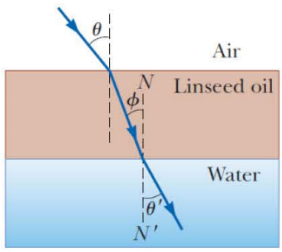
PHYS143
Physics for Engineers
Tutorial - Chapter 35 - Solutions

Question 1

Figure shows a refracted light beam in linseed oil making an angle of $\phi = 20.0°$ with the normal line NN'. The index of refraction of linseed oil is 1.48. Determine the angles (a) θ and (b) θ'. The index of refraction of air is 1 and for water is 1.33.



(a) The dashed lines are parallel, and alternate interior angles are equal between parallel lines, so the angle of refraction law at the air-oil interface is 20.0°. Applying Snell's law,

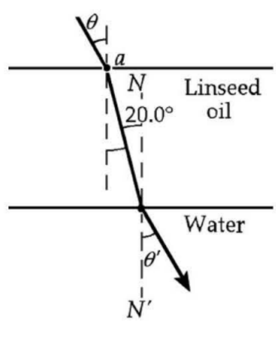
$$n_{air}\sin\theta = n_{oil}\sin\alpha$$
$$1.00\sin\theta = 1.48\sin 20.0°$$

yields $\boxed{\theta = 30.4°}$.

(b) The angle of incidence $\alpha = 20.0°$. Applying Snell's law at the oil-water interface,

$$n_{water}\sin\theta' = n_{oil}\sin\alpha$$
$$1.33\sin\theta' = 1.48\sin 20.0°$$

yields $\boxed{\theta' = 22.3°}$.



Question 2

A laser beam is incident at an angle of 30.0° from the vertical onto a solution of corn syrup in water. The beam is refracted to 19.24° from the vertical. (a) What is the index of refraction of the corn syrup solution? Assume that the light is red, with vacuum wavelength 632.8 nm. Find its (b) frequency, (c) speed, and (d) wavelength in the solution. The index of refraction of air is 1.

(a) $n_1\sin\theta_1 = n_2\sin\theta_2$

$$1.00\sin 30.0° = n\sin 19.24°$$
$$n = \boxed{1.52}$$

(b) $f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8} \text{ m/s}}{6.328 \times 10^{-7} \text{ m}} = \boxed{4.74 \times 10^{14} \text{ Hz}}$ in air and in syrup.

(c) $v = \frac{c}{n} = \frac{3.00 \times 10^{8} \text{ m/s}}{1.52} = 1.98 \times 10^{8} \text{ m/s} = \boxed{198 \text{ Mm/s}}$

(d) $\lambda = \frac{v}{f} = \frac{1.98 \times 10^{8} \text{ m/s}}{4.74 \times 10^{14} \text{ s}^{-1}} = \boxed{417 \text{ nm}}$

Question 3

A light beam containing red and violet wavelengths is incident on a slab of quartz at an angle of incidence of 50.0°. The index of refraction of quartz is 1.455 at 600 nm (red light), and its index of refraction is 1.468 at 410 nm (violet light). Find the dispersion of the slab, which is defined as the difference in the angles of refraction for the two wavelengths. The index of refraction of air is 1.

Using Snell's law gives

$$\theta_{\text{red}} = \sin^{-1}\left(\frac{n_{\text{air}} \sin\theta_i}{n_{\text{red}}}\right) = \sin^{-1}\left(\frac{(1.000)\sin 50.00^\circ}{1.455}\right)$$

and $$\theta_{\text{violet}} = \sin^{-1}\left(\frac{n_{\text{air}} \sin\theta_i}{n_{\text{violet}}}\right) = \sin^{-1}\left(\frac{(1.000)\sin 50.00^\circ}{1.468}\right)$$

Thus, the dispersion is $\theta_{\text{red}} - \theta_{\text{violet}} = \boxed{0.314^\circ}$

Question 4

A beam of light is incident from air on the surface of a liquid. If the angle of incidence is 30.0° and the angle of refraction is 22.0°, find the critical angle for total internal reflection for the liquid when surrounded by air. The index of refraction of air is 1.

Using Snell's law, the index of refraction of the liquid is found to be

$$n_{\text{liquid}} = \frac{n_{\text{air}} \sin\theta_i}{\sin\theta_r}$$

Thus, the critical angle for light going from this liquid into air is

$$\theta_c = \sin^{-1}\left(\frac{n_{\text{air}}}{n_{\text{liquid}}}\right) = \sin^{-1}\left(\frac{n_{\text{air}}}{n_{\text{air}} \sin\theta_i / \sin\theta_r}\right)$$

$$= \sin^{-1}\left(\frac{\sin\theta_r}{\sin\theta_i}\right) = \sin^{-1}\left(\frac{\sin 22.0^\circ}{\sin 30.0^\circ}\right) = \boxed{48.5^\circ}$$