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S2 New Curriculum Physics

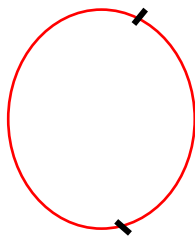
Theme: Light

Chapter 5 – Reflection of Light by curved surfaces



CURVED MIRRORS

Curved mirrors are made by cutting a part of a sphere.

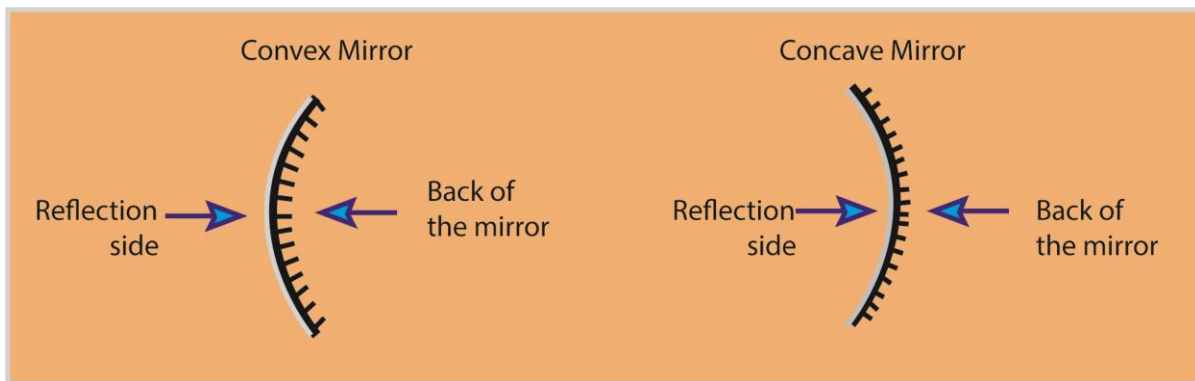


Sphere



part of the sphere cut

Types of curved mirrors



There are two types of curved mirrors namely: Concave mirror and convex mirror

A **convex mirror** is formed when the outer surface of the part of the sphere is coated with silver.

Applications of convex mirrors



Driving mirror



Security and Surveillance
in supermarkets



vehicle
inspection

A **concave mirror** is formed when the inner surface of the part of the sphere is coated with silver.

Application of concave mirrors



For inspection in dentistry

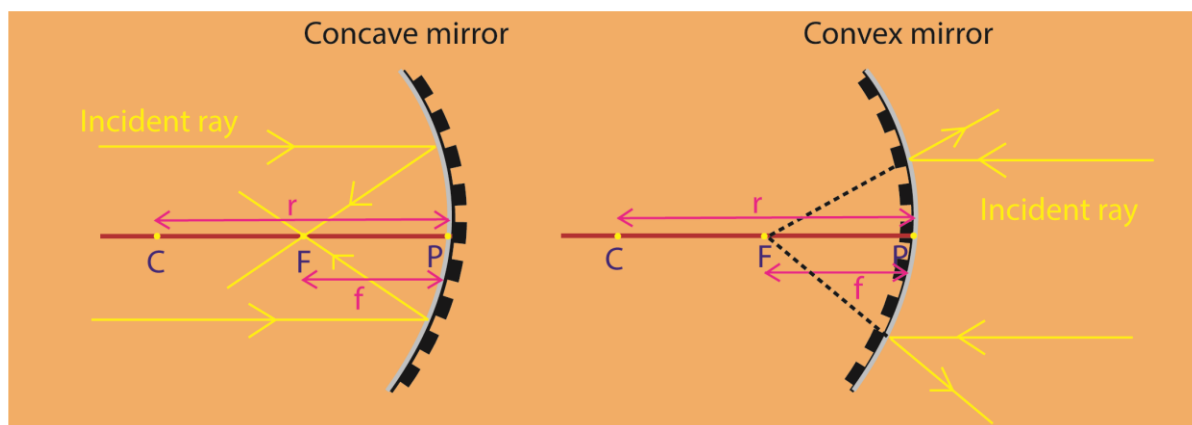


Solar Heater



Reflector in
Flashlight

Terms used for curved mirrors

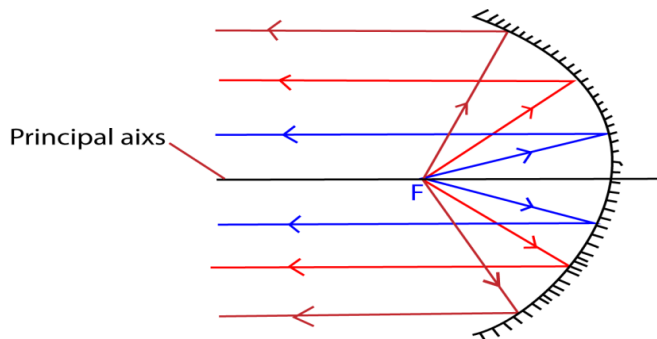


1. **Centre of curvature C:** it is the centre of the sphere of which the mirror forms part.
2. **Radius of curvature r:** it is the radius of the sphere of which the mirror forms part.
3. **Pole of the mirror:** it is the mid-point (centre) of the mirror surface.
4. **Principal axis CP:** it is the line that passes through the centre of curvature and the pole of the mirror.
5. **Secondary axes:** These are lines parallel to the principal axis of the mirror.
6. **Paraxial rays:** These are rays drawn close and parallel to the principal axis
7. **Marginal rays:** These are parallel rays furthest from the principal axis of the mirror.
8. (i) **Principal focus "F" of a concave mirror:** it is a point on the principal axis where paraxial rays incident on the mirror and parallel to the principal axis converge after reflection by the mirror.
(ii). **Principal focus "F" of a convex mirror:** it is a point on the principal axis where paraxial rays incident on the mirror and parallel to the principal axis appear to diverge from after reflection by the mirror
9. (i) **Focal length "f" of a concave mirror:** it is the distance from the pole of the mirror to the point where paraxial rays incident and parallel to the principal axis converge after reflection by the mirror.

(ii) **Focal length "f" of a convex mirror:** it is the distance from the pole of the mirror to the point where paraxial rays incident and parallel to the principal axis appear to diverge from after reflection by the mirror.
10. **Aperture of the mirror:** it is the length of the mirror surface.

Hyperbolic mirror

This is a type of concave mirror that reflects all the parallel incident beam on to a unique point F, the principal focus of the mirror.

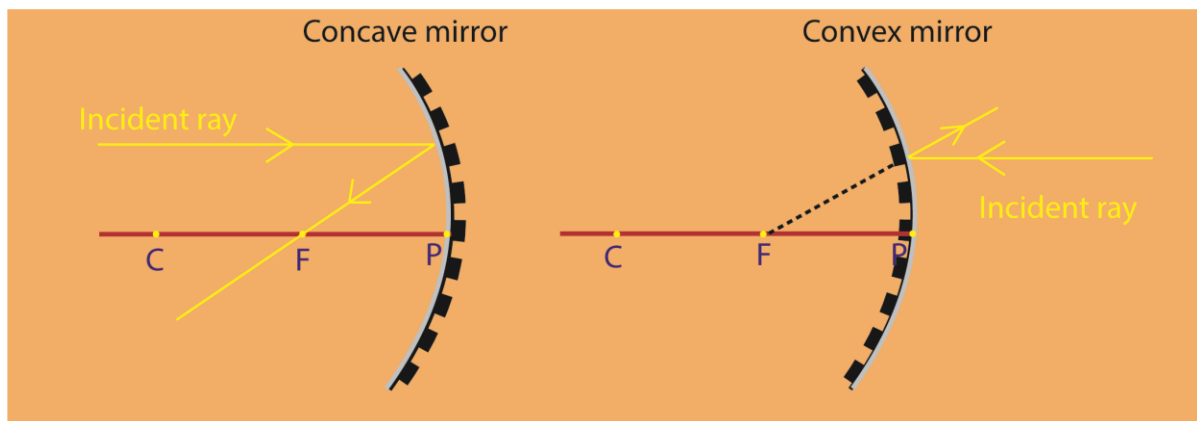


Note that in car headlight and torches, the reflecting surfaces are hyperbolic. When a bulb is placed at the principal focus of reflecting surface, a strong parallel beam of light is obtained. Hyperbolic mirrors are also used in reflecting telescopes.

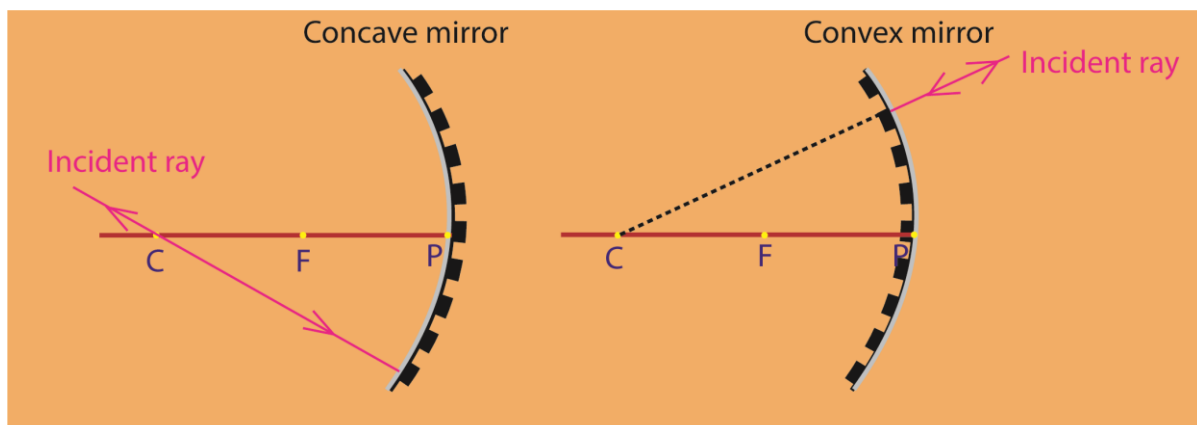
Geometrical rules for the construction of ray diagrams

The following is a set of rules for easy location of the images formed by spherical mirrors.

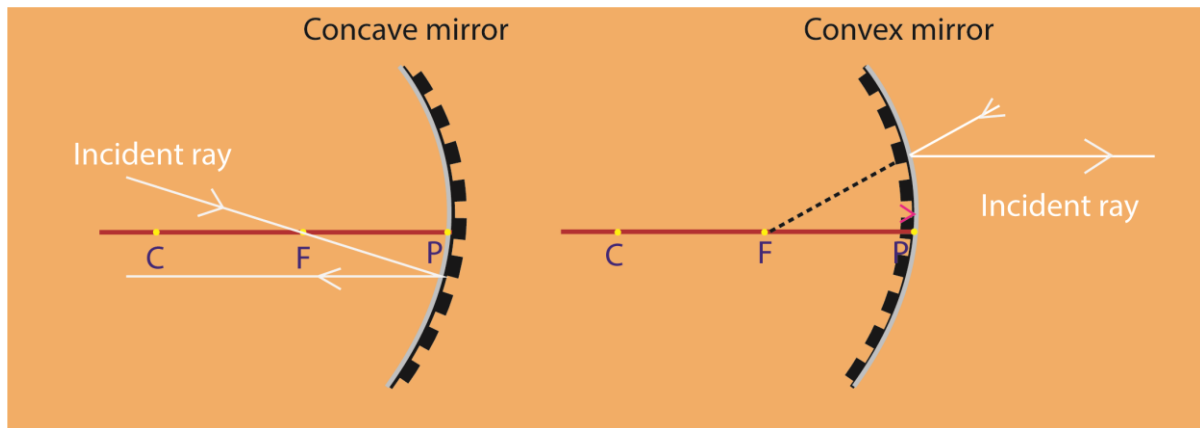
1. Rays parallel to the principal axis are reflected through the principal focus.



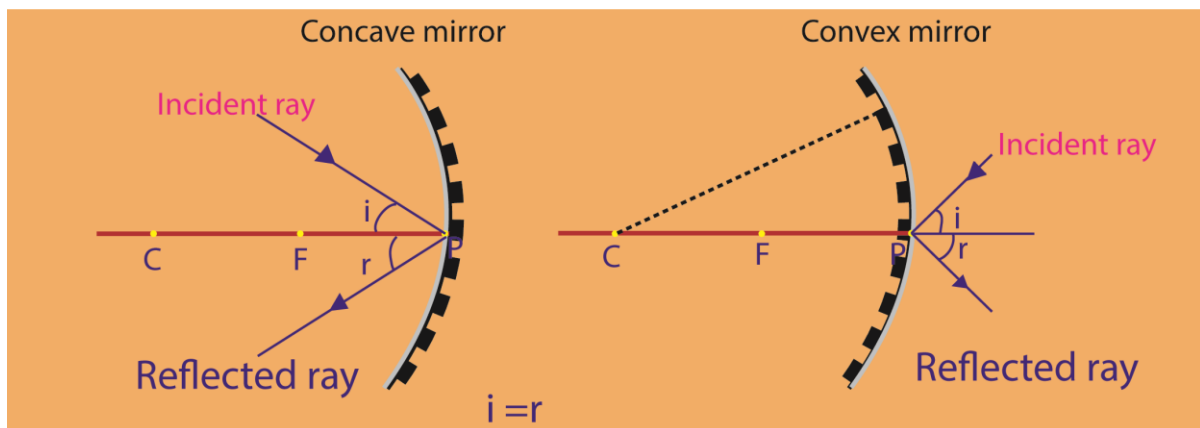
2. Rays passing through the centre of curvature are reflected back along their own paths.



3. Rays through the principal focus are reflected parallel to the principal axis.



4. Rays incident to the pole are reflected back, making the same angle with the principal axis.



NOTE:

- (i) The normal due to reflection at the mirror surface at any point must pass through the centre of curvature.
- (ii) The image position can be located by the intersection of two reflected rays initially coming from the object.

Real and virtual images

A REAL IMAGE: This is the image formed by the actual intersection of light rays from an object and can be received on the screen.

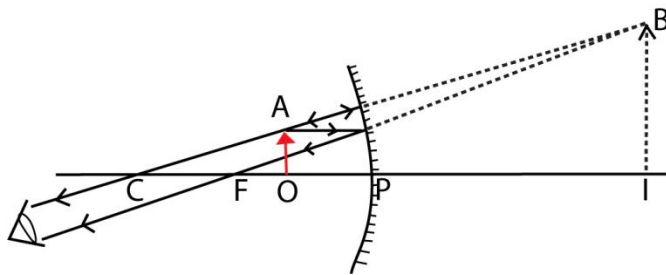
A VIRTUAL IMAGE: This is the image formed by the apparent intersection of light rays and cannot be received on the screen

IMAGES FORMED BY A CONCAVE MIRROR

The nature of the image formed by a concave mirror is either real or virtual depending on the object distance from the mirror as shown below;

Object between F and P the image is

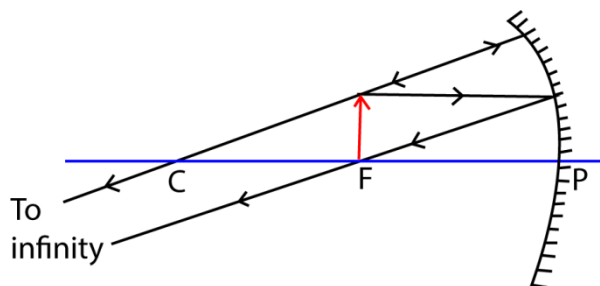
- (a) Behind the mirror
- (b) Virtual
- (c) Erect
- (d) Magnified



The property of a concave mirror to form erect, virtual and a magnified image when the object is nearer to the mirror than its focus makes it useful as a shaving mirror and also used by dentists for teeth examination.

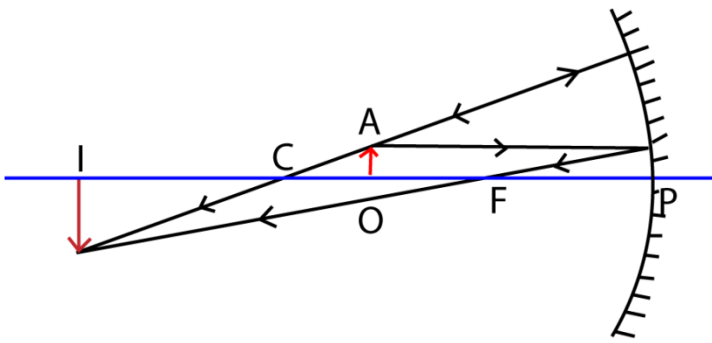
Object at F the image is

- (a) at infinity



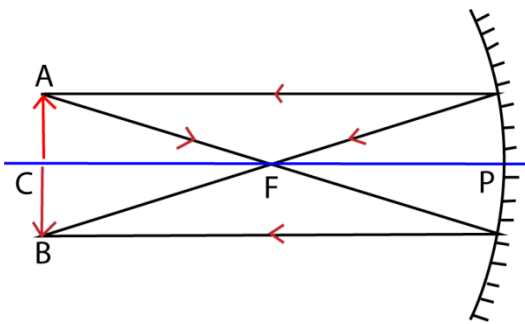
Object between F and C the image is

- (a) Beyond C
- (b) Real
- (c) Inverted
- (d) Magnified



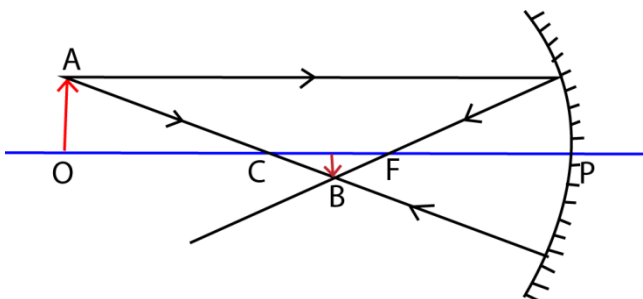
Object at C the image is

- (a) At C
- (b) Real
- (c) Inverted
- (d) Same size as the object



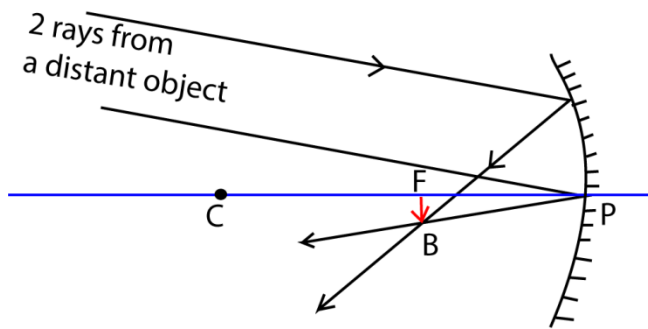
Object beyond C the image is

- (a) Between C and F
- (b) Real
- (c) Inverted
- (d) Diminished



Object at infinity the image is

- 1) At F
- 2) Real
- 3) Inverted
- 4) Diminished

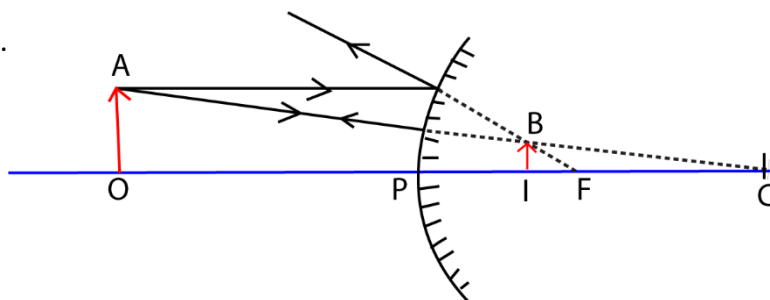


NOTE;

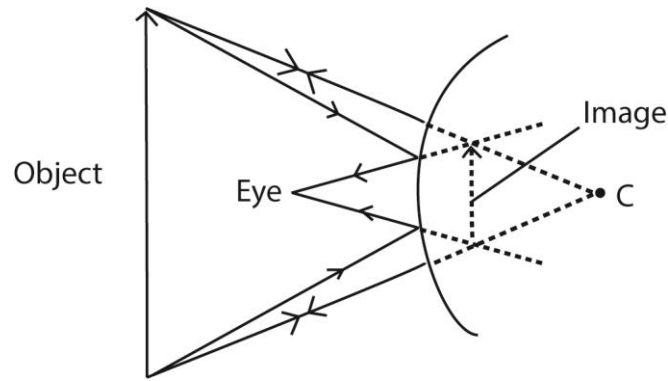
Generally the image of an object in a concave mirror is virtual only when the object is nearer to the mirror than its focus.

IMAGES FORMED BY A CONVEX MIRROR

The image of an object in a convex mirror is erect, virtual, and diminished in size no matter where the object is situated as shown below



In addition to providing an erect image, convex mirrors have got a wide field of view as illustrated below.



Construction of ray diagrams on graph paper

Step 1: On graph paper draw a central horizontal line (which acts as the principal axis) with a perpendicular line to act as the curved mirror,

Step 2: Where distances are given, choose a scale for object size and position.

Step 3: Measure the focal length **F** and radius of curvature **r** from the mirror and mark **C** and **F** as centre of curvature and principal focus respectively.

Step 4: Draw two of the principal rays to obtain the image,

Step 5: Measure the position and size of the image using the scale.

Linear magnification

$$\text{Magnification (m)} = \frac{\text{height of image (h}^1\text{)}}{\text{height of object (h)}}$$

OR

$$\text{Magnification (M)} = \frac{\text{Image of distance (v)}}{\text{object distance (u)}}$$

Curved mirror equation

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

f= focal length

u = object distance

v= image distance

Examples on concave mirror

An object is placed (a) 30cm (b) 10cm in front of a concave mirror of focal length 12cm. Find the nature and position of the image formed in each case

(a) $u = 30\text{cm}$ $f = 12\text{cm}$

$$= \frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{5-2}{60} = \frac{1}{v}$$

$$= \frac{1}{12} = \frac{1}{30} + \frac{1}{v} \Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{30} = \frac{3-2}{60} = \frac{1}{60}$$

$$= \frac{1}{12} = \frac{1}{30} + \frac{1}{v} \Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{30} = \frac{3-2}{60} = \frac{1}{60}$$

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

So the nature of the image is real because the value of v is positive, and magnified because v is larger than u

(b) $u = 10\text{cm}$ $f = 12\text{cm}$

$$= \frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{12} = \frac{1}{10} + \frac{1}{v} \Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{10} = \frac{5-6}{60} = -\frac{1}{60}$$

$$= \frac{1}{12} = \frac{1}{10} + \frac{1}{v} \Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{10} = -\frac{1}{60}$$

$$\frac{1}{12} - \frac{1}{10} = \frac{1}{v} \Rightarrow \frac{1}{v} = -\frac{1}{60}$$

$$v = -60\text{cm}$$

So the image is virtual because the value of v is negative, and magnified because v is greater than u .

Examples on convex mirror

An object is placed (a) 30cm (b) 10cm in front of a convex mirror of focal length 12cm. Find the nature and position of the image formed in each case,

Solution

(a) $f = -12\text{cm}$ (focal length "f" of convex mirror is virtual).

$$u = 30$$

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

$$= \frac{-1}{12} = \frac{1}{30} + \frac{1}{v}$$

$$= \frac{-5-2}{60} = \frac{1}{v}$$

$$v = -8.6\text{cm}$$

$$u = 10\text{cm}$$

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

$$\frac{-1}{12} = \frac{1}{10} + \frac{1}{v}$$

$$\frac{-5-6}{60} = \frac{1}{v}$$

$$v = 5.5\text{cm}$$

The images formed by a convex mirror are virtual and diminished

Trial 1

1. An object 2 cm high is placed perpendicular to the principle axis 15cm from the pole of the concave mirror. The radius of curvature of the mirror is 10cm. By construction (using a graph paper), determine the position, nature [7.5cm; real, magnified, inverted]
2. An object 15 cm long is placed vertically on the principle axis of a concave mirror and 40cm from the mirror. If the focal length of the mirror is 10cm, by graphical method determine the
 - (a) Position of the image from the mirror [13.3cm]
 - (b) Size of the image [5cm]
 - (c) Magnification cause[0.3]
 - (d) Nature of the image[real, inverted, diminished]
3. An object of height 5cm is placed 15cm in front of a concave mirror of radius of curvature 20cm. By scale drawing Find the
 - (a) Image distance from the mirror [30cm]
 - (b) Height of the image [10cm]
4.
 - (a) With the aid of a ray diagrams explain how regular and diffuse reflections are produced
 - (b) State the characteristics of images formed by plane mirrors.
5.
 - (a) What is a virtual image
 - (b) Under what conditions does a concave mirror form a virtual image?
 - (c) Describe how a focal length of concave mirror can be determined
6. An object 4cm tall is placed 4cm in a front of concave mirror of focal length 12cm. By graphical construction, find the position and nature of the image formed. [=6cm]

Experiments to measure the focal length of a concave mirror

Method I

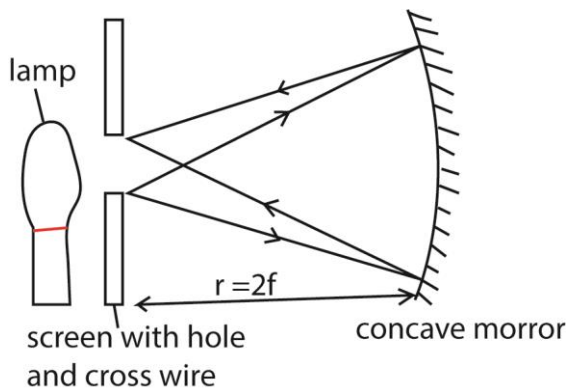
A distant object is focused on the screen.

The distance between the pole of the mirror and the screen is the focal length

Method II

A sharp image of illuminated wire gauze is formed besides the wire gauze in a mirror.

The distance between the wire gauze and the pole of the mirror is twice the focal length.

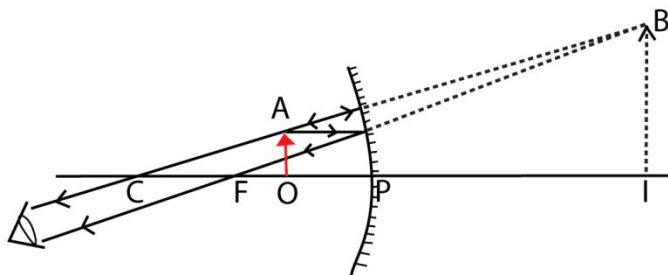


Use of curved mirror

(a) Shaving mirror

If the object is placed between the focal point and pole of the concave mirror, a virtual, erect and magnified image is formed. So it is used as magnifying mirror.

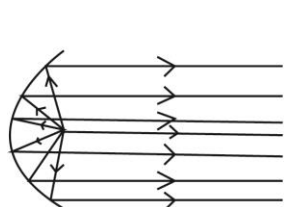
Diagram to be drawn



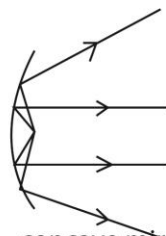
(b) Reflector

When a point source of light is placed at the principal focus of a concave mirror, the reflected beam is parallel. So concave mirrors are used as reflectors in torches and car head lamps since when the source is placed at the principal focus a parallel reflected beam is obtained. However, hyperbolic mirrors are better because they give a strong reflected beam.

Diagram to be drawn



Parabolic mirror reflect strong beam of light

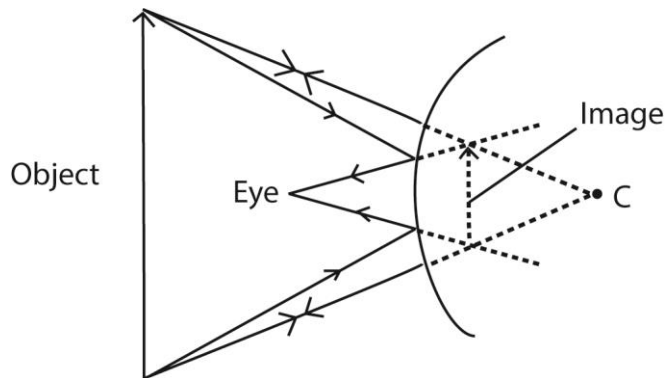


concave mirrors reflect diminishing beams

(c) Driving mirror

Convex mirrors are used as driving mirrors because they give a wider field of view than plan mirror.

Diagram to be drawn



Telescope

Both convex and concave mirrors are used in reflecting 'telescopes because of their larger aperture as their light energy losses are smaller.

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Thanks

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