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OPTICS

Snell's Law (Laws of Refraction)

1. The incident ray, refracted ray, and the normal all lie in a common plane.
2. The ratio of sine of incidence angle i to sine of refraction angle r is constant:

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = n_{21}$$

where n_1, n_2 are refractive indices of the two media.

Reflection at Plane Surface

- Image formed is virtual, upright, same size, and located symmetrically behind the mirror.
- If an object moves towards/away from mirror with velocity v, the image does the same.
- Image is laterally inverted.
- Deviation of a ray:

$$\delta = 180^\circ - 2i$$

Reflection by Spherical Mirrors

Mirror Equation

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

- f is positive for convex, negative for concave mirrors.

Magnification

$$m = \frac{h_I}{h_O} = -\frac{v}{u}$$

- $m > 0$: virtual, erect image; $m < 0$: real, inverted image.

Refraction by Spherical Surface

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Lens Maker's Formula

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Lens Formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

- Convex lens: $f > 0$, Concave lens: $f < 0$

Power of a Lens

$$P = \frac{1}{f} \quad \text{(in meters)}$$

Unit: Dioptre (D)

Combination of Lenses

- Lenses in contact:

$$\frac{1}{f_{eq}} = \sum \frac{1}{f_i}, \quad P_{eq} = \sum P_i$$

- Lenses separated by d:

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

Total Internal Reflection (TIR)

Occurs when light travels from denser to rarer medium at angle exceeding critical angle

Occurs when light travels from denser to rarer medium at angle exceeding critical angle C:

$$\sin C = \frac{n_2}{n_1} \quad (n_1 > n_2)$$

Optical Instruments

1. Simple Microscope

- For image at near point D: $M = 1 + \frac{D}{f}$
- For image at infinity: $M = \frac{D}{f}$

2. Compound Microscope

- Near point: $M = \left(\frac{v_o}{u_o}\right)\left(1 + \frac{D}{f_e}\right)$
- Infinity: $M = \left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right)$

3. Astronomical Telescope

- Near point: $M = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$
- Infinity: $M = -\frac{f_o}{f_e}$
- Length: $L = f_o + f_e$

Wave Optics

Huygens' Principle

1. Every point on a wavefront emits secondary wavelets.
2. These wavelets spread forward at the speed of light.
3. The envelope of these wavelets gives the next wavefront.

Interference of Light

- Superposition of waves → alternate bright and dark fringes.
- Conditions:
  - Coherent sources
  - Monochromatic light

Young's Double Slit Experiment (YDSE)

$$\Delta x = d\sin\theta \approx \frac{yd}{D}$$

$$\text{Constructive: } \Delta x = n\lambda$$

$$\text{Destructive: } \Delta x = \left(n + \frac{1}{2}\right)\lambda$$

$$\text{Fringe Width: } \beta = \frac{\lambda D}{d}$$

Diffraction

Single slit diffraction:

- Minima: $a\sin\theta = n\lambda$
- Central maximum width: $2\beta_0 = \frac{2\lambda D}{a}$

Polarization

Plane Polarized Light

Vibrations confined to a single plane.

Brewster's Law

$$\mu = \tan i_p$$

At i_p, reflected and refracted rays are perpendicular.

Malus' Law

$$I = I_0\cos^2\theta$$

For unpolarized light: $I = \frac{I_0}{2}$

Nicol Prism

Splits unpolarized light into two polarized components—based on double refraction.

Polaroids

Polaroid films use aligned crystals to polarize light—used in sunglasses, cameras, LCDs.