Ikigai Academy

CLASS 10 • SCIENCE • GSEB / NCERT PATTERN

Chapter 9 — Light: Reflection and Refraction

Concise chapter notes • diagrams • formulas • practice questions

Light shows two key behaviours: **reflection** (bouncing back) and **refraction** (bending while passing through). This chapter covers both, and how mirrors and lenses use them to form images.

9.1 Reflection of Light

Reflection is the bouncing back of light into the same medium after striking a smooth, polished surface.

- **Law 1:** Angle of incidence = Angle of reflection ***(∠i = ∠r)***
- **Law 2:** Incident ray, reflected ray and normal all lie in the same plane.

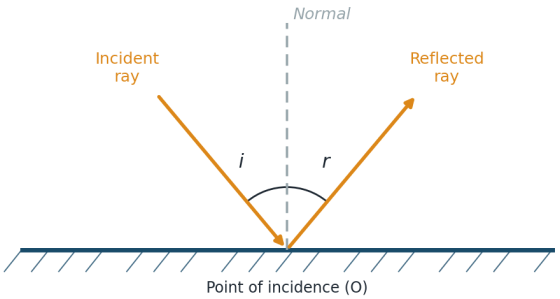

Fig. 9.1 — Laws of reflection

Regular reflection happens on a smooth surface (mirror) — parallel rays stay parallel, giving a clear image. **Irregular / diffuse reflection** happens on a rough surface (paper, wall) — rays scatter, so no clear image forms. (This is why we see non-shiny objects from any angle.)

Image Formed by a Plane Mirror

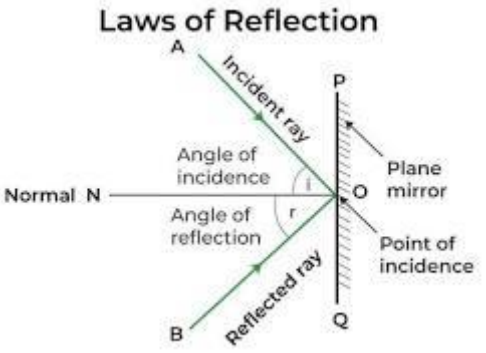

Fig. 9.2 — Image in a plane mirror

- Virtual (cannot be obtained on a screen) and erect
- Same size as the object
- Laterally inverted (left ↔ right reversed)
- Image is as far behind the mirror as the object is in front

9.2 Spherical Mirrors

Concave mirror — reflecting surface curves inward; converges light (converging mirror). **Convex mirror** — surface bulges outward; diverges light (diverging mirror).

Important Terms

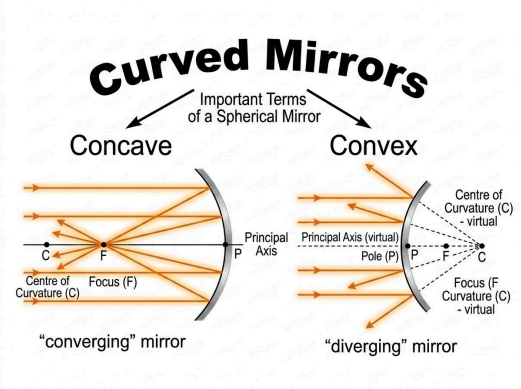

Fig. 9.3 — Pole, centre of curvature, focus

- **Pole (P):** centre of the mirror's surface
- **Centre of Curvature (C):** centre of the sphere the mirror is part of
- **Radius of Curvature (R):** distance PC
- **Principal Axis:** line through P and C
- **Principal Focus (F):** point where rays parallel to the axis meet (concave) / appear to meet (convex) after reflection
- **Focal Length (f):** distance PF

Relation: $f = R / 2$

9.2.1 Image Formation by Spherical Mirrors

Any two rays locate the image:

- Ray // to principal axis → reflects through F (concave) / appears to come from F (convex)
- Ray through F → reflects parallel to the principal axis
- Ray through C → reflects back along the same path

Concave Mirror — Six Cases

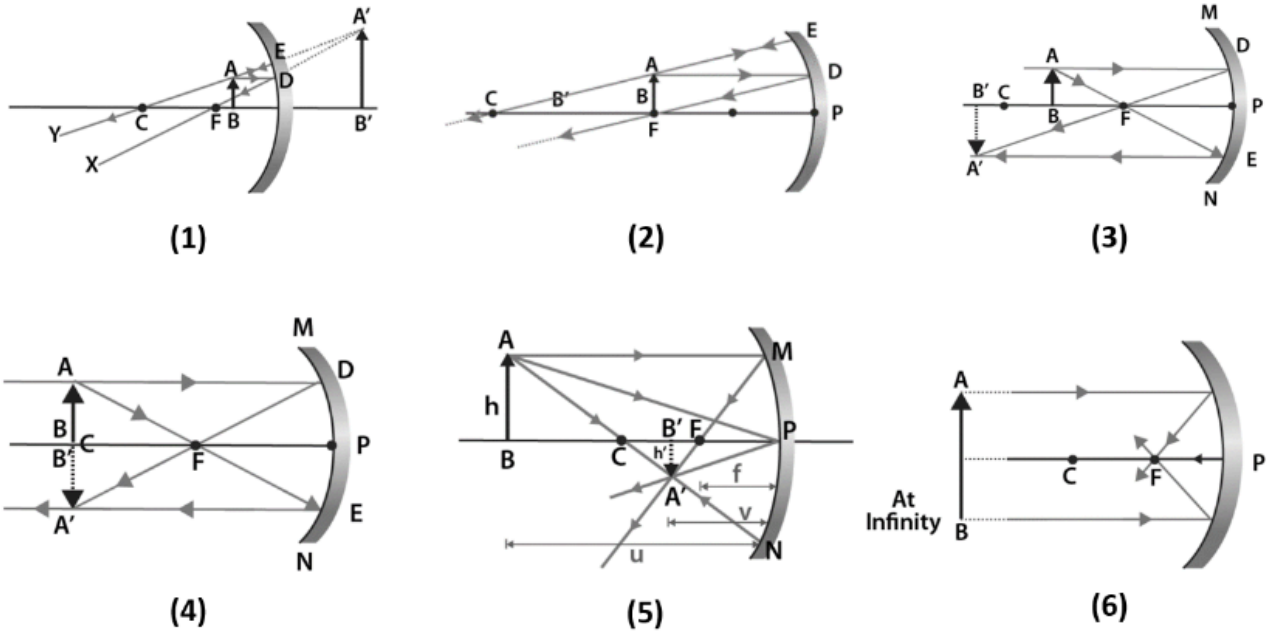

Fig. 9.4 — Concave mirror image formation

Position of object	Position of image	Size	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

Uses:

- Shaving / make-up mirrors
- Reflectors in torches, headlights, search-lights
- Solar cookers and furnaces

Convex Mirror — Two Cases

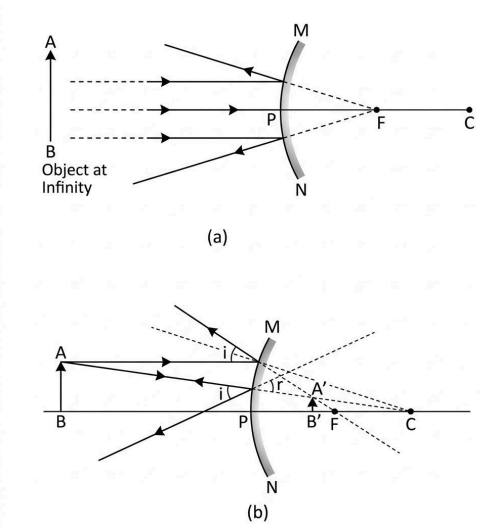

Fig. 9.5 — Convex mirror image formation

Position of object	Position of image	Size	Nature
At infinity	At F, behind mirror	Highly diminished, point	Virtual, erect
Between infinity and pole	Between P and F, behind mirror	Diminished	Virtual, erect

A convex mirror ALWAYS forms a virtual, erect, diminished image.

Uses: vehicle rear-view mirrors and shop/ATM security mirrors — both need the wider field of view a convex mirror gives.

9.2.2 Sign Convention for Mirrors

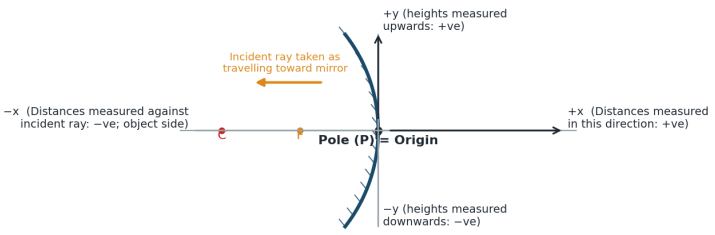

Fig. 9.6 — New Cartesian sign convention

- Pole = origin; principal axis = x-axis; object always to the left
- Distances with the incident ray (right) = positive; against it (left) = negative → object distance u is always negative
- Heights up = positive; heights down = negative

Quantity	Concave mirror	Convex mirror
Focal length (f)	Negative	Positive
Radius of curvature (R)	Negative	Positive

9.2.3 Mirror Formula and Magnification

Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

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

m negative → real, inverted image; m positive → virtual, erect image. |m|>1 enlarged, |m|<1 diminished.

Solved Example 1

An object 4 cm high is placed 15 cm from a concave mirror of focal length 10 cm. Find the image.

Given: h = 4 cm, u = −15 cm, f = −10 cm

1/v = 1/f − 1/u = 1/(−10) − 1/(−15) = −1/30 ⇒ v = −30 cm

m = −v/u = −2 ⇒ h′ = −8 cm

Answer: **Real, inverted, enlarged image 30 cm in front of the mirror (8 cm tall).**

9.3 Refraction of Light

Refraction is the bending of light as it passes obliquely from one transparent medium to another, due to a change in speed.

- Rarer → denser medium: bends TOWARDS the normal (slows down); denser → rarer: bends AWAY (speeds up)
- Along the normal: no bending, though speed still changes

9.3.1 Refraction through a Glass Slab

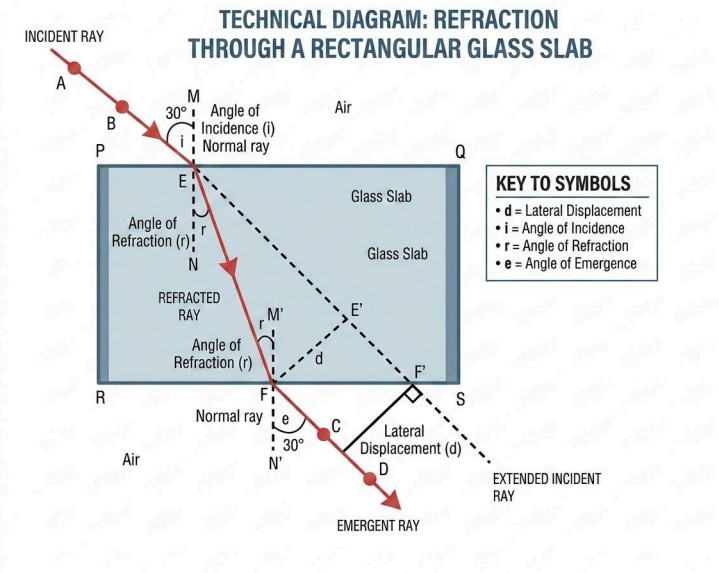

Fig. 9.7 — Refraction through a glass slab

- Bends towards the normal entering the (denser) glass, travels straight inside, bends away from the normal on exit
- Emergent ray is parallel to the incident ray, but laterally displaced
- **Law 1:** incident ray, refracted ray, normal — same plane.

Law 2 (Snell's Law): $\frac{\sin i}{\sin r} = n$

9.3.2 Refractive Index

Absolute refractive index: $n = c / v$

c = speed of light in vacuum; v = speed in the medium. Higher n ⟶ denser medium ⟶ slower light.

Relative refractive index: $_1n_2 = v_1/v_2 = n_2/n_1$

Medium	Refractive index
Air / vacuum	≈ 1.00
Water	1.33
Kerosene	1.44
Crown glass	1.52
Diamond	2.42

Note: optical density ≠ mass density — e.g. turpentine bends light more than water despite being less dense.

9.4 Refraction by Spherical Lenses

Convex lens — thicker at the middle; converges light (converging lens). **Concave lens** — thinner at the middle; diverges light (diverging lens).

Important Terms

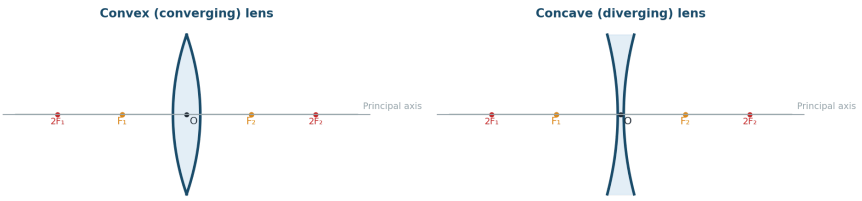

Fig. 9.8 — Optical centre and foci of a lens

- **Optical Centre (O):** centre point; a ray through O passes straight through
- **Centres of Curvature (C_1, C_2):** centres of the two surfaces — one on each side
- **Principal Foci (F_1, F_2):** one on each side of O
- **Focal Length (f):** distance from O to a principal focus

9.4.1 Image Formation by Lenses

- Ray // to axis ⟶ through F2 (convex) / appears from F1 (concave)
- Ray through optical centre O ⟶ no deviation
- Ray through F1 (convex) / towards F2 (concave) ⟶ emerges parallel to the axis

Convex Lens — Six Cases

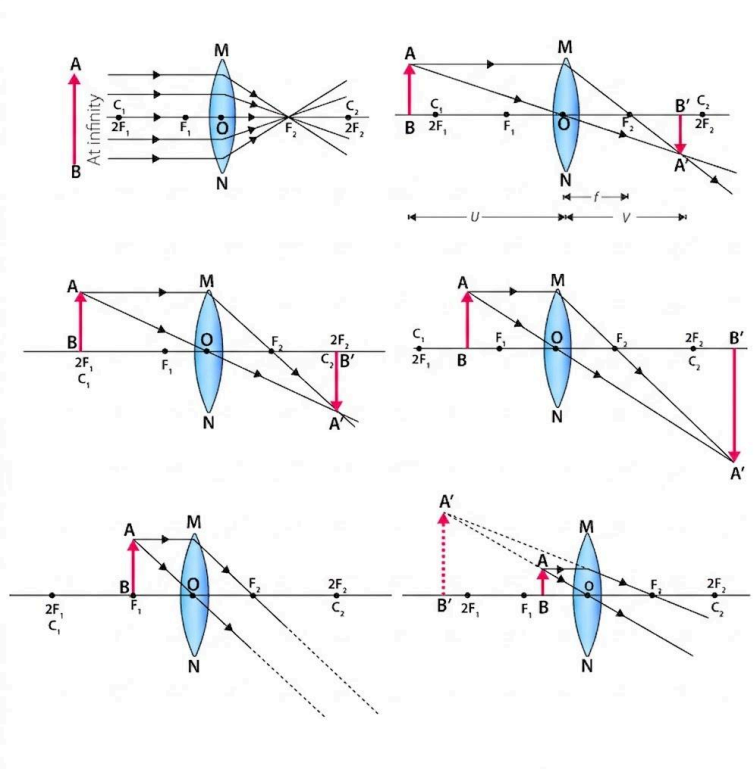

Fig. 9.9 — Convex lens image formation

Position of object	Position of image	Size	Nature
At infinity	At F2	Highly diminished, point	Real, inverted
Beyond 2F1	Between F2 and 2F2	Diminished	Real, inverted
At 2F1	At 2F2	Same size	Real, inverted
Between F1 and 2F1	Beyond 2F2	Enlarged	Real, inverted
At F1	At infinity	Highly enlarged	Real, inverted
Between F1 and O	Same side as object	Enlarged	Virtual, erect

Uses: magnifying glass, camera/projector lenses, correcting hypermetropia.

Concave Lens — Two Cases

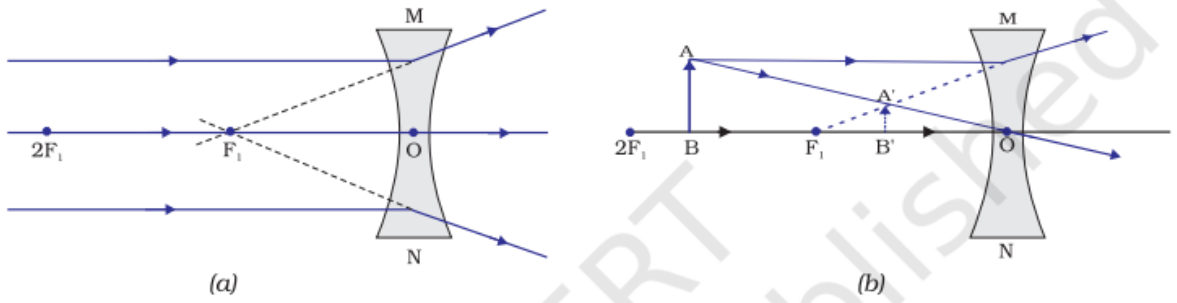

Figure 9.17 *Nature, position and relative size of the image formed by a concave lens*

Fig. 9.10 — Concave lens image formation

Position of object	Position of image	Size	Nature
At infinity	At F1	Highly diminished, point	Virtual, erect
Between infinity and O	Between O and F1	Diminished	Virtual, erect

A concave lens ALWAYS forms a virtual, erect, diminished image.

Uses: correcting myopia (short-sightedness).

9.4.2 Sign Convention for Lenses

- Same rules as mirrors, but measured from the optical centre O
- u always negative; convex lens f positive; concave lens f negative

9.4.3 Lens Formula and Magnification

Lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Magnification: $m = \frac{h'}{h} = \frac{v}{u}$

Solved Example 2

A convex lens of focal length 20 cm forms a real image twice the size of the object. Find the object distance.

Given: f = +20 cm, m = −2

m = v/u = −2 ⇒ v = −2u

1/v − 1/u = 1/f ⇒ −3/(2u) = 1/20 ⇒ u = −30 cm

Answer: Object should be placed 30 cm in front of the lens.

9.4.4 Power of a Lens

Power: $P = \frac{1}{f}$ **(f in metres)**

Unit: dioptre (D). Convex lens → P positive; concave lens → P negative.

Lenses in contact: $P = P_1 + P_2 + \ldots$

Solved Example 3

Find the power of a concave lens of focal length 50 cm.

Given: f = −50 cm = −0.5 m

P = 1/f = 1/(−0.5)

Answer: P = −2 D (negative → diverging / concave lens).

Quick Revision — Formula Sheet

Concept	Formula
Laws of reflection	∠i = ∠r
Radius & focal length	R = 2f
Mirror formula	1/v + 1/u = 1/f
Magnification (mirror)	m = h′/h = −v/u
Snell's law	sin i / sin r = n
Refractive index	n = c/v
Lens formula	1/v − 1/u = 1/f
Magnification (lens)	m = h′/h = v/u
Power of a lens	P = 1/f (f in m); unit: dioptre (D)

Practice Questions — GSEB Pattern

Section A — MCQs (1 mark each)

1. The image formed by a plane mirror is:
   (a) real, inverted (b) virtual, erect (c) real, erect (d) virtual, inverted
2. Focal length of a concave mirror with radius of curvature 30 cm:
   (a) 10 cm (b) 15 cm (c) 30 cm (d) 60 cm
3. Always forms a virtual, erect, diminished image:

(a) concave mirror (b) plane mirror (c) convex mirror (d) none

4. SI unit of power of a lens:
   (a) metre (b) dioptre (c) candela (d) lumen
5. A convex lens forms a virtual image when the object is:
   (a) at F (b) between F and 2F (c) between F and O (d) at 2F
6. Highest refractive index:
   (a) water (b) glass (c) diamond (d) kerosene
7. Rear-view mirror in vehicles:
   (a) concave (b) plane (c) convex (d) cylindrical
8. Rarer to denser medium, light bends:
   (a) away from normal (b) towards normal (c) not at all (d) along the surface

Answer key: 1-(b) 2-(b) 3-(c) 4-(b) 5-(c) 6-(c) 7-(c) 8-(b)

Section B — Very Short Answer (1 mark each)

1. Define the principal focus of a concave mirror.
   Ans: *Point on the principal axis where parallel rays meet after reflection.*
2. Power of a lens of focal length 1 m?
   Ans: *1 dioptre (P = 1/f = 1/1 = 1 D).*
3. Mirror used in solar cookers?
   Ans: *Concave mirror.*
4. Relation between radius of curvature and focal length?
   Ans: *R = 2f.*

Section C — Short Answer (2–3 marks each)

1. State the laws of reflection. [2 marks]
   - $\angle i = \angle r$
   - *Incident ray, reflected ray, normal lie in the same plane*
2. Differentiate real and virtual images. [2 marks]
   - *Real: actual intersection of rays, obtainable on screen, usually inverted*
   - *Virtual: apparent intersection, cannot be obtained on screen, usually erect*
3. Why is a convex mirror preferred as a vehicle rear-view mirror? [2 marks]
   - *Always gives an erect, diminished image*
   - *Gives a wider field of view than a plane mirror*
4. Define refractive index; give the formula for the absolute refractive index. [3 marks]
   - *Measure of how much a medium bends light*
   - $n = c/v$ *(c = speed in vacuum, v = speed in medium)*

Section D — Long Answer (5 marks each)

1. Draw the ray diagram for a concave mirror with the object between P and F. State the image's characteristics. [5 marks]
   - *Diagram: object between P & F → virtual image behind the mirror*
   - *Characteristics: virtual, erect, enlarged*
2. A concave mirror forms a 3× magnified real image of an object placed 10 cm from it. Find the image position. [5 marks]
   - $m = -3, u = -10\ cm \Rightarrow v = -30\ cm$
   - *Image is 30 cm in front of the mirror*
3. An object of height 5 cm is placed 25 cm from a convex lens of focal length 10 cm. Find the image. [5 marks]
   - $1/v = 1/10 - 1/25 = 3/50 \Rightarrow v = 16.67\ cm$
   - $m = -0.67 \Rightarrow h' = -3.33\ cm$ *— real, inverted, diminished*