Light- Reflection and Refraction

Light is a form of energy that enables us to see objects around us. It is an electromagnetic radiation that travels in straight lines and has both wave and particle properties.

Properties of Light

- Light travels in straight lines
- Speed of light in vacuum = 3×10^8 m/s
- Light can be reflected, refracted, absorbed, or transmitted
- Light exhibits both wave and particle nature
- Light does not require a medium to travel (can travel through vacuum)

Reflection of Light

Definition

Reflection of light is the phenomenon where light rays bounce back into the same medium when they strike a surface.

Terms Related to Reflection

- **Incident ray:** The light ray that falls on the reflecting surface
- **Reflected ray:** The light ray that bounces back after reflection
- **Normal:** An imaginary line perpendicular to the reflecting surface at the point of incidence
- **Angle of incidence (∠i):** Angle between incident ray and normal
- **Angle of reflection (∠r):** Angle between reflected ray and normal
- **Point of incidence:** The point where incident ray strikes the reflecting surface

Laws of Reflection

First Law: The incident ray, reflected ray, and normal all lie in the same plane.

Second Law: The angle of incidence is equal to the angle of reflection.
$\angle i = \angle r$

Types of Reflection

1. Regular Reflection (Specular Reflection)

- Occurs on smooth, polished surfaces
- All reflected rays are parallel

- Forms clear images
- Example: Plane mirror, still water surface

2. Irregular Reflection (Diffuse Reflection)

- Occurs on rough surfaces
- Reflected rays scatter in different directions
- No clear image formation
- Example: Wall, paper, wood surface

Spherical Mirrors

Definition

Spherical mirrors are curved mirrors whose reflecting surface forms part of a hollow sphere.

Types of Spherical Mirrors

1. Concave Mirror (Converging Mirror)

- **Reflecting surface curves inward**
- Converges parallel light rays to a point
- Also called converging mirror
- **Uses:** Shaving mirrors, headlights, solar cookers, telescopes

2. Convex Mirror (Diverging Mirror)

- **Reflecting surface curves outward**
- Diverges parallel light rays
- Also called diverging mirror
- **Uses:** Vehicle rear-view mirrors, security mirrors in shops

Important Terms for Spherical Mirrors

- **Pole (P):** Center point of the mirror
- **Center of curvature (C):** Center of the sphere from which mirror is cut
- **Radius of curvature (R):** Radius of the sphere from which mirror is cut
- **Principal axis:** Line joining pole and center of curvature
- **Principal focus (F):** Point where parallel rays converge (concave) or appear to diverge from (convex)

- **Focal length (f):** Distance between pole and principal focus
- **Aperture:** Effective diameter of the mirror

Relationship Between Focal Length and Radius of Curvature

f = R/2

Mirror Formula

1/f = 1/v + 1/u

Where:

- f = focal length
- v = image distance
- u = object distance

Sign Conventions for Spherical Mirrors

- All distances measured from pole of mirror
- Distances measured in direction of incident light are positive
- Distances measured opposite to incident light are negative
- Heights measured upward are positive, downward are negative

Magnification Formula

m = -v/u = h'/h

Where:

- m = magnification
- h' = height of image
- h = height of object

If m is positive: Image is virtual and erect
If m is negative: Image is real and inverted

Image Formation by Concave Mirrors

Object Position	Image Position	Nature of Image	Size
At infinity	At F	Real, inverted	Highly diminished
Beyond C	Between F and C	Real, inverted	Diminished

Object Position	Image Position	Nature of Image	Size
At C	At C	Real, inverted	Same size
Between C and F	Beyond C	Real, inverted	Magnified
At F	At infinity	Real, inverted	Highly magnified
Between F and P	Behind mirror	Virtual, erect	Magnified

Image Formation by Convex Mirrors

- **Always forms virtual, erect, and diminished images**
- Image is always between pole and focus
- Used in rear-view mirrors due to wider field of view

Refraction of Light

Definition

Refraction is the phenomenon where light changes its direction when it passes from one transparent medium to another due to change in speed of light.

Cause of Refraction

Light travels at different speeds in different media. When light passes from one medium to another, its speed changes, causing it to bend.

Terms Related to Refraction

- **Incident ray:** Ray falling on the refracting surface
- **Refracted ray:** Ray that enters the second medium
- **Normal:** Line perpendicular to the surface at point of incidence
- **Angle of incidence (∠i):** Angle between incident ray and normal
- **Angle of refraction (∠r):** Angle between refracted ray and normal

Laws of Refraction (Snell's Laws)

First Law: The incident ray, refracted ray, and normal all lie in the same plane.

Second Law: The ratio of sine of angle of incidence to sine of angle of refraction is constant for given pair of media.

$\sin\angle i/\sin\angle r = \text{constant} = n_{21}$

This is also known as **Snell's Law**.

Refractive Index

Absolute Refractive Index

$n = c/v$

Where:

- n = refractive index of medium
- c = speed of light in vacuum (3×10^8 m/s)
- v = speed of light in the medium

Relative Refractive Index

$n_{21} = n_2/n_1 = v_1/v_2 = \sin\angle i/\sin\angle r$

Where:

- n_{21} = refractive index of medium 2 with respect to medium 1

Important Points about Refraction

- Light bends **towards the normal** when going from rarer to denser medium
- Light bends **away from the normal** when going from denser to rarer medium
- **No bending occurs** when light falls normally (perpendicular) on the surface
- **Denser medium:** Higher refractive index
- **Rarer medium:** Lower refractive index

Refractive Index of Common Materials

Material	Refractive Index
Air	1.0003 ≈ 1
Water	1.33
Glass	1.5
Diamond	2.42

Refraction Through Glass Slab

When light passes through a parallel-sided glass slab:

- Light bends towards normal when entering glass (air to glass)
- Light bends away from normal when leaving glass (glass to air)

- **Emergent ray is parallel to incident ray**
- **Lateral displacement occurs** (sideways shift of light ray)

Total Internal Reflection

Critical Angle

The angle of incidence in denser medium for which angle of refraction in rarer medium is 90°.

$\sin C = 1/n = n_2/n_1$

Total Internal Reflection

When light travels from denser to rarer medium and angle of incidence exceeds critical angle, light is completely reflected back into denser medium.

Conditions for Total Internal Reflection

1. Light must travel from denser to rarer medium
2. Angle of incidence must be greater than critical angle

Applications

- **Optical fibers:** Used in communication and medical equipment
- **Prisms:** In periscopes, binoculars
- **Mirage:** Atmospheric phenomenon
- **Diamond's brilliance:** Due to multiple total internal reflections

Applications of Reflection and Refraction

Reflection Applications

- **Plane mirrors:** Looking glasses, periscopes
- **Concave mirrors:** Car headlights, torches, shaving mirrors, solar cookers
- **Convex mirrors:** Rear-view mirrors, security mirrors

Refraction Applications

- **Lenses:** Spectacles, cameras, microscopes, telescopes
- **Prisms:** Splitting white light, periscopes
- **Optical instruments:** Based on refraction principles
- **Atmospheric refraction:** Twinkling of stars, apparent position of sun

Important Phenomena Due to Refraction

1. Apparent Depth

Objects underwater appear closer to surface due to refraction.
Apparent depth = Real depth/Refractive index

2. Twinkling of Stars

Due to atmospheric refraction caused by varying air density.

3. Advanced Sunrise and Delayed Sunset

Sun appears 2 minutes earlier and sets 2 minutes later due to atmospheric refraction.

Key Points for Exams

1. **Speed of light is maximum in vacuum** and decreases in other media
2. **Focal length of concave mirror is positive**, convex mirror is negative
3. **Real images are always inverted**, virtual images are always erect
4. **Convex mirrors always form virtual, erect, diminished images**
5. **Light bends towards normal** in denser medium
6. **Critical angle depends on refractive indices** of two media
7. **Mirror formula and lens formula are similar** in structure
8. **Lateral displacement** occurs in glass slab refraction

Summary

Light reflection and refraction are fundamental optical phenomena that explain how we see objects and how various optical devices work. Reflection involves bouncing back of light from surfaces, while refraction involves bending of light when it passes between different media. Understanding these concepts is crucial for applications in mirrors, lenses, and various optical instruments that form the basis of modern technology.