8.22 Figure P8.22 depicts a beaker containing a block of glass on the bottom and water over it. The glass block contains a small air bubble at an unknown depth below the water surface. When viewed from above at an angle of 60°, the air bubble appears at a depth of 6.81 cm. What is the true depth of the air bubble?

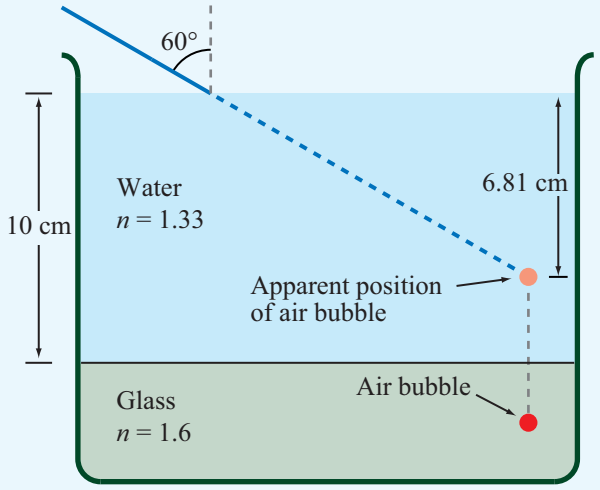

Figure P8.22 Apparent position of the air bubble in Problem 8.22.

Solution: Let

$$d_a = 6.81 \text{ cm} = \text{apparent depth},$$
$$d_t = \text{true depth}.$$

$$\theta_2 = \sin^{-1}\left[\frac{n_1}{n_2}\sin\theta_i\right] = \sin^{-1}\left[\frac{1}{1.33}\sin 60^\circ\right] = 40.6^\circ,$$
$$\theta_3 = \sin^{-1}\left[\frac{n_1}{n_3}\sin\theta_i\right] = \sin^{-1}\left[\frac{1}{1.6}\sin 60^\circ\right] = 32.77^\circ,$$
$$x_1 = (10 \text{ cm}) \times \tan 40.6^\circ = 8.58 \text{ cm},$$
$$x = d_a \cot 30^\circ = 6.81 \cot 30^\circ = 11.8 \text{ cm}.$$

Hence,

$$x_2 = x - x_1 = 11.8 - 8.58 = 3.22 \text{ cm},$$

and

$$d_2 = x_2 \cot 32.77^\circ = (3.22 \text{ cm}) \times \cot 32.77^\circ = 5 \text{ cm}.$$

Hence, $d_t = (10 + 5) = 15$ cm.