

Introduction to Optics

Introduction to Optics – Study Notes

1. What Is Optics?

- **Definition:** 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:**
 1. Explain how light propagates.
 2. Describe how light is reflected, refracted, diffracted, and absorbed.
 3. Design optical instruments (lenses, mirrors, microscopes, telescopes, fiber-optic systems, etc.).
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2. Historical Milestones

Period	Key Figure(s)	Contribution
Ancient Greece	Euclid, Ptolemy	Geometrical description of reflection & refraction (law of reflection).
17th-century	Isaac Newton (corpuscular theory) & Christiaan Huygens (wave theory)	Competing models of light.
19th-century	Thomas Young, Augustin-Jean Fresnel	Double-slit experiment & interference; established wave nature.
20th-century	Albert Einstein, Max Planck	Photoelectric effect & photon concept; quantum description of light.
Late 20th–21st-century	Development of lasers, fiber optics, photonic crystals	Modern applications in communications, medicine, manufacturing.

3. Fundamental Concepts

3.1 Light as a Wave

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- **Electromagnetic wave:** oscillating electric (E) and magnetic (B) fields perpendicular to each other and to the direction of propagation.
- **Key parameters**
 - **Wavelength (λ)** – distance between successive crests.
 - **Frequency (f)** – number of cycles per second; ($c = \lambda f$) (c = speed of light $\approx 3.00 \times 10^8 \text{ m/s}$).
 - **Amplitude** – related to intensity (energy per unit area).

3.2 Light as a Particle (Photon)

- **Photon energy:** ($E = hf = \frac{hc}{\lambda}$) (h = Planck's constant).
- Explains phenomena such as the photoelectric effect, Compton scattering, and quantum optics.

3.3 Geometrical Optics (Ray Approximation)

- **Assumption:** Light travels in straight lines (rays) when dimensions are much larger than λ .
- **Core laws:**
 1. **Law of Reflection:** Angle of incidence = angle of reflection (measured from the normal).
 2. **Law of Refraction (Snell's Law):** ($n_1 \sin \theta_1 = n_2 \sin \theta_2$).
 3. **Principle of Reversibility:** Light paths are reversible in a static medium.

3.4 Wave Optics (Physical Optics)

- **Interference:** Superposition of two or more coherent waves $\rightarrow$ constructive or destructive patterns.
- **Diffraction:** Bending of light around obstacles or through apertures; described by Huygens–Fresnel principle.
- **Polarization:** Orientation of the electric field vector; can be linear, circular, or elliptical.

4. Optical Media & Indices

Medium Refractive Index (n) Typical Values

Vacuum 1.0000 —