CHAPTER 21

Quick Quizzes

1. (c). The average power is proportional to the rms current which is non-zero even though the average current is zero. (a) is only valid for an open circuit. (b) and (d) can never be true because $i_{av} = 0$ for AC currents.

2. (b). Choices (a) and (c) are incorrect because the unaligned sine curves in Figure 21.9 mean the voltages are out of phase, and so we cannot simply add the maximum (or rms) voltages across the elements. (In other words, $\Delta V \neq \Delta V_R + \Delta V_L + \Delta V_C$ even though $\Delta v = \Delta v_R + \Delta v_L + \Delta v_C$.)

3. (b). Note that this is a DC circuit. However, changing the amount of iron inside the solenoid changes the magnetic field strength in that region and results in a changing magnetic flux through the loops of the solenoid. This changing flux will generate a back emf that opposes the current in the circuit and decreases the brightness of the bulb. The effect will be present only while the rod is in motion. If the rod is held stationary at any position, the back emf will disappear and the bulb will return to its original brightness.

4. (b), (c). The radiation pressure (a) does not change because pressure is force per unit area. In (b), the smaller disk absorbs less radiation, resulting in a smaller force. For the same reason, the momentum in (c) is reduced.

Problem Solutions

21.1 (a) $\Delta V_{max} = \sqrt{2}(\Delta V_{rms}) = \sqrt{2}(100\text{ V}) = \boxed{141\text{ V}}$

(b) $I_{rms} = \dfrac{\Delta V_{rms}}{R} = \dfrac{100\text{ V}}{5.00\ \Omega} = \boxed{20.0\text{ A}}$

(c) $I_{max} = \dfrac{\Delta V_{max}}{R} = \dfrac{141\text{ V}}{5.00\ \Omega} = \boxed{28.3\text{ A}}$ or $I_{max} = \sqrt{2}\,I_{rms} = \sqrt{2}(20.0\text{ A}) = \boxed{28.3\text{ A}}$

(d) $\wp_{av} = I_{rms}^2 R = (20.0\text{ A})^2(5.00\ \Omega) = 2.00\times 10^3\text{ W} = \boxed{2.00\text{ kW}}$

21.2 $\wp_{av} = I_{rms}^2 R = \left(\dfrac{I_{max}}{\sqrt{2}}\right)^2 R = \dfrac{1}{2}\left[\dfrac{\Delta V_{max}}{R}\right]^2 R = \dfrac{(\Delta V_{max})^2}{2R}$, so $R = \dfrac{(\Delta V_{max})^2}{2\wp_{av}}$

(a) If $\wp_{av} = 75.0\text{ W}$, then $R = \dfrac{(170\text{ V})^2}{2(75.0\text{ W})} = \boxed{193\ \Omega}$

(b) If $\wp_{av} = 100\text{ W}$, then $R = \dfrac{(170\text{ V})^2}{2(100\text{ W})} = \boxed{145\ \Omega}$

21.3 The meters measure the rms values of potential difference and current. These are

$$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}} = \frac{100\text{ V}}{\sqrt{2}} = \boxed{70.7\text{ V}}, \text{ and } I_{rms} = \frac{\Delta V_{rms}}{R} = \frac{70.7\text{ V}}{24.0\ \Omega} = \boxed{2.95\text{ A}}$$

21.4 All lamps are connected in parallel with the voltage source, so $\Delta V_{rms} = 120\text{ V}$ for each lamp. Also, the current is $I_{rms} = \wp_{av}/\Delta V_{rms}$ and the resistance is $R = \Delta V_{rms}/I_{rms}$.

$$I_{1,rms} = I_{2,rms} = \frac{150\text{ W}}{120\text{ V}} = \boxed{1.25\text{ A}} \text{ and } R_1 = R_2 = \frac{120\text{ V}}{1.25\text{ A}} = \boxed{96.0\ \Omega}$$

$$I_{3,rms} = \frac{100\text{ W}}{120\text{ V}} = \boxed{0.833\text{ A}} \text{ and } R_3 = \frac{120\text{ V}}{0.833\text{ A}} = \boxed{144\ \Omega}$$

21.5 The total resistance (series connection) is $R_{eq} = R_1 + R_2 = 8.20\ \Omega + 10.4\ \Omega = 18.6\ \Omega$, so the current in the circuit is

$$I_{rms} = \frac{\Delta V_{rms}}{R_{eq}} = \frac{15.0\ \text{V}}{18.6\ \Omega} = 0.806\ \text{A}$$

The power to the speaker is then $\wp_{av} = I_{rms}^2 R_{speaker} = (0.806\ \text{A})^2 (10.4\ \Omega) = \boxed{6.76\ \text{W}}$

21.6 (a) $\Delta V_{max} = 150\ \text{V}$, so $\Delta V_{rms} = \dfrac{\Delta V_{max}}{\sqrt{2}} = \dfrac{150\ \text{V}}{\sqrt{2}} = \boxed{106\ \text{V}}$

(b) $f = \dfrac{\omega}{2\pi} = \dfrac{377\ \text{rad/s}}{2\pi} = \boxed{60.0\ \text{Hz}}$

(c) At $t = (1/120)\ \text{s}$, $v = (150\ \text{V})\sin\left[(377\ \text{rad/s})(1/120\ \text{s})\right] = (150\ \text{V})\sin(\pi\ \text{rad}) = \boxed{0}$

(d) $I_{max} = \dfrac{\Delta V_{max}}{R} = \dfrac{150\ \text{V}}{50.0\ \Omega} = \boxed{3.00\ \text{A}}$

21.7 $X_C = \dfrac{1}{2\pi fC}$, so its units are

$$\frac{1}{(1/\text{Sec})\text{Farad}} = \frac{1}{(1/\text{Sec})(\text{Coulomb/Volt})} = \frac{\text{Volt}}{\text{Coulomb/Sec}} = \frac{\text{Volt}}{\text{Amp}} = \text{Ohm}$$

21.8 $I_{max} = \sqrt{2} I_{rms} = \dfrac{\sqrt{2}(\Delta V_{rms})}{X_C} = \sqrt{2}(\Delta V_{rms}) 2\pi fC$

(a) $I_{max} = \sqrt{2}(120\ \text{V})2\pi(60.0\ \text{Hz})\left(2.20\times 10^{-6}\ \text{C/V}\right) = 0.141\ \text{A} = \boxed{141\ \text{mA}}$

(b) $I_{max} = \sqrt{2}(240\ \text{V})2\pi(50.0\ \text{Hz})\left(2.20\times 10^{-6}\ \text{C/V}\right) = 0.235\ \text{A} = \boxed{235\ \text{mA}}$

21.9 $I_{rms} = \dfrac{\Delta V_{rms}}{X_C} = 2\pi fC(\Delta V_{rms})$, so

$$f = \frac{I_{rms}}{2\pi C(\Delta V_{rms})} = \frac{0.30\ \text{A}}{2\pi\left(4.0\times 10^{-6}\ \text{F}\right)(30\ \text{V})} = \boxed{4.0\times 10^{2}\ \text{Hz}}$$

21.10 $I_{max} = \dfrac{\Delta V_{max}}{X_C} = 2\pi fC\left(\Delta V_{max}\right)$

$$= 2\pi(90.0\text{ Hz})\left(3.70\times10^{-6}\text{ C/V}\right)(48.0\text{ V}) = 0.100\text{ A} = \boxed{100\text{ mA}}$$

21.11 $I_{rms} = \dfrac{\Delta V_{rms}}{X_C} = 2\pi fC\left(\dfrac{\Delta V_{max}}{\sqrt{2}}\right) = \pi fC\left(\Delta V_{max}\right)\sqrt{2}$,

so $$C = \frac{I}{\pi f\left(\Delta V_{max}\right)\sqrt{2}} = \frac{0.75\text{ A}}{\pi(60\text{ Hz})(170\text{ V})\sqrt{2}} = 1.7\times10^{-5}\text{ F} = \boxed{17\ \mu\text{F}}$$

21.12 $I_{rms} = \dfrac{\Delta V_{rms}}{X_C} = \left(\dfrac{\Delta V_{max}}{\sqrt{2}}\right)\omega C$,

or $$I_{rms} = \left(\frac{140\text{ V}}{\sqrt{2}}\right)(120\pi\text{ rad/s})\left(6.00\times10^{-6}\text{ F}\right) = 0.224\text{ A} = \boxed{224\text{ mA}}$$

21.13 $X_L = 2\pi fL$, and from $|\mathcal{E}| = L\left(\dfrac{\Delta I}{\Delta t}\right)$, we have $L = \dfrac{|\mathcal{E}|(\Delta t)}{\Delta I}$. The units of self inductance are then $[L] = \dfrac{[\mathcal{E}][\Delta t]}{[\Delta I]} = \dfrac{\text{Volt}\cdot\text{sec}}{\text{Amp}}$. The units of inductive reactance are given by

$$[X_L] = [f][L] = \left(\frac{1}{\text{sec}}\right)\left(\frac{\text{Volt}\cdot\text{sec}}{\text{Amp}}\right) = \frac{\text{Volt}}{\text{Amp}} = \text{Ohm}$$

21.14 $I_{max} = \dfrac{\Delta V_{max}}{X_L} = \dfrac{\Delta V_{max}}{(2\pi f)L}$

(a) $$L = \frac{\Delta V_{max}}{(2\pi f)I_{max}} = \frac{100\text{ V}}{2\pi(50.0\text{ Hz})(7.50\text{ A})} = 4.24\times10^{-2}\text{ H} = \boxed{42.4\text{ mH}}$$

(b) $$\omega = 2\pi f = \frac{\Delta V_{max}}{L\cdot I_{max}} = \frac{100\text{ V}}{\left(4.24\times10^{-2}\text{ H}\right)(2.50\text{ A})} = \boxed{942\text{ rad/s}}$$

21.15 The ratio of inductive reactance at $f_2 = 50.0\text{ Hz}$ to that at $f_1 = 60.0\text{ Hz}$ is

$$\frac{(X_L)_2}{(X_L)_1} = \frac{2\pi f_2 L}{2\pi f_1 L} = \frac{f_2}{f_1}\text{, so } (X_L)_2 = \frac{f_2}{f_1}(X_L)_1 = \frac{50.0\text{ Hz}}{60.0\text{ Hz}}(54.0\ \Omega) = 45.0\ \Omega$$

The maximum current at $f_2 = 50.0\text{ Hz}$ is then

$$I_{max} = \frac{\Delta V_{max}}{X_L} = \frac{\sqrt{2}(\Delta V_{rms})}{X_L} = \frac{\sqrt{2}(100\text{ V})}{45.0\ \Omega} = \boxed{3.14\text{ A}}$$

21.16 (a) $I_{rms} = \dfrac{\Delta V_{rms}}{X_C} = (\Delta V_{rms})(2\pi fC)$, so

$$f = \frac{I_{rms}}{(\Delta V_{rms})2\pi C} = \frac{25.0\times10^{-3}\text{ A}}{(9.00\text{ V})2\pi(2.40\times10^{-6}\text{ F})} = \boxed{184\text{ Hz}}$$

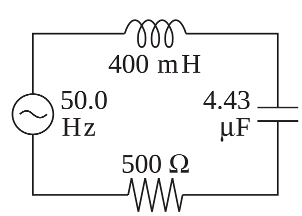
(b) $$I_{rms} = \frac{\Delta V_{rms}}{X_L} = \frac{\Delta V_{rms}}{2\pi fL} = \frac{9.00\text{ V}}{2\pi(184\text{ Hz})(0.160\text{ H})} = 4.86\times10^{-2}\text{ A} = \boxed{48.6\text{ mA}}$$

21.17 From $L = \dfrac{N\Phi_B}{I}$, the total flux through the coil is $\Phi_{B,total} = N\Phi_B = L\cdot I$ where Φ_B is the flux through a single turn on the coil. Thus,

$$(\Phi_{B,total})_{max} = L\cdot I_{max} = L\cdot\left(\frac{\Delta V_{max}}{X_L}\right)$$

$$= L\cdot\frac{\sqrt{2}(\Delta V_{rms})}{2\pi fL} = \frac{\sqrt{2}(120\text{ V})}{2\pi(60.0\text{ Hz})} = \boxed{0.450\text{ T}\cdot\text{m}^2}$$

21.18 (a) $X_L = 2\pi fL = 2\pi(50.0\text{ Hz})(400\times10^{-3}\text{ H}) = 126\ \Omega$



$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(50.0\text{ Hz})(4.43\times10^{-6}\text{ F})} = 719\ \Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(500\ \Omega)^2 + (126\ \Omega - 719\ \Omega)^2} = 776\ \Omega$$

$$\Delta V_{max} = I_{max}Z = (0.250\text{ A})(776\ \Omega) = 194\text{ V}$$

(b) $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{126\ \Omega - 719\ \Omega}{500\ \Omega}\right) = -49.9°$

Thus, $\boxed{\text{the current leads the voltage by } 49.9°}$

21.19 $X_L = 2\pi fL = 2\pi(60.0\ \text{Hz})(2.00\ \text{H}) = 754\ \Omega$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(60.0\ \text{Hz})(10.0\times10^{-6}\ \text{F})} = 265\ \Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = |X_L - X_C| = 489\ \Omega$$

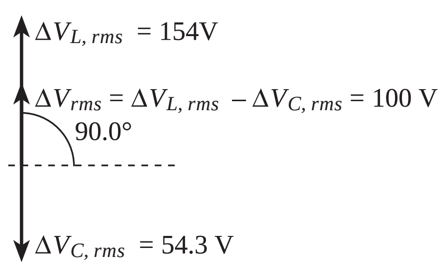
(a) $I_{rms} = \frac{\Delta V_{rms}}{Z} = \frac{100\ \text{V}}{489\ \Omega} = 0.205\ \text{A} = \boxed{205\ \text{mA}}$

(b) $\Delta V_{L,rms} = I_{rms}X_L = (0.205\ \text{A})(754\ \Omega) = \boxed{154\ \text{V}}$

(c) $\Delta V_{C,rms} = I_{rms}X_C = (0.205\ \text{A})(265\ \Omega) = \boxed{54.3\ \text{V}}$

(d) $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{754\ \Omega - 265\ \Omega}{0}\right) \to \tan^{-1}(+\infty) = \boxed{90.0°}$

(e)



21.20 (a) $X_L = 2\pi fL = 2\pi(50.0\ \text{Hz})(0.250\ \text{H}) = \boxed{78.5\ \Omega}$

(b) $X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(50.0\ \text{Hz})(2.00\times10^{-6}\ \text{F})} = 1.59\times10^3\ \Omega = \boxed{1.59\ \text{k}\Omega}$

(c) $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(150\ \Omega)^2 + (78.5\ \Omega - 1.59\times10^3\ \Omega)^2} = \boxed{1.52\ \text{k}\Omega}$

(d) $I_{max} = \frac{\Delta V_{max}}{Z} = \frac{210\ \text{V}}{1.52\times10^3\ \Omega} = 0.138\ \text{A} = \boxed{138\ \text{mA}}$

(e) $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{78.5\ \Omega - 1.59\times 10^3\ \Omega}{150\ \Omega}\right) = -84.3°$,

or $\boxed{\text{the current leads the voltage by } 84.3°}$

21.21 (a) $X_L = 2\pi fL = 2\pi(240\text{ Hz})(2.5\text{ H}) = 3.8\times 10^3\ \Omega$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(240\text{ Hz})(0.25\times 10^{-6}\text{ F})} = 2.7\times 10^3\ \Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(900\ \Omega)^2 + \left[(3.8 - 2.7)\times 10^3\ \Omega\right]^2} = \boxed{1.4\text{ k}\Omega}$$

(b) $I_{max} = \frac{\Delta V_{max}}{Z} = \frac{140\text{ V}}{1.4\times 10^3\ \Omega} = 0.10\text{ A}$

(c) $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left[\frac{(3.8 - 2.7)\times 10^3\ \Omega}{900\ \Omega}\right] = \boxed{51°}$

(d) $\phi > 0$, so $\boxed{\text{the voltage leads the current}}$

21.22 $\Delta V_{max} = 40.0\text{ V}$ and $\omega = 2\pi f = 100\text{ rad/s}$

(a) $X_L = \omega L = (100\text{ rad/s})(0.160\text{ H}) = 16.0\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{(100\text{ rad/s})(99.0\times 10^{-6}\text{ F})} = 101\ \Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(68.0\ \Omega)^2 + (16.0\ \Omega - 101\ \Omega)^2} = \boxed{109\ \Omega}$$

(b) $I_{max} = \frac{\Delta V_{max}}{Z} = \frac{40.0\text{ V}}{109\ \Omega} = 0.367\text{ A} = \boxed{367\text{ mA}}$

21.23 $X_L = 2\pi fL = 2\pi(60.0\text{ Hz})(0.400\text{ H}) = 151\ \Omega$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(60.0\text{ Hz})(3.00\times10^{-6}\text{ F})} = 884\ \Omega$$

$$Z_{RLC} = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(60.0\ \Omega)^2 + (151\ \Omega - 884\ \Omega)^2} = 736\ \Omega$$

and $I_{rms} = \dfrac{\Delta V_{rms}}{Z_{RLC}}$

(a) $Z_{LC} = \sqrt{0 + (X_L - X_C)^2} = |X_L - X_C| = 733\ \Omega$

$$\Delta V_{LC,rms} = I_{rms}\cdot Z_{LC} = \left(\frac{\Delta V_{rms}}{Z_{RLC}}\right)Z_{LC} = \left(\frac{90.0\text{ V}}{736\ \Omega}\right)(733\ \Omega) = \boxed{89.6\text{ V}}$$

(b) $Z_{RC} = \sqrt{R^2 + (0 - X_C)^2} = \sqrt{(60.0\ \Omega)^2 + (884\ \Omega)^2} = 886\ \Omega$

$$\Delta V_{RC,rms} = I_{rms}\cdot Z_{RC} = \left(\frac{\Delta V_{rms}}{Z_{RLC}}\right)Z_{RC} = \left(\frac{90.0\text{ V}}{736\ \Omega}\right)(886\ \Omega) = \boxed{109\text{ V}}$$

21.24 (a) $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(60.0\text{ Hz})(15.0\times10^{-6}\text{ F})} = 177\ \Omega$

$$Z_{RC} = \sqrt{R^2 + X_C^2} = \sqrt{(50.0\ \Omega)^2 + (177\ \Omega)^2} = 184\ \Omega$$

$$I_{RC,rms} = \frac{\Delta V_{rms}}{Z_{RC}} = \frac{120\text{ V}}{184\ \Omega} = 0.653\text{ A} = \boxed{653\text{ mA}}$$

(b) Addition of the inductor creates a full *RLC* circuit. If $I_{RLC,\mathrm{rms}} = \dfrac{I_{RC,\mathrm{rms}}}{2}$, then $Z_{RLC} = 2Z_{RC} = 2(184\ \Omega) = 368\ \Omega$.

Thus, $$Z_{RLC}^2 = R^2 + (X_L - X_C)^2 = (50.0\ \Omega)^2 + (X_L - 177\ \Omega)^2 = (368\ \Omega)^2,$$

or $$X_L - 177\ \Omega = \pm\sqrt{(368\ \Omega)^2 - (50.0\ \Omega)^2} = \pm 365\ \Omega.$$

Since $X_L \geq 0$, it is necessary to choose the positive sign, giving

$$X_L = 2\pi fL = 365\ \Omega + 177\ \Omega = 542\ \Omega, \text{ or } L = \frac{542\ \Omega}{2\pi(60.0\ \mathrm{Hz})} = \boxed{1.44\ \mathrm{H}}$$

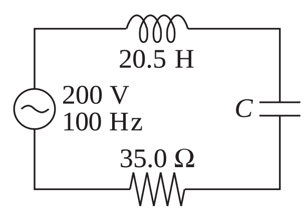
21.25 $$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(60.0\ \mathrm{Hz})(20.0 \times 10^{-12}\ \mathrm{F})} = 1.33 \times 10^8\ \Omega$$

$$Z_{RC} = \sqrt{R^2 + X_C^2} = \sqrt{(50.0 \times 10^3\ \Omega)^2 + (1.33 \times 10^8\ \Omega)^2} = 1.33 \times 10^8\ \Omega$$

and $$I_{\mathrm{rms}} = \frac{(\Delta V_{secondary})_{\mathrm{rms}}}{Z_{RC}} = \frac{5\,000\ \mathrm{V}}{1.33 \times 10^8\ \Omega} = 3.76 \times 10^{-5}\ \mathrm{A}$$

Therefore, $$\Delta V_{b,\mathrm{rms}} = I_{\mathrm{rms}} R_b = (3.76 \times 10^{-5}\ \mathrm{A})(50.0 \times 10^3\ \Omega) = \boxed{1.88\ \mathrm{V}}$$

21.26 (a) $$X_L = 2\pi fL = 2\pi(100\ \mathrm{Hz})(20.5\ \mathrm{H}) = 1.29 \times 10^4\ \Omega$$



$$Z = \frac{\Delta V_{\mathrm{rms}}}{I_{\mathrm{rms}}} = \frac{200\ \mathrm{V}}{4.00\ \mathrm{A}} = 50.0\ \Omega$$

Thus,

$$X_L - X_C = \pm\sqrt{Z^2 - R^2} = \pm\sqrt{(50.0\ \Omega)^2 - (35.0\ \Omega)^2} = \pm 35.7\ \Omega,$$

and $X_C = X_L \pm 35.7\ \Omega$ or $\dfrac{1}{2\pi fC} = 1.29 \times 10^4\ \Omega \pm 35.7\ \Omega$

This yields

$$C = \frac{1}{2\pi(100\ \mathrm{Hz})(1.29 \times 10^4\ \Omega \pm 35.7\ \Omega)} = \boxed{123\ \mathrm{nF}\ \text{ or }\ 124\ \mathrm{nF}}$$

(b) $\left(\Delta V_{rms}\right)_{coil} = I_{rms} Z_{coil} = I\sqrt{R^2 + X_L^2} = (4.00\text{ A})\sqrt{(50.0\ \Omega)^2 + \left(1.29\times 10^4\ \Omega\right)^2}$

$$= 5.15\times 10^4\text{ V} = \boxed{51.5\text{ kV}}$$

Notice that this is a very large voltage!

21.27 $X_L = 2\pi fL = 2\pi(50.0\text{ Hz})(0.185\text{ H}) = 58.1\ \Omega$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(50.0\text{ Hz})\left(65.0\times 10^{-6}\text{ F}\right)} = 49.0\ \Omega$$

$$Z_{ad} = \sqrt{R^2 + \left(X_L - X_C\right)^2} = \sqrt{(40.0\ \Omega)^2 + (58.1\ \Omega - 49.0\ \Omega)^2} = 41.0\ \Omega$$

and $I_{rms} = \dfrac{\Delta V_{rms}}{Z_{ad}} = \dfrac{\left(\Delta V_{max}/\sqrt{2}\right)}{Z_{ad}} = \dfrac{150\text{ V}}{(41.0\ \Omega)\sqrt{2}} = 2.585\text{ A}$

(a) $Z_{ab} = R = 40.0\ \Omega$, so $\left(\Delta V_{rms}\right)_{ab} = I_{rms} Z_{ab} = (2.585\text{ A})(40.0\ \Omega) = \boxed{103\text{ V}}$

(b) $Z_{bc} = X_L = 58.1\ \Omega$, and $\left(\Delta V_{rms}\right)_{bc} = I_{rms} Z_{bc} = (2.585\text{ A})(58.1\ \Omega) = \boxed{150\text{ V}}$

(c) $Z_{cd} = X_C = 49.0\ \Omega$, and $\left(\Delta V_{rms}\right)_{cd} = I_{rms} Z_{cd} = (2.585\text{ A})(49.0\ \Omega) = \boxed{127\text{ V}}$

(d) $Z_{bd} = \left|X_L - X_C\right| = 9.15\ \Omega$, so $\left(\Delta V_{rms}\right)_{bd} = I_{rms} Z_{bd} = (2.585\text{ A})(9.15\ \Omega) = \boxed{23.6\text{ V}}$

21.28 (a) $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(60.0\text{ Hz})\left(30.0\times 10^{-6}\text{ F}\right)} = 88.4\ \Omega$

$$Z = \sqrt{R^2 + X_C^2} = \sqrt{(50.0\ \Omega)^2 + (88.4\ \Omega)^2} = 102\ \Omega$$

$$I_{rms} = \frac{\Delta V_{rms}}{Z} = \frac{100\text{ V}}{102\ \Omega} = 0.984\text{ A}$$

$$\phi = \tan^{-1}\left(\frac{0 - X_C}{R}\right) = \tan^{-1}\left(\frac{-88.4\ \Omega}{50.0\ \Omega}\right) = -60.5^\circ$$

and $\textit{power factor} = \cos\phi = \cos(-60.5^\circ) = \boxed{0.492}$

$$\wp_{av} = \left(\Delta V_{rms}\right) I_{rms}\cos\phi = (100\text{ V})(0.984\text{ A})(0.492) = \boxed{48.5\text{ W}}$$

(b) $X_L = 2\pi fL = 2\pi(60.0\text{ Hz})(0.300\text{ H}) = 113\ \Omega$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{(50.0\ \Omega)^2 + (113\ \Omega)^2} = 124\ \Omega$$

$$I_{rms} = \frac{\Delta V_{rms}}{Z} = \frac{100\text{ V}}{124\ \Omega} = 0.809\text{ A}$$

$$\phi = \tan^{-1}\left(\frac{X_C - 0}{R}\right) = \tan^{-1}\left(\frac{113\ \Omega}{50.0\ \Omega}\right) = 66.1°$$

and $\quad \text{power factor} = \cos\phi = \cos(66.1°) = \boxed{0.404}$

$$\wp_{av} = (\Delta V_{rms}) I_{rms}\cos\phi = (100\text{ V})(0.809\text{ A})(0.404) = \boxed{32.7\text{ W}}$$

21.29 (a) $Z = \dfrac{\Delta V_{rms}}{I_{rms}} = \dfrac{104\text{ V}}{0.500\text{ A}} = \boxed{208\ \Omega}$

(b) $\wp_{av} = I_{rms}^2 R$ gives $R = \dfrac{\wp_{av}}{I_{rms}^2} = \dfrac{10.0\text{ W}}{(0.500\text{ A})^2} = \boxed{40.0\ \Omega}$

(c) $Z = \sqrt{R^2 + X_L^2}$, so $X_L = \sqrt{Z^2 - R^2} = \sqrt{(208\ \Omega)^2 - (40.0\ \Omega)^2} = 204\ \Omega$

and $\quad L = \dfrac{X_L}{2\pi f} = \dfrac{204\ \Omega}{2\pi(60.0\text{ Hz})} = \boxed{0.541\text{ H}}$

21.30 Since the current leads the voltage, the phase angle is negative,

so $\phi = -53°$.

(a) $\wp_{av} = I_{rms}^2 R = (\Delta V_{rms}) I_{rms}\cos\phi$, giving

$$R = \left(\frac{\Delta V_{rms}}{I_{rms}}\right)\cos\phi = \left(\frac{240\text{ V}}{6.00\text{ A}}\right)\cos(-53°) = \boxed{24\ \Omega}$$

(b) $\tan\phi = \dfrac{X_L - X_C}{R}$, so $X_L - X_C = R\tan\phi = (24\ \Omega)\tan(-53°) = \boxed{-32\ \Omega}$

(c) $\wp_{av} = (\Delta V_{rms}) I_{rms}\cos\phi = (240\text{ V})(6.0\text{ A})\cos(-53°) = 8.7\times 10^2\text{ W} = \boxed{0.87\text{ kW}}$

21.31 (a) $\wp_{av} = I_{rms}^2 R = I_{rms}\left(I_{rms}R\right) = I_{rms}\left(\Delta V_{R,rms}\right)$, so $I_{rms} = \dfrac{\wp_{av}}{\Delta V_{R,rms}} = \dfrac{14\text{ W}}{50\text{ V}} = 0.28\text{ A}$

Thus, $R = \dfrac{\Delta V_{R,rms}}{I_{rms}} = \dfrac{50\text{ V}}{0.28\text{ A}} = \boxed{1.8\times 10^2\ \Omega}$

(b) $Z = \sqrt{R^2 + X_L^2}$, which yields

$$X_L = \sqrt{Z^2 - R^2} = \sqrt{\left(\frac{\Delta V_{rms}}{I_{rms}}\right)^2 - R^2} = \sqrt{\left(\frac{90\text{ V}}{0.28\text{ A}}\right)^2 - \left(1.8\times 10^2\ \Omega\right)^2} = 2.7\times 10^2\ \Omega,$$

and $L = \dfrac{X_L}{2\pi f} = \dfrac{2.7\times 10^2\ \Omega}{2\pi\left(60\text{ Hz}\right)} = \boxed{0.71\text{ H}}$

21.32 $\omega = 2\pi f = 1000\text{ rad/s}$ and $\Delta V_{max} = 100\text{ V}$

$$X_L = \omega L = \left(1000\text{ rad/s}\right)\left(0.500\text{ H}\right) = 500\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{\left(1000\text{ rad/s}\right)\left(5.00\times 10^{-6}\text{ F}\right)} = 200\ \Omega$$

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2} = \sqrt{\left(400\ \Omega\right)^2 + \left(500\ \Omega - 200\ \Omega\right)^2} = 500\ \Omega$$

$$\wp_{av} = I_{rms}^2 R = \left(\frac{I_{max}^2}{2}\right)R = \frac{1}{2}\left(\frac{\Delta V_{max}}{Z}\right)^2 R = \frac{1}{2}\left(\frac{100\text{ V}}{500\ \Omega}\right)^2\left(400\ \Omega\right) = \boxed{8.00\text{ W}}$$

21.33 The resonance frequency of the circuit should match the broadcast frequency of the station.

$f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ gives $L = \dfrac{1}{4\pi^2 f_0^2 C}$,

or $L = \dfrac{1}{4\pi^2\left(88.9\times 10^6\text{ Hz}\right)^2\left(1.40\times 10^{-12}\text{ F}\right)} = 2.29\times 10^{-6}\text{ H} = \boxed{2.29\ \mu\text{H}}$

21.34 The broadcast frequency of the station is equal to the resonance frequency of the tuning circuit.

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{\left(0.200\times 10^{-3}\text{ H}\right)\left(30.0\times 10^{-12}\text{ F}\right)}}$$

$$= 2.05\times 10^{6}\text{ Hz} = \boxed{2.05\text{ MHz}}$$

$$\lambda = \frac{c}{f_0} = \frac{3.00\times 10^{8}\text{ m/s}}{2.05\times 10^{6}\text{ Hz}} = \boxed{146\text{ m}}$$

21.35 $$f_0 = \frac{1}{2\pi\sqrt{LC}}\text{, so } C = \frac{1}{4\pi^2 f_0^2 L}$$

For $f_0 = \left(f_0\right)_{min} = 500\text{ kHz} = 5.00\times 10^{5}\text{ Hz}$,

$$C = C_{max} = \frac{1}{4\pi^2\left(5.00\times 10^{5}\text{ Hz}\right)^2\left(2.0\times 10^{-6}\text{ H}\right)} = 5.1\times 10^{-8}\text{ F} = \boxed{51\text{ nF}}$$

For $f_0 = \left(f_0\right)_{max} = 1600\text{ kHz} = 1.60\times 10^{6}\text{ Hz}$,

$$C = C_{min} = \frac{1}{4\pi^2\left(1.60\times 10^{6}\text{ Hz}\right)^2\left(2.0\times 10^{-6}\text{ H}\right)} = 4.9\times 10^{-9}\text{ F} = \boxed{4.9\text{ nF}}$$

21.36 The resonance frequency is $\omega_0 = 2\pi f_0 = \dfrac{1}{\sqrt{LC}}$.

Also, $X_L = \omega L$ and $X_C = \dfrac{1}{\omega C}$.

(a) At resonance, $X_C = X_L = \omega_0 L = \left(\dfrac{1}{\sqrt{LC}}\right)L = \sqrt{\dfrac{L}{C}} = \sqrt{\dfrac{3.00\text{ H}}{3.00\times 10^{-6}\text{ F}}} = 1000\ \Omega$.

Thus, $Z = \sqrt{R^2 + 0^2} = R$, $I_{rms} = \dfrac{\Delta V_{rms}}{Z} = \dfrac{120\text{ V}}{30.0\ \Omega} = 4.00\text{ A}$,

and $\wp_{av} = I_{rms}^2 R = \left(4.00\text{ A}\right)^2\left(30.0\ \Omega\right) = \boxed{480\text{ W}}$

(b) At $\omega = \frac{1}{2}\omega_0$; $X_L = \frac{1}{2}\left(X_L\big|_{\omega_0}\right) = 500\ \Omega$, $X_C = 2\left(X_C\big|_{\omega_0}\right) = 2000\ \Omega$,

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(30.0\ \Omega)^2 + (500\ \Omega - 2000\ \Omega)^2} = 1500\ \Omega,$$

and $I_{rms} = \dfrac{120\text{ V}}{1500\ \Omega} = 0.0800\text{ A}$,

so $\wp_{av} = I_{rms}^2 R = (0.0800\text{ A})^2(30.0\ \Omega) = \boxed{0.192\text{ W}}$

(c) At $\omega = \frac{1}{4}\omega_0$; $X_L = \frac{1}{4}\left(X_L\big|_{\omega_0}\right) = 250\ \Omega$, $X_C = 4\left(X_C\big|_{\omega_0}\right) = 4000\ \Omega$,

$Z = 3750\ \Omega$, and $I_{rms} = \dfrac{120\text{ V}}{3750\ \Omega} = 0.0320\text{ A}$,

so $\wp_{av} = I_{rms}^2 R = (0.0320\text{ A})^2(30.0\ \Omega) = 3.07\times10^{-2}\text{ W} = \boxed{30.7\text{ mW}}$

(d) At $\omega = 2\omega_0$; $X_L = 2\left(X_L\big|_{\omega_0}\right) = 2000\ \Omega$, $X_C = \frac{1}{2}\left(X_C\big|_{\omega_0}\right) = 500\ \Omega$,

$Z = 1500\ \Omega$, and $I_{rms} = \dfrac{120\text{ V}}{1500\ \Omega} = 0.0800\text{ A}$,

so $\wp_{av} = I_{rms}^2 R = (0.0800\text{ A})^2(30.0\ \Omega) = \boxed{0.192\text{ W}}$

(e) At $\omega = 4\omega_0$; $X_L = 4\left(X_L\big|_{\omega_0}\right) = 4000\ \Omega$, $X_C = \frac{1}{4}\left(X_C\big|_{\omega_0}\right) = 250\ \Omega$,

$Z = 3750\ \Omega$, and $I_{rms} = \dfrac{120\text{ V}}{3750\ \Omega} = 0.0320\text{ A}$,

so $\wp_{av} = I_{rms}^2 R = (0.0320\text{ A})^2(30.0\ \Omega) = 3.07\times10^{-2}\text{ W} = \boxed{30.7\text{ mW}}$

The power delivered to the circuit is a maximum when the rms current is a maximum. This occurs when the frequency of the source is equal to the resonance frequency of the circuit.

21.37 $$\omega_0 = 2\pi f_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\left(10.0\times 10^{-3}\text{ H}\right)\left(100\times 10^{-6}\text{ F}\right)}} = 1000 \text{ rad/s}$$

Thus, $\omega = 2\omega_0 = 2000 \text{ rad/s}$,

$$X_L = \omega L = \left(2000 \text{ rad/s}\right)\left(10.0\times 10^{-3}\text{ H}\right) = 20.0\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{\left(2000 \text{ rad/s}\right)\left(100\times 10^{-6}\text{ F}\right)} = 5.00\ \Omega$$

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2} = \sqrt{\left(10.0\ \Omega\right)^2 + \left(20.0\ \Omega - 5.00\ \Omega\right)^2} = 18.0\ \Omega$$

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{Z} = \frac{50.0\text{ V}}{18.0\ \Omega} = 2.77\text{ A}$$

The average power is $\wp_{\text{av}} = I_{\text{rms}}^2 R = \left(2.77\text{ A}\right)^2\left(10.0\ \Omega\right) = 76.9\text{ W}$,

and the energy converted in one period is

$$E = \wp_{\text{av}}\cdot T = \wp_{\text{av}}\cdot\left(\frac{2\pi}{\omega}\right) = \left(76.9\ \frac{\text{J}}{\text{s}}\right)\cdot\left(\frac{2\pi}{2000 \text{ rad/s}}\right) = \boxed{0.242\text{ J}}$$

21.38 (a) $$\Delta V_{2,\text{rms}} = \frac{N_2}{N_1}\left(\Delta V_{1,\text{rms}}\right) = \frac{1}{13}\left(120\text{ V}\right) = \boxed{9.23\text{ V}}$$

(b) For an ideal transformer, $\left(\Delta V_{2,\text{rms}}\right) I_{2,\text{rms}} = \left(\Delta V_{1,\text{rms}}\right) I_{1,\text{rms}}$

so $$I_{2,\text{rms}} = \left(\frac{\Delta V_{1,\text{rms}}}{\Delta V_{2,\text{rms}}}\right) I_{1,\text{rms}} = \left(\frac{N_1}{N_2}\right) I_{1,\text{rms}} = \left(\frac{13}{1}\right)\left(0.350\text{ A}\right) = \boxed{4.55\text{ A}}$$

(c) $$\wp_{\text{av}} = \left(\Delta V_{2,\text{rms}}\right) I_{2,\text{rms}} = \left(9.23\text{ V}\right)\left(4.55\text{ A}\right) = \boxed{42.0\text{ W}}$$

21.39 (a) $$N_2 = \left(\frac{\Delta V_{2,\text{rms}}}{\Delta V_{1,\text{rms}}}\right) N_1 = \left(\frac{2200\text{ V}}{110\text{ V}}\right)\left(80\text{ turns}\right) = \boxed{1600\text{ turns}}$$

(b) For an ideal transformer, $(\Delta V_{1,rms}) I_{1,rms} = (\Delta V_{2,rms}) I_{2,rms}$

so $I_{1,rms} = \left(\dfrac{\Delta V_{2,rms}}{\Delta V_{1,rms}}\right) I_{2,rms} = \left(\dfrac{2200\text{ V}}{110\text{ V}}\right)(1.5\text{ A}) = \boxed{30\text{ A}}$

21.40 $\Delta V_{1,rms} = \dfrac{\Delta V_{1,max}}{\sqrt{2}} = \dfrac{170\text{ V}}{\sqrt{2}}$

Then, $\Delta V_{2,rms} = \dfrac{N_2}{N_1}(\Delta V_{1,rms}) = \dfrac{2000}{350}\left(\dfrac{170\text{ V}}{\sqrt{2}}\right) = \boxed{687\text{ V}}$.

21.41 (a) At 90% efficiency, $(\wp_{av})_{output} = 0.90(\wp_{av})_{input}$.

Thus, if $(\wp_{av})_{output} = 1000\text{ kW}$,

the input power to the primary is $(\wp_{av})_{input} = \dfrac{(\wp_{av})_{output}}{0.90} = \dfrac{1000\text{ kW}}{0.90} = \boxed{1.1\times 10^{3}\text{ kW}}$

(b) $I_{1,rms} = \dfrac{(\wp_{av})_{input}}{\Delta V_{1,rms}} = \dfrac{1.1\times 10^{3}\text{ kW}}{\Delta V_{1,rms}} = \dfrac{1.1\times 10^{6}\text{ W}}{3600\text{ V}} = \boxed{3.1\times 10^{2}\text{ A}}$

(c) $I_{2,rms} = \dfrac{(\wp_{av})_{output}}{\Delta V_{2,rms}} = \dfrac{1000\text{ kW}}{\Delta V_{1,rms}} = \dfrac{1.0\times 10^{6}\text{ W}}{120\text{ V}} = \boxed{8.3\times 10^{3}\text{ A}}$

21.42 $R_{line} = (4.50\times 10^{-4}\ \Omega/\text{m})(6.44\times 10^{5}\text{ m}) = 290\ \Omega$

(a) The power transmitted is $(\wp_{av})_{transmitted} = (\Delta V_{rms}) I_{rms}$,

so $I_{rms} = \dfrac{(\wp_{av})_{transmitted}}{\Delta V_{rms}} = \dfrac{5.00\times 10^{6}\text{ W}}{500\times 10^{3}\text{ V}} = 10.0\text{ A}$

Thus, $(\wp_{av})_{loss} = I_{rms}^2 R_{line} = (10.0\text{ A})^2(290\ \Omega) = 2.90\times 10^{4}\text{ W} = \boxed{29.0\text{ kW}}$

(b) The power input to the line is

$$\left(\wp_{av}\right)_{input} = \left(\wp_{av}\right)_{transmitted} + \left(\wp_{av}\right)_{loss} = 5.00\times10^{6}\text{ W} + 2.90\times10^{4}\text{ W} = 5.03\times10^{6}\text{ W}$$

and the fraction of input power lost during transmission is

$$fraction = \frac{\left(\wp_{av}\right)_{loss}}{\left(\wp_{av}\right)_{input}} = \frac{2.90\times10^{4}\text{ W}}{5.03\times10^{6}\text{ W}} = \boxed{0.00580\text{ or }0.580\%}$$

(c) It is impossible to deliver the needed power with an input voltage of 4.50 kV. The maximum line current with an input voltage of 4.50 kV occurs when the line is shorted out at the customer's end, and this current is

$$\left(I_{rms}\right)_{max} = \frac{\Delta V_{rms}}{R_{line}} = \frac{4500\text{ V}}{290\ \Omega} = 15.5\text{ A}$$

The maximum input power is then

$$\left(\wp_{input}\right)_{max} = \left(\Delta V_{rms}\right)\left(I_{rms}\right)_{max}$$
$$= \left(4.50\times10^{3}\text{ V}\right)\left(15.5\text{ A}\right) = 6.98\times10^{4}\text{ W} = 6.98\text{ kW}$$

This is far short of meeting the customer's request, and all of this power is lost in the transmission line.

21.43 From $v = \lambda f$, the wavelength is

$$\lambda = \frac{v}{f} = \frac{3.00\times10^{8}\text{ m/s}}{75\text{ Hz}} = 4.00\times10^{6}\text{ m} = 4000\text{ km}$$

The required length of the antenna is then,

$L = \lambda/4 = \boxed{1000\text{ km}}$, or about 621 miles. Not very practical at all.

21.44 $c = \dfrac{1}{\sqrt{\mu_0 \in_0}}$

$$= \frac{1}{\sqrt{\left(4\pi\times10^{-7}\text{ N}\cdot\text{s}^2/\text{C}^2\right)\left(8.854\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}^2\right)}} = \boxed{2.998\times10^{8}\text{ m/s}}.$$

21.45 $\frac{E_{max}}{B_{max}} = c$, so $B_{max} = \frac{E_{max}}{c} = \frac{220 \text{ V/m}}{3.00 \times 10^8 \text{ m/s}} = 7.33 \times 10^{-7} \text{ T} = \boxed{733 \text{ nT}}$

21.46 (a) From $\frac{E_{max}}{B_{max}} = c$,

$$E_{max} = B_{max}c = \left(1.5 \times 10^{-7} \text{ T}\right)\left(3.0 \times 10^8 \text{ m/s}\right) = \boxed{45 \text{ V/m}}$$

(b) The average power per unit area is

$$Intensity = \frac{E_{max}B_{max}}{2\mu_0} = \frac{\left(45 \text{ V/m}\right)\left(1.5 \times 10^{-7} \text{ T}\right)}{2\left(4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}\right)} = \boxed{2.7 \text{ W/m}^2}$$

21.47 The distance between adjacent antinodes in a standing wave is $\lambda/2$.

Thus, $\lambda = 2\left(6.00 \text{ cm}\right) = 12.0 \text{ cm} = 0.120 \text{ m}$, and

$$c = \lambda f = \left(0.120 \text{ m}\right)\left(2.45 \times 10^9 \text{ Hz}\right) = \boxed{2.94 \times 10^8 \text{ m/s}}$$

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

$$\wp_{av} = \left(Intensity\right)\left(4\pi r^2\right) = \left(1340 \frac{\text{W}}{\text{m}^2}\right)\left[4\pi\left(1.49 \times 10^{11} \text{ m}\right)^2\right] = \boxed{3.74 \times 10^{26} \text{ W}}$$

21.49 From $Intensity = \frac{E_{max}B_{max}}{2\mu_0}$ and $\frac{E_{max}}{B_{max}} = c$, we find $Intensity = \frac{cB_{max}^2}{2\mu_0}$.

Thus,

$$B_{max} = \sqrt{\frac{2\mu_0}{c}\left(Intensity\right)} = \sqrt{\frac{2\left(4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}\right)}{3.00 \times 10^8 \text{ m/s}}\left(1340 \text{ W/m}^2\right)} = \boxed{3.35 \times 10^{-6} \text{ T}}$$

Then, $E_{max} = B_{max}c = \left(3.35 \times 10^{-6} \text{ T}\right)\left(3.00 \times 10^8 \text{ m/s}\right) = \boxed{1.01 \times 10^3 \text{ V/m}}$

21.50 $f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{5.50 \times 10^{-7} \text{ m}} = \boxed{5.45 \times 10^{14} \text{ Hz}}$

21.51 (a) For the AM band,

$$\lambda_{min} = \frac{c}{f_{max}} = \frac{3.00\times10^{8}\ \text{m/s}}{1600\times10^{3}\ \text{Hz}} = \boxed{188\ \text{m}}$$

$$\lambda_{max} = \frac{c}{f_{min}} = \frac{3.00\times10^{8}\ \text{m/s}}{540\times10^{3}\ \text{Hz}} = \boxed{556\ \text{m}}$$

(b) For the FM band,

$$\lambda_{min} = \frac{c}{f_{max}} = \frac{3.00\times10^{8}\ \text{m/s}}{108\times10^{6}\ \text{Hz}} = \boxed{2.78\ \text{m}}$$

$$\lambda_{max} = \frac{c}{f_{min}} = \frac{3.00\times10^{8}\ \text{m/s}}{88\times10^{6}\ \text{Hz}} = \boxed{3.4\ \text{m}}$$

21.52 $\lambda = \frac{c}{f} = \frac{3.00\times10^{8}\ \text{m/s}}{27.33\times10^{6}\ \text{Hz}} = \boxed{11.0\ \text{m}}$

21.53 The total distance traveled (out and back) was

$$2d = c(\Delta t)_{total} = \left(3.00\times10^{8}\ \text{m/s}\right)\left(4.00\times10^{-4}\ \text{s}\right) = 12.0\times10^{4}\ \text{m}$$

Thus, the distance to the object is $d = 6.00\times10^{4}\ \text{m} = \boxed{60.0\ \text{km}}$

21.54 The transit time for the radio wave is

$$t_R = \frac{d_R}{c} = \frac{100\times10^{3}\ \text{m}}{3.00\times10^{8}\ \text{m/s}} = 3.33\times10^{-4}\ \text{s} = 0.333\ \text{ms},$$

and that for the sound wave is

$$t_s = \frac{d_s}{v_{sound}} = \frac{3.0\ \text{m}}{343\ \text{m/s}} = 8.7\times10^{-3}\ \text{s} = 8.7\ \text{ms}$$

Thus, $\boxed{\text{the radio listeners hear the news 8.4 ms before the studio audience}}$ because radio waves travel so much faster than sound waves.

21.55 (a) $\Delta V_{2,\text{rms}} = \dfrac{N_2}{N_1}\left(\Delta V_{1,\text{rms}}\right)$,

so $N_2 = N_1\left(\dfrac{\Delta V_{2,\text{rms}}}{\Delta V_{1,\text{rms}}}\right) = (240 \text{ turns})\left(\dfrac{9.0 \text{ V}}{120 \text{ V}}\right) = \boxed{18 \text{ turns}}$

(b) For an ideal transformer, $(\wp_{\text{av}})_{input} = (\wp_{\text{av}})_{ouput} = \left(\Delta V_{2,\text{rms}}\right) I_{2,\text{rms}}$,

Thus, $(\wp_{\text{av}})_{input} = (9.0 \text{ V})(0.400 \text{ A}) = \boxed{3.6 \text{ W}}$

21.56 (a) $Z = \sqrt{R^2 + (2\pi fL)^2} = \sqrt{(80.0\ \Omega)^2 + \left[2\pi(60.0 \text{ Hz})(2.50 \text{ H})\right]^2} = 946\ \Omega$

Thus $I_{\text{rms}} = \dfrac{\Delta V_{\text{rms}}}{Z} = \dfrac{110 \text{ V}}{946\ \Omega} = 0.116 \text{ A} = \boxed{116 \text{ mA}}$.

(b) $I_{\text{DC}} = \dfrac{\Delta V_{\text{DC}}}{R} = \dfrac{110 \text{ V}}{80.0\ \Omega} = \boxed{1.38 \text{ A}}$

(c) $\wp_{\text{AC}} = I_{\text{rms}}^2 R = (0.116 \text{ A})^2(80.0\ \Omega) = \boxed{1.08 \text{ W}}$

$\wp_{\text{DC}} = I_{\text{DC}}^2 R = (1.38 \text{ A})^2(80.0\ \Omega) = \boxed{151 \text{ W}}$

21.57 $R = \dfrac{(\Delta V)_{\text{DC}}}{I_{\text{DC}}} = \dfrac{12.0 \text{ V}}{0.630 \text{ A}} = 19.0\ \Omega$

$Z = \sqrt{R^2 + (2\pi fL)^2} = \dfrac{\Delta V_{\text{rms}}}{I_{\text{rms}}} = \dfrac{24.0 \text{ V}}{0.570 \text{ A}} = 42.1\ \Omega$

Thus, $L = \dfrac{\sqrt{Z^2 - R^2}}{2\pi f} = \dfrac{\sqrt{(42.1\ \Omega)^2 - (19.0\ \Omega)^2}}{2\pi(60.0 \text{ Hz})} = 9.96 \times 10^{-2} \text{ H} = \boxed{99.6 \text{ mH}}$

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 the Earth's surface is $I_{\text{surface}} = 0.6 I_{\text{incoming}}$ and only 50% of this is absorbed. Since $I = \frac{\wp_{\text{av}}}{A} = \frac{(\Delta E/\Delta t)}{A}$, the absorbed energy is

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

$$= (0.5)(0.6)(1340\text{ W/m}^2)(0.4\text{ m}^2)(3600\text{ s}) = 6\times 10^5\text{ J}\ \boxed{\sim 10^6\text{ J}}$$

21.59 $$Z = \sqrt{R^2 + (X_C)^2} = \sqrt{R^2 + (2\pi fC)^{-2}}$$

$$= \sqrt{(200\ \Omega)^2 + \left[2\pi(60\text{ Hz})(5.0\times 10^{-6}\text{ F})\right]^{-2}} = 5.7\times 10^2\ \Omega$$

Thus, $\wp_{\text{av}} = I_{\text{rms}}^2 R = \left(\frac{\Delta V_{\text{rms}}}{Z}\right)^2 R = \left(\frac{120\text{ V}}{5.7\times 10^2\ \Omega}\right)^2 (200\ \Omega) = 8.9\text{ W} = 8.9\times 10^{-3}\text{ kW}$

and $cost = \Delta E\cdot(rate) = \wp_{\text{av}}\cdot\Delta t\cdot(rate)$

$$= (8.9\times 10^{-3}\text{ kW})(24\text{ h})(8.0\text{ cents/kWh}) = \boxed{1.7\text{ cents}}$$

21.60 $X_L = \omega L$, so $\omega = X_L/L$

Then, $X_C = \frac{1}{\omega C} = \frac{1}{C(X_L/L)}$ which gives

$$L = (X_L\cdot X_C)C = [(12\ \Omega)(8.0\ \Omega)]C \text{ or } L = (96\ \Omega^2)C \qquad (1)$$

From $\omega_0 = 2\pi f_0 = \frac{1}{\sqrt{LC}}$, we obtain $LC = \frac{1}{(2\pi f_0)^2}$.

Substituting from Equation (1), this becomes $\left(96\ \Omega^2\right)C^2 = \dfrac{1}{\left(2\pi f_0\right)^2}$

or $$C = \frac{1}{\left(2\pi f_0\right)\sqrt{96\ \Omega^2}} = \frac{1}{\left[2\pi\left(2000/\pi\ \text{Hz}\right)\right]\sqrt{96\ \Omega^2}} = 2.6\times10^{-5}\ \text{F} = \boxed{26\ \mu\text{F}}$$

Then, from Equation (1),

$$L = \left(96\ \Omega^2\right)\left(2.6\times10^{-5}\ \text{F}\right) = 2.5\times10^{-3}\ \text{H} = \boxed{2.5\ \text{mH}}.$$

21.61 (a) The box cannot contain a capacitor since a steady DC current cannot flow in a series circuit containing a capacitor. Since the AC and DC currents are different, even when a 3.0 V potential difference is used in both cases, the box must contain a reactive element. The conclusion is that the box must contain a $\boxed{\text{resistor and inductor}}$ connected in series.

(b) $$R = \frac{\Delta V_{DC}}{I_{DC}} = \frac{3.00\ \text{V}}{0.300\ \text{A}} = \boxed{10\ \Omega}$$

$$Z = \frac{\Delta V_{rms}}{I_{rms}} = \frac{3.00\ \text{V}}{0.200\ \text{A}} = 15\ \Omega$$

Since $Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \left(2\pi fL\right)^2}$, we find

$$L = \frac{\sqrt{Z^2 - R^2}}{2\pi f} = \frac{\sqrt{\left(15\ \Omega\right)^2 - \left(10\ \Omega\right)^2}}{2\pi\left(60\ \text{Hz}\right)} = \boxed{30\ \text{mH}}$$

21.62 (a) The required frequency is $f = \dfrac{c}{\lambda} = \dfrac{3.00\times10^{8}\ \text{m/s}}{3.00\times10^{-2}\ \text{m}} = 1.0\times10^{10}\ \text{Hz}$. Therefore, the resonance frequency of the circuit is $f_0 = \dfrac{1}{2\pi\sqrt{LC}} = 1.0\times10^{10}\ \text{Hz}$, giving

$$C = \frac{1}{\left(2\pi f_0\right)^2 L} = \frac{1}{\left(2\pi\times10^{10}\ \text{Hz}\right)^2\left(400\times10^{-12}\ \text{H}\right)} = 6.3\times10^{-13}\ \text{F} = \boxed{0.63\ \text{pF}}$$

(b) $C = \dfrac{\epsilon_0 A}{d} = \dfrac{\epsilon_0 l^2}{d}$, so

$$l = \sqrt{\frac{C \cdot d}{\epsilon_0}} = \sqrt{\frac{\left(6.3\times10^{-13}\text{ F}\right)\left(1.0\times10^{-3}\text{ m}\right)}{8.85\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}}} = 8.5\times10^{-3}\text{ m} = \boxed{8.5\text{ mm}}$$

(c) $X_C = X_L = \left(2\pi f_0\right)L = 2\pi\left(1.0\times10^{10}\text{ Hz}\right)\left(400\times10^{-12}\text{ H}\right) = \boxed{25\ \Omega}$

21.63 (a) $\dfrac{E_{max}}{B_{max}} = c$, so

$$B_{max} = \frac{E_{max}}{c} = \frac{0.20\times10^{-6}\text{ V/m}}{3.00\times10^{8}\text{ m/s}} = \boxed{6.7\times10^{-16}\text{ T}}$$

(b) $\mathit{Intensity} = \dfrac{E_{max}B_{max}}{2\mu_0}$

$$= \frac{\left(0.20\times10^{-6}\text{ V/m}\right)\left(6.7\times10^{-16}\text{ T}\right)}{2\left(4\pi\times10^{-7}\text{ T}\cdot\text{m/A}\right)} = \boxed{5.3\times10^{-17}\text{ W/m}^2}$$

(c) $\wp_{av} = \left(\mathit{Intensity}\right)\cdot A = \left(\mathit{Intensity}\right)\left[\dfrac{\pi d^2}{4}\right]$

$$= \left(5.3\times10^{-17}\text{ W/m}^2\right)\left[\frac{\pi\left(20.0\text{ m}\right)^2}{4}\right] = \boxed{1.7\times10^{-14}\text{ W}}$$

21.64 (a) $Z = \dfrac{\Delta V_{rms}}{I_{rms}} = \dfrac{12\text{ V}}{2.0\text{ A}} = \boxed{6.0\ \Omega}$

(b) $R = \dfrac{\Delta V_{DC}}{I_{DC}} = \dfrac{12\text{ V}}{3.0\text{ A}} = 4.0\ \Omega$

From $Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \left(2\pi fL\right)^2}$, we find

$$L = \frac{\sqrt{Z^2 - R^2}}{2\pi f} = \frac{\sqrt{\left(6.0\ \Omega\right)^2 - \left(4.0\ \Omega\right)^2}}{2\pi\left(60\text{ Hz}\right)} = 1.2\times10^{-2}\text{ H} = \boxed{12\text{ mH}}$$

21.65 (a) The radiation pressure on the perfectly reflecting sail is

$$p = \frac{2(\text{Intensity})}{c} = \frac{2\left(1340\ \text{W/m}^2\right)}{3.00\times10^8\ \text{m/s}} = 8.93\times10^{-6}\ \text{N/m}^2,$$

so the total force on the sail is

$$F = p\cdot A = \left(8.93\times10^{-6}\ \text{N/m}^2\right)\left(6.00\times10^4\ \text{m}^2\right) = \boxed{0.536\ \text{N}}$$

(b) $a = \dfrac{F}{m} = \dfrac{0.536\ \text{N}}{6000\ \text{kg}} = \boxed{8.93\times10^{-5}\ \text{m/s}^2}$

(c) From $\Delta x = v_i t + \frac{1}{2}at^2$, with $v_i = 0$, the time is

$$t = \sqrt{\frac{2(\Delta x)}{a}} = \sqrt{\frac{2\left(3.84\times10^8\ \text{m}\right)}{8.93\times10^{-5}\ \text{m/s}^2}} = \left(2.93\times10^6\ \text{s}\right)\left(\frac{1\ \text{d}}{8.64\times10^4\ \text{s}}\right) = \boxed{33.9\ \text{d}}$$

21.66 We know that $\dfrac{N_1}{N_2} = \dfrac{\Delta V_{1,\text{rms}}}{\Delta V_{2,\text{rms}}} = \dfrac{\left(I_{1,\text{rms}}Z_1\right)}{\left(I_{2,\text{rms}}Z_2\right)} = \left(\dfrac{I_{1,\text{rms}}}{I_{2,\text{rms}}}\right)\dfrac{Z_1}{Z_2}$.

Also, for an ideal transformer,

$$\left(\Delta V_{1,\text{rms}}\right)I_{1,\text{rms}} = \left(\Delta V_{2,\text{rms}}\right)I_{2,\text{rms}} \text{ which gives } \frac{I_{1,\text{rms}}}{I_{2,\text{rms}}} = \frac{\Delta V_{2,\text{rms}}}{\Delta V_{1,\text{rms}}}.$$

Therefore, $\dfrac{N_1}{N_2} = \left(\dfrac{\Delta V_{2,\text{rms}}}{\Delta V_{1,\text{rms}}}\right)\dfrac{Z_1}{Z_2}$, or $\dfrac{N_1}{N_2}\left(\dfrac{\Delta V_{1,\text{rms}}}{\Delta V_{2,\text{rms}}}\right) = \dfrac{Z_1}{Z_2}$.

This gives $\dfrac{N_1}{N_2}\left(\dfrac{N_1}{N_2}\right) = \dfrac{Z_1}{Z_2}$, or $\dfrac{N_1}{N_2} = \sqrt{\dfrac{Z_1}{Z_2}} = \sqrt{\dfrac{8000\ \Omega}{8.0\ \Omega}} = \boxed{32}$

21.67 Consider a cylindrical volume with volume of

$$V = 1.00\ \text{Liter} = 1.00 \times 10^{-3}\ \text{m}^3$$

and cross-sectional area $A = 1.00\ \text{m}^2$.

The length of this one liter cylinder is

$$d = \frac{V}{A} = \frac{1.00 \times 10^{-3}\ \text{m}^3}{1.00\ \text{m}^2} = 1.00 \times 10^{-3}\ \text{m}$$

Imagine this cylinder placed at the top of the Earth's atmosphere, with its length perpendicular to the incident wavefronts. Then, all the energy in the one liter volume of sunlight will strike the atmosphere in the time required for sunlight to travel the length of the cylinder. This time is

$$\Delta t = \frac{d}{c} = \frac{1.00 \times 10^{-3}\ \text{m}}{3.00 \times 10^{8}\ \text{m/s}} = 3.33 \times 10^{-12}\ \text{s}$$

The energy passing through the $1.00\ \text{m}^2$ area of the end of the cylinder in this time is

$$\Delta E = \wp_{\text{av}} \cdot \Delta t = \left[\left(\textit{Intensity}\right) \cdot A\right] \cdot \Delta t$$

$$= \left(1340\ \text{W/m}^2\right)\left(1.00\ \text{m}^2\right)\left(3.33 \times 10^{-12}\ \text{s}\right) = \boxed{4.47 \times 10^{-9}\ \text{J}}$$

Answers to Even Numbered Conceptual Questions

2. At resonance, $X_L = X_C$. This means that the impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$ reduces to $Z = R$.

4. The purpose of the iron core is to increase the flux and to provide a pathway in which nearly all the flux through one coil is led through the other.

6. The fundamental source of an electromagnetic wave is a moving charge. For example, in a transmitting antenna of a radio station, charges are caused to move up and down at the frequency of the radio station. These moving charges set up electric and magnetic fields, the electromagnetic wave, in the space around the antenna.

8. As an electromagnetic wave travels through space, the things that move are fluctuations in electric and magnetic fields oriented at right angles to one another. These fluctuations in the fields transport energy as they travel along.

10. The average value of an alternating current is zero because its direction is positive as often as it is negative, and its time average is zero. The average value of the square of the current is not zero, however, since the square of positive and negative values are always positive and cannot cancel.

12. The brightest portion of your face shows where you radiate the most. Your nostrils and the openings of your ear canals are particularly bright. Brighter still are the pupils of your eyes.

14. No, the only element that dissipates energy in an AC circuit is a resistor. Inductors and capacitors store energy during one half of a cycle and release that energy during the other half of the cycle, so they dissipate no net energy.

16. No. Only conductors in which the current is varying in time will emit electromagnetic waves.

18. If the capacitance and the inductance are each doubled, the resonance frequency will be cut in half. The value of the resistance does not affect the resonance frequency.

Answers to Even Numbered Problems

2. (a) $193\ \Omega$ (b) $145\ \Omega$

4. $I_{1,\text{rms}} = I_{2,\text{rms}} = 1.25\ \text{A}$, $R_1 = R_2 = 96.0\ \Omega$, $I_{3,\text{rms}} = 0.833\ \text{A}$, $R_3 = 144\ \Omega$

6. (a) 106 V (b) 60.0 Hz (c) 0 (d) 3.00 A

8. (a) 141 mA (b) 235 mA

10. 100 mA

12. 224 mA

14. (a) 42.4 mH (b) $942\ \text{rad/s}$

16. (a) 184 Hz (b) 48.6 mA

18. (a) 194 V (b) current leads by 49.9°

20. (a) $78.5\ \Omega$ (b) $1.59\ \text{k}\Omega$ (c) $1.52\ \text{k}\Omega$
(d) 138 mA (e) current leads the voltage by 84.3°

22. (a) $109\ \Omega$ (b) 367 mA

24. (a) 653 mA (b) 1.44 H

26. (a) 123 nF or 124 nF (b) 51.5 kV

28. (a) 0.492, 48.5 W (b) 0.404, 32.7 W

30. (a) $24\ \Omega$ (b) $-32\ \Omega$ (c) 0.87 kW

32. 8.00 W

34. 2.05 MHz, 146 m

36. (a) 480 W (b) 0.192 W (c) 30.7 mW (d) 0.192 W (e) 30.7 mW
Maximum power is delivered at resonance frequency.

38. (a) 9.23 V (b) 4.55 A (c) 42.0 W

40. 687 V

42. (a) 29.0 kW (b) 0.580%
(c) The maximum power that can be transmitted at 4.50 kV is far less than 5.00 MW and it is all lost in the transmission line.

44. 2.998×10^8 m/s

46. (a) 45 V/m (b) $2.7\ \text{W/m}^2$

48. 3.74×10^{26} W

50. 5.45×10^{14} Hz

52. 11.0 m

54. Radio listeners hear the news 8.4 ms before the studio audience because radio waves travel much faster than sound waves.

56. (a) 116 mA (b) 1.38 A (c) $\wp_{AC} = 1.08$ W, $\wp_{DC} = 151$ W

58. $\sim 10^6$ J

60. 2.5 mH, 26 μF

62. (a) 0.63 pF (b) 8.5 mm (c) $25\ \Omega$

64. (a) $6.0\ \Omega$ (b) 12 mH

66. 32