

55. (a) No refraction occurs at the surface ab , so the angle of incidence at surface ac is $90^\circ - \phi$. For total internal reflection at the second surface, $n_g \sin(90^\circ - \phi)$ must be greater than n_a . Here n_g is the index of refraction for the glass and n_a is the index of refraction for air. Since $\sin(90^\circ - \phi) = \cos \phi$, we want the largest value of ϕ for which $n_g \cos \phi \geq n_a$. Recall that $\cos \phi$ decreases as ϕ increases from zero. When ϕ has the largest value for which total internal reflection occurs, then $n_g \cos \phi = n_a$, or

$$\phi = \cos^{-1} \left(\frac{n_a}{n_g} \right) = \cos^{-1} \left(\frac{1}{1.52} \right) = 48.9^\circ .$$

The index of refraction for air is taken to be unity.

- (b) We now replace the air with water. If $n_w = 1.33$ is the index of refraction for water, then the largest value of ϕ for which total internal reflection occurs is

$$\phi = \cos^{-1} \left(\frac{n_w}{n_g} \right) = \cos^{-1} \left(\frac{1.33}{1.52} \right) = 29.0^\circ .$$