10 LIGHT—REFLECTION AND REFRACTION

CHAPTER AT A GLANCE

LIGHT

- It is the form of energy which brings the sensation of light.
- It travels with the speed of 3×10^8 ms^{-1} in vacuum in a straight line path.

Reflection

- The light incident on a polished surface gets reflected back into the same medium.
- A highly polished surface, such as a mirror, reflects most of the light falling on it and follows the laws of reflection.

Refraction

Continued o
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Laws of reflection

- Angle of incidence = Angle reflection,

  i.e. $\angle i = \angle r$
- The incident ray, the reflected ray a normal at the point of incidence, a lies in the same plane.

Types of mirror

Important terms related to spherical mirror

- Pole (P)
- Centre of curvature (C)
- Radius of curvature (R) = CP
- Focus (F)
- Focal length (f) = FP = $\frac{CP}{2}$

Nature of Image

Real image

- Actual interaction of light rays.
- Can be formed on the screen.
- Always inverted.

Virtual image

- Appear to mee
- Cannot be form on screen.
- Always erect.

Plane mirror

Properties

- $m = +1$
- It is always virtual and erect.
- The size of image is equal to that of the object.
- The image is formed at the same distance behind the mirror as the object is in front of the mirror.
- The image is laterally inverted.

Spherical mirror

- Magnification: $m = -\frac{v}{u}$
- Mirror formula: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$
- Obeys a set of sign convention rules for u, v and f.

- Focal length of mirror is independent
  - (*i*) material of mirror
  - (*ii*) medium in which it is placed
  - (*iii*) wavelength of incident light

Concave mirror

- Silvered at outer surface
- Reflecting surface curved inward

To be continued on next page

Convex mirror

- Silvered at inner surface
- Reflecting surface curved outward

To be continued on next page

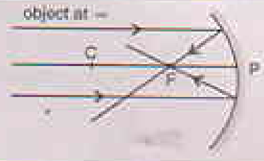
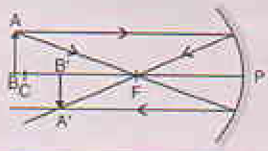
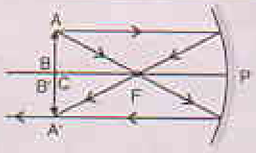
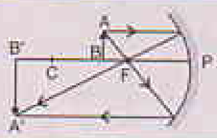
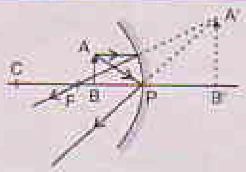
Concave mirror

Rules for image formation

- Rays, parallel to the principal axis, get reflected back through focus.
- Rays, passing through the focus, will emerge parallel to the principal axis after reflection.
- Rays from the centre of curvature get reflected back along its own path.
- A ray of light incident obliquely at pole gets reflected at the same angle on the other side of principal axis into the same medium.

Used

- by a dentist
- in shaving mirror
- in search light
- in headlamps
- in Ophthalmoscope

Position of Object	Position of Image	Nature of Image	Ray Diagram
(i) At infinity	At focus	Real, inverted and diminished.	 $u = -$ ve, f is –ve
(ii) Beyond C	Between F and C	Real, inverted and diminished.	 u is –ve, v is –ve and f is –ve.
(iii) At C	At C	Real, inverted and same size.	 u, v, f are all –ve.
(iv) Between F and C	Beyond C	Real, inverted and enlarged.	 u, v, f are all –ve.
(v) At F	At infinity	Real, inverted and highly enlarged	 u, v, f are all –ve.
(vi) Between F and P	Behind the mirror	Virtual, enlarged and erect image	 u, f are –ve v is +ve.

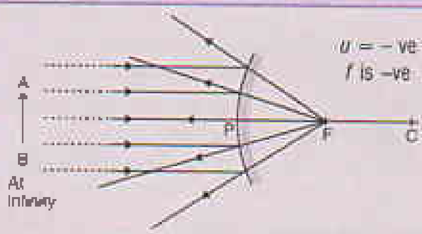
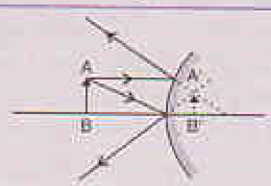
Convex mirror

Rules for image formation

- Rays parallel to principal axis get reflected and appear to come from the principal focus.
- Rays going towards the principal focus, will emerge parallel to the principal axis after reflection.
- Rays from the centre of curvature get reflected back along its own path.
- A ray of light incident obliquely at pole gets reflected at the same angle on the other side of principal axis into the same medium.

Uses

- As a rear-view mirror.
- In shops to check theft.
- At traffic junctions.
- To lighten large area.

Position of Object	Position of Image	Nature of Image	Ray Diagram
(i) At infinity	At focus, behind the mirror	Virtual, erect and diminished size	 $u = -$ ve, f is –ve
(ii) At any other position	Between P and F and behind the mirror	Virtual, erect and diminished.	 u is –ve, v is –ve and f is –ve.

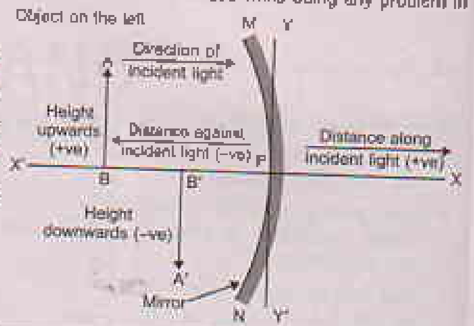
New Cartesian Sign Conventions for reflection of light by spherical mirror. The set of rules, to use '+' or '–' signs with the values while doing any problem in optics, is called sign convention. They are—

(i) The object is always placed to the left of the mirror, so that the incident light moves left to right.

(ii) All distances are to be measured from the pole of the mirror, i.e. from origin of coordinate axis.

(iii) The distances measured in the direction of the incident light will be taken as '+ve' (along positive X-axis) while those measured to the left of the origin (along negative X-axis) will be taken as '–ve'.

(iv) All measurements of heights above the principal axis (along positive Y-axis) are to be taken as '+ ve' and below it (along negative Y axis) are taken as '–ve'.



Refraction
The deviation in the path of ray of light when it travels from one medium to another.

→ By spherical lens → To be continued on next page

Follows ↓

Laws of Refraction

- Snell's law of refraction
  $\frac{\sin i}{\sin r}$ = constant = n_{21}
  Where n_{21} = Refractive index of medium 2 with respect to the medium 1.
- The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

- Wavelength and velocity of light ray changes while frequency remains same.
- Intensity of light decreases.

Causes ↓

It occurs due to different speeds of light in different media.

Optical density is the ability of the medium to refract light rays.

When the light rays travel from optically

Rarer to denser medium

- Slow down
- Bend towards the normal
- $\angle i > \angle r$

Denser to rarer medium

- Speed up
- Bend away from the normal
- $\angle i < \angle r$

The extent of the change in direction of the ray of light in a given pair of media.

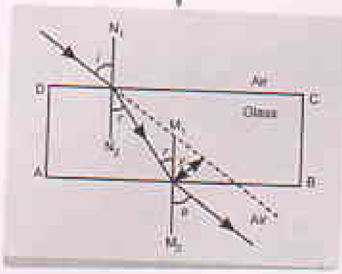
Known as ↓

Refractive index 'n'

- $n_{21} = \frac{\text{Speed of light in medium (1)}}{\text{Speed of light in medium (2)}} = \frac{v_1}{v_2}$
- $n_{12} = \frac{\text{Speed of light in medium (2)}}{\text{Speed of light in medium (1)}} = \frac{v_2}{v_1}$
- Principle of reversibility of light:
  $n_{21} \times n_{12} = 1$
- $n_m = \frac{\text{Speed of light in vacuum or air}}{\text{Speed of light in medium}} = \frac{c}{v}$
- The medium with larger refractive index is optically denser medium than the other.
- It has no unit as it is the ratio of two same quantities.

Through glass slab

- Refraction takes place at both parallel surfaces.
- For air-glass interface, $\angle r < \angle i$.
- At the second parallel surface, i.e. at glass-air interface, $\angle e > \angle r$.
- The emergent ray is parallel to the incident ray.
- Angle of emergence ($\angle e$) = Angle of incidence ($\angle i$).



Effects of refraction

Effects of Refraction of Light

(a) The bottom of a tank or pond, filled with water appears to be raised.
(b) A coin placed at the bottom of a glass tumbler, appears to be raised.
(c) When a straight rod or a spoon or a pencil, partly immersed in water, viewed from the sides, they appear to be broken/bent.
(d) The part of the rod/pencil/spoon inside water also appears thick, if viewed from the sides.
(e) When a lemon kept in water in a bowl/glass tumbler/jar viewed from side, it appears larger than their actual size.
(f) An ink mark or a line drawn on a piece of paper appears to be raised when viewed by keeping a glass slab/glass beaker over it.

Refraction by Spherical Lens

Obeys laws of refraction

- Obeys a set of sign convention rules for u, v and f.
- Lens formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
- Magnification: $m = +\frac{v}{u}$

Important terms

- Optical centre: O
- Centre of curvature: C_1 and C_2
- Radius of curvature: $R_1 = OC_1$ and $R_2 = OC_2$
- Principal axis of lens: Line joining C_1 and C_2.
- Focus: F
- Focal length, $f = OF$

Types of spherical lens

Convex lens

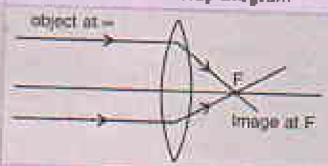
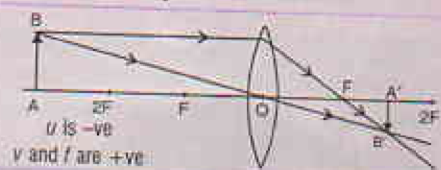
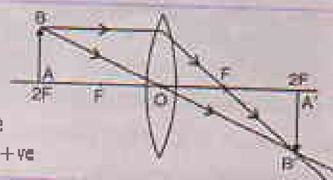
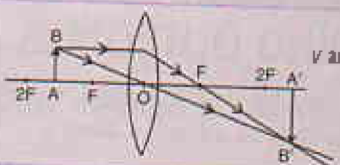
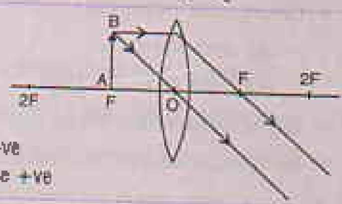
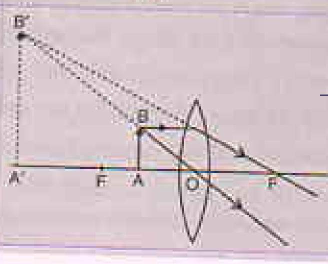
- Thicker at centre.
- Thinner at edges.
- Both refractive surfaces are convex.
- Converges light rays.

Image formation rules

- Rays parallel to the principal axis, will pass through second principal focus after refraction.
- Rays passing through the focus will emerge parallel to the principal axis after refraction.
- Rays passing through the optical centre, will emerge without any deviation after refraction through the lens.

Used in

- Telescope
- Camera
- Projector
- Microscope
- Magnifying glass
- Hypermetropic eye defect correction

Position of Object	Position of Image	Nature of Image	Ray Diagram
(i) At infinity	At focus	Real, inverted and diminished	
(ii) Beyond 2F	Between F and 2F	Real, inverted and diminished.	
(iii) At 2F	At 2F	Real, inverted size to size.	
(iv) Between F and 2F	Beyond 2F	Real, inverted and enlarged.	
(v) At F	At ∞	Real, inverted and enlarged	
(vi) Between F and optical centre	On the same side of the lens	Virtual, erect and enlarged	

Concave lens

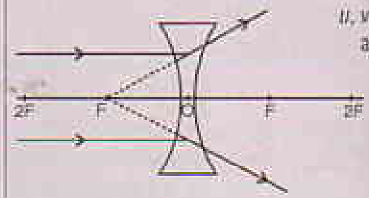
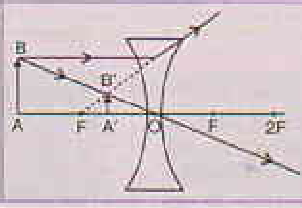
- Thinner at the middle.
- Thicker at the edges.
- Both refractive surfaces are concave.
- Diverges light rays.

Image formation rules

- Rays parallel to principal axis appear to diverge from the principal focus, which is located on the same side of the incident ray.
- Ray going towards the principal focus, will emerge parallel to the principal axis after refraction.
- Rays passing through the optical centre will emerge without any deviation after refraction through the lens.

Used in

- Wide-angle spyhole indoors
- Myopic eye defect correction

Position of Object	Position of Image	Nature of Image	Ray Diagram
(i) At infinity	At focus	Virtual, erect and diminished	
(ii) At any position between ∞ and optical centre	Between F and oprical centre	Virtual, erect and diminished.	

Power of a lens: The degree of convergence or divergence of light rays after refraction through the lens is expressed in terms of power of lens. It is defined as the reciprocal of focal length in metre.

$$\text{Power} = \frac{1}{\text{Focal length in metre}} \quad \text{or} \quad P = \frac{1}{f(m)}$$

- Power of convex lens is positive while that of concave lens is negative.
- Power of lens combination, $P = P_1 + P_2 + P_3 + ... + P_n$
- Unit of power is dioptre (D).