PHYSICS

REFLECTION OF LIGHT

Concepts Covered

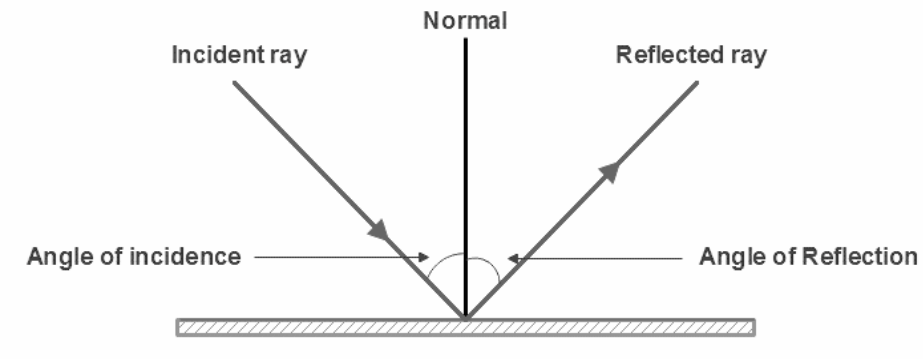
- Light
- Reflection and its laws
- Real and virtual image
- Image formation by spherical mirrors
- Use of spherical mirrors
- New cartesian sign convention
- Mirror formula
- Magnification

Light

- Light is a form of energy that enables us to see objects which emit or reflect light.
- It travels in a straight line and this property is called rectilinear propagation of light.
- Our eyes are most sensitive to yellow colour and least sensitive to violet and red colour. Due to this reason, commercial vehicles are painted with yellow colour, and sodium lamps are used in road lights.

Reflection

Bouncing back of light when it strikes on any surface is called Reflection of light.



Incident ray

The ray of light which falls on a surface (or a mirror) is called the incident ray of light.

Reflected ray

The ray of light which gets reflected from a surface (or a mirror) is called the reflected ray of light.

Normal

The normal is a line at the right angle to the reflecting surface at the point of incidence.

Angle of Incidence (∠i)

The Angle between the incident ray and the Normal is called the Angle of Incidence.

Angle of Reflection (∠r)

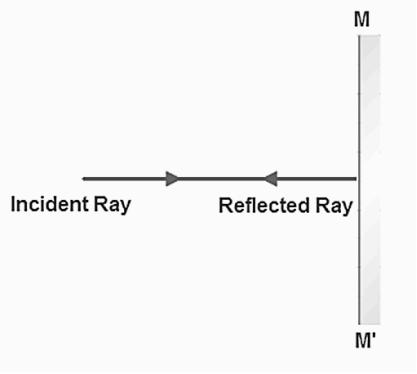
The Angle between the reflected ray and the Normal is called the Angle of Reflection.

Laws of Reflection:

(1) Angle of incidence is equal to the angle of reflection i.e. ∠i = ∠r

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

Note: When a ray of light falls on a mirror normally or at a right angle it gets reflected back along the same path.



Example:

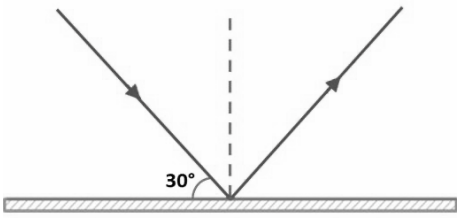
Find the angle of reflection in the following figure

Solution: From the given figure

∠i = 90°- 30° = 60°

From the first law of reflection we know, ∠i = ∠r

So, ∠r = 60°



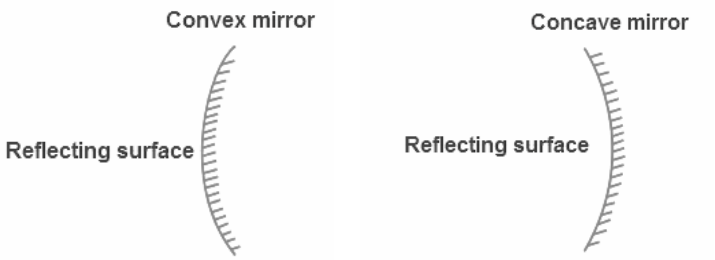
(ii) Spherical Mirror:

A mirror whose polished reflecting surface is a part of a hollow sphere of glass is called a spherical mirror. For a spherical mirror, one of the two curved surfaces is coated with a thin layer of silver. Thus, one side of the spherical mirror is made opaque and the other side acts as a reflecting surface.

There are two types of the spherical mirror.

(i) Convex mirror

(ii) Concave mirror



(i) Concave (Converging) Mirror:

A spherical mirror whose inner hollow surface is the reflecting surface.

(ii) Convex (Diverging) Mirror:

A spherical mirror whose outer bulging surface is the reflecting surface.

Important terms related to Spherical Mirrors

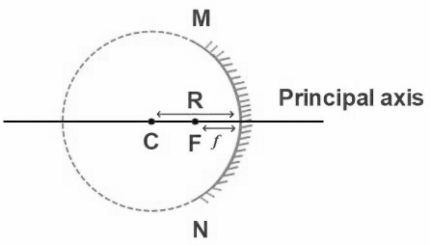
Pole (P): The centre of the spherical mirror is called the pole, it is denoted by the letter P.

Aperture (MN): It is the effective diameter of the spherical mirror's reflecting part

Center of Curvature (C): The centre of the hollow glass sphere of which the mirror was a part.

Radius of Curvature (R): The distance between the pole and the centre of curvature is called the radius of curvature.

Principal axis: The line joining the pole and center of curvature is called the principal axis.



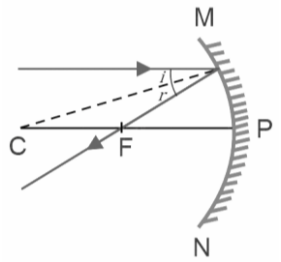
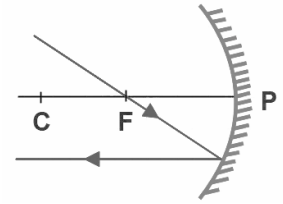
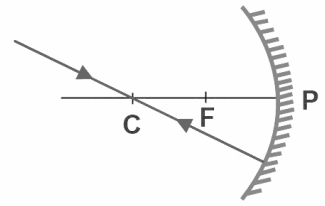
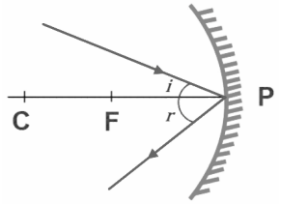
Focus (F): The point on the principal axis where all the parallel light rays actually meet or appear to meet after reflection from a spherical mirror is called its focus.

Focal length (f): The distance between the pole and the focus.

Relationship between focal length and radius of curvature:

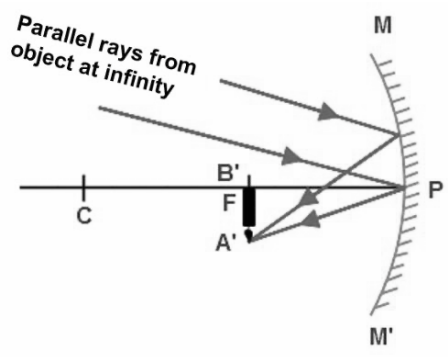
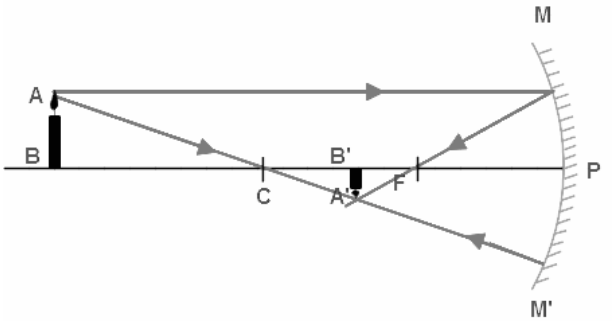
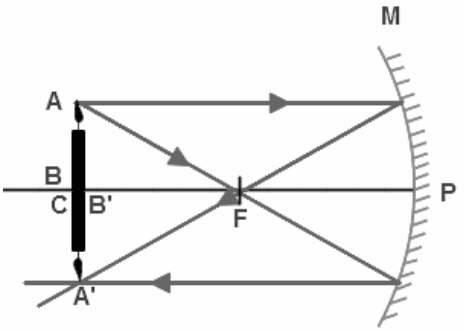
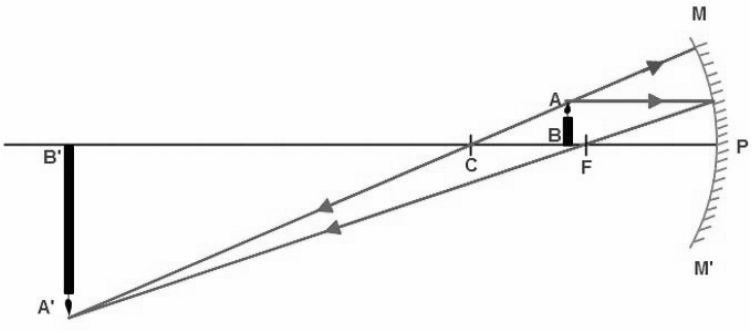
$$f = \frac{R}{2}$$

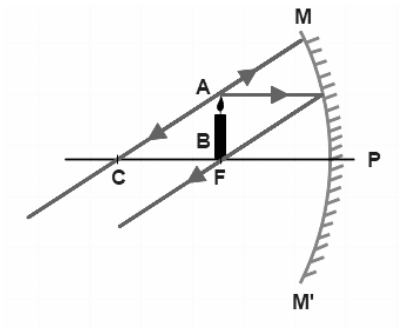
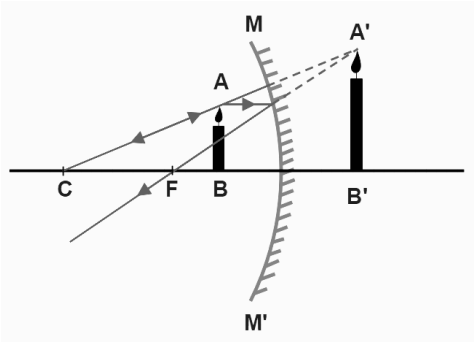
Rules for Image Formation by Concave Mirror

(i) A ray parallel to the principal axis after reflection will pass through the principal focus.	
(ii) A ray passing through the principal focus of the concave mirror after reflection will emerge parallel to the principal axis.	
(iii) A ray of light passing through the centre of curvature of a concave mirror is reflected back along the same path as the incident ray.	
(iv) A ray incident at P obliquely to the principal axis of a concave mirror is reflected obliquely making an equal angle.	

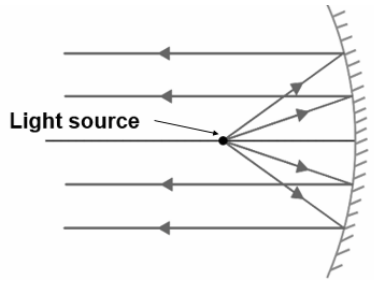
Ray diagrams for Images formed by the Concave Mirror

- To make the ray diagram for image formation by a mirror any two-incident rays are sent to the mirror and the intersection of reflected rays is seen. The intersection point gives the position of the image
- When an extended object AB is placed at different positions in front of a concave mirror then the following cases arise:

(i) When Object is at Infinity: **Image Position -** At 'F' **Nature -** Real, inverted **Size -** Point sized or highly diminished	
(ii) When Object is beyond 'C' **Image Position** - Between 'F' and 'C' **Nature** - Real, inverted **Size** – Diminished	
(iii) When Object is at 'C' **Image Position** - At 'C' **Nature** - Real, inverted **Size** – Same size as that of the object	
(iv) When Object is placed between 'F' and 'C' **Image Position -** Beyond 'C' **Nature -** Real, inverted **Size –** Enlarged	

(v) When Object is placed at 'F' **Image Position** - At infinity **Nature** - Real, inverted **Size** – Highly enlarged	
(vi) When the Object is between 'P' and 'F' **Image Position** – Behind the mirror **Nature** – Virtual, erect **Size** – Enlarged	

Uses of Concave Mirror

▪ Used in torches, searchlights, and vehicle headlights to get the powerful parallel beam of light. (Light source is placed at focus)	
▪ Concave mirrors are used by dentists to see large images of the teeth of patients. (Teeth have to be placed between pole and focus).	
▪ A concave mirror is used as a shaving mirror to see a larger image of the face.	

▪ Concave mirrors are used to concentrate sunlight to produce heat in a solar cooker.	

Example:

(1) For what position of an object, the size of the image formed by a concave mirror is equal to that of the object.

Answer: When the object is at centre of curvature.

(2) What types of images concave mirrors can form.

Answer: Concave mirror can form both real and virtual images and images can be diminished, of the same size, and enlarged as well.

Tell the position and nature of image formed by concave mirror in following cases:

(i) When object is beyond Centre of curvature.

(ii) When object is between pole and focus.

(iii) When object is at focus.

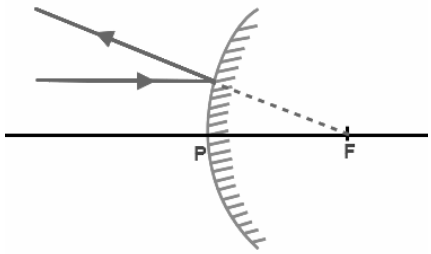
Answer Key

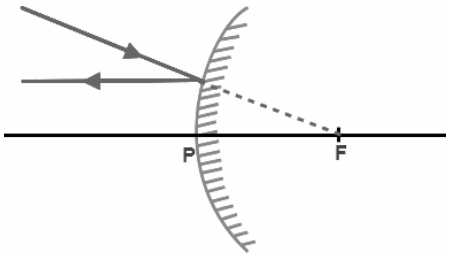
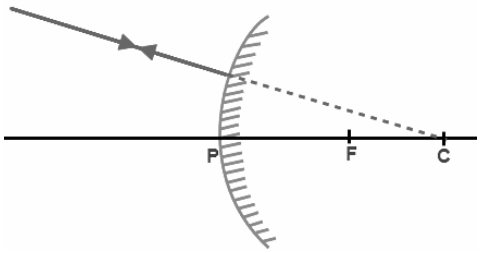
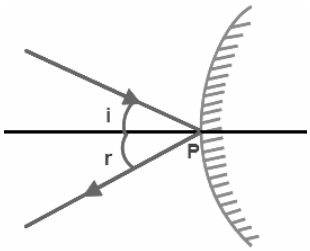
(i) Position - Between 'F' and 'C'
Nature - Real, inverted

(ii) Position – Behind the mirror
Nature – Virtual, erect

(iii) Position - At infinity
Nature - Real, inverted

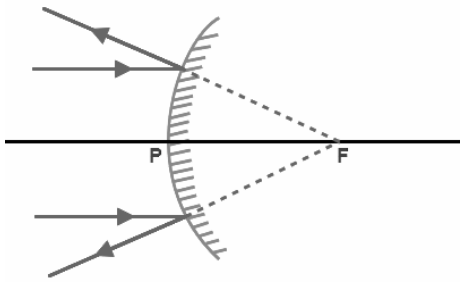
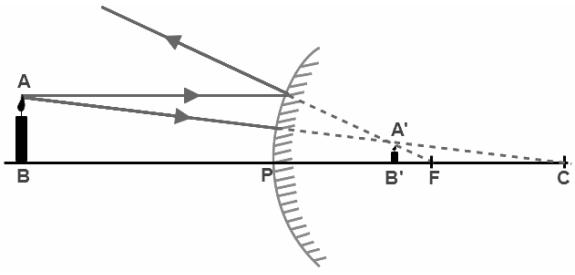
Rules for Image Formation by Convex Mirror

(i) A ray of light parallel to the principal axis of a convex mirror after reflection appears to diverge from the principal focus.	

(ii) A ray that is directed towards the focus of the convex mirror after reflection will emerge parallel to the principal axis.	
(iii) A ray directed towards the center of curvature of a convex mirror appears to be reflected back from the centre of curvature.	
(iv) A ray incident at P obliquely to the principal axis is reflected obliquely at the same angle.	

Ray diagrams of Images formed by the Convex Mirror

- To make the ray diagram for image formation by a mirror any two-incident rays are sent to the mirror and the intersection of reflected rays is seen. The intersection point gives the position of the image.
- When an extended object AB is placed at different positions in front of a convex mirror then the following cases arise:

(i) When Object is placed at Infinity: **Position -** At '**F**' **Nature –** Virtual, erect **Size –** Point size	
(ii) When Object is placed between pole and Infinity: **Position –** Between 'P' and '**F**' **Nature –** Virtual, erect **Size –** Diminished	

Uses of Convex Mirror

(i) Convex mirrors are used as rear-view mirrors in vehicles because a full-length image of a tall building/tree can be seen in a small convex mirror. (a) they always give an erect though the diminished image. (b) they have a wider field of view as they are curved outwards.	 
(ii) Convex mirrors are used at blind turns and on points of merging traffic to facilitate the vision of both sides' traffic.	
(iii) Used in shops as a security mirror.	

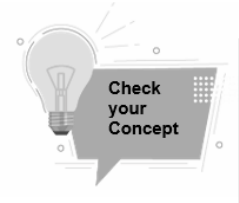
Example:

Which mirror is used in the rearview mirror and why?

Answer: Convex mirror is used in the rearview mirror because

(a) they always give an erect though the diminished image.

(b) they have a wider field of view as they are curved outwards.



(1) Which of the following mirror can form only diminished virtual image

(A) Concave Mirror

(B) Convex Mirror

(C) Plane Mirror

(D) None of the above

(2) Which of the following mirror can form virtual image

(A) Concave Mirror

(B) Convex Mirror

(C) Plane Mirror

(D) All of the above

Answer Key

(1) (B)

(2) (D)

New Cartesian Sign Convention

(i) The object is placed to the left of the mirror.

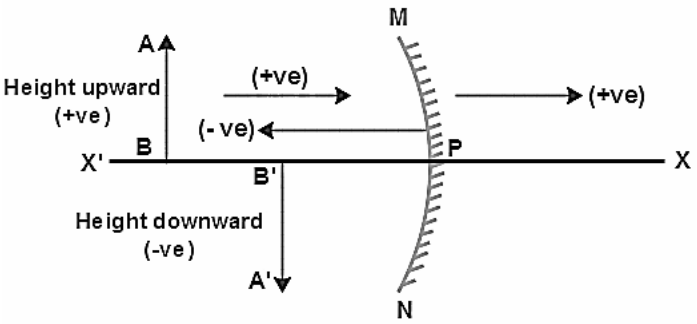
(ii) All distances parallel to the principal axis are measured from the pole of the mirror.

(iii) All distances measured in the direction of the incident ray (along +X-axis) are taken as positive and those measured against the direction of the incident ray (along −X-axis) are taken as negative.

(iv) Distance measured perpendicular to and above the principal axis is taken as positive.

(v) Distances measured perpendicular to and below the principal axis are taken as negative.

- The focal length of concave mirror = Negative
- The focal length of convex mirror = Positive



Mirror Formula

where $\mathbf{v}$ = Image distance

$\mathbf{u}$ = Object distance

$\mathbf{f}$ = Focal length

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

Magnification of Spherical Mirrors

It is the ratio of the height of the image to the height of the object.

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

$$m=\frac{h_i}{h_o}$$

Also,

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

Remarks:

If '$\mathbf{m}$' is negative, the image is real.

If '$\mathbf{m}$' is positive, the image is virtual.

If $h_i = h_o$ then $m = 1$, i.e., the size of the image is equal to the object.

If $h_i > h_o$ then $m > 1$ i.e., the image is enlarged.

If $h_i < h_o$ then $m < 1$ i.e., image is diminished.

When you say you will be somewhere in a 'jiffy', you are referring to an existing unit of measurement. A 'jiffy' is the time it takes light to travel one centimeter in a vacuum.

Example:

(1) Suppose the height of the object is $3\ \text{cm}$. the height of the image is $12\ \text{cm}$. what is the magnification?

Solution: Given

Height of image $= \mathbf{h' = 12\ cm}$

Height of object $= \mathbf{h = 3\ cm}$

Therefore,

$$\mathbf{m} = \frac{\text{Height of image}}{\text{Height of object}} = \frac{\mathbf{h'}}{\mathbf{h}}\ \mathbf{m} = \frac{\mathbf{12}}{\mathbf{3}}$$

$\mathbf{m = 4}$

$\therefore$ Magnification is $\mathbf{4}$

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

Solution: Since the Image produced is real. Hence, magnification will be negative

Magnification $= \mathbf{m = -3}$

Object distance $= \mathbf{u = -10\ cm}$

Let the image distance $= \mathbf{v}$

Magnification in mirror $= \frac{\mathbf{-v}}{\mathbf{u}}$

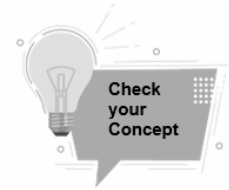
$$\mathbf{-3} = \frac{\mathbf{-v}}{\mathbf{-10}}$$

$$\mathbf{-3 \times -10 = -v}$$

$$\mathbf{30 = -v}$$

$$\mathbf{v = -30\ cm}$$

$\therefore$ The image is located $\mathbf{30\ cm}$ in front of the mirror



(1) Find the focal length of a convex mirror whose radius of curvature is $32\ \text{cm}$.

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

(3) A convex mirror used for rear-view on an automobile has a radius of curvature of $3.00\ \text{m}$. If a bus is located at $5.00\ \text{m}$ from this mirror, find the position of the image.

Answer Key

(1) 16 cm

(2) 37.5 cm, Real and Inverted

(3) 1.15m behind the mirror

Solved Examples

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

Solution: Here, object distance, u = - 10 cm focal length, f = 15 cm, image distance, v =?

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

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

$f = 6\ cm$

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

(2) An object $1\ cm$ tall is placed $4\ cm$ in front of a mirror. To produce an upright image of $3\ cm$ height, one needs a

(A) Convex mirror of radius of curvature $12\ cm$

(B) Concave mirror of radius of curvature $12\ cm$

(C) Concave mirror of radius of curvature $4\ cm$

(D) Plane mirror of height $12\ cm$

Solution: Given, $h_0 = 1\ cm; h_i = 3\ cm$ and $u = -4\ cm$

$m=\frac{h_1}{h_0}=\frac{3}{1}=3$

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

$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}=\frac{1}{12}-\frac{1}{4}$

$=\frac{1-3}{12}=\frac{-2}{12}=\frac{1}{6}$

$f = -6\ cm$

The mirror must be a concave mirror of the focal length of $6\ cm$ i.e.,

$R = 2f = -12\ cm$

(3) A rod of length $10\ cm$ lies along the principal axis of a concave mirror of focal length $10\ cm$ in such a way that the end close to the pole is $20\ cm$ away from it. Find the length of the image of the rod. [HOTS]

Solution: Focal length $f = -10\ cm$

$\therefore$ Radius of curvature $R = 2f$

$= -20$ cm

Length of the $rod\ AB = 10\ cm$

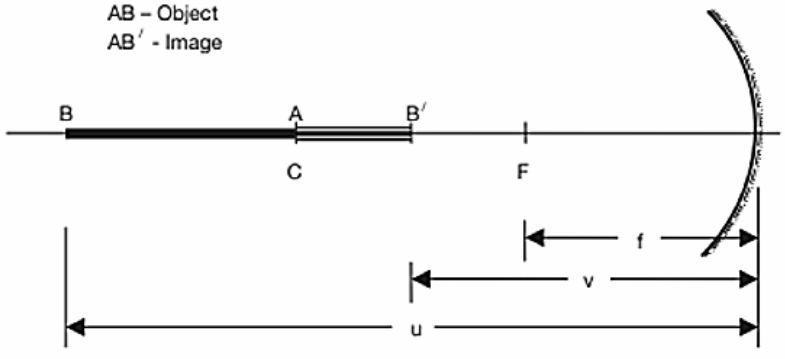
Distance of the end $A = 20\ cm$

$= R$

Since the near end,' A ' of the rod is at the centre of curvature, its image A^1 will also be at ' C '.

Distance of the end B of the road

$= 20 + 10 = 30\ cm$



$\therefore u = -30\ cm$ (from Cartesian sign convention)

$f = -10\ cm$

From mirror formula

$\frac{1}{f}=\frac{1}{u}+\frac{1}{v} \Rightarrow \frac{1}{-10}=\frac{1}{-30}+\frac{1}{v} \Rightarrow \frac{1}{v}=\frac{-1}{10}+\frac{1}{30} \Rightarrow\Rightarrow \frac{1}{v}=\frac{-30+10}{30\times 10}$

$\frac{1}{v}=\frac{-20}{300} \Rightarrow v=\frac{-30}{2}=-15\ cm$

Length of the image $= A^1B^1 = 20 - 15 = 5\ cm$

Exercise

OBJECTIVE TYPE QUESTIONS

(1) A mirror forms a virtual image of a real object.

(A) It must be a convex mirror.
(B) It must be a concave mirror.
(C) It must be a plane mirror.
(D) It may be any of the mirrors mentioned above.

(2) The angle of incidence is the angle between

(A) The incident ray and the surface of the mirror
(B) The reflected ray and the surface of the mirror
(C) The normal to the surface and the incident ray
(D) The normal to the surface and the reflected ray

(3) The angle of reflection is the angle between

(A) the incident ray and the surface of the mirror
(B) the reflected ray and the surface of the mirror
(C) the normal to the surface and the incident ray
(D) the normal to the surface and the reflected ray

(4) An object is placed at the Centre of the curvature of a concave mirror. The distance between its image and the pole is

(A) equal to f
(B) between f and 2f
(C) equal to 2f
(D) greater then 2f

(5) An object of size 2.0 cm is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror equals the radius of curvature. The size of the image will be

(A) 0.5 cm
(B) 1.5 cm
(C) 1.0 cm
(D) 2.0 cm

(6) The magnification m of an image formed by a spherical mirror is negative. It means, the image is

(A) Smaller than the object
(B) Larger than the object
(C) Erect
(D) Inverted

(7) A point object is placed on the principal axis of a spherical mirror. The object-distance u is

(A) definitely negative
(B) definitely positive
(C) positive if the object is to the left of the Centre of curvature
(D) positive if the object is to the right of the Centre of curvature

(8) $f = \frac{R}{2}$ is valid

(A) for convex mirrors but not for concave mirrors
(B) for the concave mirror but not for convex mirrors
(C) for both convex and concave mirrors
(D) neither for convex mirrors nor for a concave mirror

(9) A ray of light is incident on a concave mirror. If it is parallel to the principal axis, the reflected ray will

(A) pass through the focus
(B) pass through the Centre of curvature
(C) pass through the pole
(D) retrace its path

(10) If an incident ray passes through the Centre of curvature of a spherical mirror, the reflected ray will

(A) pass through the pole
(B) pass through the focus
(C) retrace its path
(D) be parallel to the principal axis

(11) To get an image larger than the object, one can use

(A) a convex mirror but not a concave mirror
(B) a concave mirror but not a convex mirror
(C) either a convex mirror or a concave mirror
(D) a plane mirror

(12) An object of height 4 cm is kept at a distance of 30 cm from the pole of a diverging mirror. If the focal length of the mirror is 10 cm, the height of the image formed in [CBSE 2022]

(A) $+3.0$ cm
(B) $+2.5$ cm
(C) $+1.0$ cm
(D) $+0.75$ cm

(13) The laws of reflection hold true for: [CBSE 2020, 2011]

(A) plane mirrors only
(B) concave mirrors only
(C) convex mirrors only
(D) all reflecting surfaces

(14) The radius of curvature of a converging mirror is 30 cm. At what distance from the mirror should an object be placed to obtain a virtual image?

(A) Infinity
(B) 30 cm
(C) Between 15 cm and 30 cm
(D) Between 0 cm and 15 cm

(15) When an object is kept within the focus of a concave mirror, an enlarged image is formed behind the mirror. This image is: [CBSE 2020]

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

(16) A full-length image of a distant tall building can be seen by using: [CBSE 2012, 13]

(A) A concave mirror
(B) A convex mirror
(C) A plane mirror
(D) Both concave as well as a plane mirror

(17) Your school laboratory has one large window. To find the focal length of a concave mirror using one of the walls as a screen, the experiment may be performed: [CBSE 2017]

(A) On the same wall as the window.
(B) On the wall adjacent to the window.
(C) On the wall opposite the window.
(D) Only on the table as per laboratory arrangement.

(18) To determine the focal length of a concave mirror by obtaining the image of a distant object on the screen, the position of the screen should be: [CBSE 2020]

(A) parallel to the plane of a concave mirror
(B) perpendicular to the plane of the concave mirror
(C) inclined at an angle $60°$ to the plane of the mirror
(D) in any direction with respect to the plane of the concave mirror

(19) If you focus a distant object of the shape using a concave mirror, the image obtained must be of the shape [CBSE 2017]

(A)  (B) 

(C)  (D) 

(20) An optical device has been given to a student and he determines its focal length by focusing the image of the sun on a screen placed 24 cm from the device on the same side as the sun. Select the correct statement about the device.

(A) Convex mirror of focal length **12 cm** **[CBSE 2010]**

(B) Convex lens of focal length **24 cm**

(C) Concave mirror of focal length **24 cm**

(D) Convex lens of focal length **12 cm**

Answer Key

(I) OBJECTIVE TYPE QUESTIONS

(1)	(D)	**(6)**	(D)	**(11)**	(B)	**(16)**	(B)
(2)	(C)	**(7)**	(A)	**(12)**	(B)	**(17)**	(D)
(3)	(D)	**(8)**	(C)	**(13)**	(D)	**(18)**	(A)
(4)	(C)	**(9)**	(A)	**(14)**	(D)	**(19)**	(C)
(5)	(D)	**(10)**	(C)	**(15)**	(D)	**(20)**	(C)