19.2 (a) For a positively charged particle, the direction of the force is that predicted by the right hand rule. These are:

(a′) **in plane of page and to left** (b′) **into the page**

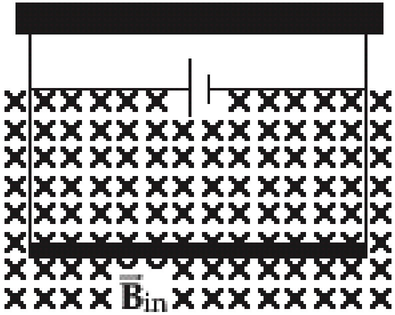
(c′) **out of the page** (d′) **in plane of page and toward the top**

(e′) **into the page** (f′) **out of the page**

(b) For a negatively charged particle, the direction of the force is exactly opposite what the right hand rule predicts for positive charges. Thus, the answers for part (b) are **reversed from those given in part (a)**.

19.3 Since the particle is positively charged, use the right hand rule. In this case, start with the fingers of the right hand in the direction of $\vec{\mathbf{v}}$ and the thumb pointing in the direction of $\vec{\mathbf{F}}$. As you start closing the hand, the fingers point in the direction of $\vec{\mathbf{B}}$ after they have moved 90°. The results are

19.18 To have zero tension in the wires, the magnetic force per unit length must be directed upward and equal to the weight per unit length of the conductor. Thus,



$$\frac{|\vec{F}_m|}{L} = BI = \frac{mg}{L}, \text{ or}$$

$$I = \frac{(m/L)g}{B} = \frac{(0.040\ \text{kg/m})(9.80\ \text{m/s}^2)}{3.60\ \text{T}} = \boxed{0.109\ \text{A}}$$

From the right hand rule, the current must be $\boxed{\text{to the right}}$ if the force is to be upward when the magnetic field is into the page.

19.38 Assume that the wire on the right is wire 1 and that on the left is wire 2. Also, choose the positive direction for the magnetic field to be out of the page and negative into the page.

(a) At the point half way between the two wires,

$$B_{net} = -B_1 - B_2 = -\left[\frac{\mu_0 I_1}{2\pi r_1} + \frac{\mu_0 I_2}{2\pi r_2}\right] = -\frac{\mu_0}{2\pi r}(I_1 + I_2)$$

$$= -\frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)}{2\pi\left(5.00\times 10^{-2}\ \text{m}\right)}(10.0\ \text{A}) = -4.00\times 10^{-5}\ \text{T}$$

or $B_{net} = \boxed{40.0\ \mu\text{T into the page}}$

(b) At point P_1, $B_{net} = +B_1 - B_2 = \frac{\mu_0}{2\pi}\left[\frac{I_1}{r_1} - \frac{I_2}{r_2}\right]$

$$B_{net} = \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)}{2\pi}\left[\frac{5.00\ \text{A}}{0.100\ \text{m}} - \frac{5.00\ \text{A}}{0.200\ \text{m}}\right] = \boxed{5.00\ \mu\text{T out of page}}$$

20.10 $|\mathcal{E}| = \frac{\Delta\Phi_B}{\Delta t} = \frac{B(\Delta A)\cos\theta}{\Delta t}$

$$= \frac{(0.15\text{ T})\left[\pi(0.12\text{ m})^2 - 0\right]\cos 0°}{0.20\text{ s}} = 3.4\times10^{-2}\text{ V} = \boxed{34\text{ mV}}$$

20.18 From $\varepsilon = B\ell v$, the required speed is

$$v = \frac{\varepsilon}{B\ell} = \frac{IR}{B\ell} = \frac{(0.500\ \text{A})(6.00\ \Omega)}{(2.50\ \text{T})(1.20\ \text{m})} = \boxed{1.00\ \text{m/s}}$$

20.37 $\left|\mathcal{E}_{av}\right| = L\left|\frac{\Delta I}{\Delta t}\right| = \left(3.00\times10^{-3}\text{ H}\right)\left(\frac{1.50\text{ A}-0.20\text{ A}}{0.20\text{ s}}\right) = 2.0\times10^{-2}\text{ V} = \boxed{20\text{ mV}}$

20.53 (a) The current in the solenoid reaches $I = 0.632 I_{max}$ in a time of $t = \tau = L/R$, where

$$L = \frac{\mu_0 N^2 A}{\ell} = \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)\left(12\,500\right)^2\left(1.00\times 10^{-4}\ \text{m}^2\right)}{7.00\times 10^{-2}\ \text{m}} = 0.280\ \text{H}$$

Thus, $$t = \frac{0.280\ \text{H}}{14.0\ \Omega} = 2.00\times 10^{-2}\ \text{s} = \boxed{20.0\ \text{ms}}$$

(b) The change in the solenoid current during this time is

$$\Delta I = 0.632 I_{\text{max}} - 0 = 0.632\left(\frac{\Delta V}{R}\right) = 0.632\left(\frac{60.0\ \text{V}}{14.0\ \Omega}\right) = 2.71\ \text{A}$$

so the average back emf is

$$\mathcal{E}_{back} = L\left(\frac{\Delta I}{\Delta t}\right) = (0.280\ \text{H})\left(\frac{2.71\ \text{A}}{2.00\times 10^{-2}\ \text{s}}\right) = \boxed{37.9\ \text{V}}$$

21.48 At Earth's location, the wave fronts of the solar radiation are spheres whose radius is the Sun-Earth distance. Thus, from $Intensity = \frac{\mathcal{P}_{\text{av}}}{A} = \frac{\mathcal{P}_{\text{av}}}{4\pi r^2}$, the total power is

$$\mathcal{P}_{\text{av}} = (Intensity)\left(4\pi r^2\right) = \left(1\,340\ \frac{\text{W}}{\text{m}^2}\right)\left[4\pi\left(1.49\times10^{11}\ \text{m}\right)^2\right] = \boxed{3.74\times10^{26}\ \text{W}}$$

21.51 (a) For the AM band,

$$\lambda_{\min} = \frac{c}{f_{\max}} = \frac{3.00 \times 10^{8}\ \text{m/s}}{1\,600 \times 10^{3}\ \text{Hz}} = \boxed{188\ \text{m}}$$

$$\lambda_{\max} = \frac{c}{f_{\min}} = \frac{3.00 \times 10^{8}\ \text{m/s}}{540 \times 10^{3}\ \text{Hz}} = \boxed{556\ \text{m}}$$

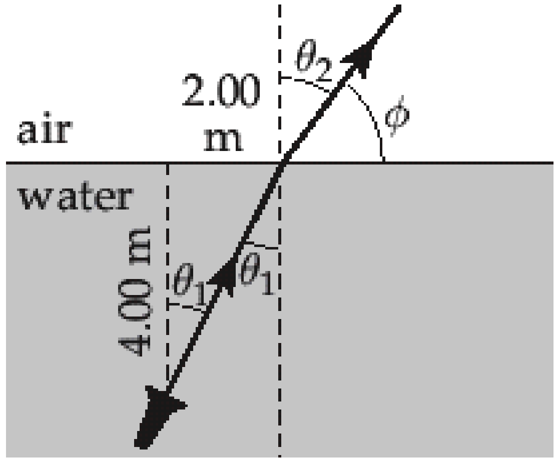
21.58 Suppose you cover a 1.7 m-by-0.3 m section of beach blanket. Suppose the elevation angle of the Sun is 60°. Then the target area you fill in the Sun's field of view is $(1.7\text{ m})(0.3\text{ m})\cos 30° = 0.4\text{ m}^2$.

The intensity the radiation at Earth's surface is $I_{\text{surface}} = 0.6 I_{\text{incoming}}$ and only 50% of this is absorbed. Since $I = \dfrac{\mathcal{P}_{\text{av}}}{A} = \dfrac{(\Delta E/\Delta t)}{A}$, the absorbed energy is

$$\Delta E = (0.5 I_{\text{surface}}) A(\Delta t) = \left[0.5(0.6 I_{\text{incoming}})\right] A(\Delta t)$$

$$= (0.5)(0.6)(1\,340\text{ W/m}^2)(0.4\text{ m}^2)(3\,600\text{ s}) = 6 \times 10^5\text{ J}\ \boxed{\sim 10^6\text{ J}}$$

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

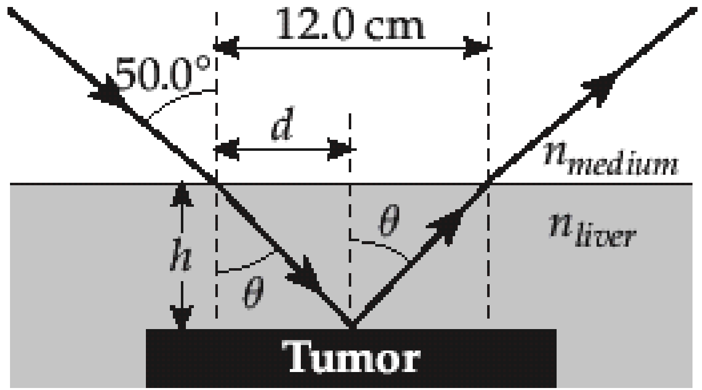
$$\theta_2 = \sin^{-1}\left[\frac{n_1 \sin\theta_1}{n_2}\right]$$

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

and the angle the refracted ray makes with the surface is

$$\phi = 90.0° - \theta_2 = 90.0° - 36.6° = \boxed{53.4°}$$

22.24 From Snell's law, $\sin\theta = \left(\dfrac{n_{medium}}{n_{liver}}\right)\sin 50.0°$

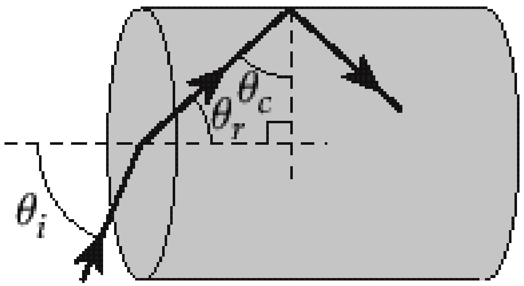


But, $\dfrac{n_{medium}}{n_{liver}} = \dfrac{c/v_{medium}}{c/v_{liver}} = \dfrac{v_{liver}}{v_{medium}} = 0.900$

so, $\theta = \sin^{-1}\left[(0.900)\sin 50.0°\right] = 43.6°$

From the law of reflection,

22.38 The critical angle for this material in air is



$$\theta_c = \sin^{-1}\left(\frac{n_{air}}{n_{pipe}}\right) = \sin^{-1}\left(\frac{1.00}{1.36}\right) = 47.3°$$

Thus, $\theta_r = 90.0° - \theta_c = 42.7°$ and from Snell's law,

$$\theta_i = \sin^{-1}\left(\frac{n_{pipe}\sin\theta_r}{n_{air}}\right) = \sin^{-1}\left(\frac{(1.36)\sin 42.7°}{1.00}\right) = \boxed{67.2°}$$