Chapter 33

1. Since $\Delta\lambda \ll \lambda$, we find Δf is equal to

$$\left|\Delta\left(\frac{c}{\lambda}\right)\right| \approx \frac{c\Delta\lambda}{\lambda^2} = \frac{(3.0\times10^8\text{ m/s})(0.0100\times10^{-9}\text{ m})}{(632.8\times10^{-9}\text{ m})^2} = 7.49\times10^9\text{ Hz}.$$

34. In this case, we replace $I_0\cos^2 70°$ by $\frac{1}{2}I_0$ as the intensity of the light after passing through the first polarizer. Therefore,

$$I_f = \frac{1}{2}I_0\cos^2(90°-70°) = \frac{1}{2}(43\text{ W/m}^2)(\cos^2 20°) = 19\text{ W/m}^2.$$

45. Note that the normal to the refracting surface is vertical in the diagram. The angle of refraction is $\theta_2 = 90°$ and the angle of incidence is given by $\tan\theta_1 = L/D$, where D is the height of the tank and L is its width. Thus

$$\theta_1 = \tan^{-1}\left(\frac{L}{D}\right) = \tan^{-1}\left(\frac{1.10\text{ m}}{0.850\text{ m}}\right) = 52.31°.$$

The law of refraction yields

$$n_1 = n_2\frac{\sin\theta_2}{\sin\theta_1} = (1.00)\left(\frac{\sin 90°}{\sin 52.31°}\right) = 1.26,$$

where the index of refraction of air was taken to be unity.

47. The law of refraction states

$$n_1\sin\theta_1 = n_2\sin\theta_2.$$

We take medium 1 to be the vacuum, with $n_1 = 1$ and $\theta_1 = 32.0°$. Medium 2 is the glass, with $\theta_2 = 21.0°$. We solve for n_2:

$$n_2 = n_1\frac{\sin\theta_1}{\sin\theta_2} = (1.00)\left(\frac{\sin 32.0°}{\sin 21.0°}\right) = 1.48.$$

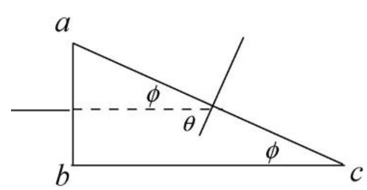
57. Reference to Fig. 33-24 may help in the visualization of why there appears to be a "circle of light" (consider revolving that picture about a vertical axis). The depth and the

radius of that circle (which is from point *a* to point *f* in that figure) is related to the tangent of the angle of incidence. Thus, the diameter *D* of the circle in question is

$$D = 2h\tan\theta_c = 2h\tan\left[\sin^{-1}\left(\frac{1}{n_w}\right)\right] = 2(80.0\,\text{cm})\tan\left[\sin^{-1}\left(\frac{1}{1.33}\right)\right] = 182\text{ cm}.$$

58. The critical angle is $\theta_c = \sin^{-1}\left(\frac{1}{n}\right) = \sin^{-1}\left(\frac{1}{1.8}\right) = 34°$.

59. (a) No refraction occurs at the surface *ab*, so the angle of incidence at surface *ac* is 90° – ϕ, as shown in the figure below.



For total internal reflection at the second surface, n_g sin (90° – ϕ) 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° – ϕ) = cos ϕ, we want the largest value of ϕ for which $n_g \cos\phi \geq n_a$. Recall that cos ϕ 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

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

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

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