

Now, $\frac{h_i}{h_o}=-\frac{v}{u}$

$$h_i=-\frac{v}{u}\times h_o=\frac{f}{2\times f}\times 4=2 \text{ cm}$$ **(1)**

Q.13 Which mirror is used as a reflector in solar cooker? **[Textbook]**

(a) Concave (b) Convex
(c) Plane (d) Cylindrical

Sol (*a*) Concave mirror is used as a reflector in solar cooker. **(1)**

Q.14 A concave mirror has radius of curvature of 1 m. Light from a distant star is incident on the mirror. The distance of the image of the star from the mirror is **[Textbook]**

(a) 0.5 m (b) 1 m
(c) 2 m (d) 0.25 m

Sol (*a*) As, the star is distant, $u = \infty$

Given, $R = 1$ m and $f = 50$ cm

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

$$\frac{1}{v} - \frac{1}{\infty} = \frac{1}{50}$$

$\Rightarrow$ $v = 50 \text{ cm} = 0.5 \text{ m}$ **(1)**

Q.15 A convex mirror is used to form an image of a real object. Then, tick the wrong statement. **[Textbook]**

(a) The image lies between the pole and the focus
(b) The image is diminished in size
(c) The image is erect
(d) The image is real

Sol (*d*) The image formed by a convex mirror is always virtual, erect, diminished in size and formed between the pole and the focus. **(1)**

Q.16 Is the path of light rays reversible? (Yes/No) **[Textbook]**

Sol Yes, the rays of light are reversible when the rays are incident normally on the reflecting surface. In this case, angle of incidence is zero. So, from laws of reflection, angle of reflection will also be zero. This is possible if the reflected ray retracks, along the path of incident ray. **(1)**

Q.17 A ray of light is incident normally on a plane mirror, what will be the angle of reflection? **[Textbook]**

Sol The angle of reflection is 0°. **(1)**

Q.18 What is the focal length of a plane mirror? **[Textbook]**

Sol Focal length of the plane mirror is infinity as its radius of curvature is infinity. **(1)**

Q.19 The least distance between an object and real image formed by a concave mirror of a focal length f is zero when the object is at $2f$ from mirror. (True/False) **[Textbook]**

Sol True, because if the object is at $2f$ image will also be formed at $2f$. **(1)**

Q.20 A diminished virtual image can be obtained only in .... type of mirror. **[Textbook]**

Sol Convex mirror always form virtual diminished image of object. **(1)**

Q.21 Which one is having a larger field of view, convex or concave or plane mirror? **[Textbook]**

Sol Convex mirror is having a larger wider field of view. **(1)**

Q.22 Why can a convex mirror be used as a driving mirror? **[Textbook]**

Sol Convex mirror is used as a driving mirror because it always forms a diminished, erect image and has a wider field of view. **(1)**

Q.23 Under what conditions, the formula "radius of curvature is twice focal length" for a spherical mirror holds good? **[Textbook]**

Sol The condition for $f = R/2$ to hold good

(i) the aperture of the mirror should be small.
(ii) the rays should be paraxial. Hence, angle θ which rays make with principal axis is very small. Hence, $\tan\theta \approx \theta$. **(1)**

Q.24 Why cannot you photograph a virtual image? **[Textbook]**

Sol As the rays forming the image never really converge. Hence, the virtual images are not formed on the screen. **(1)**

2 MARKS *Questions*

Exams' Questions

Q.25 An object is placed 12 cm in front of a convex mirror of focal length 18 cm. Determine the position and nature of the image. **[2019, Textbook]**

Sol According to question,

$$f = 18 \text{ cm} \quad \text{and } u = -12 \text{ cm}$$

Using mirror formula,

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

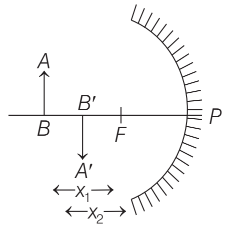
Hence, $\frac{1}{v} = \frac{1}{18} - \frac{1}{(-12)} \Rightarrow \frac{1}{v} = \frac{18+12}{18 \times 12}$ or $v = 7.2$ cm **(2)**

Q.26 An object is placed at a distance x_1 from the focus of a concave mirror. Its real image is formed at a distance x_2 from the focus. Show that the focal length of the mirror is $\sqrt{x_1 x_2}$. **[2015]**

Sol Now, according to mirror equation,

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

$\Rightarrow$ $u = f + x_1$ and $v = f + x_2$



(1)

$$\Rightarrow \quad -\frac{1}{(f+x_2)} - \frac{1}{(f+x_1)} = \frac{1}{-f}$$

$$\Rightarrow \quad \frac{f+x_1+f+x_2}{(f+x_2)(f+x_1)} = \frac{1}{f}$$

$$2f^2 + fx_1 + fx_2 = f^2 + fx_1 + fx_2 + x_1x_2$$

$$\Rightarrow \quad f^2 = x_1x_2 \Rightarrow f = \sqrt{x_1x_2}$$ **(1)**

Q.27 Draw a neat ray diagram to show the formation of image of a linear object by a convex mirror. **[2013 Instant]**

Sol **Image formation in spherical mirror** Refer to text on page 177. **(2)**

Q.28 Can a concave mirror ever produce a virtual image? Explain with a ray diagram. **[2013 Instant]**

Sol Yes, concave mirror can produce a virtual image of an object placed between pole and focus of concave mirror.

Refer to ray diagram on page 179. **(2)**

Q.29 Draw a neat labelled ray diagram to show the formation of virtual image by a concave mirror. **[2012]**

Sol **Image formation in spherical mirror** Refer to text on page 177. **(2)**

Q.30 A convex mirror produces a magnification of 1/2, when the object is placed at a distance of 0.8 m from it. Find the focal length of the mirror. **[2010]**

Sol $m = -\frac{v}{u} = \frac{1}{2}$, $u = -0.8$ m

$$\Rightarrow v = -\frac{u}{2} = -\frac{(-0.8)}{2} = +0.4 \text{ m}$$ **(1)**

Using, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ (mirror formula)

$$\Rightarrow \quad \frac{1}{f} = \frac{1}{-0.8} + \frac{1}{0.4} = \frac{-1+2}{0.8} = \frac{1}{0.8}$$

$\therefore \quad f = 0.8$ m **(1)**

Q.31 A dentist has a small mirror of focal length 16 mm. He views the cavity in the tooth of a patient by holding the mirror at a distance of 8 mm from the cavity. Find the magnification. **[2007, Textbook]**

Sol Concave mirror is used by dentist such that $f = -16$ mm and $u = -8$ mm

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

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-16} - \left(\frac{1}{-8}\right)$$

$$\Rightarrow \quad \frac{1}{v} = \frac{-1}{16} + \frac{1}{8} = \frac{-1+2}{16}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{16} \Rightarrow v = 16 \text{ mm}$$ **(1)**

So, $$m = -\frac{v}{u} = -\frac{16}{(-8)} = 2$$ **(1)**

Q.32 Find the position and nature of the image formed, when an object is placed 15 cm in front of a concave mirror of focal length 20 cm. **[2006]**

Sol Given, $u = -15$ cm and $f = -20$ cm

Using the mirror formula,

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

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

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{-20} - \left(\frac{1}{-15}\right) = -\frac{1}{20} + \frac{1}{15}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{-15+20}{300} = \frac{5}{300}$$ **(1/2)**

$$\Rightarrow \quad v = 60 \text{ cm}$$

As, $$m = -\frac{v}{u} \Rightarrow m = -\frac{60 \text{ cm}}{(-15 \text{ cm})} = 4$$ **(1/2)**

The image formed is virtual, erect and magnified. **(1)**

Q.33 An observer walks towards a plane mirror at a speed of 120 m/min. At what speed does he approach his image? **[2005]**

Sol The speed with which an observer approaches towards his image is double the speed with which he walks towards a plane mirror. **(1)**

Speed at which observer approaches his image

$$= 2 \times 120 \text{ m/min} = 240 \text{ m/min}$$ **(1)**

Q.34 A concave shaving mirror is of focal length 50 cm.How far should the mirror be held from the face to produce an image of two fold magnification? **[2004]**

Sol $m = -\frac{v}{u} = 2$ and $f = -50$ cm $\Rightarrow v = -2u$ **(1/2)**

Using the mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ **(1/2)**

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

$$\Rightarrow \quad \frac{2-1}{2u} = \frac{1}{f} \Rightarrow f = 2u$$ **(1/2)**

$$\therefore \quad u = \frac{f}{2} = -\frac{50}{2} = -25 \text{ cm}$$ **(1/2)**

Q.35 An object is held 6 cm from a concave mirror of focal length 12 cm. Find the position, nature and magnification of the image. **[2002]**

Sol Given, $u = -6$ cm and $f = -12$ cm

Using the mirror formula,

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

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

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{-12} - \left(\frac{1}{-6}\right) \Rightarrow \frac{1}{v} = -\frac{1}{12} + \frac{1}{6}$$

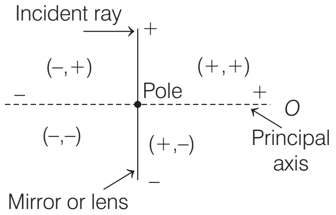
$$\Rightarrow \quad \frac{1}{v} = \frac{-1+2}{12} = \frac{1}{12} \Rightarrow v = 12 \text{ cm}$$ **(1)**

As, $$m = -\frac{v}{u} = \frac{-12}{-6} = 2$$

The image formed is virtual, erect and magnified. **(1)**

Q.36 Discuss the sign convention used in ray optics. **[2001]**

Sol Sign convention



(1)

The following sign convention is used:

(i) all distances are measured from the pole.

(ii) distances measured in the direction of incident rays are taken as positive, while opposite to the direction of incident rays are taken as negative.

(iii) distances above the principal axis are taken as positive and below the principal axis are taken as negative. **(1)**

Important Questions

Q.37 Describe the image produced by placing an object 30 cm in front of a convex mirror having a focal length of 10 cm. **[Textbook]**

Sol Given, $u = -30$ cm, $f = 10$ cm [for convex mirror]

$$\Rightarrow \quad \frac{1}{u} + \frac{1}{v} = \frac{1}{f} \quad \text{[applying mirror formula]}$$

$$\therefore \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{10} - \frac{1}{(-30)} = \frac{2}{15}$$

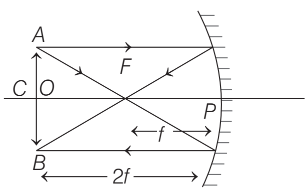
$$v = \frac{15}{2} = 7.5 \text{ cm}$$

$$m = \frac{-v}{u} = \frac{7.5}{30} = \frac{1}{4} = 0.25$$

So, the image is virtual, erect, diminished. **(2)**

Q.38 Show mathematically where the object should be placed so that the size of the image will be equal to the size of the object in case of a concave mirror. Give ray diagram. **[Textbook]**

Sol At C



As, the size of image = size of object

$$h' = h$$

$$\Rightarrow \quad m = \frac{h'}{h} = -\frac{v}{u} = 1 \Rightarrow v = -u$$

From mirror formula,

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

$$\Rightarrow \quad \frac{1}{-u} - \frac{1}{u} = \frac{-1}{f} \quad \text{[using sign convention]}$$

$$\Rightarrow \quad \frac{2}{u} = \frac{1}{f} \Rightarrow u = 2f$$

Object should be placed at $2f$ (or C) to get an image of the size of object. **(2)**

Q.39 When an object is moved from very long distance to the focus, in what way will the nature and size of the image be affected in case of a concave mirror? **[Textbook]**

Sol As the object is moved from infinity to focus, its nature will remain the same, that is real and inverted but size will change from diminished to magnified. However, when the object is between focus and pole, nature of image will change and it will become virtual, erect and magnified. **(2)**

Q.40 A virtual image, we always say, cannot be caught on a screen. Yet when we see a virtual image we are obviously bringing it on to screen, (i.e. the retina) of our eye. Is there a contradiction? **[Textbook]**

Sol It is not a contradiction. Even in formation of virtual image some light is reflected. This reflected light is in fact forming a real image on our retina. It appear as virtual object for the eye lens. **(2)**

Q.41 A light ray is incident on a plane mirror at angle of 45°. Find out deviation produced by a plane mirror.

Sol Deviation produced by a plane mirror is given by

$$D = 180° - 2i$$ **(1)**

$$\Rightarrow \quad D = 180° - 2\,(45°) = 180° - 90°$$

$$\therefore \quad D = 90°$$ **(1)**

3 MARKS *Questions*

Exams' Questions

Q.42 A real image of transverse magnification n is formed by a concave mirror of focal length f. Show that the object is placed at a distance of $(n+1)\,f\,/\,n$ from the mirror. **[2016, Textbook]**

Sol Let the image distance be v unit,
object distance be u unit
and focal length of concave mirror be f unit.

$\because$ Transverse magnification, $n = \frac{-v}{u} \Rightarrow v = -nu$ ...(i)

According to mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$ **(1)**

Apply the sign convention of u, v and f for concave mirror,

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

$$\Rightarrow \quad -\frac{1}{nu} - \frac{1}{u} = -\frac{1}{f} \quad [\because \gamma = -nu \text{ (from Eq. (i)}]$$

$$\Rightarrow \quad \frac{1}{nu} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1+n}{nu} = \frac{1}{f}$$

$$\Rightarrow \quad (n+1) f = nu \Rightarrow u = (n+1)\frac{f}{n}$$ **(2)**

Q.43 A plane mirror and a convex mirror are placed at 30 cm and 40 cm, are respectively infront of an object such that the images formed by both the mirrors coincide. Calculate the focal length of the convex mirror. **[2014]**

Sol For plane mirror, $u = 30$ cm and $v = 30$ cm

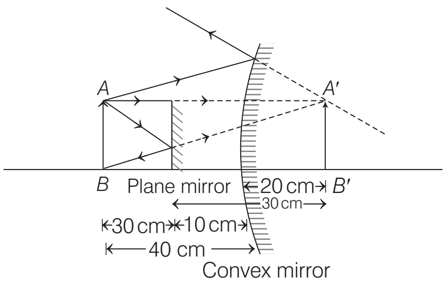
For convex mirror, $u = -40$ cm, $v = 20$ cm

Using the mirror formula,

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$ **(1)**

$$\Rightarrow \quad \frac{1}{-40} + \frac{1}{20} = \frac{1}{f} \Rightarrow \frac{-1+2}{40} = \frac{1}{f}$$

$$\Rightarrow \quad f = 40 \text{ cm}$$ **(1)**



(1)

Important Questions

Q.44 An image, produced by a convex mirror is $\frac{1}{n}$th of the size of the object. Prove that the object must be at a distance of $(n-1)f$ from the mirror, where f is the focal length of the mirror. **[Textbook]**

Sol Height of image,

$$h' = \frac{h}{n} \Rightarrow m = \frac{h'}{h} = \frac{1}{n}$$ ...(i)

$$m = -\frac{v}{u}$$ ...(ii) **(1)**

From Eqs. (i) and (ii), we get

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

i.e. $\quad u = -nv$ **(1)**

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$ [applying mirror formula]

$$\Rightarrow \quad \frac{1}{-nv} + \frac{1}{v} = \frac{1}{f} \text{ or } v = \left(\frac{n-1}{n}\right) f$$ **(1)**

Q.45 A convex mirror produces a magnification of 1/3, when an object is placed at a distance of 60 cm from it. Where the object should be placed so that the size of the image becomes 1/2 of the object?

Sol Given, $u = -60$ cm and $m = \frac{1}{3}$

As, $\quad m = -\frac{v}{u}$

$$\therefore \quad \frac{1}{3} = \frac{-v}{-60} \Rightarrow v = 20 \text{ cm}$$ **(1/2)**

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

$$\Rightarrow \quad \frac{1}{f} = \frac{1}{20} + \frac{1}{(-60)} = \frac{3-1}{60} = \frac{2}{60}$$ **(1)**

$$\therefore \quad f = 30 \text{ cm}$$

For $\quad m = \frac{1}{2}, -\frac{v}{u} = \frac{1}{2} \Rightarrow v = -\frac{u}{2}$ **(1/2)**

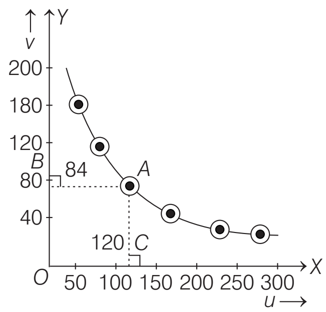
$$\therefore \quad \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{-u/2} + \frac{1}{u} = \frac{1}{30}$$

$$\frac{-2}{u} + \frac{1}{u} = \frac{1}{30} \Rightarrow u = -30 \text{ cm}$$ **(1)**

Q.46 Plot the u-v graph from the following values:
u....250, 200, 150, 120, 100, 80, 70 cm.
v.......... 60.9; 65.2, 73.2, 84, 96.5, 127.5, 166.5 cm.
Find out the focal length from the graph. **[Textbook]**

Sol **Scale** On X-axis 10 small division = 50 cm

On Y-axis : 10 small division = 40 cm



Focal length, $f = \frac{OB + OC}{4} = \frac{84 + 120}{4} = \frac{304}{4} = 76$ cm **(3)**

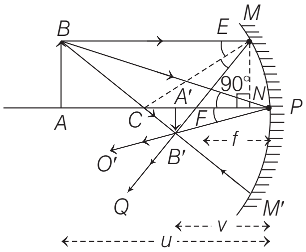
7 MARKS Questions

Exams' Questions

Q.47 (i) Derive spherical mirror formula $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$, where all the symbols have their usual meaning.

(ii) Given some uses of spherical mirrors. **[2015]**

Sol (i)



(1)

In above figure, triangles $A'B'F$ and ENF are similar.

So, $$\frac{A'B'}{NE}=\frac{A'F}{NF}$$

Since, the aperture of concave mirror is small, therefore, $NF \approx PF$ and $NE = AB$.

So, $$\frac{A'B'}{AB}=\frac{A'F}{PF}$$

As, $$A'F = PA' - PF$$

$\therefore$ $$\frac{A'B'}{AB}=\frac{PA'-PF}{PF} \quad \text{...(i)}$$

Also, $$\frac{A'B'}{AB}=\frac{PA'}{PA} \quad \text{...(ii)}$$

[$\because$ Triangles ABP and $A'B'P$ are similar]

From Eqs. (i) and (ii), we get

$$\frac{PA'-PF}{PF}=\frac{PA'}{PA} \quad \text{...(iii)}$$

Using sign convention, $PA = -u$, $PA' = -v$ and $PF = -f$

Substituting values in Eq. (iii), we get

$$\frac{-v-(-f)}{-f}=\frac{-v}{-u}$$

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

Dividing both sides by v, we get

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

This is the mirror formula for spherical mirror. **(4)**

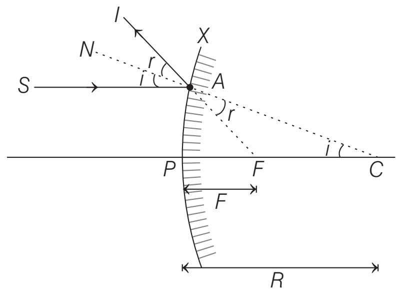
(ii) **Uses of spherical mirrors** Refer to text on page 180. **(2)**

Q.48 Establish a relation between

(i) R and f and

(ii) u, v and f for a convex mirror. **[2015, Textbook]**

Sol (i) Consider the reflection of light through a convex mirror.



$\because$ $\angle SAN = \angle PCA = i$ (corresponding angles)

$\angle NAI = \angle FAC = r$ (vertically opposite angles)

$\because$ According to law of reflection,

$\angle i = \angle r$ **(3)**

$\Rightarrow$ $\angle CAF = \angle FCA$ $\Rightarrow$ $AF = FC$

$\because$ Radius of curvature,

$$R = PC = PF + PC = PF + AF = 2PF$$

[$\because AF \approx FP$]

As per sign convention for convex mirror,

$R = +R$

$PF = +f$

$\Rightarrow$ $R = 2f$ or $f = \frac{R}{2}$ **(2)**

(ii) Refer to solution 47. **(2)**

Important Question

Q.49 Describe the appearance and position of the image produced by a concave mirror as the object moves from infinity towards the mirror, with the help of ray diagrams. **[Textbook]**

Sol Refer to table on page 178. **(7)**

Chapter Test

1 MARK *Questions*

1 An object is placed between two plane mirrors inclined at an angle of 60°. The number of images formed will be
(a) 7 (b) 6 (c) 5 (d) 8

2 Concave mirror produces virtual image for all positions of the object. **[Textbook]**
(Correct the sentence if necessary)

3 Diminished, virtual image can be produced by a convex mirror for all positions of the object. **[Textbook]**
(Correct the sentence if necessary)

4 Convex mirror is used in motor cycles for rear view. (True/False)

5 Your face appears magnified when you look at a mirror. What type of mirror is it?

6 Image produced by a mirror is laterally inverted. (Make the correction, if necessary, by changing the underlined words.)

7 Draw a ray diagram to show the formation of image with magnification one due to reflection from a concave mirror.

8 The focal length of concave mirror is positive and that of a convex mirror is negative.
(Correct the sentence if necessary.)

9 A .... magnification means the image is inverted. (Fill in the blank)

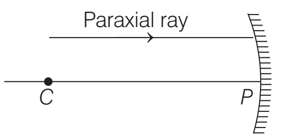
2 MARKS *Questions*

10 An object is placed 20 cm from a concave mirror of focal length 15 cm. What is the position, nature and size of image formed?

11 A half diminished virtual erect image is formed 12 cm behind a mirror. What type of mirror is used? Calculate the focal length of the mirror used.

12 An object is x focal lengths to the left of principal focus of a concave mirror. Show that the image will be $\left(\frac{x}{1-x}\right)$ of focal length of the left of the focus.

13 Complete the ray diagram by drawing the normal at the point of incidence. [Take, $PC = 12$ cm]



14 What is the difference between centre of curvature and pole of a concave mirror in terms of its focal length?

15 A convex mirror misguides us about the speed of vehicle behind us. Comment.

16 A convex and a concave mirror are fitted on a wall. How will you distinguish between them without touching them?

17 Write the assumptions which are used in deriving the formulae for reflection.

3 MARKS *Questions*

18 An object is placed in front of a concave mirror of focal length 20 cm. The image formed is three times the size of the object. Calculate the two possible distances of the object from the mirror.

19 An object is placed infront of a convex mirror of focal length 30 cm. If the image is quarter of the size of the object, find the position of the image.

7 MARKS *Questions*

20 An object is placed at a distance of 1m infront of a convex mirror. A plane mirror is placed at a distance of 0.40 m from the convex mirror on the same side as the object. Find the focal length of convex mirror if the images formed by the mirrors coincide.

21 Establish a relation between

(i) R and f (ii) u, v and f for a convex mirror.

HINTS and ANSWERS

1. (c)

4. True

5. Concave

9. Negative $\left(\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \text{ and } m = \frac{-v}{u}\right)$

10. – 60 cm, real, inverted, magnified

11. Convex, 24 cm $\left(u = f, \frac{1}{f} = \frac{1}{u} + \frac{1}{v}\right)$

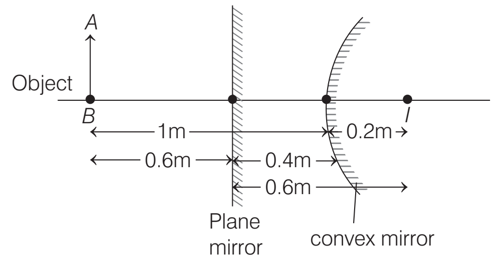
17. $m = \frac{-v}{u} = 3$, (for virtual magnitude image)

and $m = \frac{-v}{u} = -3$ (for virtual, real magnitude image)

solving, we get ans. ....

18. 13.3 cm, 26.7 cm $\left(m = \frac{-v}{u} = \frac{1}{4} \text{ and } \frac{1}{f} = \frac{1}{v} + \frac{1}{u}\right)$

19. + 22.5 cm, virtual, erect



For plane mirror $|u| = |v| = 0.6$ m **(3)**

For convex mirror, $u = -1$ m, $v = +0.2$ m **(2)**

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

20. + 0.25 m