Chapter-10

1. Introduction to Wave and Light

- **Waves** are disturbances that transmit **energy** through a medium (like water or air) or no medium (like light in space).
- **Light** is an **electromagnetic wave**, meaning it can travel **through a vacuum** and doesn't require a medium.

2. Denser Medium vs Rarer Medium

- **Denser medium**: where **light slows down** (e.g., glass, water)
- **Rarer medium**: where **light speeds up** (e.g., air, vacuum)
- This change in speed causes **refraction** (bending) of light.

3. Refraction of Light

3.1 Causes of Refraction

- Light travels slower in denser media (lower speed) → it **bends toward the normal**.
- In rarer media, it **bends away from the normal**.

3.2 Refraction through a Glass Slab

- A light ray entering the slab bends **toward the normal**.
- Upon exiting, it bends **away from the normal**, emerging **parallel** to the incident ray but **displaced sideways**.

3.3 Terminology Related to Refraction

- **Incident Ray**: Incoming light
- **Angle of Incidence (i)**: Between incident ray & normal
- **Refracted Ray**: Ray inside new medium
- **Angle of Refraction (r)**: Between refracted ray & normal
- **Normal**: Perpendicular at point of incidence
- **Emergent Ray**: Exits the medium
- **Emergent Angle (e)**: Between emergent ray & normal

3.4 Laws of Refraction (Snell's Laws)

1. Incident ray, refracted ray, and normal lie in the **same plane**.
2. Snell's Law (Refraction)
3. $\sin i / \sin r = \text{constant} = n$
4. **Where:**
5. **i** = Angle of incidence
6. **r** = Angle of refraction
7. **n** = Refractive index of the medium

Refractive Index (n)

The refractive index is the ratio of the speed of light in air to its speed in a medium, or the ratio of the sine of angles of incidence and refraction:

$n = \sin i / \sin r = v_{air} / v_{medium}$

Where:

- **i** = Angle of incidence
- **r** = Angle of refraction
- $\mathbf{v_{air}}$ = Speed of light in air
- $\mathbf{v_{medium}}$ = Speed of light in the medium

Typical values:

- n (water) ≈ 1.33
- n (glass) ≈ 1.5

5. Consequences of Refraction

A) At Water–Air Interface

- **Apparent depth**: Objects look shallower when underwater.
- **Stick-in-water effect**: A stick appears bent at water's surface.

B) Atmospheric Refraction

- **Sunrise/Sunset**: Visible even when sun below horizon due to bending.
- **Twinkling of stars**: Caused by air layers bending light randomly.
- **Looming**: Distant objects appear floating or higher.
- **Distorted sunsets/moonrises**: Appear flattened or stretched.
- **Daylight stars/planets**: Rarely seen due to extreme refraction at horizon.
- **Improved visibility**: Refraction over heated ground creates mirages.

6. Total Internal Reflection (TIR) & Critical Angle

- **Critical angle**: Minimum angle of incidence in denser medium above which **TIR occurs**.
- **Condition** for Total Internal Reflection
  - **:** Light must travel from a **denser to a rarer medium**, and the **angle of incidence (i)** must be **greater than the critical angle (θ_c)**.
  - $i > \theta_c$
- Only under this condition will **total internal reflection** occur.
- **Critical angle formula**:

Critical Angle Formula

$\sin \theta_c = n_2 / n_1$

Where:

- $\mathbf{\theta_c}$ = Critical angle

- n_1 = Refractive index of denser medium
- n_2 = Refractive index of rarer medium

This formula is valid only when light travels from a **denser to a rarer medium**.

A) Consequences of TIR

- **Sparkling diamonds**: Light trapped inside, then ejected through facets.
- **Bright air-bubble surfaces**: TIR inside the bubble.
- **Mirages**: Light reflects within warm air layers, showing false water.

B) Applications of TIR

- **Optical fibers**:
  - Structure: Transparent core, cladding with lower refractive index.
  - Working: Light reflects inside core with TIR, travels long distances.
  - Uses: **Telecommunication** (internet, cable TV), **endoscopy in medicine**, **surgical imaging**.
  - **Endoscopy** Breakdown:
    - Uses optical fibers to carry light into the body.
    - Allows doctors to see internal organs.
    - Enables **minimally invasive (keyhole) surgery**.

7. Dispersion of Light

- **Dispersion**: White light decomposes into colors (ROYGBIV) when passing through a prism.
- **Cause**: Each color has a different refractive index → bends differently.
- **Example**: Rainbows—sunlight disperses and reflects inside raindrops forming colored arc.

8. Lenses & Image Formation

8.1 Lens Terminology

- **Principal Axis**: Central straight line through lens
- **Optical Centre (O)**: Point where light passes undeviated
- **Centre of Curvature**: Centre of the original sphere of which lens is part
- **Principal Focus (F)**: Point where parallel incident rays converge (convex) or appear to diverge from (concave)
- **Focal Length (f)**: Distance from O to F

8.2 Types of Lenses

- **Convex (Converging)**: Thicker in middle
- **Concave (Diverging)**: Thicker at edges

8.3 Light-Ray Rules

1. **Parallel ray** → passes through focus
2. **Focus-ray** → emerges parallel
3. **Centre-ray** → passes straight

8.4 Image Formation by Convex Lens

Object Position	Image Position & Nature
At Infinity	At F, real, inverted, highly diminished
Beyond 2F	Between F & 2F, real, inverted, diminished
At 2F	At 2F, real, inverted, same size
Between F & 2F	Beyond 2F, real, inverted, enlarged
At F	No image (rays parallel)
Between F & O	Virtual, upright, enlarged

8.5 Concave Lens

- Always produces **virtual**, **upright**, **reduced** image between lens and focus.

8.6 Lens Power

Power of a Lens

$P = {}^{1}/_{f\,(m)}$

Where:
P = Power of the lens (in diopters)
f = Focal length (in meters)

- **Positive** → Convex lens
- **Negative** → Concave lens

9. Human Eye: Structure & Function

- **Cornea**: Transparent front surface; aids focusing
- **Pupil**: Adjustable aperture controls light entry
- **Lens**: Focuses light on retina
- **Ciliary Muscles**: Adjust lens shape (accommodation)
- **Retina**: Contains photoreceptors (rods/cones)
- **Optic Nerve**: Transmits images to brain

9.1 Understanding Accommodation

- **Distant vision**: Lens flattens using ciliary relaxation
- **Near vision**: Lens thickens using ciliary contraction

9.2 Far Point & Near Point

- **Far point (D)**: Farthest distance seen clearly (∞ in normal eye)
- **Near point**: Closest distance seen clearly (25 cm typical)

10. Defects of Vision & Corrections

A) Myopia (Near-sighted)

- Light focuses **before** retina

- Caused by elongated eyeball or strong lens
- Corrected with **concave lens**

B) Hypermetropia (Far-sighted)

- Light focuses **behind** retina
- Caused by short eyeball or weak lens
- Corrected with **convex lens**

11. Alternatives to Spectacles

a) Contact Lenses

- Thin lenses on cornea for vision correction
- Advantages: More natural vision
- Use: Cleanliness essential to avoid infection

b) Laser Eye Surgery

- Reshapes cornea permanently
- **LASIK**: Cuts flap, reshapes deeper layer
- **PRK**: Reshapes surface layer
- **Pros**: No glasses needed
- **Cons**: Costly, slight risks of dry eyes/irregular vision

12. Other Eye Conditions

a) Cataract

- Cloudy lens leading to blurred vision
- Treated via **surgical lens replacement**

b) Night Blindness

- Difficulty seeing in dim light
- Caused by deficiency in **vitamin A**
- Treatment: Dietary improvement (carrots, leafy vegetables)

c) Colour Blindness

- Genetic inability to distinguish colors (often red-green)
- No cure, but **lenses** and **apps** can help

d) Corneal Injuries

- **Corneal ulcer**: infection on the cornea
- **Corneal edema**: swelling
- **Keratoconus**: cornea shape change
- **Corneal transplant**: replacing damaged cornea

Interesting Facts

- The **cornea** has no blood vessels; it gets oxygen directly from air.
- LASIK reshaping takes **under 10 minutes** per eye.
- A **rainbow** is a full circle; we usually see only the top half.
- **Optical fibers** can transmit light signals across the world with <1% loss per kilometer.

Quick Revision Summary

- **Refraction**: Light bends entering a denser/rarer medium
- **TIR**: Full reflection inside dense medium; lens basis of fiber optics
- **Dispersion**: White light splits into colors
- **Lens rules** produce varied image types; power derived from focal length
- **Eye**: adjusts via accommodation, can be corrected by lenses or surgery
- Includes **cataract**, **night blindness**, **colour blindness**, and **cornea issues**

Common Mistakes

- Confusing emergence and incident angles
- Misidentifying virtual vs real rays in lens diagrams
- Labeling defects incorrectly (e.g. using concave for hypermetropia)
- Forgetting negative vs positive lens power
- Misunderstanding accommodation process