Answers to Even Numbered Conceptual Questions

2. Ceilings are generally painted a light color so they will reflect more light, making the room brighter. Textured materials are often used on the ceiling to diffuse the reflected light and reduce glare (specular reflections).

14. Total internal reflection occurs only when light attempts to move from a medium of high index of refraction to a medium of lower index of refraction. Thus, light moving from air (n = 1) to water (n = 1.33) cannot undergo total internal reflection.

Problem Solutions

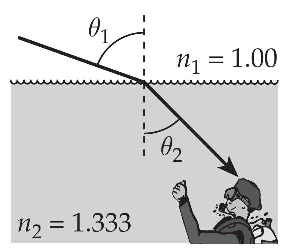
22.1 The total distance the light travels is

$$\Delta d = 2\left(D_{\substack{\text{center to}\\\text{center}}} - R_{Earth} - R_{Moon}\right)$$

$$= 2\left(3.84\times10^{8} - 6.38\times10^{6} - 1.76\times10^{6}\right)\text{ m} = 7.52\times10^{8}\text{ m}$$

Therefore, $$v = \frac{\Delta d}{\Delta t} = \frac{7.52\times10^{8}\text{ m}}{2.51\text{ s}} = \boxed{3.00\times10^{8}\text{ m/s}}$$

22.7 $n_1 \sin\theta_1 = n_2 \sin\theta_2$



$\sin\theta_1 = 1.333 \sin 45.0°$

$\sin\theta_1 = (1.333)(0.707) = 0.943$

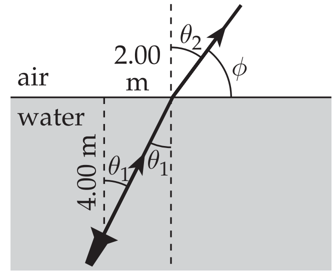
$\theta_1 = 70.5° \;\rightarrow\; \boxed{19.5° \text{ above the horizontal}}$

22.11 (a) $\lambda_{water} = \dfrac{\lambda_0}{n_{water}}$, so $\lambda_0 = n_{water}\lambda_{water} = (1.333)(438\text{ nm}) = \boxed{584\text{ nm}}$

(b) $\lambda_0 = n_{water}\lambda_{water} = n_{benzene}\lambda_{benzene}$

and $$\frac{n_{benzene}}{n_{water}} = \frac{\lambda_{water}}{\lambda_{benzene}} = \frac{438\text{ nm}}{390\text{ nm}} = \boxed{1.12}$$

22.16 The angle of incidence is



$$\theta_1 = \tan^{-1}\left[\frac{2.00\text{ m}}{4.00\text{ m}}\right] = 26.6°$$

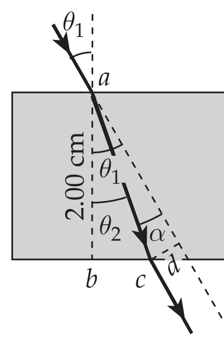
Therefore, Snell's law gives

$$\theta_2 = \sin^{-1}\left[\frac{n_1 \sin\theta_1}{n_2}\right]$$

$$= \sin^{-1}\left[\frac{(1.333)\sin 26.6°}{1.00}\right] = 36.6°$$

and the angle the refracted ray makes with the surface is

22.19 The angle of refraction at the first surface is $\theta_2 = 19.5°$ (see Problem 18). Let h represent the distance from point a to c (that is, the hypotenuse of triangle abc). Then,



$$h = \frac{2.00\text{ cm}}{\cos\theta_2} = \frac{2.00\text{ cm}}{\cos 19.5°} = 2.12\text{ cm}$$

Also, $\alpha = \theta_1 - \theta_2 = 30.0° - 19.5° = 10.5°$, so

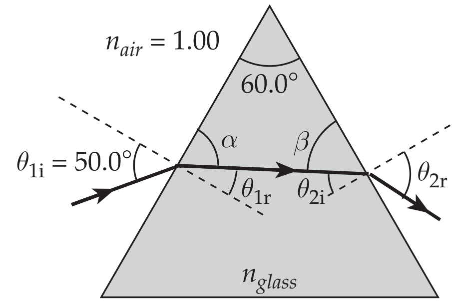
$$d = h\sin\alpha = (2.12\text{ cm})\sin 10.5° = \boxed{0.388\text{ cm}}$$

22.29 Using Snell's law gives

$$\theta_{red} = \sin^{-1}\left(\frac{n_{air}\sin\theta_i}{n_{red}}\right) = \sin^{-1}\left(\frac{(1.000)\sin 83.00°}{1.331}\right) = \boxed{48.22°}$$

and $$\theta_{blue} = \sin^{-1}\left(\frac{n_{air}\sin\theta_i}{n_{blue}}\right) = \sin^{-1}\left(\frac{(1.000)\sin 83.00°}{1.340}\right) = \boxed{47.79°}$$

22.32 For the violet light, $n_{glass} = 1.66$, and



$$\theta_{1r} = \sin^{-1}\left(\frac{n_{air}\sin\theta_{1i}}{n_{glass}}\right)$$

$$= \sin^{-1}\left(\frac{1.00\sin 50.0°}{1.66}\right) = 27.5°$$

$$\alpha = 90° - \theta_{1r} = 62.5°, \beta = 180.0° - 60.0° - \alpha = 57.5°,$$

and $\theta_{2i} = 90.0° - \beta = 32.5°$. The final angle of refraction of the violet light is

$$\theta_{2r} = \sin^{-1}\left(\frac{n_{glass}\sin\theta_{2i}}{n_{air}}\right) = \sin^{-1}\left(\frac{1.66\sin 32.5°}{1.00}\right) = 63.2°$$

Following the same steps for the red light $\left(n_{glass} = 1.62\right)$ gives

$$\theta_{1r} = 28.2°,\ \alpha = 61.8°, \beta = 58.2°, \theta_{2i} = 31.8°, \text{and } \theta_{2r} = 58.6°$$

Thus, the angular dispersion of the emerging light is

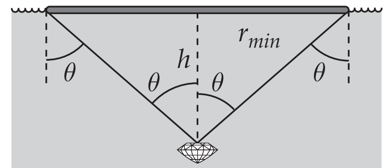
$$Dispersion = \theta_{2r}\big|_{violet} - \theta_{2r}\big|_{red} = 63.2° - 58.6° = \boxed{4.6°}$$

22.37 When light attempts to cross a boundary from one medium of refractive index n_1 into a new medium of refractive index $n_2 < n_1$, total internal reflection will occur if the angle of incidence exceeds the critical angle given by $\theta_c = \sin^{-1}\left(n_2/n_1\right)$.

(a) If $n_1 = 1.53$ and $n_2 = n_{air} = 1.00$, then $\theta_c = \sin^{-1}\left(\frac{1.00}{1.53}\right) = \boxed{40.8°}$

(b) If $n_1 = 1.53$ and $n_2 = n_{water} = 1.333$, then $\theta_c = \sin^{-1}\left(\frac{1.333}{1.53}\right) = \boxed{60.6°}$

22.40 The circular raft must cover the area of the surface through which light from the diamond could emerge. Thus, it must form the base of a cone (with apex at the diamond) whose half angle is θ, where θ is greater than or equal to the critical angle.



The critical angle at the water-air boundary is

$$\theta_c = \sin^{-1}\left(\frac{n_{air}}{n_{water}}\right) = \sin^{-1}\left(\frac{1.00}{1.333}\right) = 48.6°$$

Thus, the minimum diameter of the raft is

$$2r_{min} = 2h\tan\theta_{min} = 2h\tan\theta_c = 2(2.00\text{ m})\tan 48.6° = \boxed{4.54\text{ m}}$$