MahaScience9

CLASS 9 SCIENCE · MAHARASHTRA STATE BOARD

CHAPTER 11

Reflection of Light

Chapter Notes

1. Light and reflection

Light is a form of energy that makes things visible. It travels in a **straight line** at about **3×10^8 m/s** in air or vacuum. We see an object when light from it enters our eyes.

When light falls on a surface and **bounces back** into the same medium, it is called **reflection of light**. Smooth, shiny surfaces such as mirrors reflect most of the light falling on them.

Laws of reflection

1. The incident ray, the reflected ray and the **normal** at the point of incidence all lie in the **same plane**.
2. The **angle of incidence (i)** is equal to the **angle of reflection (r)**: $\angle i = \angle r$.

The **normal** is the line drawn perpendicular to the surface at the point where the ray strikes it.

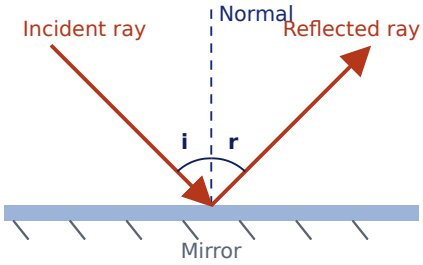


Fig. 11.1 Laws of reflection

REGULAR REFLECTION

Happens on **smooth** surfaces such as a mirror or still water. Parallel rays stay parallel after reflection, so a **clear image** is formed.

IRREGULAR (DIFFUSED) REFLECTION

Happens on **rough** surfaces such as paper or a wall. Parallel rays scatter in different directions, so no image forms, but the surface is seen from everywhere. The laws of reflection still hold at each point.

2. Mirrors

A **mirror** is a smooth, highly polished surface that reflects light regularly. Mirrors are of two main kinds: **plane mirrors** (flat) and **spherical mirrors** (curved, part of a hollow sphere).

2.1 Plane mirror

The image formed by a plane mirror is:

- **virtual** (cannot be taken on a screen) and **erect** (upright)
- **the same size** as the object
- as far **behind** the mirror as the object is in front of it
- **laterally inverted**: left appears right and right appears left (AMBULANCE is written in mirror letters for this reason)

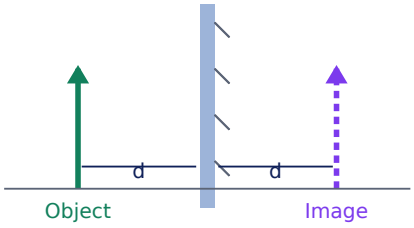


Fig. 11.2 Image in a plane mirror (same distance, same size)

MULTIPLE IMAGES

When two plane mirrors are kept at an angle θ, the number of images formed is **n = (360° ÷ θ) − 1**. At 90°, n = 3; at 60°, n = 5; at 45°, n = 7. Plane mirrors are used in the **periscope** and the **kaleidoscope**.

2.2 Spherical mirrors

A spherical mirror is a part of a hollow glass sphere with one surface polished.

- **Concave mirror:** the reflecting surface is curved **inwards** (the inner side of the sphere). It is a **converging** mirror: parallel rays meet at a point after reflection.
- **Convex mirror:** the reflecting surface is curved **outwards**. It is a **diverging** mirror: parallel rays spread out after reflection and appear to come from a point behind it.

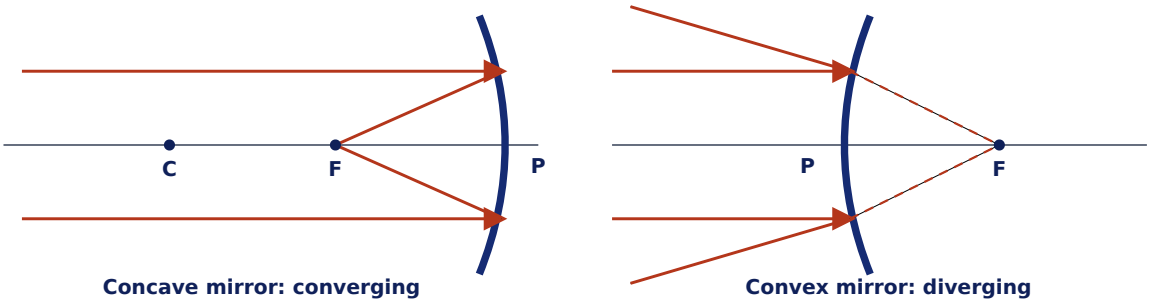


Fig. 11.3 Concave and convex mirrors with parallel rays

2.3 Terms related to spherical mirrors

Term	Meaning
Pole (P)	The centre of the reflecting surface of the mirror.
Centre of curvature (C)	The centre of the sphere of which the mirror is a part.
Radius of curvature (R)	The radius of that sphere; the distance PC.
Principal axis	The straight line passing through P and C.
Principal focus (F)	The point where rays parallel to the principal axis meet (concave) or appear to come from (convex) after reflection.
Focal length (f)	The distance PF. **f = R ÷ 2**.
Aperture	The width (diameter) of the reflecting surface.

Note: if a spherical mirror breaks, each piece is still a spherical mirror of the same type with the **same centre and radius of curvature**, but its own pole and principal axis. So three mirrors cut from one sphere have the same C and R but different poles and principal axes.

3. Rules for drawing ray diagrams

1. A ray **parallel to the principal axis** passes through F after reflection (concave), or appears to come from F (convex).
2. A ray passing **through F** (or directed towards F for convex) becomes **parallel** to the principal axis after reflection.
3. A ray passing **through C** (or directed towards C) falls along the normal and **retraces its path**.
4. A ray falling on the **pole** reflects at the same angle on the other side of the principal axis.

The image is formed where at least two reflected rays meet (**real image**) or appear to meet when extended backwards (**virtual image**, shown with dotted lines).

4. Image formation by a concave mirror

Position of object	Position of image	Size of image	Nature
At infinity	At F	Highly diminished (point)	Real, inverted
Beyond C	Between F and C	Diminished	Real, inverted
At C	At C	Same size	Real, inverted
Between C and F	Beyond C	Enlarged	Real, inverted
At F	At infinity	Highly enlarged	Real, inverted
Between P and F	Behind the mirror	Enlarged	**Virtual, erect**

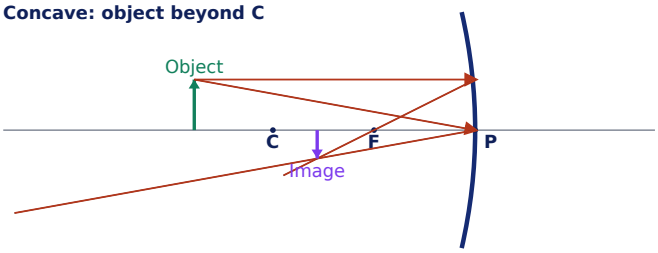


Fig. 11.4 Object beyond C

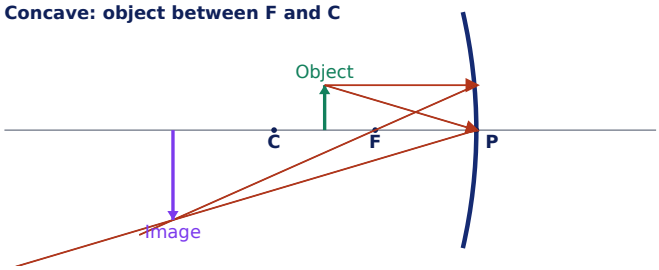


Fig. 11.5 Object between C and F

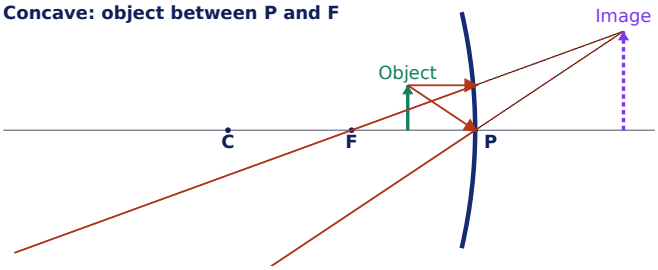


Fig. 11.6 Object between P and F (virtual image)

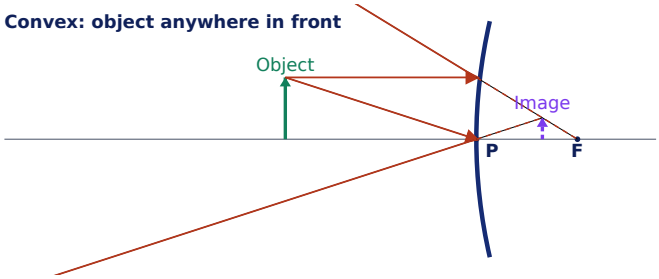


Fig. 11.7 Convex mirror (virtual, small image)

5. Image formation by a convex mirror

Position of object	Position of image	Size and nature
At infinity	At F, behind the mirror	Highly diminished (point); virtual, erect
Anywhere between infinity and P	Between P and F, behind the mirror	Diminished; virtual, erect

Comparison of mirrors

Mirror	Type of image	Size of image
Plane	Always virtual and erect	Same size as object
Concave	Mostly real and inverted; virtual and erect only when object is between P and F	Can be diminished, same size or enlarged
Convex	Always virtual and erect	Always diminished

6. Uses of spherical mirrors

CONCAVE MIRROR

- **Torches, car headlamps, floodlights:** the bulb is kept at the focus, so reflected light goes out as a strong parallel beam.
- **Shaving and make-up mirrors:** the face is within F, so an enlarged, erect image is seen.
- **Dentists' mirrors**, to see enlarged images of teeth.
- **Solar cookers and furnaces:** sun's rays are converged at the focus, producing a lot of heat. That is why paper kept at the focus catches fire.

CONVEX MIRROR

- **Rear-view (side) mirrors of vehicles:** they always give an erect image and show a much wider area behind the vehicle.
- **Street lights:** they spread light over a large area.
- **Security mirrors** in shops and at sharp turns on roads (blind turns).

7. Sign convention and mirror formula

New Cartesian sign convention (the object is always kept on the left of the mirror):

- All distances are measured from the **pole (P)**.
- Distances measured in the direction of incident light (to the right) are **positive**; opposite to it (to the left) are **negative**.
- Heights **above** the principal axis are positive; **below** are negative.

So for a concave mirror, f and R are negative; for a convex mirror, f and R are positive. The object distance u is always negative.

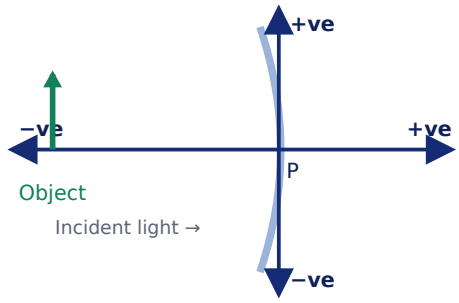


Fig. 11.8 New Cartesian sign convention

Mirror formula: $1/v + 1/u = 1/f$ | Magnification: $m = h_2/h_1 = -v/u$

Here **u** = object distance, **v** = image distance, **f** = focal length, h_1 = height of object and h_2 = height of image. If **m is negative**, the image is real and inverted; if **m is positive**, it is virtual and erect. If $|m| > 1$ the image is enlarged; if $|m| < 1$ it is diminished.

8. Solved numericals (textbook)

Q1. h_1 = 7 cm, u = 25 cm in front of a concave mirror, f = 15 cm. Find the screen position, and the size and nature of the image.

u = −25 cm, f = −15 cm. $1/v = 1/f - 1/u = -1/15 + 1/25 = (-5 + 3)/75 = -2/75 \rightarrow$ **v = −37.5 cm**.

$m = -v/u = -(-37.5)/(-25) = -1.5 \rightarrow h_2 = m \times h_1 = -1.5 \times 7 =$ **−10.5 cm**.

The screen must be kept **37.5 cm in front of the mirror**. The image is **real, inverted and enlarged** (10.5 cm tall).

Q2. A convex mirror has f = 18 cm. The image is half the height of the object. Find the object distance.

f = +18 cm, m = +1/2 (virtual, erect). m = −v/u → v = −u/2.
1/v + 1/u = 1/f → −2/u + 1/u = 1/18 → −1/u = 1/18 → **u = −18 cm**.
The object is **18 cm in front of the mirror** (and the image is 9 cm behind it).

Q3. A 10 cm stick lies along the principal axis of a concave mirror (f = 10 cm), its nearer end 20 cm from the pole. Find the length of the image.

Near end: u = −20 cm = 2f, so it is at C and its image is at **v = −20 cm**.
Far end: u = −30 cm. 1/v = −1/10 + 1/30 = −2/30 → **v = −15 cm**.
Length of image = 20 − 15 = **5 cm** (real and inverted).

9. Important questions for the exam

1. Write the differences between plane, concave and convex mirrors based on the type and size of image.
2. Why are concave mirrors used in solar devices? Why does paper kept at the focus of a concave mirror catch fire in sunlight?
3. Why are convex mirrors used as side mirrors on cars?
4. Which mirror is used in: periscope, floodlights, shaving mirror, kaleidoscope, street lights, car headlamps? (Plane, concave, concave, plane, convex, concave)
5. Draw ray diagrams for all six positions of an object in front of a concave mirror.
6. State the New Cartesian sign convention for spherical mirrors.
7. What type of mirror is each piece of a broken spherical mirror? Which of P, C, R and the principal axis are common to three mirrors made from the same sphere?