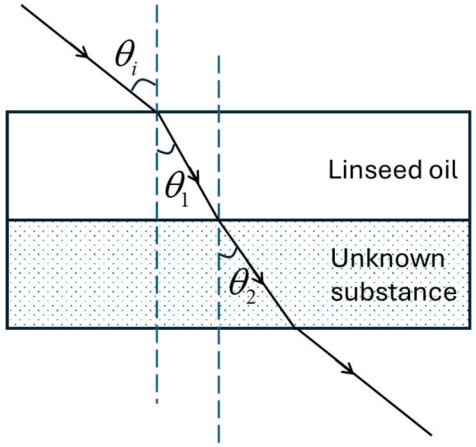
Chapter 33: The Nature and Propagation of Light

Group Members:

1. A light ray enters a layer of linseed oil ($n_{linseed} = 1.48$) with an angle of incidence $\theta_i = 35.0^\circ$ as shown to the right. [Assume air (n=1) is on top of the linseed oil.]



   a. Determine the first angle of refraction θ_1.

From the air-linseed oil interface, we can use Snell's law to find θ_1,

$$n_{air} \sin\theta_i = n_{oil} \sin\theta_1$$

$$\theta_1 = \sin^{-1}\left(\frac{n_{air}}{n_{oil}} \sin\theta_i\right)$$

$$\theta_1 = \sin^{-1}\left(\frac{1}{1.48} \sin 35.0^\circ\right) = 22.8^\circ$$

   b. Then, the refracted ray enters an unknown substance. If one determine the second angle of refraction $\theta_2 = 25.0^\circ$, what is the index of refraction $n_{unknown}$ for this unknown medium.

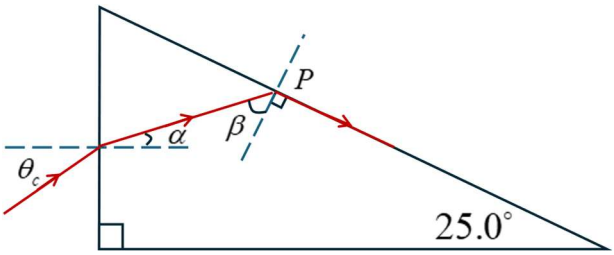
Again, at the linseed oil-unknown interface, we employ Snell's law,

$$n_{oil} \sin\theta_1 = n_{unknown} \sin\theta_2$$

$$n_{unknown} = \frac{n_{oil} \sin\theta_1}{\sin\theta_2}$$

$$n_{unknown} = \frac{1.48 \sin 22.80^\circ}{\sin 25.0^\circ} = 1.36$$

2. A light ray enters the left face of a right-angle prism $\left(n_{prism}=1.65\right)$ at an angle of θ_c with respect to the normal as shown. The refracted ray hits the right side of the prism at *P*. Depending on the incident angle θ_c, the light ray can refract out of the prism or get totally internally reflected at *P*. [Assume air $n=1$ outside of the prism.]



   a. Working backward, assuming that the ray gets total internally reflected at *P*, calculate the critical angle β needed for the ray incident at *P* from the inside of the prism.

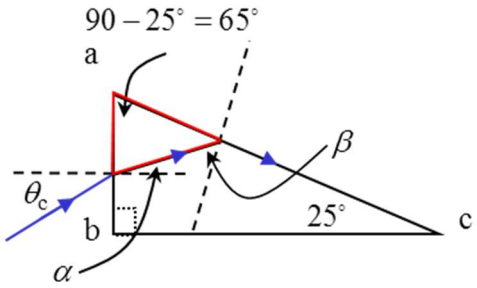
It is easier to work backward from the right face ac of the prism where the light ray is totally internal reflected. At face ac, we have:

$$n\sin\beta=1$$

$$\beta=\sin^{-1}\left(\frac{1}{n}\right)=\sin^{-1}\left(\frac{1}{1.65}\right)=37.305^\circ$$

   b. Using geometry of the prism, calculate the angle α that the refracted ray inside of the prism must be traveling along.

The two angles α and β are related through the red triangle:



$$\left(90^\circ-\alpha\right)+\left(90^\circ-\beta\right)+65^\circ=180^\circ$$

$$\alpha=65^\circ-\beta$$

$$\alpha=65^\circ-37.305^\circ=27.695^\circ$$

c. Then use Snell's Law to calculate the critical angle θ_c such all rays entering the prism on the left face with $\theta \le \theta_c$ will eventually be total internally reflected at *P*.

And at the left face of the prism where the ray enters the prism, Snell's law gives,

$$\sin\theta_c = n\sin\alpha$$

Substituting $\alpha = 27.695^\circ$ into the above equation, we then have,

$$\sin\theta_c = (1.65)\sin 27.695^\circ = 0.76686$$
$$\theta_c = 50.1^\circ$$