Problem 8.23   A penny lies at the bottom of a water fountain at a depth of 30 cm. Determine the diameter of a piece of paper which, if placed to float on the surface of the water directly above the penny, would totally obscure the penny from view. Treat the penny as a point and assume that $n = 1.33$ for water.
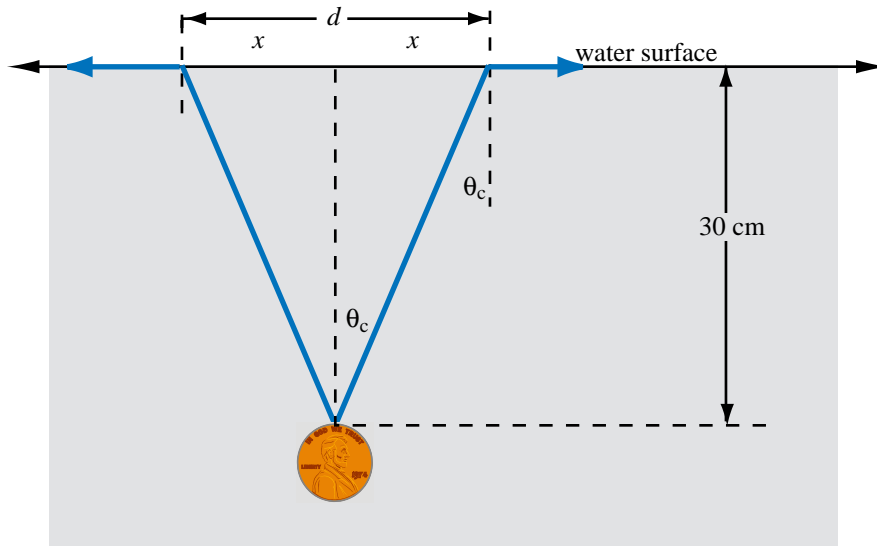
Solution:

Figure P8.23: Light cone bounded by total internal reflection.

$$\theta_c = \sin^{-1}\left[\frac{1}{1.33}\right] = 48.75°,$$

$$d = 2x = 2[(30 \text{ cm})\tan\theta_c] = (60 \text{ cm}) \times \tan 48.75° = 68.42 \text{ cm}.$$