HW 6 Solutions

34.3 $\frac{E}{B} = c$ or $\frac{220}{B} = 3.00 \times 10^8;$ so $B = 7.33 \times 10^{-7}\ \text{T} = \boxed{733\ \text{nT}}$

34.4 $\frac{E_{\text{max}}}{B_{\text{max}}} = v$ is the generalized version of Equation 34.13.

$$B_{\text{max}} = \frac{E_{\text{max}}}{v} = \frac{7.60 \times 10^{-3}\ \text{V/m}}{(2/3)(3.00 \times 10^8\ \text{m/s})}\left(\frac{\text{N}\cdot\text{m}}{\text{V}\cdot\text{C}}\right)\left(\frac{\text{T}\cdot\text{C}\cdot\text{m}}{\text{N}\cdot\text{s}}\right) = 3.80 \times 10^{-11}\ \text{T} = \boxed{38.0\ \text{pT}}$$

34.7 (a) $B = \frac{E}{c} = \frac{100\ \text{V/m}}{3.00 \times 10^8\ \text{m/s}} = 3.33 \times 10^{-7}\ \text{T} = \boxed{0.333\ \mu\text{T}}$

(b) $\lambda = \frac{2\pi}{k} = \frac{2\pi}{1.00 \times 10^7\ \text{m}^{-1}} = \boxed{0.628\ \mu\text{m}}$

(c) $f = \frac{c}{\lambda} = \frac{3.00 \times 10^8\ \text{m/s}}{6.28 \times 10^{-7}\ \text{m}} = \boxed{4.77 \times 10^{14}\ \text{Hz}}$

34.11 $S = I = \frac{U}{At} = \frac{Uc}{V} = uc$

$$\frac{\text{Energy}}{\text{Unit Volume}} = u = \frac{I}{c} = \frac{1000\ \text{W/m}^2}{3.00 \times 10^8\ \text{m/s}} = \boxed{3.33\ \mu\text{J/m}^3}$$

34.13 $r = (5.00\ \text{mi})(1609\ \text{m/mi}) = 8.04 \times 10^3\ \text{m}$

$$S = \frac{\mathcal{P}}{4\pi r^2} = \frac{250 \times 10^3\ \text{W}}{4\pi(8.04 \times 10^3\ \text{m})^2} = \boxed{307\ \mu\text{W/m}^2}$$

34.30 (a) If $\mathcal{P}_S$ is the total power radiated by the Sun, and r_E and r_M are the radii of the orbits of the planets Earth and Mars, then the intensities of the solar radiation at these planets are:

$$I_E = \frac{\mathcal{P}_S}{4\pi r_E^2} \quad \text{and} \quad I_M = \frac{\mathcal{P}_S}{4\pi r_M^2}$$

Thus,

$$I_M = I_E\left(\frac{r_E}{r_M}\right)^2 = \left(1340\ \text{W/m}^2\right)\left(\frac{1.496 \times 10^{11}\ \text{m}}{2.28 \times 10^{11}\ \text{m}}\right)^2 = \boxed{577\ \text{W/m}^2}$$

(b) Mars intercepts the power falling on its circular face:

$$\mathcal{P}_M = I_M\left(\pi R_M^2\right) = \left(577\ \text{W/m}^2\right)\pi\left(3.37 \times 10^6\ \text{m}\right)^2 = \boxed{2.06 \times 10^{16}\ \text{W}}$$

(c) If Mars behaves as a perfect absorber, it feels pressure $P = \frac{S_M}{c} = \frac{I_M}{c}$

and force $F = PA = \frac{I_M}{c}\left(\pi R_M^2\right) = \frac{\mathcal{P}_M}{c} = \frac{2.06 \times 10^{16}\ \text{W}}{3.00 \times 10^8\ \text{m/s}} = \boxed{6.87 \times 10^7\ \text{N}}$

(d) The attractive gravitational force exerted on Mars by the Sun is

$$F_g = \frac{GM_S M_M}{r_M^2} = \frac{\left(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)\left(1.991 \times 10^{30}\ \text{kg}\right)\left(6.42 \times 10^{23}\ \text{kg}\right)}{\left(2.28 \times 10^{11}\ \text{m}\right)^2} = 1.64 \times 10^{21}\ \text{N}$$

which is $\boxed{\sim 10^{13}\ \text{times stronger}}$ than the repulsive force of (c).

34.31 (a) The total energy absorbed by the surface is

$$U = \left(\tfrac{1}{2}I\right)At = \left[\tfrac{1}{2}\left(750\ \frac{\text{W}}{\text{m}^2}\right)\right]\left(0.500\times 1.00\ \text{m}^2\right)(60.0\ \text{s}) = \boxed{11.3\ \text{kJ}}$$

(b) The total energy incident on the surface in this time is $2U = 22.5$ kJ, with $U = 11.3$ kJ being absorbed and $U = 11.3$ kJ being reflected. The total momentum transferred to the surface is

$$p = (\text{momentum from absorption}) + (\text{momentum from reflection})$$

$$p = \left(\frac{U}{c}\right) + \left(\frac{2U}{c}\right) = \frac{3U}{c} = \frac{3\left(11.3\times 10^3\ \text{J}\right)}{3.00\times 10^8\ \text{m/s}} = \boxed{1.13\times 10^{-4}\ \text{kg}\cdot\text{m/s}}$$

34.43 (a) $f\lambda = c$ gives $(5.00\times 10^{19}\ \text{Hz})\lambda = 3.00\times 10^8\ \text{m/s}$: $\boxed{\lambda = 6.00\times 10^{-12}\ \text{m} = 6.00\ \text{pm}}$

(b) $f\lambda = c$ gives $(4.00\times 10^{9}\ \text{Hz})\lambda = 3.00\times 10^8\ \text{m/s}$: $\boxed{\lambda = 0.075\ \text{m} = 7.50\ \text{cm}}$

*34.58 The area over which we model the antenna as radiating is the lateral surface of a cylinder,

$$A = 2\pi r\ell = 2\pi\left(4.00\times 10^{-2}\ \text{m}\right)(0.100\ \text{m}) = 2.51\times 10^{-2}\ \text{m}^2$$

(a) The intensity is then: $S = \dfrac{\mathcal{P}}{A} = \dfrac{0.600\ \text{W}}{2.51\times 10^{-2}\ \text{m}^2} = \boxed{23.9\ \text{W/m}^2}$

(b) The standard is: $0.570\ \dfrac{\text{mW}}{\text{cm}^2} = 0.570\left(\dfrac{\text{mW}}{\text{cm}^2}\right)\left(\dfrac{1.00\times 10^{-3}\ \text{W}}{1.00\ \text{mW}}\right)\left(\dfrac{1.00\times 10^{4}\ \text{cm}^2}{1.00\ \text{m}^2}\right) = 5.70\ \dfrac{\text{W}}{\text{m}^2}$

While it is on, the telephone is over the standard by $\dfrac{23.9\ \text{W/m}^2}{5.70\ \text{W/m}^2} = \boxed{4.19\ \text{times}}$

34.64 Think of light going up and being absorbed by the bead which presents face area πr_b^2.

If we take the bead to be perfectly absorbing, the light pressure is $P = \dfrac{S_{av}}{c} = \dfrac{I}{c} = \dfrac{F_\ell}{A}$

(a) $F_\ell = F_g$ so $I = \dfrac{F_\ell c}{A} = \dfrac{F_g c}{A} = \dfrac{mgc}{\pi r_b^2}$

From the definition of density, $\rho = \dfrac{m}{V} = \dfrac{m}{\frac{4}{3}\pi r_b^3}$ so $\dfrac{1}{r_b} = \left(\tfrac{4}{3}\pi\rho/m\right)^{1/3}$

Substituting for r_b, $I = \dfrac{mgc}{\pi}\left(\dfrac{4\pi\rho}{3m}\right)^{2/3} = gc\left(\dfrac{4\rho}{3}\right)^{2/3}\left(\dfrac{m}{\pi}\right)^{1/3} = \boxed{\dfrac{4\rho gc}{3}\left(\dfrac{3m}{4\pi\rho}\right)^{1/3}}$

(b) $\mathcal{P} = IA = \boxed{\dfrac{\pi r^2 4\rho gc}{3}\left(\dfrac{3m}{4\pi\rho}\right)^{1/3}}$