Chapter 23
Reflection and Refraction of Light

Reflection: Two types

- Specular
- Diffuse

Law of Reflection

- The angle of incidence is equal to the angle of reflection
  - $\theta_i = \theta_r$

Plane of incidence—The incident and reflected rays and the normal all lie in a plane

Normal—a line perpendicular to the surface where the incident ray touched
Reflection: plane waves

Refraction: Snell’s Law

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

Note the light bends towards the normal in the higher index medium.

Snell’s Law: Derivation

\[ \frac{\sin \theta_1}{\sin \theta_2} = \frac{\lambda_1}{\lambda_2} \]

\[ \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1} \]

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
Snell’s Law example

• Light is incident on a material at an angle of incidence of 25°. The light in the material is observed to have an angle of transmission of 15°.
• What is the index of refraction of the material assuming it is in air?
• What is the angle of the transmitted ray if the material is under water (n=1.3) where the light has the same angle of incidence?

Snell’s Law: Example

• A ray of light is incident on an equilateral prism of index n=1.5 at an angle of incidence of 35°. At what angle with respect to the normal does the ray leave the prism? What is the angle of deviation, δ?

Prism Refraction

- \( \sin \theta_2 = n \sin \theta_1 \)
- \( n \sin \theta_2 = \sin \theta_3 \)
- \( \alpha + (90 - \theta_1) + (90 - \theta_2) = 180 \)
- \( \alpha = \theta_1 + \theta_2 \)
Image formation: refraction

Where does the fish see the bird?

Total Internal Reflection:
Critical Angle
- When a ray of light travels from a higher index material to a lower index material there is an angle of incidence above which no light is transmitted.
Critical Angle: Derivation

\[ n_i \sin \theta_i = n_c \sin \theta_c \]
when \( \theta_i = 90 \), \( \theta_i = \theta_c \)
\[ n_i \sin \theta_c = n_c \]

\[ \theta_c = \sin^{-1}\left(\frac{n_i}{n_c}\right) \]
\( n_i > n_c \)

Optical Fibers

Optical Fibers

TIR: Example

• What is the index of refraction of the core of an optical fiber is the cladding has \( n = 1.20 \) and the critical angle at the core cladding boundary is \( 67^\circ \)?
• What is the acceptance angle?
**Brewster’s Angle:**

**polarization of light due to reflection**

- When the reflected ray is perpendicular to the transmitted ray the light is completely polarized upon reflection

\[ n_i \sin \theta_B = n_t \sin \theta_t \]

but \( \theta_t + \theta_B = 90 \), so \( \theta_t = 90 - \theta_B \)

\[ n_i \sin \theta_B = n_i \sin(90 - \theta_B) = n_i \cos \theta_B \]

\[ \sin \theta_B = \tan \theta_B = \frac{n_i}{n_t} \rightarrow \theta_B = \tan^{-1}\left(\frac{n_i}{n_t}\right) \]

**Brewster’s Angle: example**

- What is Brewster’s angle going from an air to glass (\( n=1.5 \)) interface?
- What is Brewster’s angle going from a glass to air interface?