Homework 5

Chapter 34

P34.4 $\vec{\mathbf{F}} = m\vec{\mathbf{a}} = q\vec{\mathbf{E}} + q\vec{\mathbf{v}} \times \vec{\mathbf{B}}$ so

$\vec{\mathbf{a}} = \dfrac{-e}{m}\left[\vec{\mathbf{E}} + \vec{\mathbf{v}} \times \vec{\mathbf{B}}\right]$ where

$$\vec{\mathbf{v}} \times \vec{\mathbf{B}} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 10.0 & 0 & 0 \\ 0 & 0 & 0.400 \end{vmatrix} = -(4.00\ \mathrm{T \cdot m/s})\hat{\mathbf{j}}$$

Then

$$\vec{\mathbf{a}} = \left(\frac{-1.60 \times 10^{-19}\ \mathrm{C}}{9.11 \times 10^{-31}\ \mathrm{kg}}\right) \times \left[(2.50\ \mathrm{V/m})\hat{\mathbf{i}} + (5.00\ \mathrm{V/m})\hat{\mathbf{j}} - (4.00\ \mathrm{T \cdot m/s})\hat{\mathbf{j}}\right]$$

$$= \left(-1.76 \times 10^{11}\right)\left[2.50\hat{\mathbf{i}} + 1.00\hat{\mathbf{j}}\right]\ \mathrm{m/s^2}$$

$$\vec{\mathbf{a}} = \boxed{\left(-4.39\hat{\mathbf{i}} - 1.76\hat{\mathbf{j}}\right) \times 10^{11}\ \mathrm{m/s^2}}$$

P34.9 (a) Since the light from this star travels at 3.00×10^8 m/s, the last bit of light will hit the Earth in

$$t = \frac{d}{c} = \frac{6.44 \times 10^{18} \text{ m}}{2.998 \times 10^8 \text{ m/s}} = 2.15 \times 10^{10} \text{ s} = \boxed{681 \text{ years}}$$

(b) From Table C.4 (in Appendix C of the textbook), the average Earth-Sun distance is $d = 1.496 \times 10^{11}$ m, giving the transit time as

$$t = \frac{d}{c} = \left(\frac{1.496 \times 10^{11} \text{ m}}{2.998 \times 10^8 \text{ m/s}} \right) \left(\frac{1 \text{ min}}{60 \text{ s}} \right) = \boxed{8.32 \text{ min}}$$

(c) Also from Table C.4, the average Earth-Moon distance is $d = 3.84 \times 10^8$ m, giving the time for the round trip as

$$t = \frac{2d}{c} = \frac{2\left(3.84 \times 10^8 \text{ m}\right)}{2.998 \times 10^8 \text{ m/s}} = \boxed{2.56 \text{ s}}$$

P34.17 Since the separation of the burn marks is $d_{\text{A to A}} = 6 \text{ cm} \pm 5\% = \frac{\lambda}{2}$, then $\lambda = 12 \text{ cm } \pm 5\%$ and

$$v = \lambda f = (0.12 \text{ m } \pm 5\%)\left(2.45 \times 10^9 \text{ s}^{-1}\right)$$

$$= \boxed{2.9 \times 10^8 \text{ m/s } \pm 5\%}$$

P34.22 (a) $$\frac{P}{\text{area}}=\frac{\text{energy}}{\Delta t\cdot\text{area}}=\frac{600\times10^{3}\text{ Wh}}{(30\text{ d})(13.0\text{ m})(9.50\text{ m})}\left(\frac{1\text{ d}}{24\text{ h}}\right)=\boxed{6.75\text{ W/m}^2}$$

(b) The car uses gasoline at the rate of $(55\text{ mi/h})\left(\frac{\text{gal}}{25\text{ mi}}\right)$. Its rate of energy conversion is

$$P=44.0\times10^{6}\text{ J/kg}\left(\frac{2.54\text{ kg}}{1\text{ gal}}\right)(55\text{ mi/h})\left(\frac{\text{gal}}{25\text{ mi}}\right)\left(\frac{1\text{ h}}{3\,600\text{ s}}\right)$$
$$=6.83\times10^{4}\text{ W}$$

Its power-per-footprint-area is

$$\frac{P}{\text{area}}=\frac{6.83\times10^{4}\text{ W}}{(2.10\text{ m})(4.90\text{ m})}=\boxed{6.64\times10^{3}\text{ W/m}^2}$$

(c) A powerful automobile that is running on sunlight would have to carry on its roof a solar panel huge compared with the size of the car.

(d) Agriculture and forestry for food and fuels, space heating of large and small buildings, water heating, and heating for drying and many other processes are current and potential applications of solar energy.

P34.43 (a) The radiation pressure is

$$P = \frac{2S}{c} = \frac{2I}{c}$$

The force on area A is

$$F = PA = \frac{2\left(1\,370\text{ W/m}^2\right)}{3.00\times10^8\text{ m/s}}\left(6.00\times10^5\text{ m}^2\right) = \boxed{5.48\text{ N}}$$

(b) The acceleration is:

$$a = \frac{F}{m} = \frac{5.48\text{ N}}{6\,000\text{ kg}} = 9.13\times10^{-4}\text{ m/s}^2$$

$$= \boxed{913\ \mu\text{m/s}^2\text{ away from the Sun}}$$

(c) It will arrive at time t, where $d = \frac{1}{2}at^2$ or,

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2\left(3.84\times10^8\text{ m}\right)}{\left(9.13\times10^{-4}\text{ m/s}^2\right)}} = 9.17\times10^5\text{ s} = \boxed{10.6\text{ days}}$$

P34.65 (a) The magnetic-field amplitude is

$$B_{\text{max}} = \frac{E_{\text{max}}}{c} = \frac{0.200\times10^{-6}\text{ V/m}}{3.00\times10^8\text{ m/s}} = \boxed{6.67\times10^{-16}\text{ T}}$$

(b) The intensity is the Poynting vector averaged over one or more cycles, given by

$$S_{\text{avg}} = \frac{E_{\text{max}}^2}{2\mu_0 c} = \frac{\left(0.200\times10^{-6}\text{ V/m}\right)^2}{2\left(4\pi\times10^{-7}\text{ T}\cdot\text{m/A}\right)\left(3.00\times10^8\text{ m/s}\right)}$$

$$= \boxed{5.31\times10^{-17}\text{ W/m}^2}$$

(c) The power tells how fast the antenna receives energy. It is

$$P = S_{\text{avg}}A = S_{\text{avg}}\pi\left(\frac{d}{2}\right)^2 = \left(5.31\times10^{-17}\text{ W/m}^2\right)\pi\left(\frac{20.0\text{ m}}{2}\right)^2$$

$$= \boxed{1.67\times10^{-14}\text{ W}}$$

(d) The force tells how fast the antenna receives momentum. It is

$$F = PA = \left(\frac{S_{\text{avg}}}{c}\right)A = \left(\frac{5.31\times 10^{-17}\ \text{W/m}^2}{3.00\times 10^8\ \text{m/s}}\right)\pi\left(\frac{20.0\ \text{m}}{2}\right)^2$$

$$= \boxed{5.56\times 10^{-23}\ \text{N}}$$

(approximately the weight of 3 000 hydrogen atoms!)

P34.76 We are given $f = 90.0$ MHz and $E_{\text{max}} = 200\ \text{mV/m} = 2.00\times 10^{-3}\ \text{V/m}$

(a) The wavelength of the wave is $\lambda = \frac{c}{f} = \boxed{3.33\ \text{m}}$

(b) Its period is $T = \frac{1}{f} = 1.11\times 10^{-8}\ \text{s} = \boxed{11.1\ \text{ns}}$

(c) We obtain the maximum value of the magnetic field from

$$B_{\text{max}} = \frac{E_{\text{max}}}{c} = 6.67\times 10^{-12}\ \text{T} = \boxed{6.67\ \text{pT}}$$

(d) $$\boxed{\vec{\mathbf{E}} = \left(2.00\times 10^{-3}\right)\cos 2\pi\left(\frac{x}{3.33} - 90.0\times 10^6 t\right)\hat{\mathbf{j}}}$$

$$\boxed{\vec{\mathbf{B}} = \left(6.67\times 10^{-12}\right)\cos 2\pi\left(\frac{x}{3.33} - 90.0\times 10^6 t\right)\hat{\mathbf{k}}}$$

where $\vec{\mathbf{E}}$ is in V/m, $\vec{\mathbf{B}}$ in tesla, x in meters, and t in seconds.

(e) $$I = \frac{E_{\text{max}}^2}{2\mu_0 c} = \frac{\left(2.00\times 10^{-3}\ \text{V/m}\right)^2}{2\left(4\pi\times 10^{-7}\ \text{T}\cdot\text{m/A}\right)\left(3.00\times 10^8\ \text{m/s}\right)}$$

$$= \boxed{5.31\times 10^{-9}\ \text{W/m}^2}$$

(f) From Equation 34.26, $I = cu_{\text{avg}}$ so $u_{\text{avg}} = \frac{I}{c} = \boxed{1.77\times 10^{-17}\ \text{J/m}^3}$

(g) From Equation 34.30, the pressure is

$$P = \frac{2I}{c} = \frac{(2)\left(5.31\times 10^{-9}\ \text{W/m}^2\right)}{3.00\times 10^8\ \text{m/s}} = \boxed{3.54\times 10^{-17}\ \text{Pa}}$$