PHYS 111
1ST semester 1439-1440

Dr. Nadyah Alanazi

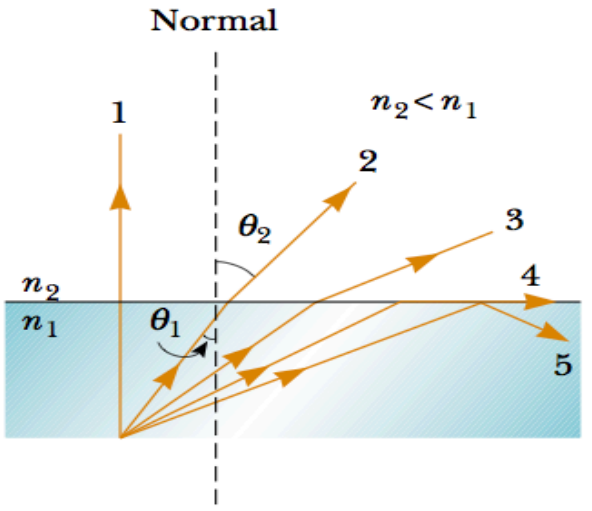
Lecture 16

Chapter 35

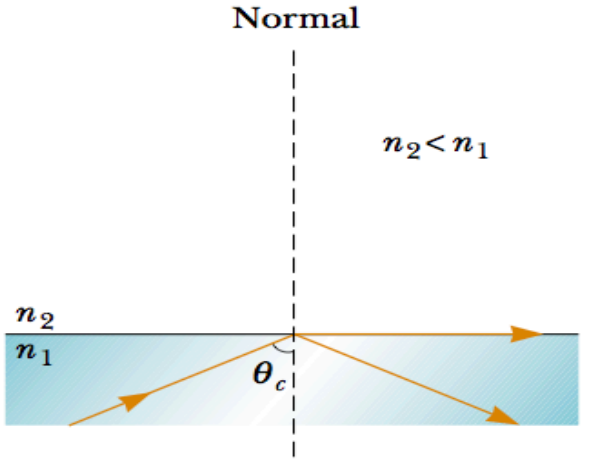
The Nature of Light and the Laws of Geometric Optics

35.8 Total Internal Reflection

- The **total internal reflection** can occur when light is directed from a medium having a given index of refraction toward one having a **lower** index of refraction.
- Consider a light beam traveling from medium 1 to medium 2 ($n_1 > n_2$)
- The refracted rays are bent away from the normal because $n_1 > n_2$. At some particular angle of incidence θ_c , called the **critical angle,** the refracted light ray moves parallel to the boundary so that $\theta_2 = 90°$
- For angles of incidence greater than θ_c , the beam is entirely reflected at the boundary,



(a)



(b)

35.8 Total Internal Reflection

- We can use Snell's law of refraction to find the critical angle. When $\theta_1 = \theta_c$, $\theta_2 = 90°$

$$n_1 \sin \theta_c = n_2 \sin 90° = n_2$$

$$\sin \theta_c = \frac{n_2}{n_1} \qquad (\text{for } n_1 > n_2)$$

Problems

- **12.** The wavelength of red helium–neon laser light in air is 632.8 nm. (a) What is its frequency? (b) What is its wavelength in glass that has an index of refraction of 1.50? (c) What is its speed in the glass?

(a) $$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{6.328 \times 10^{-7} \text{ m}} = \boxed{4.74 \times 10^{14} \text{ Hz}}$$

(b) $$\lambda_{\text{glass}} = \frac{\lambda_{\text{air}}}{n} = \frac{632.8 \text{ nm}}{1.50} = \boxed{422 \text{ nm}}$$

(c) $$v_{\text{glass}} = \frac{c_{\text{air}}}{n} = \frac{3.00 \times 10^8 \text{ m/s}}{1.50} = 2.00 \times 10^8 \text{ m/s} = \boxed{200 \text{ Mm/s}}$$

Problems

- **13.** An underwater scuba diver sees the Sun at an apparent angle of 45.0° above the horizon. What is the actual elevation angle of the Sun above the horizon?

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

$$\sin\theta_1 = 1.333 \sin 45°$$

$$\sin\theta_1 = (1.33)(0.707) = 0.943$$

$$\theta_1 = 70.5° \rightarrow \boxed{19.5° \text{ above the horizon}}$$

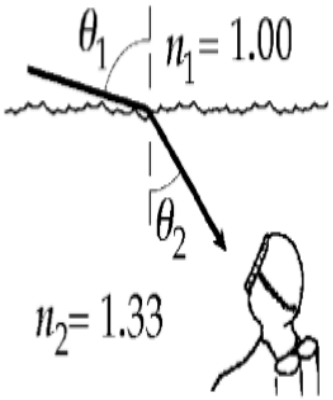


FIG. P35.13

Problems

- **14.** A ray of light is incident on a flat surface of a block of crown glass that is surrounded by water. The angle of refraction is 19.6°. Find the angle of reflection.

We find the angle of incidence:

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

$$1.333 \sin\theta_1 = 1.52 \sin 19.6°$$

$$\theta_1 = 22.5°$$

The angle of reflection of the beam in water is then also $\boxed{22.5°}$.

Problems

- **17.** A light ray initially in water enters a transparent substance at an angle of incidence of 37.0°, and the transmitted ray is refracted at an angle of 25.0°. Calculate the speed of light in the transparent substance.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2: \qquad 1.333 \sin 37.0° = n_2 \sin 25.0°$$

$$n_2 = 1.90 = \frac{c}{v}: \qquad v = \frac{c}{1.90} = 1.58 \times 10^8 \text{ m/s} = \boxed{158 \text{ Mm/s}}$$

- **HW 19.** A ray of light strikes a flat block of glass (n = 1.50) of thickness 2.00 cm at an angle of 30.0° with the normal. Trace the light beam through the glass, and find the angles of incidence and refraction at each surface.

Problems

- **36.** For 589-nm light, calculate the critical angle for the following materials surrounded by air: (a) diamond, (b) flint glass, and (c) ice.

$n \sin\theta = 1$. From Table 35.1,

(a) $$\theta = \sin^{-1}\left(\frac{1}{2.419}\right) = \boxed{24.4^\circ}$$

(b) $$\theta = \sin^{-1}\left(\frac{1}{1.66}\right) = \boxed{37.0^\circ}$$

(c) $$\theta = \sin^{-1}\left(\frac{1}{1.309}\right) = \boxed{49.8^\circ}$$