1. Determine the maximum angle $\theta$ for which the light rays incident on the end of the pipe in Figure P35.38 are subject to total internal reflection along the walls of the pipe. Assume that the pipe has an index of refraction of 1.25 and the outside medium is air.

\[ n_1 = 1.00, \quad n_2 = 1.25 \]

\[ \theta_1, \theta_2, \theta_3 \]

\[ \sin \theta_1 = \frac{n_2}{n_1} \sin \theta_2 \]

\[ \sin \theta_1 = \frac{n_2}{n_1} \sin \theta_2 \]

\[ \theta_2 = 90^\circ - \theta_3 \quad \text{and} \quad \sin \theta_3 = \frac{n_1}{n_2}, \quad \theta_3 = \sin^{-1} \left( \frac{n_1}{n_2} \right) \]

\[ \Rightarrow \sin \theta_1 = \frac{n_2}{n_1} \sin \left[ 90^\circ - \sin^{-1} \left( \frac{n_1}{n_2} \right) \right] \]

\[ \sin \theta_1 = 0.75 \]

\[ \theta_1 = 48.6^\circ \]
2. A light ray enters a rectangular block of plastic at an angle of $\theta_1 = 42.0^\circ$ and emerges at an angle of $\theta_2 = 75.0^\circ$, as shown in Figure P35.71.

(a) Determine the index of refraction of the plastic.

(b) If the light ray enters the plastic at a point $L = 50.0$ cm from the bottom edge, how long does it take the light ray to travel through the plastic?

\[ n_1 = 1.00, \quad n_2 \text{ is unknown} \]

From left interface:

\[ n_1 \sin \theta_1 = n_2 \sin \theta_3 \quad \Rightarrow \quad n_2 = \frac{\sin(42^\circ)}{\sin \theta_3} \]  

Equate and use $\theta_3 = 90 - \theta_4$: \[ \sin(42^\circ) = \frac{\sin(75^\circ)}{\sin \theta_4} \]

Since $\sin(90 - x) = \cos x$, we have: \[ \frac{\sin 42^\circ}{\cos \theta_4} = \frac{\sin 75^\circ}{\sin \theta_4} \Rightarrow \tan \theta_4 = \frac{\sin 75^\circ}{\sin 42^\circ} \]

$\theta_4 = 55.28^\circ$, plugging this back in: \[ n_2 = 1.18 \]

\[ L = \frac{d}{\sin \theta_1} \]

\[ V = \frac{c}{n_1} \]

\[ d = \frac{L}{\sin(34.7^\circ)} \]

\[ d = 1.878 \text{ m} \]

\[ V = \frac{3 \times 10^8}{1.18} = 2.54 \times 10^8 \text{ m/s} \]

\[ t = \frac{1.878}{2.54 \times 10^8} = 3.46 \text{ ns} \]
3. PSEB 35.P.036. For 589 nm light, calculate the critical angle for the following materials surrounded by air.

(a) fused quartz

(b) gallium phosphide

(c) sodium chloride

\[
\sin \theta_c = \frac{n_2}{n_1}
\]

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\( n_{a} = \text{air} \)

\( n_{i} = \text{material} \)

\begin{align*}
\textbf{a)} & \quad n_{\text{fused quartz}} = 1.46 \\
\sin \theta_c &= \frac{1}{1.46} \\
\theta_c &= 43.3^\circ
\end{align*}

\begin{align*}
\textbf{b)} & \quad n_{\text{gallium phosphide}} = 3.50 \\
\sin \theta_c &= \frac{1}{3.5} \\
\theta_c &= 16.6^\circ
\end{align*}

\begin{align*}
\textbf{c)} & \quad n_{\text{sodium chloride}} = 1.54 \\
\sin \theta_c &= \frac{1}{1.54} \\
\theta_c &= 40.5^\circ
\end{align*}
A narrow white light beam is incident on a block of fused quartz at an angle of 26.0°. Find the angular width of the light beam inside the quartz. (Refer to Figure 35.20 and assume that the wavelength range of white light is 400 - 700 nm.)

at 400 nm, \( n_2 = 1.47 \)

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

\[ \sin \theta_2 = 1.47 \sin \theta_2 \]

\[ \theta_2 = 17.350° \]

at 700 nm, \( n_2 = 1.458 \)

\[ n_1 \sin \theta_1 = n_2 \sin \theta_3 \]

\[ \sin \theta_3 = 1.458 \sin \theta_3 \]

\[ \theta_3 = 17.498° \]

Width = \( \theta_3 - \theta_2 \)

Width = 0.148°