

Introduction to Optics

Introduction to Optics – Study Notes

1. What Is Optics?

- **Definition:** Optics is the branch of physics that deals with the behavior and properties of light (electromagnetic radiation in the visible, infrared, and ultraviolet ranges) and its interaction with matter.
- **Main Goals**
 - Explain how light propagates.
 - Describe how light is reflected, refracted, diffracted, and absorbed.
 - Design systems that control light (lenses, mirrors, fiber optics, lasers, etc.).

2. Fundamental Concepts

Concept	Description	Key Equation / Principle
Wave-Particle Duality	Light exhibits both wave-like and particle-like behavior.	Photon energy: $(E = h\nu)$
Speed of Light in Vacuum	Constant universal speed.	$(c = 3.00 \times 10^8 \text{ m}\cdot\text{s}^{-1})$
Refractive Index (n)	Ratio of light speed in vacuum to speed in a medium.	$(n = \frac{c}{v})$
Wavelength (λ) & Frequency (f)	λ is the distance between successive wave crests; f is the number of cycles per second.	$(c = \lambda f)$
Amplitude	Height of the electric (or magnetic) field; determines intensity.	Intensity ∝ amplitude ²
Polarization	Orientation of the electric field vector.	Linear, circular, elliptical

3. Types of Optics

Category	Focus	Typical Applications
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Geometrical (Ray) Optics	Light treated as straight rays; uses laws of reflection & refraction.	Lenses, mirrors, optical instruments, eye glasses.
Physical (Wave) Optics	Light treated as a wave; explains interference, diffraction, polarization.	Holography, fiber optics, spectroscopy.
Quantum Optics	Photon description; deals with quantum states of light.	Quantum communication, laser cooling, single-photon sources.

4. Geometrical Optics

4.1 Laws of Reflection

1. **Incident ray**, **reflected ray**, and **normal** lie in the same plane.
2. Angle of incidence equals angle of reflection: $(\theta_i = \theta_r)$.

4.2 Laws of Refraction (Snell's Law)

$$[n_1 \sin \theta_1 = n_2 \sin \theta_2]$$

- (n_1, n_2) – refractive indices of the two media.
- (θ_1) – incident angle; (θ_2) – refracted angle.

4.3 Mirrors

- **Plane Mirror:** Image is virtual, upright, same size, located behind the mirror at the same distance as the object.
- **Spherical Mirror:**
 - **Concave:** Real or virtual image depending on object distance.
 - **Convex:** Always virtual, upright, reduced.
- **Mirror Equation:** $(\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i})$
(f = focal length, (d_o) = object distance, (d_i) = image distance)

4.4 Lenses

- **Thin Lens Approximation:** Thickness $\ll$ focal length.
- **Lens Types:** Convex (converging) and concave (diverging)