33-13. We use $I = E_m^2/2\mu_0 c$ to calculate E_m:

$$\begin{aligned} E_m &= \sqrt{2\mu_0 I c} = \sqrt{2(4\pi \times 10^{-7}\,\mathrm{T\cdot m/A})(1.40\times 10^3\,\mathrm{W/m^2})(2.998\times 10^8\,\mathrm{m/s})} \\ &= 1.03 \times 10^3\ \mathrm{V/m}\ . \end{aligned}$$

The magnetic field amplitude is therefore

$$B_m = \frac{E_m}{c} = \frac{1.03\times 10^3\,\mathrm{V/m}}{2.998\times 10^8\,\mathrm{m/s}} = 3.43\times 10^{-6}\ \mathrm{T}\ .$$

33-28. We require $F_\mathrm{grav} = F_r$ or

$$G\frac{mM_s}{d_{es}^2} = \frac{2IA}{c}\ .$$

For I use either 1340 $\mathrm{W/m^2}$ or $3.90\times 10^{26}\ \mathrm{W}/4\pi d_{es}^2$ (for $d_{es} = 1.50\times 10^{11}$ m this produces $I = 1380\,\mathrm{W/m^2}$) and solve for the area A:

$$\begin{aligned} A &= \frac{cGmM_s}{2Id_{es}^2} = \frac{(4\pi)(6.67\times 10^{-11}\,\mathrm{N\cdot m^2/kg^2})(1500\,\mathrm{kg})(1.99\times 10^{30}\,\mathrm{kg})(2.998\times 10^8\,\mathrm{m/s})}{2(3.90\times 10^{26}\,\mathrm{W})} \\ &= 9.62\times 10^5\,\mathrm{m^2} = 0.962\ \mathrm{km^2}\ \text{(first method: } 9.90\times 10^5\mathrm{m^2}\ )\ . \end{aligned}$$

In using the second method you can see that this balance does not depend on distance from the Sun.

33-37. As the polarized beam of intensity I_0 passes the first polarizer, its intensity is reduced to $I_0\cos^2\theta$. After passing through the second polarizer, for which the direction of polarization is at an angle $90° - \theta$ from that of the first one, the intensity is $I = I_0\cos^2(\theta)\cos^2(90° - \theta) = I_0\cos^2(\theta)\sin^2(\theta) = \frac{1}{4}\ I_0\sin^2(2\theta)$. Thus, $\sin^2(2\theta) = 2/5$, which leads to $\theta = 19.6°$.

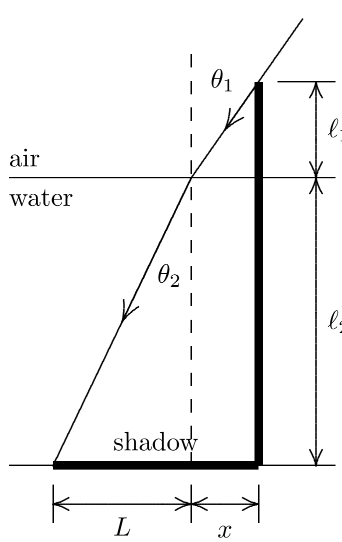
33-49. Consider a ray that grazes the top of the pole, as shown in the diagram below. Here $\theta_1 = 35°$, $\ell_1 = 0.50\,\mathrm{m}$, and $\ell_2 = 1.50\,\mathrm{m}$. The length of the shadow is $x + L$. x is given by $x = \ell_1\tan\theta_1 = (0.50\,\mathrm{m})\tan 35° = 0.35\,\mathrm{m}$. According to the law of refraction, $n_2\sin\theta_2 = n_1\sin\theta_1$. We take $n_1 = 1$ and $n_2 = 1.33$ (from Table 33–1). Then,

$$\theta_2 = \sin^{-1}\left(\frac{\sin\theta_1}{n_2}\right) = \sin^{-1}\left(\frac{\sin 35.0°}{1.33}\right) = 25.55°\ .$$

L is given by

$$L = \ell_2\tan\theta_2 = (1.50\,\mathrm{m})\tan 25.55° = 0.72\,\mathrm{m}\ .$$

The length of the shadow is $0.35\,\mathrm{m} + 0.72\,\mathrm{m} = 1.07\,\mathrm{m}$.



33-51. (a) Approximating $n = 1$ for air, we have

$$n_1 \sin\theta_1 = (1)\sin\theta_5 \implies 56.9^\circ = \theta_5$$

and with the more accurate value for n_{air} in Table 33-1, we obtain 56.8°.

(b) Eq. 33-44 leads to

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 = n_3 \sin\theta_3 = n_4 \sin\theta_4$$

so that

$$\theta_4 = \sin^{-1}\left(\frac{n_1}{n_4}\sin\theta_1\right) = 35.3^\circ \ .$$

33-53. We label the light ray's point of entry A, the vertex of the prism B, and the light ray's exit point C. Also, the point in Fig. 33-55 where ψ is defined (at the point of intersection of the extrapolations of the incident and emergent rays) is denoted D. The angle indicated by ADC is the supplement of ψ, so we denote it $\psi_{\text{s}} = 180^\circ - \psi$. The angle of refraction in the glass is $\theta_2 = \frac{1}{n}\sin\theta$. The angles between the interior ray and the nearby surfaces is the complement of θ_2, so we denote it $\theta_{2\text{c}} = 90^\circ - \theta_2$. Now, the angles in the triangle ABC must add to 180°:

$$180^\circ = 2\theta_{2\text{c}} + \phi \implies \theta_2 = \frac{\phi}{2} \ .$$

Also, the angles in the triangle ADC must add to 180°:

$$180^\circ = 2\,(\theta - \theta_2) + \psi_{\text{s}} \implies \theta = 90^\circ + \theta_2 - \frac{1}{2}\psi_{\text{s}}$$

which simplifies to $\theta = \theta_2 + \frac{1}{2}\psi$. Combining this with our previous result, we find $\theta = \frac{1}{2}(\phi + \psi)$. Thus, the law of refraction yields

$$n = \frac{\sin(\theta)}{\sin(\theta_2)} = \frac{\sin\left(\frac{1}{2}(\phi + \psi)\right)}{\sin\left(\frac{1}{2}\,\phi\right)} \ .$$

33-59. Let the angle from the normal at A for total internal reflection be denoted: θ_A. Then:

$$\sin(\theta_A) = \frac{n_2}{n_1}$$

At the entry point, let θ_1 denote the angle from the normal of the refracted ray:

$$\sin(\theta_1) = \frac{1}{n_1}\,\sin(\theta)$$

Note that θ_A and θ_1 are complementary: $\theta_A + \theta_1 = 90^\circ$, so $\sin(\theta_A) = \cos(\theta_1)$. Further:

$$\sin(\theta_1) = \sqrt{1 - \cos^2(\theta_1)} = \sqrt{1 - \sin^2(\theta_A)} = \sqrt{1 - n_2^2/n_1^2}$$

SO:

$$\sin(\theta) = n_1 \sin(\theta_1) = n_1\,\sqrt{1 - n_2^2/n_1^2} = \sqrt{n_1^2 - n_2^2}$$

$$\theta = \sin^{-1}\left(\sqrt{1.58^2 - 1.53^2}\right) = 23.2^\circ$$

33-64. (a) We use Eq. 33-49: $\theta_{\text{B}} = \tan^{-1} n_w = \tan^{-1}(1.33) = 53.1^\circ$.

(b) Yes, since n_w depends on the wavelength of the light.