



AMBITION INSTITUTE

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CHAPTER – 9

MIRROR

LENS

LIGHT

RAY

REFLECTION & REFRACTION

CLASS 10th

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

$$n = \frac{c}{v}$$

$$P = \frac{1}{f}$$

SCIENCE

NOTES

PHYSICS

SCIENCE

REFLECTION OF LIGHT

What is Light?

Light is a form of energy that makes objects visible. It travels in **straight lines** (rectilinear propagation) with a speed of 3×10^8 m/s in vacuum.

When light falls on a smooth, polished surface such as a mirror, it bounces back. This is called **reflection**.

Reflection of Light

The bouncing back of light when it strikes a smooth, polished surface is called **reflection of light**.

Laws of Reflection

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

These laws hold for **every** reflecting surface, including curved ones.

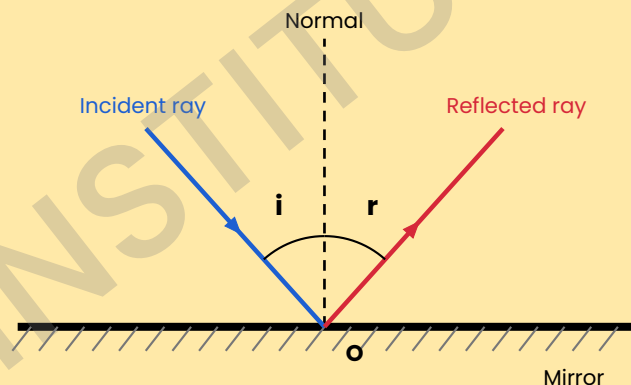


Image Formed by a Plane Mirror

- The image is **virtual** and **erect**.
- The image is the **same size** as the object.
- The image is formed as far **behind** the mirror as the object is in front of it.
- The image is **laterally inverted** (the left side of the object appears as the right side).

Real Image vs Virtual Image

Real Image

- Can be obtained on a screen
- Formed when light rays actually meet
- Usually inverted

Virtual Image

- Cannot be obtained on a screen
- Formed when rays only appear to meet
- Usually erect

SPHERICAL MIRRORS

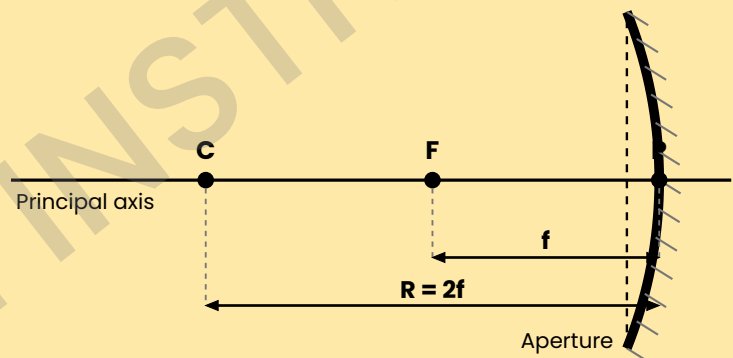
Concave and Convex Mirrors

A **spherical mirror** is a mirror whose reflecting surface is a part of a hollow sphere.

- **Concave mirror:** the reflecting surface is curved **inwards**. It **converges** a parallel beam of light (converging mirror).
- **Convex mirror:** the reflecting surface is curved **outwards**. It **diverges** a parallel beam of light (diverging mirror).

Important Terms

- **Pole (P):** the centre of the reflecting surface.
- **Centre of curvature (C):** the centre of the hollow sphere of which the mirror is a part.
- **Radius of curvature (R):** the distance PC.
- **Principal axis:** the straight line passing through P and C.
- **Principal focus (F):** the point on the principal axis where rays parallel to the axis meet (concave) or appear to come from (convex) after reflection.
- **Focal length (f):** the distance PF.
- **Aperture:** the diameter of the reflecting surface.



Relation between R and f

$$R = 2f \text{ or } f = R/2$$

Concave vs Convex at a Glance

Feature	Concave mirror	Convex mirror
Reflecting surface	Curved inwards	Curved outwards
Effect on parallel beam	Converges (converging mirror)	Diverges (diverging mirror)
Principal focus	Real, in front of the mirror	Virtual, behind the mirror
Sign of focal length	Negative	Positive

IMAGE FORMATION BY MIRRORS

Rules for Drawing Ray Diagrams

1. A ray **parallel** to the principal axis passes through F (concave) or appears to diverge from F (convex) after reflection.
2. A ray passing through F (concave), or directed towards F (convex), becomes **parallel** to the principal axis after reflection.
3. A ray passing through C (concave), or directed towards C (convex), is reflected **back along the same path**.
4. A ray falling on the pole P is reflected making **equal angles** with the principal axis.

Concave Mirror

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

Convex Mirror

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

- A **concave mirror** forms real or virtual images, depending on where the object is placed.
- A **convex mirror** always forms a virtual, erect and diminished image.

USES, SIGN CONVENTION & MIRROR FORMULA

Uses of Mirrors

Concave mirrors

- Torches, vehicle headlights and searchlights (strong parallel beam)
- Shaving mirrors (enlarged, erect image)
- Dentists' mirrors (enlarged view of teeth)
- Solar furnaces (concentrate sunlight)

Convex mirrors

- Rear-view mirrors of vehicles
- They give an erect, diminished image and a **wider field of view**, so the driver can see more of the traffic behind

New Cartesian Sign Convention

- The object is always placed to the **left** of the mirror.
- All distances are measured from the **pole (P)** of the mirror.
- Distances measured in the direction of the incident light (to the right, +x) are **positive**; against it (to the left, -x) are **negative**.
- Heights measured **upwards**, perpendicular to the principal axis, are positive; **downwards** are negative.
- So **f is negative** for a concave mirror, **f is positive** for a convex mirror and **u is always negative**.

Mirror Formula and Magnification

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

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

Here **u** = object distance, **v** = image distance, **f** = focal length, **h** = object height, **h** = image height.

- **m negative** → real and inverted image; **m positive** → virtual and erect image.
- $|m| > 1$ enlarged; $|m| < 1$ diminished; $|m| = 1$ same size.

Numerical Example

Q. A 4 cm tall object is placed 15 cm in front of a concave mirror of focal length 10 cm. Find the position, nature and size of the image.

Given: $u = -15$ cm, $f = -10$ cm, $h = 4$ cm

Mirror formula: $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{-1}{10} + \frac{1}{15} = -\frac{1}{30}$, so **$v = -30$ cm**

Magnification: $m = -\frac{v}{u} = -\frac{(-30)}{(-15)} = -2$, so **$h = m \times h = -8$ cm**

Answer: The image is formed 30 cm in front of the mirror; it is real, inverted and enlarged (8 cm tall).

REFRACTION OF LIGHT

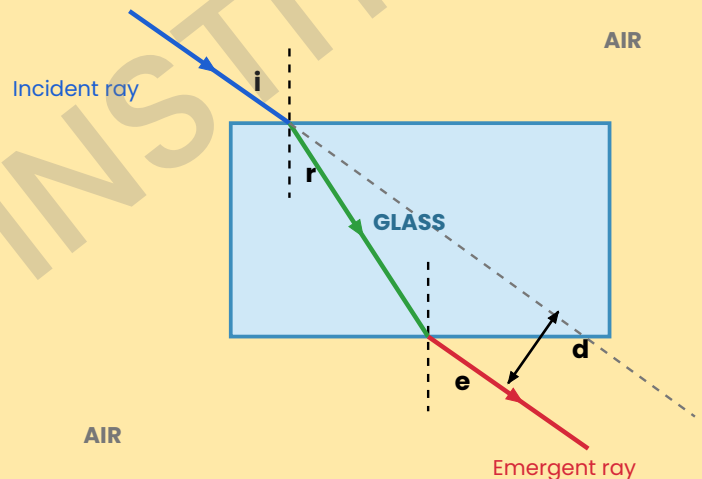
What is Refraction?

The **bending of light** when it passes obliquely from one transparent medium to another is called **refraction**. It happens because the **speed of light changes** from medium to medium.

- Rarer → denser medium: the ray bends **towards** the normal.
- Denser → rarer medium: the ray bends **away from** the normal.
- A ray falling along the normal ($i = 0^\circ$) goes straight without bending.

Refraction Through a Rectangular Glass Slab

- Light bends **twice**: towards the normal on entering the glass, away from the normal on leaving it.
- The emergent ray is **parallel** to the incident ray (angle $i =$ angle e).
- The emergent ray is shifted sideways. This shift (d) is called **lateral displacement**.



Laws of Refraction

1. The incident ray, the refracted ray and the normal at the point of incidence all lie in the **same plane**.
2. **Snell's law**: for a given colour of light and a given pair of media, the ratio $\sin i / \sin r$ is constant.

$$\sin i / \sin r = n_{21}$$

n_{21} is the refractive index of medium 2 with respect to medium 1.

Refractive Index

The refractive index tells us how much a medium bends light, or how much it slows light down.

$$n = c / v$$

Here c = speed of light in vacuum (3×10^8 m/s) and v = speed of light in the medium. A larger n means the medium is **optically denser** and light travels **slower** in it.

REFRACTIVE INDEX OF MATERIALS

Absolute Refractive Index of Some Materials

Material	Refractive index (n)	Speed of light ($\times 10^8$ m/s)
Air	1.0003	3.00
Ice	1.31	2.29
Water	1.33	2.26
Alcohol	1.36	2.21
Kerosene	1.44	2.08
Fused quartz	1.46	2.05
Turpentine oil	1.47	2.04
Benzene	1.50	2.00
Crown glass	1.52	1.97
Rock salt	1.54	1.95
Dense flint glass	1.65	1.82
Ruby	1.71	1.75
Diamond	2.42	1.24

Speeds are approximate values from $v = c / n$ with $c = 3 \times 10^8$ m/s.

Optical Density vs Mass Density

Optical density tells how strongly a medium slows light (its refractive index). It is **not** the same as mass density.

Example: kerosene ($n = 1.44$) is optically denser than water ($n = 1.33$), but its mass density is lower than that of water.

Refraction in Everyday Life

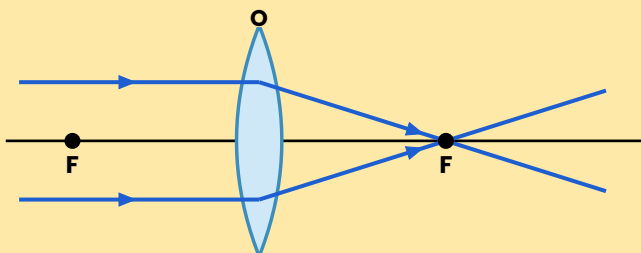
- A pencil partly dipped in water looks **bent** at the water surface.
- A pond looks **shallower** than it really is.
- Letters seen through a thick glass slab appear slightly **raised**.
- Diamond sparkles because its very high refractive index bends light strongly inside it.

SPHERICAL LENSES

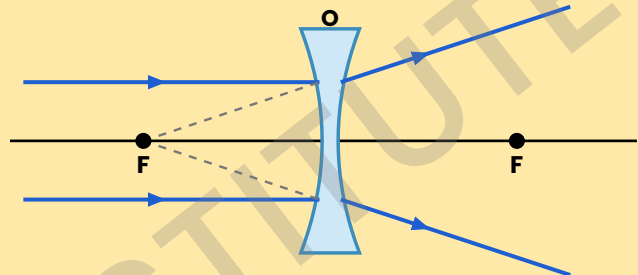
Convex and Concave Lenses

A transparent material bounded by two surfaces, of which one or both are spherical, forms a **lens**.

- **Convex lens:** bulges outwards, thicker at the centre than at the edges. It **converges** light (converging lens).
- **Concave lens:** curved inwards, thicker at the edges than at the centre. It **diverges** light (diverging lens).



Convex lens (converging)



Concave lens (diverging)

Important Terms

- **Optical centre (O):** the central point of a lens. A ray passing through it goes **undeviated**.
- **Principal axis:** the imaginary line passing through the two centres of curvature of the lens.
- **Principal focus (F):** a lens has **two** principal foci, F_1 and F_2 , one on each side.
- **Focal length (f):** the distance between the optical centre and the principal focus.
- **2F:** for a thin lens, the point at a distance $2f$ from the optical centre.
- **Aperture:** the effective diameter of the circular outline of the lens.

Rules for Drawing Ray Diagrams

Ray	Convex lens	Concave lens
Parallel to principal axis	Passes through the principal focus on the other side	Appears to diverge from the principal focus on the same side
Through / towards the principal focus	A ray through F_1 emerges parallel to the principal axis	A ray directed towards F_2 emerges parallel to the principal axis
Through the optical centre	Goes straight without deviation	Goes straight without deviation

IMAGE FORMATION BY LENSES

Convex Lens

Position of object	Position of image	Size of image	Nature of image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size as object	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Highly enlarged	Real and inverted
Between F_1 and optical centre O	On the same side as the object	Enlarged	Virtual and erect

Concave Lens

Position of object	Position of image	Size of image	Nature of image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O	Between F_1 and O	Diminished	Virtual and erect

- A **convex lens** forms a real, inverted image whenever the object is beyond F. When the object is between F and O it acts as a **magnifying glass** (virtual, erect, enlarged image).
- A **concave lens** always forms a virtual, erect and diminished image.

Uses of Lenses

Convex lens

- Magnifying glass
- Camera, microscope, telescope
- Spectacles for hypermetropia (far-sightedness)

Concave lens

- Spectacles for myopia (short-sightedness)
- Door peepholes

LENS FORMULA, MAGNIFICATION & POWER

Sign Convention for Lenses

- The same New Cartesian sign convention is used, with all distances measured from the **optical centre (o)**.
- **f is positive** for a convex lens and **negative** for a concave lens. **u is always negative**.
- **v is positive** for a real image (on the right) and **negative** for a virtual image (on the left).

Lens Formula and Magnification

$$1/v - 1/u = 1/f$$

$$m = h'/h = v/u$$

- **m negative** → real and inverted image; **m positive** → virtual and erect image.

Power of a Lens

The degree of convergence or divergence of light rays produced by a lens is called its **power**.

$$P = 1/f \text{ (f in metres)}$$

- SI unit of power: **diopetre (D)**, where $1 \text{ D} = 1 \text{ m}^{-1}$.
- **Convex lens**: positive power. **Concave lens**: negative power.
- For lenses placed in contact: **$P = P_1 + P_2 + P_3 + \dots$**
- Example: $f = +50 \text{ cm} = +0.5 \text{ m}$ gives $P = +2 \text{ D}$. $f = -25 \text{ cm} = -0.25 \text{ m}$ gives $P = -4 \text{ D}$.

Numerical Example

Q. A 5 cm tall object is placed 20 cm from a convex lens of focal length 10 cm. Find the image position, nature and size.

Given: $u = -20 \text{ cm}$, $f = +10 \text{ cm}$, $h = 5 \text{ cm}$

Lens formula: $1/v = 1/f + 1/u = 1/10 - 1/20 = 1/20$, so **$v = +20 \text{ cm}$**

Magnification: $m = v/u = 20/(-20) = -1$, so **$h = -5 \text{ cm}$**

Answer: The image is formed 20 cm on the other side of the lens (at $2F$); it is real, inverted and the same size as the object.

QUICK REVISION

Formulas at a Glance

Concept	Mirror	Lens
Formula	$1/v + 1/u = 1/f$	$1/v - 1/u = 1/f$
Magnification (m)	$h/h = -v/u$	$h/h = v/u$
Focal length	$f = R / 2$	$P = 1 / f$ (f in metres)
Sign of f	Concave: negative, Convex: positive	Convex: positive, Concave: negative
Refractive index	$n = c / v$	$\sin i / \sin r = n_{21}$

Key Points to Remember

- Light travels in straight lines at 3×10^8 m/s in vacuum.
- Laws of reflection: angle i = angle r , and incident ray, reflected ray and normal lie in one plane.
- Concave mirror and convex lens are **converging**; convex mirror and concave lens are **diverging**.
- A convex mirror and a concave lens always give a **virtual, erect, diminished** image.
- Light bends **towards** the normal in a denser medium and **away** from it in a rarer medium.
- Negative magnification means a **real, inverted** image; positive means **virtual, erect**.
- Power is positive for a convex lens and negative for a concave lens.

Common Mistakes to Avoid

- Forgetting the sign convention: u is always negative, and f is negative for a concave mirror.
- Putting f in centimetres in $P = 1/f$. Convert it to **metres** first.
- Mixing up the mirror formula ($1/v + 1/u$) with the lens formula ($1/v - 1/u$).
- Confusing a concave **mirror** (converging) with a concave **lens** (diverging).
- Missing arrows on rays in ray diagrams.