33

Alternating Current Circuits

CHAPTER OUTLINE

ANSWERS TO QUESTIONS

***Q33.1** (i) Answer (d). $\Delta V_{avg} = \dfrac{\Delta V_{\max}}{2}$

(ii) Answer (c). The average of the squared voltage is

$\left([\Delta V]^2\right)_{\text{avg}} = \dfrac{(\Delta V_{\max})^2}{2}$. Then its square root is

$\Delta V_{rms} = \dfrac{\Delta V_{\max}}{\sqrt{2}}$

***Q33.2** Answer (c). AC ammeters and voltmeters read rms values. With an oscilloscope you can read a maximum voltage, or test whether the average is zero.

***Q33.3** (i) Answer (f). The voltage varies between +170 V and −170 V.
(ii) Answer (d).
(iii) $170\text{V}/\sqrt{2} = 120$ V. Answer (c).

Q33.4 The capacitive reactance is proportional to the inverse of the frequency. At higher and higher frequencies, the capacitive reactance approaches zero, making a capacitor behave like a wire. As the frequency goes to zero, the capacitive reactance approaches infinity—the resistance of an open circuit.

Q33.5 The second letter in each word stands for the circuit element. For an inductor *L*, the emf $\mathcal{E}$ leads the current *I*—thus *ELI*. For a capacitor *C*, the current leads the voltage across the device. In a circuit in which the capacitive reactance is larger than the inductive reactance, the current leads the source emf—thus *ICE*.

Q33.6 The voltages are not added in a scalar form, but in a vector form, as shown in the phasor diagrams throughout the chapter. Kirchhoff's loop rule is true at any instant, but the voltages across different circuit elements are not simultaneously at their maximum values. Do not forget that an inductor can induce an emf in itself and that the voltage across it is 90° *ahead* of the current in the circuit in phase.

Q33.7 In an *RLC* series circuit, the phase angle depends on the source frequency. At very low frequency the capacitor dominates the impedance and the phase angle is near −90°. The phase angle is zero at the resonance frequency, where the inductive and capacitive reactances are equal. At very high frequencies ϕ approaches +90°.

***Q33.8** (i) Inductive reactance doubles when frequency doubles. Answer (f).
(ii) Capacitive reactance is cut in half when frequency doubles. Answer (b).
(iii) The resistance remains unchanged. Answer (d).

***Q33.9** At resonance the inductive reactance and capacitive reactance cancel out. Answer (c).

***Q33.10** At resonance the inductive reactance and capacitive reactance add to zero. $\tan^{-1}(X_L - X_C)/R = 0$. Answer (c).

***Q33.11** (a) The circuit is in resonance. (b) $10\ \Omega/20\ \Omega = 0.5$ (c) The resistance of the load could be increased to make a greater *fraction* of the emf's power go to the load. Then the emf would put out a lot less power and less power would reach the load.

Q33.12 The person is doing work at a rate of $\mathcal{P} = Fv\cos\theta$. One can consider the emf as the "force" that moves the charges through the circuit, and the current as the "speed" of the moving charges. The $\cos\theta$ factor measures the effectiveness of the cause in producing the effect. Theta is an angle in real space for the vacuum cleaner and phi is the analogous angle of phase difference between the emf and the current in the circuit.

***Q33.13** The resonance is high-Q, so at 1 000 Hz both X_L and X_C are equal and much larger than R. Now X_C at 500 Hz is twice as large as at 1 kHz. And X_L at 1.5 kHz is 1.5 times larger than at 1 kHz. Again, X_C at 1 500 Hz is two-thirds as large as at 1 kHz. And X_L at 500 Hz is half as large as at 1 kHz. The resistance does not change with frequency. The ranking is then a > f > b = e > c > d > g = h = i.

Q33.14 In 1881, an assassin shot President James Garfield. The bullet was lost in his body. Alexander Graham Bell invented the metal detector in an effort to save the President's life. The coil is preserved in the Smithsonian Institution. The detector was thrown off by metal springs in Garfield's mattress, a new invention itself. Surgeons went hunting for the bullet in the wrong place. Garfield died.

Q33.15 No. A voltage is only induced in the secondary coil if the flux through the core changes in time.

Q33.16 The Q factor determines the selectivity of the radio receiver. For example, a receiver with a very low Q factor will respond to a wide range of frequencies and might pick up several adjacent radio stations at the same time. To discriminate between 102.5 MHz and 102.7 MHz requires a high-Q circuit. Typically, lowering the resistance in the circuit is the way to get a higher quality resonance.

***Q33.17** In its intended use, the transformer takes in energy by electric transmission at 12 kV and puts out nearly the same energy by electric transmission at 120 V. With the small generator putting energy into the secondary side of the transformer at 120 V, the primary side has 12 kV induced across it. It is deadly dangerous for the repairman.

SOLUTIONS TO PROBLEMS

Section 33.1 **AC Sources**

Section 33.2 **Resistors in an AC Circuit**

P33.1 $\Delta v(t) = \Delta V_{\max}\sin(\omega t) = \sqrt{2}\Delta V_{\text{rms}}\sin(\omega t) = 200\sqrt{2}\sin\left[2\pi(100t)\right] = \boxed{(283\text{ V})\sin(628t)}$

P33.2 $\Delta V_{\text{rms}} = \dfrac{170\text{ V}}{\sqrt{2}} = 120\text{ V}$

(a) $\mathcal{P} = \dfrac{(\Delta V_{\text{rms}})^2}{R} \to R = \dfrac{(120\text{ V})^2}{75.0\text{ W}} = \boxed{193\ \Omega}$

(b) $R = \dfrac{(120\text{ V})^2}{100\text{ W}} = \boxed{144\ \Omega}$

P33.3 Each meter reads the rms value.

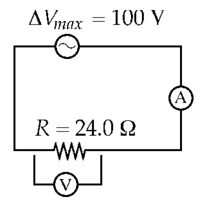


FIG. P33.3

$$\Delta V_{\text{rms}} = \frac{100\ \text{V}}{\sqrt{2}} = \boxed{70.7\ \text{V}}$$

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{R} = \frac{70.7\ \text{V}}{24.0\ \Omega} = \boxed{2.95\ \text{A}}$$

P33.4 (a) $\Delta v_R = \Delta V_{\max} \sin \omega t$

$\Delta v_R = 0.250(\Delta V_{\max})$, so, $\sin \omega t = 0.250$, or $\omega t = \sin^{-1}(0.250)$.

The smallest angle for which this is true is $\omega t = 0.253$ rad. Thus, if $t = 0.010\,0$ s,

$$\omega = \frac{0.253\ \text{rad}}{0.010\,0\ \text{s}} = \boxed{25.3\ \text{rad/s}}.$$

(b) The second time when $\Delta v_R = 0.250(\Delta V_{\max})$, $\omega t = \sin^{-1}(0.250)$ again. For this occurrence, $\omega t = \pi - 0.253$ rad $= 2.89$ rad (to understand why this is true, recall the identity $\sin(\pi - \theta) = \sin\theta$ from trigonometry). Thus,

$$t = \frac{2.89\ \text{rad}}{25.3\ \text{rad/s}} = \boxed{0.114\ \text{s}}$$

P33.5 $i_R = I_{\max} \sin \omega t$ becomes $0.600 = \sin(\omega\, 0.007\,00)$

Thus, $(0.007\,00)\omega = \sin^{-1}(0.600) = 0.644$

and $\omega = 91.9\ \text{rad/s} = 2\pi f$ so $\boxed{f = 14.6\ \text{Hz}}$

P33.6 $\Delta V_{\max} = 15.0\ \text{V}$ and $R_{\text{total}} = 8.20\ \Omega + 10.4\ \Omega = 18.6\ \Omega$

$$I_{\max} = \frac{\Delta V_{\max}}{R_{\text{total}}} = \frac{15.0\ \text{V}}{18.6\ \Omega} = 0.806\ \text{A} = \sqrt{2} I_{\text{rms}}$$

$$\mathcal{P}_{\text{speaker}} = I_{\text{rms}}^2 R_{\text{speaker}} = \left(\frac{0.806\ \text{A}}{\sqrt{2}}\right)^2 (10.4\ \Omega) = \boxed{3.38\ \text{W}}$$

Section 33.3 **Inductors in an AC Circuit**

P33.7 (a) $$X_L = \frac{\Delta V_{\max}}{I_{\max}} = \frac{100}{7.50} = 13.3\ \Omega$$

$$L = \frac{X_L}{\omega} = \frac{13.3}{2\pi(50.0)} = 0.042\,4\ \text{H} = \boxed{42.4\ \text{mH}}$$

(b) $$X_L = \frac{\Delta V_{\max}}{I_{\max}} = \frac{100}{2.50} = 40.0\ \Omega$$

$$\omega = \frac{X_L}{L} = \frac{40.0}{42.4 \times 10^{-3}} = \boxed{942\ \text{rad/s}}$$

P33.8 At 50.0 Hz, $X_L = 2\pi(50.0\text{ Hz})L = 2\pi(50.0\text{ Hz})\left(\frac{X_L|_{60.0\text{ Hz}}}{2\pi(60.0\text{ Hz})}\right) = \frac{50.0}{60.0}(54.0\ \Omega) = 45.0\ \Omega$

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

P33.9 $i_L(t) = \frac{\Delta V_{\max}}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right) = \frac{(80.0\text{ V})\sin[(65.0\pi)(0.015\,5) - \pi/2]}{(65.0\pi\text{ rad/s})(70.0\times10^{-3}\text{ H})}$

$$i_L(t) = (5.60\text{ A})\sin(1.59\text{ rad}) = \boxed{5.60\text{ A}}$$

P33.10 $\omega = 2\pi f = 2\pi(60.0/\text{s}) = 377\text{ rad/s}$

$$X_L = \omega L = (377/\text{s})(0.020\,0\text{ V}\cdot\text{s/A}) = 7.54\ \Omega$$

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{X_L} = \frac{120\text{ V}}{7.54\ \Omega} = 15.9\text{ A}$$

$$I_{\max} = \sqrt{2}I_{\text{rms}} = \sqrt{2}(15.9\text{ A}) = 22.5\text{ A}$$

$$i(t) = I_{\max}\sin\omega t = (22.5\text{ A})\sin\left(\frac{2\pi(60.0)}{\text{s}}\cdot\frac{1\text{ s}}{180}\right) = (22.5\text{ A})\sin 120° = 19.5\text{ A}$$

$$U = \frac{1}{2}Li^2 = \frac{1}{2}(0.020\,0\text{ V}\cdot\text{s/A})(19.5\text{ A})^2 = \boxed{3.80\text{ J}}$$

P33.11 $L = \frac{N\Phi_B}{I}$ where Φ_B is the flux through each turn. $N\Phi_{B,\max} = LI_{\max} = \frac{X_L}{\omega}\frac{(\Delta V_{L,\max})}{X_L}$

$$N\Phi_{B,\max} = \frac{\sqrt{2}(\Delta V_{L,\text{rms}})}{2\pi f} = \frac{120\text{ V}\cdot\text{s}}{\sqrt{2}\pi(60.0)}\left(\frac{\text{T}\cdot\text{C}\cdot\text{m}}{\text{N}\cdot\text{s}}\right)\left(\frac{\text{N}\cdot\text{m}}{\text{J}}\right)\left(\frac{\text{J}}{\text{V}\cdot\text{C}}\right) = \boxed{0.450\text{ T}\cdot\text{m}^2}$$

Section 33.4 **Capacitors in an AC Circuit**

P33.12 (a) $X_C = \frac{1}{2\pi f C}$: $\frac{1}{2\pi f(22.0\times10^{-6})} < 175\ \Omega$

$$\frac{1}{2\pi(22.0\times10^{-6})(175)} < f \qquad \boxed{f > 41.3\text{ Hz}}$$

(b) $X_C \propto \frac{1}{C}$, so $X(44) = \frac{1}{2}X(22)$: $\boxed{X_C < 87.5\ \Omega}$

P33.13 $I_{\max} = \sqrt{2}I_{\text{rms}} = \frac{\sqrt{2}(\Delta V_{\text{rms}})}{X_C} = \sqrt{2}(\Delta V_{\text{rms}})2\pi f C$

(a) $I_{\max} = \sqrt{2}(120\text{ V})2\pi(60.0/\text{s})(2.20\times10^{-6}\text{ C/V}) = \boxed{141\text{ mA}}$

(b) $I_{\max} = \sqrt{2}(240\text{ V})2\pi(50.0/\text{s})(2.20\times10^{-6}\text{ F}) = \boxed{235\text{ mA}}$

P33.14 $Q_{\max} = C(\Delta V_{\max}) = C\left[\sqrt{2}(\Delta V_{\text{rms}})\right] = \boxed{\sqrt{2}C(\Delta V_{\text{rms}})}$

P33.15 $I_{\max} = (\Delta V_{\max})\omega C = (48.0\text{ V})(2\pi)(90.0\text{ s}^{-1})(3.70\times10^{-6}\text{ F}) = \boxed{100\text{ mA}}$

P33.16 $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi(60.0/\text{s})(1.00\times10^{-3}\ \text{C/V})} = 2.65\ \Omega$

$\Delta v_C(t) = \Delta V_{\max}\sin\omega t$, to be zero at $t = 0$

$$i_C = \frac{\Delta V_{\max}}{X_C}\sin(\omega t+\phi) = \frac{\sqrt{2}(120\ \text{V})}{2.65\ \Omega}\sin\left[2\pi\frac{60\ \text{s}^{-1}}{180\ \text{s}^{-1}} + 90.0°\right] = (64.0\ \text{A})\sin(120° + 90.0°)$$

$$= \boxed{-32.0\ \text{A}}$$

Section 33.5 **The *RLC* Series Circuit**

P33.17 (a) $X_L = \omega L = 2\pi(50.0)(400\times10^{-3}) = 126\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi(50.0)(4.43\times10^{-6})} = 719\ \Omega$$

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

$$\Delta V_{\max} = I_{\max}Z = (250\times10^{-3})(776) = \boxed{194\ \text{V}}$$

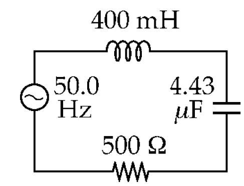


FIG. P33.17

(b) $\phi = \tan^{-1}\left(\dfrac{X_L - X_C}{R}\right) = \tan^{-1}\left(\dfrac{126-719}{500}\right) = \boxed{-49.9°}$. Thus, the $\boxed{\text{current leads the voltage}}$.

P33.18 $\omega L = \dfrac{1}{\omega C} \to \omega = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{(57.0\times10^{-6})(57.0\times10^{-6})}} = 1.75\times10^4\ \text{rad/s}$

$$f = \frac{\omega}{2\pi} = \boxed{2.79\ \text{kHz}}$$

P33.19 (a) $X_L = \omega L = 2\pi(50.0\ \text{s}^{-1})(250\times10^{-3}\ \text{H}) = \boxed{78.5\ \Omega}$

(b) $X_C = \dfrac{1}{\omega C} = \left[2\pi(50.0\ \text{s}^{-1})(2.00\times10^{-6}\ \text{F})\right]^{-1} = \boxed{1.59\ \text{k}\Omega}$

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

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

(e) $\phi = \tan^{-1}\left[\dfrac{X_L - X_C}{R}\right] = \tan^{-1}(-10.1) = \boxed{-84.3°}$

P33.20 (a) $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{68.0^2 + (16.0 - 101)^2} = \boxed{109\ \Omega}$

$X_L = \omega L = (100)(0.160) = 16.0\ \Omega$

$X_C = \dfrac{1}{\omega C} = \dfrac{1}{(100)(99.0 \times 10^{-6})} = 101\ \Omega$

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

(c) $\tan\phi = \dfrac{X_L - X_C}{R} = \dfrac{16.0 - 101}{68.0} = -1.25$:

$\phi = -0.896\ \text{rad} = -51.3°$

$\boxed{I_{\max} = 0.367\ \text{A}}$ $\boxed{\omega = 100\ \text{rad/s}}$ $\boxed{\phi = -0.896\ \text{rad} = -51.3°}$

P33.21 $X_L = 2\pi f L = 2\pi(60.0)(0.460) = 173\ \Omega$

$X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi(60.0)(21.0 \times 10^{-6})} = 126\ \Omega$

(a) $\tan\phi = \dfrac{X_L - X_C}{R} = \dfrac{173\ \Omega - 126\ \Omega}{150\ \Omega} = 0.314$

$\phi = 0.304\ \text{rad} = \boxed{17.4°}$

(b) Since $X_L > X_C$, ϕ is positive; so $\boxed{\text{voltage leads the current}}$.

P33.22 For the source-capacitor circuit, the rms source voltage is $\Delta V_s = (25.1\ \text{mA})X_C$. For the circuit with resistor, $\Delta V_s = (15.7\ \text{mA})\sqrt{R^2 + X_C^2} = (25.1\ \text{mA})X_C$. This gives $R = 1.247 X_C$. For the circuit with ideal inductor, $\Delta V_s = (68.2\ \text{mA})|X_L - X_C| = (25.1\ \text{mA})X_C$. So $|X_L - X_C| = 0.368\,0 X_C$. Now for the full circuit

$$\Delta V_s = I\sqrt{R^2 + (X_L - X_C)^2}$$

$$(25.1\ \text{mA})X_C = I\sqrt{(1.247X_C)^2 + (0.368X_C)^2}$$

$$\boxed{I = 19.3\ \text{mA}}$$

P33.23 $X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi(60.0\ \text{Hz})(20.0 \times 10^{-12}\ \text{F})} = 1.33 \times 10^8\ \Omega$

$Z = \sqrt{(50.0 \times 10^3\ \Omega)^2 + (1.33 \times 10^8\ \Omega)^2} \approx 1.33 \times 10^8\ \Omega$

$I_{\text{rms}} = \dfrac{\Delta V_{\text{rms}}}{Z} = \dfrac{5\,000\ \text{V}}{1.33 \times 10^8\ \Omega} = 3.77 \times 10^{-5}\ \text{A}$

$(\Delta V_{\text{rms}})_{\text{body}} = I_{\text{rms}} R_{\text{body}} = (3.77 \times 10^{-5}\ \text{A})(50.0 \times 10^3\ \Omega) = \boxed{1.88\ \text{V}}$

P33.24 $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi(50.0)(65.0\times10^{-6})} = 49.0\ \Omega$

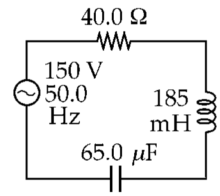


FIG. P33.24

$X_L = \omega L = 2\pi(50.0)(185\times10^{-3}) = 58.1\ \Omega$

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

$I_{\max} = \dfrac{\Delta V_{\max}}{Z} = \dfrac{150}{41.0} = 3.66\ \text{A}$

(a) $\Delta V_R = I_{\max} R = (3.66)(40) = \boxed{146\ \text{V}}$

(b) $\Delta V_L = I_{\max} X_L = (3.66)(58.1) = 212.5 = \boxed{212\ \text{V}}$

(c) $\Delta V_C = I_{\max} X_C = (3.66)(49.0) = 179.1\ \text{V} = \boxed{179\ \text{V}}$

(d) $\Delta V_L - \Delta V_C = 212.5 - 179.1 = \boxed{33.4\ \text{V}}$

P33.25 $R = 300\ \Omega$

$X_L = \omega L = 2\pi\left(\dfrac{500}{\pi}\ \text{s}^{-1}\right)(0.200\ \text{H}) = 200\ \Omega$

$X_C = \dfrac{1}{\omega C} = \left[2\pi\left(\dfrac{500}{\pi}\ \text{s}^{-1}\right)(11.0\times10^{-6}\ \text{F})\right]^{-1} = 90.9\ \Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = 319\ \Omega$ and

$\phi = \tan^{-1}\left(\dfrac{X_L - X_C}{R}\right) = 20.0°$

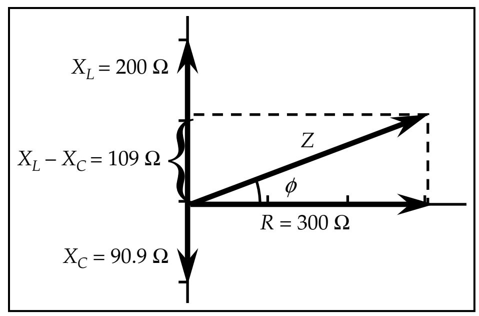


FIG. P33.25

***P33.26** Let X_c represent the initial capacitive reactance. Moving the plates to half their original separation doubles the capacitance and cuts $X_C = \dfrac{1}{\omega C}$ in half. For the current to double, the total impedance must be cut in half: $Z_i = 2Z_f$, $\sqrt{R^2 + (X_L - X_C)^2} = 2\sqrt{R^2 + \left(X_L - \dfrac{X_C}{2}\right)^2}$. With $X_L = R$, algebra then gives

$$R^2 + (R - X_C)^2 = 4\left(R^2 + \left(R - \frac{X_C}{2}\right)^2\right)$$

$$2R^2 - 2RX_C + X_C^2 = 8R^2 - 4RX_C + X_C^2$$

$$\boxed{X_C = 3R}$$

Section 33.6 **Power in an AC Circuit**

P33.27 $\omega = 1\,000$ rad/s, $R = 400\ \Omega$, $C = 5.00\times10^{-6}$ F, $L = 0.500$ H

$\Delta V_{\max} = 100$ V, $\omega L = 500\ \Omega$, $\left(\dfrac{1}{\omega C}\right) = 200\ \Omega$

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} = \sqrt{400^2 + 300^2} = 500\ \Omega$$

$$I_{\max} = \frac{\Delta V_{\max}}{Z} = \frac{100}{500} = 0.200\ \text{A}$$

The average power dissipated in the circuit is $\mathcal{P} = I_{\text{rms}}^2 R = \left(\dfrac{I_{\max}^2}{2}\right)R$.

$$\mathcal{P} = \frac{(0.200\ \text{A})^2}{2}(400\ \Omega) = \boxed{8.00\ \text{W}}$$

P33.28 $Z = \sqrt{R^2 + (X_L - X_C)^2}$ or $(X_L - X_C) = \sqrt{Z^2 - R^2}$

$$(X_L - X_C) = \sqrt{(75.0\ \Omega)^2 - (45.0\ \Omega)^2} = 60.0\ \Omega$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{60.0\ \Omega}{45.0\ \Omega}\right) = 53.1°$$

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{Z} = \frac{210\ \text{V}}{75.0\ \Omega} = 2.80\ \text{A}$$

$$\mathcal{P} = (\Delta V_{\text{rms}}) I_{\text{rms}} \cos\phi = (210\ \text{V})(2.80\ \text{A})\cos(53.1°) = \boxed{353\ \text{W}}$$

P33.29 (a) $\mathcal{P} = I_{\text{rms}}(\Delta V_{\text{rms}})\cos\phi = (9.00)180\cos(-37.0°) = 1.29\times10^3$ W

$\mathcal{P} = I_{\text{rms}}^2 R$ so $1.29\times10^3 = (9.00)^2 R$ and $R = \boxed{16.0\ \Omega}$

(b) $\tan\phi = \dfrac{X_L - X_C}{R}$ becomes $\tan(-37.0°) = \dfrac{X_L - X_C}{16}$: so $X_L - X_C = \boxed{-12.0\ \Omega}$

P33.30 $X_L = \omega L = 2\pi(60.0/\text{s})(0.025\,0\ \text{H}) = 9.42\ \Omega$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(20.0)^2 + (9.42)^2}\ \Omega = 22.1\ \Omega$$

(a) $I_{\text{rms}} = \dfrac{\Delta V_{\text{rms}}}{Z} = \dfrac{120\ \text{V}}{22.1\ \Omega} = \boxed{5.43\ \text{A}}$

(b) $\phi = \tan^{-1}\left(\dfrac{9.42}{20.0}\right) = 25.2°$ so power factor $= \cos\phi = \boxed{0.905}$

(c) We require $\phi = 0$. Thus, $X_L = X_C$: $9.42\ \Omega = \dfrac{1}{2\pi(60.0\ \text{s}^{-1})C}$

and $C = \boxed{281\ \mu\text{F}}$

(d) $\mathcal{P}_b = \mathcal{P}_d$ or $(\Delta V_{\text{rms}})_b (I_{\text{rms}})_b \cos\phi_b = \dfrac{(\Delta V_{\text{rms}})_d^2}{R}$

$$(\Delta V_{\text{rms}})_d = \sqrt{R(\Delta V_{\text{rms}})_b (I_{\text{rms}})_b \cos\phi_b} = \sqrt{(20.0\ \Omega)(120\ \text{V})(5.43\ \text{A})(0.905)} = \boxed{109\ \text{V}}$$

***P33.31** Consider a two-wire transmission line taking in power $\mathcal{P}$

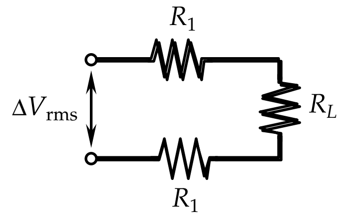


FIG. P33.31

$$I_{\text{rms}}=\frac{\mathcal{P}}{\Delta V_{\text{rms}}}.\text{ Then power loss }=I_{\text{rms}}^2R_{\text{line}}=\frac{\mathcal{P}}{100}.$$

Thus, $\left(\dfrac{\mathcal{P}}{\Delta V_{\text{rms}}}\right)^2(2R_1)=\dfrac{\mathcal{P}}{100}$ or $R_1=\dfrac{(\Delta V_{\text{rms}})^2}{200\mathcal{P}}$

$R_1=\dfrac{\rho\ell}{A}=\dfrac{(\Delta V_{\text{rms}})^2}{200\mathcal{P}}$ or $A=\dfrac{\pi(2r)^2}{4}=\dfrac{200\rho\mathcal{P}\ell}{(\Delta V_{\text{rms}})^2}$

and the diameter is $2r=\sqrt{\dfrac{800\rho\mathcal{P}\ell}{\pi(\Delta V)^2}}$

(a) $2r=\sqrt{\dfrac{800(1.7\times10^{-8}\ \Omega\text{m})\ 20\ 000\ \text{W}\ (18\ 000\ \text{m})}{\pi(\Delta V)^2}}=\boxed{39.5\ \text{V}\cdot\text{m}/\Delta V}$

(b) The diameter is inversely proportional to the potential difference.

(c) $2r=39.5\ \text{V·m}/1\ 500\ \text{V}=\boxed{2.63\ \text{cm}}$

(d) $\Delta V=39.5\ \text{V·m}/0.003\ \text{m}=\boxed{13.2\ \text{kV}}$

***P33.32** (a) $X_L=\omega L=2\pi(60/\text{s})\ 0.1\ \text{H}=37.7\ \Omega$
$Z=(100^2+37.7^2)^{1/2}=107\ \Omega$
power factor $=\cos\phi=100/107=\boxed{0.936}$

(b) The power factor cannot in practice be made 1.00. If the inductor were removed or if the generator were replaced with a battery, so that either $L=0$ or $f=0$, the power factor would be 1, but we would not have a magnetic buzzer.

(c) We want resonance, with $\phi=0$. We insert a capacitor in series with

$X_L=X_C$ so $37.7\ \Omega=1\ \text{s}/2\pi C\ 60$ and $C=\boxed{70.4\ \mu\text{F}}$

P33.33 One-half the time, the left side of the generator is positive, the top diode conducts, and the bottom diode switches off. The power supply sees resistance

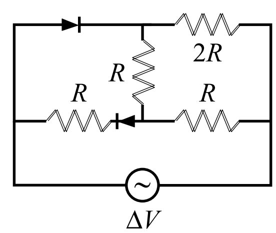


FIG. P33.33

$$\left[\frac{1}{2R}+\frac{1}{2R}\right]^{-1}=R\text{ and the power is }\frac{(\Delta V_{\text{rms}})^2}{R}.$$

The other half of the time the right side of the generator is positive, the upper diode is an open circuit, and the lower diode has zero resistance. The equivalent resistance is then

$R_{\text{eq}}=R+\left[\dfrac{1}{3R}+\dfrac{1}{R}\right]^{-1}=\dfrac{7R}{4}$ and $\mathcal{P}=\dfrac{(\Delta V_{\text{rms}})^2}{R_{\text{eq}}}=\dfrac{4(\Delta V_{\text{rms}})^2}{7R}$

The overall time average power is: $\dfrac{\left[(\Delta V_{\text{rms}})^2/R\right]+\left[4(\Delta V_{\text{rms}})^2/7R\right]}{2}=\boxed{\dfrac{11(\Delta V_{\text{rms}})^2}{14R}}$

Section 33.7 **Resonance in a Series *RLC* Circuit**

P33.34 (a) $f = \dfrac{1}{2\pi\sqrt{LC}}$

$$C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4\pi^2\left(10^{10}/\text{s}\right)^2 400\times10^{-12}\ \text{Vs}}\frac{\text{A}}{}\left(\frac{\text{C}}{\text{As}}\right) = \boxed{6.33\times10^{-13}\ \text{F}}$$

(b) $C = \dfrac{\kappa \in_0 A}{d} = \dfrac{\kappa \in_0 \ell^2}{d}$

$$\ell = \left(\frac{Cd}{\kappa \in_0}\right)^{1/2} = \left(\frac{6.33\times10^{-13}\ \text{F}\times10^{-3}\ \text{mm}}{1\times8.85\times10^{-12}\ \text{F}}\right)^{1/2} = \boxed{8.46\times10^{-3}\ \text{m}}$$

(c) $X_L = 2\pi f L = 2\pi\times10^{10}/\text{s}\times400\times10^{-12}\ \text{Vs/A} = \boxed{25.1\ \Omega}$

P33.35 $\omega_0 = 2\pi\left(99.7\times10^6\right) = 6.26\times10^8\ \text{rad/s} = \dfrac{1}{\sqrt{LC}}$

$$C = \frac{1}{\omega_0^2 L} = \frac{1}{\left(6.26\times10^8\right)^2\left(1.40\times10^{-6}\right)} = \boxed{1.82\ \text{pF}}$$

P33.36 $L = 20.0\ \text{mH},\ C = 1.00\times10^{-7},\ R = 20.0\ \Omega,\ \Delta V_{\max} = 100\ \text{V}$

(a) The resonant frequency for a series *RLC* circuit is $f = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC}} = \boxed{3.56\ \text{kHz}}$.

(b) At resonance, $I_{\max} = \dfrac{\Delta V_{\max}}{R} = \boxed{5.00\ \text{A}}$

(c) From Equation 33.38, $Q = \dfrac{\omega_0 L}{R} = \boxed{22.4}$

(d) $\Delta V_{L,\max} = X_L I_{\max} = \omega_0 L I_{\max} = \boxed{2.24\ \text{kV}}$

P33.37 The resonance frequency is $\omega_0 = \dfrac{1}{\sqrt{LC}}$. Thus, if $\omega = 2\omega_0$,

$$X_L = \omega L = \left(\frac{2}{\sqrt{LC}}\right)L = 2\sqrt{\frac{L}{C}} \quad \text{and} \quad X_C = \frac{1}{\omega C} = \frac{\sqrt{LC}}{2C} = \frac{1}{2}\sqrt{\frac{L}{C}}$$

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2} = \sqrt{R^2 + 2.25\left(\frac{L}{C}\right)} \quad \text{so} \quad I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{Z} = \frac{\Delta V_{\text{rms}}}{\sqrt{R^2 + 2.25(L/C)}}$$

and the energy delivered in one period is $E = \mathcal{P}\Delta t$:

$$E = \frac{\left(\Delta V_{\text{rms}}\right)^2 R}{R^2 + 2.25(L/C)}\left(\frac{2\pi}{\omega}\right) = \frac{\left(\Delta V_{\text{rms}}\right)^2 RC}{R^2 C + 2.25L}\left(\pi\sqrt{LC}\right) = \frac{4\pi\left(\Delta V_{\text{rms}}\right)^2 RC\sqrt{LC}}{4R^2C + 9.00L}$$

With the values specified for this circuit, this gives:

$$E = \frac{4\pi(50.0\ \text{V})^2(10.0\ \Omega)\left(100\times10^{-6}\ \text{F}\right)^{3/2}\left(10.0\times10^{-3}\ \text{H}\right)^{1/2}}{4(10.0\ \Omega)^2\left(100\times10^{-6}\ \text{F}\right) + 9.00\left(10.0\times10^{-3}\ \text{H}\right)} = \boxed{242\ \text{mJ}}$$

P33.38 The resonance frequency is $\omega_0 = \dfrac{1}{\sqrt{LC}}$. Thus, if $\omega = 2\omega_0$,

$X_L = \omega L = \left(\dfrac{2}{\sqrt{LC}}\right)L = 2\sqrt{\dfrac{L}{C}}$ and $X_C = \dfrac{1}{\omega C} = \dfrac{\sqrt{LC}}{2C} = \dfrac{1}{2}\sqrt{\dfrac{L}{C}}$

Then $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 2.25\left(\dfrac{L}{C}\right)}$ so $I_{\text{rms}} = \dfrac{\Delta V_{\text{rms}}}{Z} = \dfrac{\Delta V_{\text{rms}}}{\sqrt{R^2 + 2.25(L/C)}}$

and the energy delivered in one period is

$$E = \mathcal{P}\Delta t = \frac{(\Delta V_{\text{rms}})^2 R}{R^2 + 2.25(L/C)}\left(\frac{2\pi}{\omega}\right) = \frac{(\Delta V_{\text{rms}})^2 RC}{R^2 C + 2.25L}\left(\pi\sqrt{LC}\right) = \boxed{\frac{4\pi(\Delta V_{\text{rms}})^2 RC\sqrt{LC}}{4R^2C + 9.00L}}$$

P33.39 For the circuit of Problem 20, $\omega_0 = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{(160\times10^{-3}\text{ H})(99.0\times10^{-6}\text{ F})}} = 251\text{ rad/s}$

$$Q = \frac{\omega_0 L}{R} = \frac{(251\text{ rad/s})(160\times10^{-3}\text{ H})}{68.0\ \Omega} = \boxed{0.591}$$

For the circuit of Problem 21, $Q = \dfrac{\omega_0 L}{R} = \dfrac{L}{R\sqrt{LC}} = \dfrac{1}{R}\sqrt{\dfrac{L}{C}} = \dfrac{1}{150\ \Omega}\sqrt{\dfrac{460\times10^{-3}\text{ H}}{21.0\times10^{-6}\text{ F}}} = \boxed{0.987}$

The $\boxed{\text{circuit of Problem 21}}$ has a sharper resonance.

Section 33.8 **The Transformer and Power Transmission**

P33.40 (a) $\Delta V_{2,\text{rms}} = \dfrac{1}{13}(120\text{ V}) = \boxed{9.23\text{ V}}$

(b) $\Delta V_{1,\text{rms}} I_{1,\text{rms}} = \Delta V_{2,\text{rms}} I_{2,\text{rms}}$

$(120\text{ V})(0.350\text{ A}) = (9.23\text{ V})I_{2,\text{rms}}$

$I_{2,\text{rms}} = \dfrac{42.0\text{ W}}{9.23\text{ V}} = \boxed{4.55\text{ A}}$ for a transformer with no energy loss.

(c) $\mathcal{P} = \boxed{42.0\text{ W}}$ from part (b).

P33.41 $(\Delta V_{\text{out}})_{\max} = \dfrac{N_2}{N_1}(\Delta V_{\text{in}})_{\max} = \left(\dfrac{2\,000}{350}\right)(170\text{ V}) = 971\text{ V}$

$(\Delta V_{\text{out}})_{\text{rms}} = \dfrac{(971\text{ V})}{\sqrt{2}} = \boxed{687\text{ V}}$

P33.42 (a) $(\Delta V_{2,\text{rms}}) = \dfrac{N_2}{N_1}(\Delta V_{1,\text{rms}})$ $\qquad N_2 = \dfrac{(2\,200)(80)}{110} = \boxed{1\,600\text{ windings}}$

(b) $I_{1,\text{rms}}(\Delta V_{1,\text{rms}}) = I_{2,\text{rms}}(\Delta V_{2,\text{rms}})$ $\qquad I_{1,\text{rms}} = \dfrac{(1.50)(2\,200)}{110} = \boxed{30.0\text{ A}}$

(c) $0.950 I_{1,\text{rms}}(\Delta V_{1,\text{rms}}) = I_{2,\text{rms}}(\Delta V_{2,\text{rms}})$ $\qquad I_{1,\text{rms}} = \dfrac{(1.20)(2\,200)}{110(0.950)} = \boxed{25.3\text{ A}}$

P33.43 (a) $R=\left(4.50\times10^{-4}\ \Omega/\mathrm{M}\right)\left(6.44\times10^{5}\ \mathrm{m}\right)=290\ \Omega$ and $I_{\mathrm{rms}}=\dfrac{\mathcal{P}}{\Delta V_{\mathrm{rms}}}=\dfrac{5.00\times10^{6}\ \mathrm{W}}{5.00\times10^{5}\ \mathrm{V}}=10.0\ \mathrm{A}$

$\mathcal{P}_{\mathrm{loss}}=I_{\mathrm{rms}}^{2}R=(10.0\ \mathrm{A})^{2}(290\ \Omega)=\boxed{29.0\ \mathrm{kW}}$

(b) $\dfrac{\mathcal{P}_{\mathrm{loss}}}{\mathcal{P}}=\dfrac{2.90\times10^{4}}{5.00\times10^{6}}=\boxed{5.80\times10^{-3}}$

(c) It is impossible to transmit so much power at such low voltage. Maximum power transfer occurs when load resistance equals the line resistance of 290 Ω, and is

$\dfrac{\left(4.50\times10^{3}\ \mathrm{V}\right)^{2}}{2\cdot2(290\ \Omega)}=17.5$ kW, far below the required 5 000 kW.

Section 33.9 **Rectifiers and Filters**

P33.44 (a) Input power $=8$ W

Useful output power $=I\Delta V=0.3\ \mathrm{A}(9\ \mathrm{V})=2.7\ \mathrm{W}$

$\text{efficiency}=\dfrac{\text{useful output}}{\text{total input}}=\dfrac{2.7\ \mathrm{W}}{8\ \mathrm{W}}=\boxed{0.34}=34\%$

(b) Total input power = Total output power

$8\ \mathrm{W}=2.7\ \mathrm{W}+\text{wasted power}$

$\text{wasted power}=\boxed{5.3\ \mathrm{W}}$

(c) $E=\mathcal{P}\,\Delta t=8\ \mathrm{W}(6)(31\ \mathrm{d})\left(\dfrac{86\,400\ \mathrm{s}}{1\ \mathrm{d}}\right)\left(\dfrac{1\ \mathrm{J}}{1\ \mathrm{Ws}}\right)=1.29\times10^{8}\ \mathrm{J}\left(\dfrac{\$0.135}{3.6\times10^{6}\ \mathrm{J}}\right)=\boxed{\$4.8}$

P33.45 (a) The input voltage is $\Delta V_{\mathrm{in}}=IZ=I\sqrt{R^{2}+X_{C}^{2}}=I\sqrt{R^{2}+\left(\dfrac{1}{\omega C}\right)^{2}}$. The output voltage is

$\Delta V_{\mathrm{out}}=IR$. The gain ratio is $\dfrac{\Delta V_{\mathrm{out}}}{\Delta V_{\mathrm{in}}}=\dfrac{IR}{I\sqrt{R^{2}+(1/\omega C)^{2}}}=\dfrac{R}{\sqrt{R^{2}+(1/\omega C)^{2}}}$.

(b) As $\omega\to0$, $\dfrac{1}{\omega C}\to\infty$ and $\dfrac{\Delta V_{\mathrm{out}}}{\Delta V_{\mathrm{in}}}\to\boxed{0}$.

As $\omega\to\infty$, $\dfrac{1}{\omega C}\to0$ and $\dfrac{\Delta V_{\mathrm{out}}}{\Delta V_{\mathrm{in}}}\to\dfrac{R}{R}=\boxed{1}$.

(c) $\dfrac{1}{2}=\dfrac{R}{\sqrt{R^{2}+(1/\omega C)^{2}}}$

$R^{2}+\dfrac{1}{\omega^{2}C^{2}}=4R^{2}\qquad\omega^{2}C^{2}=\dfrac{1}{3R^{2}}\qquad\omega=2\pi f=\dfrac{1}{\sqrt{3}RC}\qquad\boxed{f=\dfrac{1}{2\pi\sqrt{3}RC}}$

P33.46 (a) The input voltage is $\Delta V_{\text{in}} = IZ = I\sqrt{R^2 + X_C^2} = I\sqrt{R^2 + (1/\omega C)^2}$. The output voltage is

$$\Delta V_{\text{out}} = IX_C = \frac{I}{\omega C}.\ \text{The gain ratio is}\ \frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{I/\omega C}{I\sqrt{R^2 + (1/\omega C)^2}} = \frac{1/\omega C}{\sqrt{R^2 + (1/\omega C)^2}}.$$

(b) As $\omega \to 0$, $\dfrac{1}{\omega C} \to \infty$ and R becomes negligible in comparison. Then $\dfrac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} \to \dfrac{1/\omega C}{1/\omega C} = \boxed{1}$.

As $\omega \to \infty$, $\dfrac{1}{\omega C} \to 0$ and $\dfrac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} \to \boxed{0}$.

(c) $$\frac{1}{2} = \frac{1/\omega C}{\sqrt{R^2 + (1/\omega C)^2}} \qquad R^2 + \left(\frac{1}{\omega C}\right)^2 = \frac{4}{\omega^2 C^2} \qquad R^2\omega^2 C^2 = 3 \qquad \omega = 2\pi f = \frac{\sqrt{3}}{RC}$$

$$\boxed{f = \frac{\sqrt{3}}{2\pi RC}}$$

P33.47 For this RC high-pass filter, $\dfrac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \dfrac{R}{\sqrt{R^2 + X_C^2}}$.

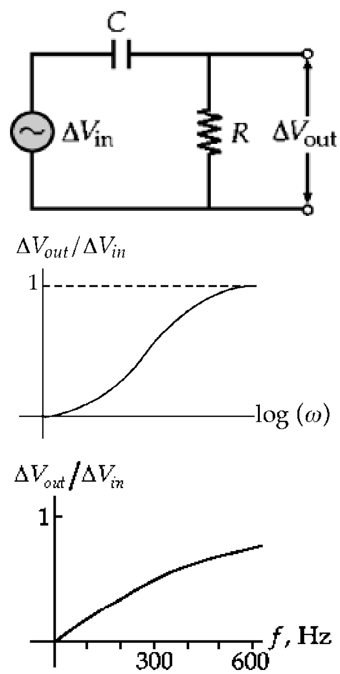


FIG. P33.47

(a) When $\dfrac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = 0.500$,

then $\dfrac{0.500\ \Omega}{\sqrt{(0.500\ \Omega)^2 + X_C^2}} = 0.500$ or $X_C = 0.866\ \Omega$.

If this occurs at $f = 300$ Hz, the capacitance is

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(300\ \text{Hz})(0.866\ \Omega)}$$
$$= 6.13 \times 10^{-4}\ \text{F} = \boxed{613\ \mu\text{F}}$$

(b) With this capacitance and a frequency of 600 Hz,

$$X_C = \frac{1}{2\pi(600\ \text{Hz})(6.13 \times 10^{-4}\ \text{F})} = 0.433\ \Omega$$

$$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{R}{\sqrt{R^2 + X_C^2}} = \frac{0.500\ \Omega}{\sqrt{(0.500\ \Omega)^2 + (0.433\ \Omega)^2}} = \boxed{0.756}$$

P33.48 For the filter circuit, $\dfrac{\Delta V_{out}}{\Delta V_{in}} = \dfrac{X_C}{\sqrt{R^2 + X_C^2}}$.

(a) At $f = 600$ Hz, $X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi(600\text{ Hz})(8.00\times10^{-9}\text{ F})} = 3.32\times10^4\ \Omega$

and $\dfrac{\Delta V_{out}}{\Delta V_{in}} = \dfrac{3.32\times10^4\ \Omega}{\sqrt{(90.0\ \Omega)^2 + (3.32\times10^4\ \Omega)^2}} \approx \boxed{1.00}$

(b) At $f = 600$ kHz, $X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi(600\times10^3\text{ Hz})(8.00\times10^{-9}\text{ F})} = 33.2\ \Omega$

and $\dfrac{\Delta V_{out}}{\Delta V_{in}} = \dfrac{33.2\ \Omega}{\sqrt{(90.0\ \Omega)^2 + (33.2\ \Omega)^2}} = \boxed{0.346}$

P33.49 $\dfrac{\Delta v_{out}}{\Delta v_{in}} = \dfrac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$

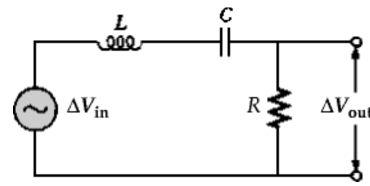


FIG. P33.49(a)

(a) At 200 Hz: $\dfrac{1}{4} = \dfrac{(8.00\ \Omega)^2}{(8.00\ \Omega)^2 + [400\pi L - 1/400\pi C]^2}$

At 4 000 Hz: $(8.00\ \Omega)^2 + \left[8\,000\pi L - \dfrac{1}{8\,000\pi C}\right]^2 = 4(8.00\ \Omega)^2$

At the low frequency, $X_L - X_C < 0$. This reduces to $400\pi L - \dfrac{1}{400\pi C} = -13.9\ \Omega$ [1]

For the high frequency half-voltage point, $8\,000\pi L - \dfrac{1}{8\,000\pi C} = +13.9\ \Omega$ [2]

Solving Equations (1) and (2) simultaneously gives $C = \boxed{54.6\ \mu\text{F}}$ and $L = \boxed{580\ \mu\text{H}}$

(b) When $X_L = X_C$, $\dfrac{\Delta v_{out}}{\Delta v_{in}} = \left(\dfrac{\Delta v_{out}}{\Delta v_{in}}\right)_{max} = \boxed{1.00}$

(c) $X_L = X_C$ requires $f_0 = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(5.80\times10^{-4}\text{ H})(5.46\times10^{-5}\text{ F})}} = \boxed{894\text{ Hz}}$

(d) At 200 Hz, $\dfrac{\Delta v_{out}}{\Delta v_{in}} = \dfrac{R}{Z} = \dfrac{1}{2}$ and $X_C > X_L$,

so the phasor diagram is as shown:

$\phi = -\cos^{-1}\left(\dfrac{R}{Z}\right) = -\cos^{-1}\left(\dfrac{1}{2}\right)$ so

$\boxed{\Delta v_{out}\text{ leads }\Delta v_{in}\text{ by }60.0°}$.

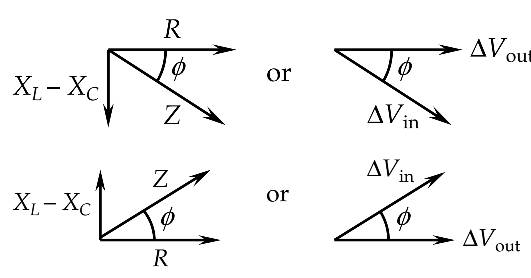


FIG. P33.49(d)

At f_0, $X_L = X_C$ so

$\boxed{\Delta v_{out}\text{ and }\Delta v_{in}\text{ have a phase difference of }0°}$.

At 4 000 Hz, $\dfrac{\Delta v_{out}}{\Delta v_{in}} = \dfrac{R}{Z} = \dfrac{1}{2}$ and $X_L - X_C > 0$

Thus, $\phi = \cos^{-1}\left(\dfrac{1}{2}\right) = 60.0°$

or $\boxed{\Delta v_{out}\text{ lags }\Delta v_{in}\text{ by }60.0°}$

continued on next page

(e) At 200 Hz and at 4 kHz,

$$\mathcal{P} = \frac{\left(\Delta v_{\text{out,rms}}\right)^2}{R} = \frac{\left((1/2)\Delta v_{\text{in,rms}}\right)^2}{R} = \frac{(1/2)\left[(1/2)\Delta v_{\text{in,max}}\right]^2}{R} = \frac{(10.0\text{ V})^2}{8(8.00\ \Omega)} = \boxed{1.56\text{ W}}$$

$$\text{At } f_0,\ \mathcal{P} = \frac{\left(\Delta v_{\text{out,rms}}\right)^2}{R} = \frac{\left(\Delta v_{\text{in,rms}}\right)^2}{R} = \frac{(1/2)\left[\Delta v_{\text{in,max}}\right]^2}{R} = \frac{(10.0\text{ V})^2}{2(8.00\ \Omega)} = \boxed{6.25\text{ W}}$$

(f) We take $Q = \dfrac{\omega_0 L}{R} = \dfrac{2\pi f_0 L}{R} = \dfrac{2\pi(894\text{ Hz})\left(5.80\times10^{-4}\text{ H}\right)}{8.00\ \Omega} = \boxed{0.408}$

Additional Problems

P33.50 The equation for $\Delta v(t)$ during the first period (using $y = mx + b$) is:

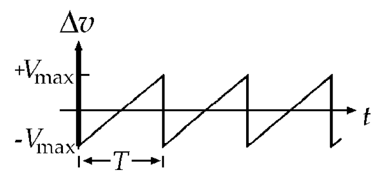


FIG. P33.50

$$\Delta v(t) = \frac{2(\Delta V_{\max})t}{T} - \Delta V_{\max}$$

$$\left[(\Delta v)^2\right]_{\text{avg}} = \frac{1}{T}\int_0^T \left[\Delta v(t)\right]^2 dt = \frac{(\Delta V_{\max})^2}{T}\int_0^T \left[\frac{2}{T}t - 1\right]^2 dt$$

$$\left[(\Delta v)^2\right]_{\text{avg}} = \frac{(\Delta V_{\max})^2}{T}\left(\frac{T}{2}\right)\frac{\left[2t/T-1\right]^3}{3}\Bigg|_{t=0}^{t=T} = \frac{(\Delta V_{\max})^2}{6}\left[(+1)^3-(-1)^3\right] = \frac{(\Delta V_{\max})^2}{3}$$

$$\Delta V_{\text{rms}} = \sqrt{\left[(\Delta v)^2\right]_{\text{avg}}} = \sqrt{\frac{(\Delta V_{\max})^2}{3}} = \boxed{\frac{\Delta V_{\max}}{\sqrt{3}}}$$

***P33.51** (a) $Z^2 = R^2 + (X_L - X_C)^2$ $\quad 760^2 = 400^2 + (700 - X_C)^2 \quad 417\,600 = (700 - X_C)^2$

There are two values for the square root. We can have $646.2 = 700 - X_C$ or $-646.2 = 700 - X_C$.

$\boxed{X_C \text{ can be } 53.8\ \Omega \text{ or it can be } 1.35\text{ k}\Omega.}$

(b) If we were below resonance, with inductive reactance 700 Ω and capacitive reactance 1.35 kΩ, raising the frequency would increase the power. We must be above resonance, with inductive reactance 700 Ω and $\boxed{\text{capacitive reactance } 53.8\ \Omega.}$

(c) $760^2 = 200^2 + (700 - X_C)^2 \quad 537\,600 = (700 - X_C)^2$ Here $+733 = 700 - X_C$ has no solution so we must have $-733.2 = 700 - X_C$ and $\boxed{X_C = 1.43\text{ k}\Omega}$.

P33.52 The angular frequency is $\omega = 2\pi 60/\text{s} = 377/\text{s}$. When S is open, R, L, and C are in series with the source:

$$R^2 + \left(X_L - X_C\right)^2 = \left(\frac{\Delta V_s}{I}\right)^2 = \left(\frac{20\text{ V}}{0.183\text{ A}}\right)^2 = 1.194\times 10^4\ \Omega^2 \qquad (1)$$

When S is in position 1, a parallel combination of two R's presents equivalent resistance $\frac{R}{2}$, in series with L and C:

$$\left(\frac{R}{2}\right)^2 + \left(X_L - X_C\right)^2 = \left(\frac{20\text{ V}}{0.298\text{ A}}\right)^2 = 4.504\times 10^3\ \Omega^2 \qquad (2)$$

When S is in position 2, the current by passes the inductor. R and C are in series with the source:

$$R^2 + X_C^2 = \left(\frac{20\text{ V}}{0.137\text{ A}}\right)^2 = 2.131\times 10^4\ \Omega^2 \qquad (3)$$

Take equation (1) minus equation (2):

$$\frac{3}{4}R^2 = 7.440\times 10^3\ \Omega^2 \qquad \boxed{R = 99.6\ \Omega}$$

Only the positive root is physical. We have shown than only one resistance value is possible. Now equation (3) gives

$X_C = \left[2.131\times 10^4 - (99.6)^2\right]^{1/2}\ \Omega = 106.7\ \Omega = \dfrac{1}{\omega C}$ Only the positive root is physical and only one capacitance is possible.

$$C = \left(\omega X_C\right)^{-1} = \left[(377/\text{s})106.7\ \Omega\right]^{-1} = \boxed{2.49\times 10^{-5}\text{ F} = C}$$

Now equation (1) gives

$$X_L - X_C = \pm\left[1.194\times 10^4 - (99.6)^2\right]^{1/2}\ \Omega = \pm 44.99\ \Omega$$

$$X_L = 106.7\ \Omega + 44.99\ \Omega = 61.74\ \Omega \quad \text{or} \quad 151.7\ \Omega = \omega L$$

$$L = \frac{X_L}{\omega} = \boxed{0.164\text{ H or }0.402\text{ H} = L}$$

Two values for self-inductance are possible.

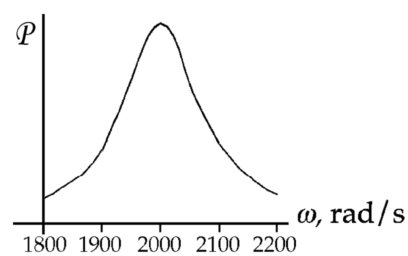
P33.53 $$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(0.050\,0\text{ H})(5.00\times 10^{-6}\text{ F})}} = 2\,000\text{ s}^{-1}$$

so the operating angular frequency of the circuit is

$$\omega = \frac{\omega_0}{2} = 1\,000\text{ s}^{-1}$$

Using Equation 33.37, $\mathcal{P} = \dfrac{\left(\Delta V_{\text{rms}}\right)^2 R\omega^2}{R^2\omega^2 + L^2\left(\omega^2 - \omega_0^2\right)^2}$

$$\mathcal{P} = \frac{(400)^2(8.00)(1\,000)^2}{(8.00)^2(1\,000)^2 + (0.050\,0)^2\left[(1.00 - 4.00)\times 10^6\right]^2} = \boxed{56.7\text{ W}}$$



$(Q \approx 12.5)$

FIG. P33.53

***P33.54** (a) At the resonance frequency X_L and X_C are equal. The certain frequency must be $\boxed{\text{higher}}$ than the resonance frequency for the inductive reactance to be the greater.

(b) $\boxed{\text{It is possible}}$ to determine the values for L and C, because we have three independent equations in the three unknowns L, C, and the unknown angular frequency ω.
The equations are
$2\,000^2 = 1/LC \quad 12 = \omega L \quad$ and $\quad 8 = 1/\omega C$

(c) We eliminate $\omega = 12/L$ to have $8\ \omega C = 1 = 8(12/L)C = 96C/L$ so $L = 96C$
Then $4\,000\,000 = 1/96\ C^2$ so $\boxed{C = 51.0\ \mu\text{F and } L = 4.90\text{ mH}}$

***P33.55** The lowest-frequency standing-wave state is NAN. The distance between the clamps we represent as $d = d_{\text{NN}} = \dfrac{\lambda}{2}$. The speed of transverse waves on the string is $v = f\lambda = \sqrt{\dfrac{T}{\mu}} = f2d$.
The magnetic force on the wire oscillates at 60 Hz, so the wire will oscillate in resonance at 60 Hz.

$$\frac{T}{0.019\ \text{kg/m}} = (60/\text{s})^2\,4d^2 \qquad \boxed{T = \left(274\ \text{kg/m}\cdot\text{s}^2\right)d^2}$$

Any values of T and d related according to this expression will work, including $\boxed{\text{if } d = 0.200\text{ m} \quad T = 10.9\text{ N}}$. We did not need to use the value of the current and magnetic field. If we assume the subsection of wire in the field is 2 cm wide, we can find the rms value of the magnetic force:

$F_B = I\ell B\sin\theta = (9\text{ A})(0.02\text{ m})(0.015\,3T)\sin 90° = 2.75\text{ mN}$

So a small force can produce an oscillation of noticeable amplitude if internal friction is small.

***P33.56** $\phi = \tan^{-1}\left(\dfrac{\omega L - 1/\omega C}{R}\right)$ changes from $-90°$ for $\omega = 0$ to 0 at the resonance frequency to $+90°$ as ω goes to infinity.
The slope of the graph is $d\phi/d\omega$:

$$\frac{d\phi}{d\omega} = \frac{1}{1+\left(\dfrac{\omega L - 1/\omega C}{R}\right)^2}\frac{1}{R}\left(L - \frac{1}{C}(-1)\frac{1}{\omega^2}\right)$$

At resonance we have $\omega_0 L = 1/\omega_0 C$ and $LC = 1/\omega_0^2$.

Substituting, the slope at the resonance point is

$$\left.\frac{d\phi}{d\omega}\right|_{\omega_0} = \frac{1}{1+0^2}\frac{1}{R}\left(L + \frac{1}{C}LC\right) = \frac{2L}{R} = \frac{2Q}{\omega_0}$$

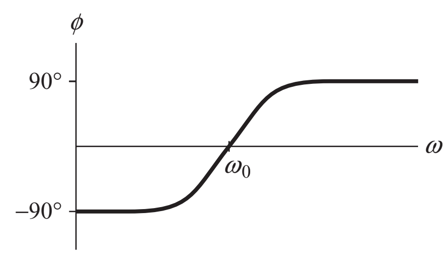


FIG. P33.56

P33.57 (a) When ωL is very large, the bottom branch carries negligible current. Also, $\dfrac{1}{\omega C}$ will be negligible compared to $200\ \Omega$ and $\dfrac{45.0\text{ V}}{200\ \Omega} = \boxed{225\text{ mA}}$ flows in the power supply and the top branch.

(b) Now $\dfrac{1}{\omega C} \to \infty$ and $\omega L \to 0$ so the generator and bottom branch carry $\boxed{450\text{ mA}}$.

P33.58 (a) With both switches closed, the current goes only through generator and resistor.

$$\boxed{i(t) = \frac{\Delta V_{max}}{R}\cos\omega t}$$

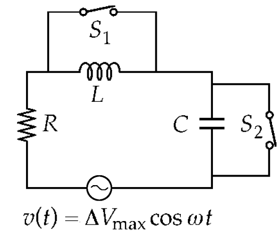


FIG. P33.58

(b) $$\boxed{\mathcal{P} = \frac{1}{2}\frac{(\Delta V_{max})^2}{R}}$$

(c) $$\boxed{i(t) = \frac{\Delta V_{max}}{\sqrt{R^2+\omega^2 L^2}}\cos\left[\omega t + \tan^{-1}\left(\frac{\omega L}{R}\right)\right]}$$

(d) For $$0 = \phi = \tan^{-1}\left(\frac{\omega_0 L - (1/\omega_0 C)}{R}\right)$$

We require $\omega_0 L = \dfrac{1}{\omega_0 C}$, so $\boxed{C = \dfrac{1}{\omega_0^2 L}}$

(e) At this resonance frequency, $Z = \boxed{R}$

(f) $$U = \frac{1}{2}C(\Delta V_C)^2 = \frac{1}{2}CI^2X_C^2$$

$$U_{max} = \frac{1}{2}CI_{max}^2X_C^2 = \frac{1}{2}C\frac{(\Delta V_{max})^2}{R^2}\frac{1}{\omega_0^2C^2} = \boxed{\frac{(\Delta V_{max})^2 L}{2R^2}}$$

(g) $$U_{max} = \frac{1}{2}LI_{max}^2 = \boxed{\frac{1}{2}L\frac{(\Delta V_{max})^2}{R^2}}$$

(h) Now $\omega = 2\omega_0 = \dfrac{2}{\sqrt{LC}}$.

So $$\phi = \tan^{-1}\left(\frac{\omega L - (1/\omega C)}{R}\right) = \tan^{-1}\left(\frac{2\sqrt{L/C} - (1/2)\sqrt{L/C}}{R}\right) = \boxed{\tan^{-1}\left(\frac{3}{2R}\sqrt{\frac{L}{C}}\right)}.$$

(i) Now $\omega L = \dfrac{1}{2}\dfrac{1}{\omega C}$ $\qquad \omega = \boxed{\dfrac{1}{\sqrt{2LC}}} = \dfrac{\omega_0}{\sqrt{2}}$

P33.59 (a) $$I_{R,rms} = \frac{\Delta V_{rms}}{R} = \frac{100\text{ V}}{80.0\ \Omega} = \boxed{1.25\text{ A}}$$

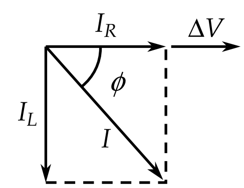


FIG. P33.59

(b) The total current will $\boxed{\text{lag}}$ the applied voltage as seen in the phasor diagram at the right.

$$I_{L,rms} = \frac{\Delta V_{rms}}{X_L} = \frac{100\text{ V}}{2\pi(60.0\text{ s}^{-1})(0.200\text{ H})} = 1.33\text{ A}$$

Thus, the phase angle is: $\phi = \tan^{-1}\left(\dfrac{I_{L,rms}}{I_{R,rms}}\right) = \tan^{-1}\left(\dfrac{1.33\text{ A}}{1.25\text{ A}}\right) = \boxed{46.7°}$.

P33.60 Suppose each of the 20 000 people uses an average power of 500 W. (This means 12 kWh per day, or \$36 per 30 days at 10¢per kWh.) Suppose the transmission line is at 20 kV. Then

$$I_{rms} = \frac{\mathcal{P}}{\Delta V_{rms}} = \frac{(20\,000)(500\text{ W})}{20\,000\text{ V}} \boxed{\sim 10^3\text{ A}}$$

If the transmission line had been at 200 kV, the current would be only $\boxed{\sim 10^2\text{ A}}$.

P33.61 $R = 200\ \Omega,\ L = 663\text{ mH},\ C = 26.5\ \mu\text{F},\ \omega = 377\text{ s}^{-1},\ \Delta V_{max} = 50.0\text{ V}$

$$\omega L = 250\ \Omega,\ \left(\frac{1}{\omega C}\right) = 100\ \Omega,\ Z = \sqrt{R^2 + (X_L - X_C)^2} = 250\ \Omega$$

(a) $I_{max} = \dfrac{\Delta V_{max}}{Z} = \dfrac{50.0\text{ V}}{250\ \Omega} = \boxed{0.200\text{ A}}$

$\phi = \tan^{-1}\left(\dfrac{X_L - X_C}{R}\right) = \boxed{36.8°}$ (ΔV leads I)

(b) $\Delta V_{R,max} = I_{max} R = \boxed{40.0\text{ V}}$ at $\boxed{\phi = 0°}$

(c) $\Delta V_{C,max} = \dfrac{I_{max}}{\omega C} = \boxed{20.0\text{ V}}$ at $\boxed{\phi = -90.0°}$ (I leads ΔV)

(d) $\Delta V_{L,max} = I_{max}\omega L = \boxed{50.0\text{ V}}$ at $\boxed{\phi = +90.0°}$ (ΔV leads I)

P33.62 $L = 2.00\text{ H},\ C = 10.0 \times 10^{-6}\text{ F},\ R = 10.0\ \Omega,\ \Delta v(t) = (100 \sin \omega t)$

(a) The resonant frequency ω_0 produces the maximum current and thus the maximum power delivery to the resistor.

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(2.00)(10.0\times 10^{-6})}} = \boxed{224\text{ rad/s}}$$

(b) $\mathcal{P} = \dfrac{(\Delta V_{max})^2}{2R} = \dfrac{(100)^2}{2(10.0)} = \boxed{500\text{ W}}$

(c) $I_{rms} = \dfrac{\Delta V_{rms}}{Z} = \dfrac{\Delta V_{rms}}{\sqrt{R^2 + (\omega L - (1/\omega C))^2}}$ and $(I_{rms})_{max} = \dfrac{\Delta V_{rms}}{R}$

$I_{rms}^2 R = \dfrac{1}{2}(I_{rms}^2)_{max} R$ or $\dfrac{(\Delta V_{rms})^2}{Z^2} R = \dfrac{1}{2}\dfrac{(\Delta V_{rms})^2}{R^2} R$

This occurs where $Z^2 = 2R^2$: $R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2 = 2R^2$

$\omega^4 L^2 C^2 - 2L\omega^2 C - R^2\omega^2 C^2 + 1 = 0$ or $L^2C^2\omega^4 - (2LC + R^2C^2)\omega^2 + 1 = 0$

$$\left[(2.00)^2(10.0\times 10^{-6})^2\right]\omega^4 - \left[2(2.00)(10.0\times 10^{-6}) + (10.0)^2(10.0\times 10^{-6})^2\right]\omega^2 + 1 = 0$$

Solving this quadratic equation, we find that $\omega^2 = 51\,130$, or $48\,894$

$\omega_1 = \sqrt{48\,894} = \boxed{221\text{ rad/s}}$ and $\omega_2 = \sqrt{51\,130} = \boxed{226\text{ rad/s}}$

P33.63 (a) From Equation 33.41, $\frac{N_1}{N_2}=\frac{\Delta V_1}{\Delta V_2}$.

Let input impedance $Z_1=\frac{\Delta V_1}{I_1}$ and the output impedance $Z_2=\frac{\Delta V_2}{I_2}$

so that $\frac{N_1}{N_2}=\frac{Z_1 I_1}{Z_2 I_2}$ But from Eq. 33.42, $\frac{I_1}{I_2}=\frac{\Delta V_2}{\Delta V_1}=\frac{N_2}{N_1}$

So, combining with the previous result we have $\boxed{\frac{N_1}{N_2}=\sqrt{\frac{Z_1}{Z_2}}}$.

(b) $\frac{N_1}{N_2}=\sqrt{\frac{Z_1}{Z_2}}=\sqrt{\frac{8\,000}{8.00}}=\boxed{31.6}$

P33.64 $\mathcal{P}=I_{\text{rms}}^2 R=\left(\frac{\Delta V_{\text{rms}}}{Z}\right)^2 R$, so $250\text{ W}=\frac{(120\text{ V})^2}{Z^2}(40.0\ \Omega)$: $Z=\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}$

$$250=\frac{(120)^2(40.0)}{(40.0)^2+\left[2\pi f(0.185)-\left[1/2\pi f\left(65.0\times10^{-6}\right)\right]\right]^2}$$ and

$$250=\frac{576\,000 f^2}{1\,600 f^2+\left(1.162\,4 f^2-2\,448.5\right)^2}$$

$$1=\frac{2\,304 f^2}{1\,600 f^2+1.351\,1 f^4-5\,692.3 f^2+5\,995\,300}$$ so $1.351\,1 f^4-6\,396.3 f^2+5\,995\,300=0$

$$f^2=\frac{6\,396.3\pm\sqrt{(6\,396.3)^2-4(1.351\,1)(5\,995\,300)}}{2(1.351\,1)}=3\,446.5\text{ or }1\,287.4$$

$f=\boxed{58.7\text{ Hz or }35.9\text{ Hz}}$ There are two answers because we could be above resonance or below resonance.

P33.65 $I_R=\frac{\Delta V_{\text{rms}}}{R}$; $I_L=\frac{\Delta V_{\text{rms}}}{\omega L}$; $I_C=\frac{\Delta V_{\text{rms}}}{(\omega C)^{-1}}$

(a) $I_{\text{rms}}=\sqrt{I_R^2+(I_C-I_L)^2}=\boxed{\Delta V_{\text{rms}}\sqrt{\left(\frac{1}{R^2}\right)+\left(\omega C-\frac{1}{\omega L}\right)^2}}$

(b) $\tan\phi=\frac{I_C-I_L}{I_R}=\Delta V_{\text{rms}}\left[\frac{1}{X_C}-\frac{1}{X_L}\right]\left(\frac{1}{\Delta V_{\text{rms}}/R}\right)$

$\boxed{\tan\phi=R\left[\frac{1}{X_C}-\frac{1}{X_L}\right]}$

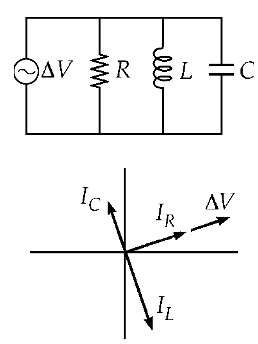


FIG. P33.65

***P33.66** An *RLC* series circuit, containing a 35.0-Ω resistor, a 205-mH inductor, a capacitor, and a power supply with rms voltage 200 V and frequency 100 Hz, carries rms current 4.00 A. Find the capacitance of the capacitor.

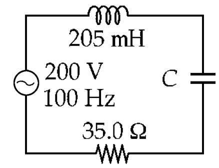


FIG. P33.66

We solve for C

$2500 = 35^2 + (129 - 1/628C)^2 \quad 1275 = (129 - 1/628C)^2$

There are two possibilities: $35.7 = 129 - 1/628C$ and $-35.7 = 129 - 1/628C$

$1/628C = 93.1$ or $1/628C = 164.5$

$$\boxed{C = \text{either } 17.1\ \mu\text{F or } 9.67\ \mu\text{F}}$$

P33.67 (a) $X_L = X_C = 1\,884\ \Omega$ when $f = 2\,000$ Hz

$$L = \frac{X_L}{2\pi f} = \frac{1\,884\ \Omega}{4\,000\pi \text{ rad/s}} = 0.150 \text{ H and}$$

$$C = \frac{1}{(2\pi f)X_C} = \frac{1}{(4\,000\pi \text{ rad/s})(1\,884\ \Omega)} = 42.2 \text{ nF}$$

$$X_L = 2\pi f(0.150 \text{ H}) \qquad X_C = \frac{1}{(2\pi f)(4.22\times10^{-8} \text{ F})}$$

$$Z = \sqrt{(40.0\ \Omega)^2 + (X_L - X_C)^2}$$

f (Hz)	X_L (Ω)	X_C (Ω)	Z (Ω)
300	283	12 600	1 2300
600	565	6 280	5 720
800	754	4 710	3 960
1 000	942	3 770	2 830
1 500	1 410	2 510	1 100
2 000	1 880	1 880	40
3 000	2 830	1 260	1 570
4 000	3 770	942	2 830
6 000	5 650	628	5 020
10 000	9 420	377	9 040

(b) Impedance, Ω

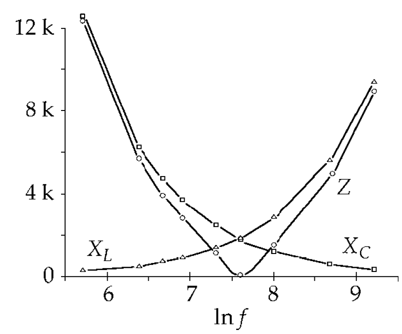


FIG. P33.67(b)

P33.68 $\omega_0 = \dfrac{1}{\sqrt{LC}} = 1.00\times10^6$ rad/s

For each angular frequency, we find

$$Z = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$$

then $I = \dfrac{1.00\text{ V}}{Z}$

and $\mathcal{P} = I^2(1.00\ \Omega)$

The full width at half maximum is:

$$\Delta f = \frac{\Delta\omega}{2\pi} = \frac{(1.000\,5 - 0.999\,5)\omega_0}{2\pi}$$

$$\Delta f = \frac{1.00\times10^3\text{ s}^{-1}}{2\pi} = 159\text{ Hz}$$

while

$$\frac{R}{2\pi L} = \frac{1.00\ \Omega}{2\pi(1.00\times10^{-3}\text{ H})} = 159\text{ Hz}$$

$\dfrac{\omega}{\omega_0}$	$\omega L\ (\Omega)$	$\dfrac{1}{\omega C}\ (\Omega)$	$Z\ (\Omega)$	$\mathcal{P} = I^2 R$ (W)
0.9990	999.0	1001.0	2.24	0.19984
0.9991	999.1	1000.9	2.06	0.23569
0.9993	999.3	1000.7	1.72	0.33768
0.9995	999.5	1000.5	1.41	0.49987
0.9997	999.7	1000.3	1.17	0.73524
0.9999	999.9	1000.1	1.02	0.96153
1.0000	1000	1000.0	1.00	1.00000
1.0001	1000.1	999.9	1.02	0.96154
1.0003	1000.3	999.7	1.17	0.73535
1.0005	1000.5	999.5	1.41	0.50012
1.0007	1000.7	999.3	1.72	0.33799
1.0009	1000.9	999.1	2.06	0.23601
1.0010	1001	999.0	2.24	0.20016

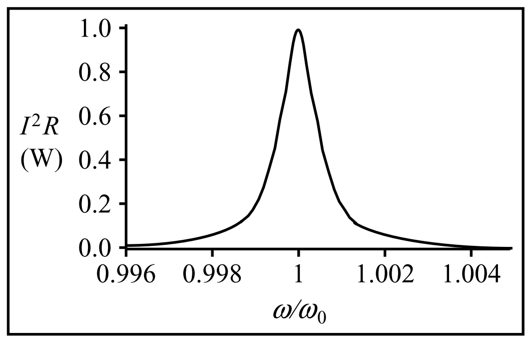


FIG. P33.68

***P33.69** (a) We can use $\sin A + \sin B = 2\sin\left(\dfrac{A}{2}+\dfrac{B}{2}\right)\cos\left(\dfrac{A}{2}-\dfrac{B}{2}\right)$ to find the sum of the two sine functions to be

$$E_1 + E_2 = (24.0\text{ cm})\sin(4.5t + 35.0°)\cos 35.0°$$

$$E_1 + E_2 = (19.7\text{ cm})\sin(4.5t + 35.0°)$$

Thus, the total wave has amplitude $\boxed{19.7\text{ cm}}$ and has a constant phase difference of $\boxed{35.0°}$ from the first wave.

(b) In units of cm, the resultant phasor is

$$\vec{\mathbf{y}}_R = \vec{\mathbf{y}}_1 + \vec{\mathbf{y}}_2 = (12.0\hat{\mathbf{i}}) + (12.0\cos 70.0°\hat{\mathbf{i}} + 12.0\sin 70.0\hat{\mathbf{j}})$$
$$= 16.1\hat{\mathbf{i}} + 11.3\hat{\mathbf{j}}$$

$$\vec{\mathbf{y}}_R = \sqrt{(16.1)^2 + (11.3)^2}\ \text{at}\ \tan^{-1}\left(\frac{11.3}{16.1}\right) = \boxed{19.7\text{ cm at }35.0°}$$

The answers are identical.

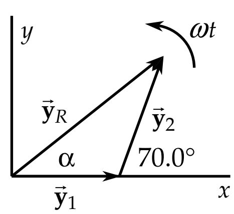


FIG. P33.69(b)

continued on next page

(c) $\vec{\mathbf{y}}_R = 12.0\cos 70.0°\hat{\mathbf{i}} + 12.0\sin 70.0°\hat{\mathbf{j}}$
$+15.5\cos 80.0°\hat{\mathbf{i}} - 15.5\sin 80.0°\hat{\mathbf{j}}$
$+17.0\cos 160°\hat{\mathbf{i}} + 17.0\sin 160°\hat{\mathbf{j}}$

$$\vec{\mathbf{y}}_R = -9.18\hat{\mathbf{i}} + 1.83\hat{\mathbf{j}} = \boxed{9.36\text{ cm at }169°}$$

The wave function of the total wave is
$y_R = (9.36\text{ cm})\sin(15x - 4.5t + 169°)$.

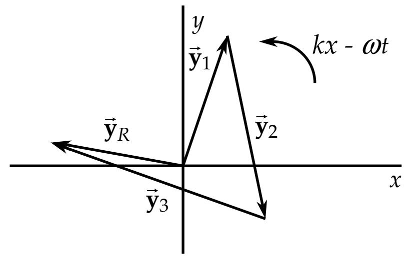


FIG. P33.69(c)

ANSWERS TO EVEN PROBLEMS

P33.2 (a) 193 Ω (b) 144 Ω

P33.4 (a) 25.3 rad/s (b) 0.114 s

P33.6 3.38 W

P33.8 3.14 A

P33.10 3.80 J

P33.12 (a) greater than 41.3 Hz (b) less than 87.5 Ω

P33.14 $\sqrt{2}C(\Delta V_{\text{rms}})$

P33.16 –32.0 A

P33.18 2.79 kHz

P33.20 (a) 109 Ω (b) 0.367 A (c) $I_{\max} = 0.367$ A, $\omega = 100$ rad/s, $\phi = -0.896$ rad

P33.22 19.3 mA

P33.24 (a) 146 V (b) 212 V (c) 179 V (d) 33.4 V

P33.26 Cutting the plate separation in half doubles the capacitance and cuts in half the capacitive reactance to $X_C/2$. The new impedance must be half as large as the old impedance for the new current to be doubled. For the new impedance we then have

$(R^2 + [R - X_C/2]^2)^{1/2} = 0.5(R^2 + [R - X_C]^2)^{1/2}$. Solving yields $X_C = 3R$.

P33.28 353 W

P33.30 (a) 5.43 A (b) 0.905 (c) 281 μF (d) 109 V

P33.32 (a) 0.936 (b) Not in practice. If the inductor were removed or if the generator were replaced with a battery, so that either $L = 0$ or $f = 0$, the power factor would be 1, but we would not have a magnetic buzzer. (c) 70.4 μF

P33.34 (a) 633 fF (b) 8.46 mm (c) 25.1 Ω

P33.36 (a) 3.56 kHz (b) 5.00 A (c) 22.4 (d) 2.24 kV

P33.38 $\dfrac{4\pi(\Delta V_{\text{rms}})^2 RC\sqrt{LC}}{4R^2C+9L}$

P33.40 (a) 9.23 V (b) 4.55 A (c) 42.0 W

P33.42 (a) 1 600 turns (b) 30.0 A (c) 25.3 A

P33.44 (a) 0.34 (b) 5.3 W (c) \$4.8

P33.46 (a) See the solution. (b) 1; 0 (c) $\dfrac{\sqrt{3}}{2\pi RC}$

P33.48 (a) 1.00 (b) 0.346

P33.50 See the solution.

P33.52 Only one value for R and only one value for C are possible. Two values for L are possible. $R = 99.6\ \Omega$, $C = 24.9\ \mu\text{F}$, and $L = 164$ mH or 402 mH

P33.54 (a) Higher. At the resonance frequency $X_L = X_C$. As the frequency increases, X_L goes up and X_C goes down. (b) It is. We have three independent equations in the three unknowns L, C, and the certain f. (c) $L = 4.90$ mH and $C = 51.0\ \mu\text{F}$

P33.56 See the solution.

P33.58 (a) $i(t) = \dfrac{\Delta V_{\max}}{R}\cos\omega t$ (b) $\mathcal{P} = \dfrac{(\Delta V_{\max})^2}{2R}$ (c) $i(t) = \dfrac{\Delta V_{\max}}{\sqrt{R^2+\omega^2L^2}}\cos\left[\omega t + \tan^{-1}\left(\dfrac{\omega L}{R}\right)\right]$

(d) $C = \dfrac{1}{\omega_0^2 L}$ (e) $Z = R$ (f) $\dfrac{(\Delta V_{\max})^2 L}{2R^2}$ (g) $\dfrac{(\Delta V_{\max})^2 L}{2R^2}$ (h) $\tan^{-1}\left(\dfrac{3}{2R}\sqrt{\dfrac{L}{C}}\right)$ (i) $\dfrac{1}{\sqrt{2LC}}$

P33.60 $\sim 10^3$ A

P33.62 (a) 224 rad/s (b) 500 W (c) 221 rad/s and 226 rad/s

P33.64 The frequency could be either 58.7 Hz or 35.9 Hz. We can be either above or below resonance.

P33.66 An *RLC* series circuit, containing a 35.0-Ω resistor, a 205-mH inductor, a capacitor, and a power supply with rms voltage 200 V and frequency 100 Hz, carries rms current 4.00 A. Find the capacitance of the capacitor. Answer: It could be either 17.1 μF or 9.67 μF.

P33.68 See the solution.