Because the sine of 90° equals 1, the following relationship results.

CRITICAL ANGLE

$$\sin \theta_c = \frac{n_r}{n_i} \quad \text{for } n_i > n_r$$

$$\text{sine (critical angle)} = \frac{\text{index of refraction of second medium}}{\text{index of refraction of first medium}}$$

but only if index of refraction of first medium > index of refraction of second medium

Note that this equation can be used only when n_i is greater than n_r. In other words, *total internal reflection occurs only when light moves along a path from a medium of higher index of refraction to a medium of lower index of refraction.* If n_i were less than n_r, this equation would give $\sin \theta_c > 1$, which is an impossible result because by definition the sine of an angle can never be greater than 1.

When the second substance is air, the critical angle is small for substances with large indices of refraction. Diamonds, which have an index of refraction of 2.419, have a critical angle of 24.4°. By comparison, the critical angle for crown glass, a very clear optical glass, where $n = 1.52$, is 41.0°. Because diamonds have such a small critical angle, most of the light that enters a cut diamond is totally internally reflected. The reflected light eventually exits the diamond from the most visible faces of the diamond. Jewelers cut diamonds so that the maximum light entering the upper surface is reflected back to these faces.

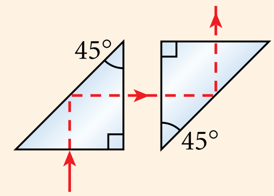
Quick Lab

Periscope

MATERIALS LIST

- **two 90° prisms**

Align the two prisms side by side as shown below.



Note that this configuration can be used like a periscope to see an object above your line of sight if the configuration is oriented vertically and to see around a corner if it is oriented horizontally. How would you arrange the prisms to see behind you? Draw your design on paper and test it.

SAMPLE PROBLEM C

Critical Angle

PROBLEM

Find the critical angle for a water-air boundary if the index of refraction of water is 1.333.

SOLUTION

Given: $n_i = 1.333 \quad n_r = 1.000$

Unknown: $\theta_c = ?$

Use the equation for critical angle on this page.

$$\sin \theta_c = \frac{n_r}{n_i}$$

$$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.333}\right)$$

$$\boxed{\theta_c = 48.6°}$$

TIP *Remember that the critical angle equation is valid only if the light is moving from a higher to a lower index of refraction.*