# Chapter 33 Solutions

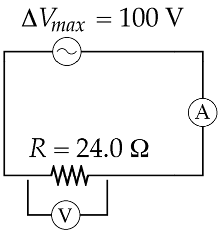
**33.1** $\Delta v(t) = \Delta V_{\max} \sin(\omega t) = \sqrt{2}\ \Delta V_{\text{rms}} \sin(\omega t) = 200\sqrt{2}\ \sin[2\pi(100t)] = \boxed{(283\text{ V})\sin(628t)}$

**33.2** $\Delta V_{\text{rms}} = \dfrac{170\text{ V}}{\sqrt{2}} = 120\text{ V}$

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

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

**33.3** Each meter reads the rms value.




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

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

**33.4** (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 $t = 0.0100$ s,

$\omega = \dfrac{0.253\text{ rad}}{0.0100\text{ s}} = \boxed{25.3\text{ rad/s}}$

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

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

**33.5** $i_R = I_{\max} \sin \omega t$ becomes $0.600 = \sin(\omega\ 0.00700)$

Thus, $(0.00700)\omega = \sin^{-1}(0.600) = 0.644$

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

**33.6** $\mathcal{P} = I_{rms}(\Delta V_{rms})$ and $\Delta V_{rms} = 120$ V for each bulb (parallel circuit), so:

$$I_1 = I_2 = \frac{\mathcal{P}_1}{\Delta V_{rms}} = \frac{150 \text{ W}}{120 \text{ V}} = \boxed{1.25 \text{ A}}, \quad \text{and} \quad R_1 = \frac{\Delta V_{rms}}{I_1} = \frac{120 \text{ V}}{1.25 \text{ A}} = \boxed{96.0\ \Omega} = R_2$$

$$I_3 = \frac{\mathcal{P}_3}{\Delta V_{rms}} = \frac{100 \text{ W}}{120 \text{ V}} = \boxed{0.833 \text{ A}}, \quad \text{and} \quad R_3 = \frac{\Delta V_{rms}}{I_3} = \frac{120 \text{ V}}{0.833 \text{ A}} = \boxed{144\ \Omega}$$

**33.7** $\Delta V_{max} = 15.0$ V and $R_{total} = 8.20\ \Omega + 10.4\ \Omega = 18.6\ \Omega$

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

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

**33.8** For $I_{max} = 80.0$ mA, $I_{rms} = \dfrac{80.0 \text{ mA}}{\sqrt{2}} = 56.6$ mA

$$(X_L)_{min} = \frac{V_{rms}}{I_{rms}} = \frac{50.0 \text{ V}}{0.0566 \text{ A}} = 884\ \Omega$$

$$X_L = 2\pi f L \rightarrow L = \frac{X_L}{2\pi f} \geq \frac{884\ \Omega}{2\pi(20.0)} \geq \boxed{7.03 \text{ H}}$$

**33.9** (a) $X_L = \dfrac{\Delta V_{max}}{I_{max}} = \dfrac{100}{7.50} = 13.3\ \Omega$

$$L = \frac{X_L}{\omega} = \frac{13.3}{2\pi(50.0)} = 0.0424 \text{ H} = \boxed{42.4 \text{ mH}}$$

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

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

**33.10** At 50.0 Hz, $X_L = 2\pi(50.0 \text{ Hz})L = 2\pi(50.0 \text{ Hz})\left(\dfrac{X_L\big|_{60.0 \text{ Hz}}}{2\pi(60.0 \text{ Hz})}\right) = \dfrac{50.0}{60.0}(54.0\ \Omega) = 45.0\ \Omega$

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

**33.11** $$i_L(t) = \frac{\Delta V_{\max}}{\omega L}\sin(\omega t - \pi/2) = \frac{(80.0\text{ V})\sin\left[(65.0\pi)(0.0155) - \pi/2\right]}{(65.0\pi\text{ rad/s})(70.0\times 10^{-3}\text{ H})}$$

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

**33.12** $$\omega = 2\pi f = 2\pi(60.0\text{ / s}) = 377\text{ rad / s}$$

$$X_L = \omega L = (377\text{ / s})(0.0200\text{ V}\cdot\text{s / A}) = 7.54\ \Omega$$

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

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

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

$$U = \tfrac{1}{2}Li^2 = \tfrac{1}{2}\left(0.0200\ \frac{\text{V}\cdot\text{s}}{\text{A}}\right)(19.5\text{ A})^2 = \boxed{3.80\text{ J}}$$

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

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

**33.14** (a) $X_C = \dfrac{1}{2\pi fC}$: $\dfrac{1}{2\pi f(22.0\times 10^{-6})} < 175\ \Omega$

$$\frac{1}{2\pi(22.0\times 10^{-6})(175)} < f \qquad \boxed{f > 41.3\text{ Hz}}$$

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

**33.15** $$I_{\max} = \sqrt{2}\,I_{\text{rms}} = \frac{\sqrt{2}(\Delta V_{\text{rms}})}{X_C} = \sqrt{2}(\Delta V_{\text{rms}})2\pi fC$$

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

(b) $I_{\max} = \sqrt{2}\,(240\text{ V})2\pi(50.0\text{ / s})(2.20\times 10^{-6}\text{ F}) = \boxed{235\text{ mA}}$

**33.16** $Q_{max} = C(\Delta V_{max}) = C\left[\sqrt{2}(\Delta V_{rms})\right] = \boxed{\sqrt{2}\,C(\Delta V_{rms})}$

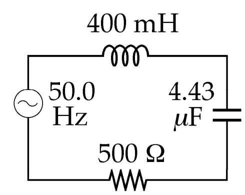
**33.17** $I_{max} = (\Delta V_{max})\omega C = (48.0\text{ V})(2\pi)(90.0\text{ s}^{-1})(3.70\times10^{-6}\text{ F}) = \boxed{100\text{ mA}}$

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

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

$$i_C = \frac{\Delta V_{max}}{X_C}\sin(\omega t + \phi) = \frac{\sqrt{2}\ (120\text{ V})}{2.65\ \Omega}\sin\left[2\pi\frac{60\text{ s}^{-1}}{180\text{ s}^{-1}} + 90.0°\right] = (64.0\text{ A})\sin(120° + 90.0°) = \boxed{-32.0\text{ A}}$$

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




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

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

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

(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 $\boxed{\text{Current leads the voltage.}}$

**33.20** $\omega L = \dfrac{1}{\omega C} \rightarrow \omega = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{(57.0\times10^{-6})(57.0\times10^{-6})}} = 1.75\times10^4\text{ rad / s}$

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

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

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

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

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

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

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

$\phi = -0.896\ \text{rad} = -51.3°$

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

**33.23** $X_L = 2\pi f L = 2\pi(60.0)(0.460) = 173\ \Omega$

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

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

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

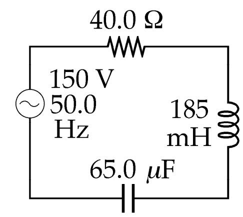
(b) Since $X_L > X_C$, $\phi$ is positive; so $\boxed{\text{voltage leads the current}}$.

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

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

$I_{\text{rms}} = \dfrac{\Delta V_{\text{rms}}}{Z} = \dfrac{5000\ \text{V}}{1.33 \times 10^8\ \Omega} = 3.77 \times 10^{-5}\ \text{A}$

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




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

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

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

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

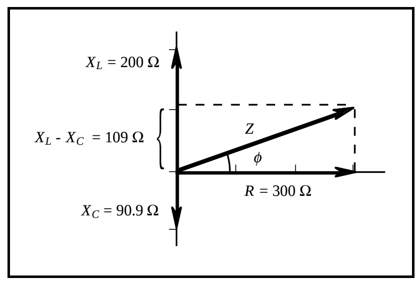
(a) $\Delta V_R = I_{\max} R = (3.66)(40) = \boxed{146\ \text{V}}$

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

**33.26** $R = 300\ \Omega$

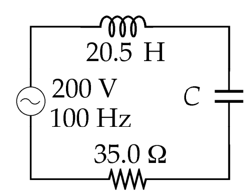



$X_L = \omega L = 2\pi\left(\dfrac{500}{\pi}\ \text{s}^{-1}\right)(0.200\ \text{H}) = 200\ \Omega$

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

$Z = \sqrt{R^2 + (X_L - X_C)^2} = 319\ \Omega$ and $\phi = \tan^{-1}\left(\dfrac{X_L - X_C}{R}\right) = 20.0°$

**33.27** (a) $X_L = 2\pi(100\ \text{Hz})(20.5\ \text{H}) = 1.29\times10^4\ \Omega$




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

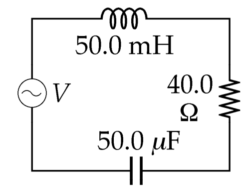
$(X_L - X_C)^2 = Z^2 - R^2 = (50.0\ \Omega)^2 - (35.0\ \Omega)^2$

$X_L - X_C = 1.29\times10^4\ \Omega - \dfrac{1}{2\pi(100\ \text{Hz})C} = \pm35.7\ \Omega$ $\boxed{C = 123\ \text{nF or } 124\ \text{nF}}$

(b) $\Delta V_{L,\text{rms}} = I_{\text{rms}} X_L = (4.00\ \text{A})\left(1.29\times10^4\ \Omega\right) = \boxed{51.5\ \text{kV}}$

Notice that this is a very large voltage!

**33.28** $X_L = \omega L = [(1000\ /\ \text{s})(0.0500\ \text{H})] = 50.0\ \Omega$




$X_C = 1/\omega C = \left[(1000\ /\ \text{s})(50.0 \times 10^{-6}\ \text{F})\right]^{-1} = 20.0\ \Omega$

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

$Z = \sqrt{(40.0)^2 + (50.0 - 20.0)^2} = 50.0\ \Omega$

(a) $I_{\text{rms}} = (\Delta V_{\text{rms}})\ /\ Z = 100\ \text{V}\ /\ 50.0\ \Omega$

$I_{\text{rms}} = \boxed{2.00\ \text{A}}$

$\phi = \text{Arctan}\left(\frac{X_L - X_C}{R}\right)$

$\phi = \text{Arctan}\ \frac{30.0\ \Omega}{40.0\ \Omega} = 36.9°$

(b) $\mathcal{P} = (\Delta V_{\text{rms}}) I_{\text{rms}} \cos\phi = 100\ \text{V}(2.00\ \text{A}) \cos 36.9° = \boxed{160\ \text{W}}$

(c) $\mathcal{P}_R = I_{\text{rms}}^2 R = (2.00\ \text{A})^2\ 40.0\ \Omega = \boxed{160\ \text{W}}$

**33.29** $\omega = 1000\ \text{rad/s}$, $R = 400\ \Omega$, $C = 5.00 \times 10^{-6}\ \text{F}$, $L = 0.500\ \text{H}$

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

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

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

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

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

**Goal Solution**

An ac voltage of the form $\Delta v = (100\text{ V})\sin(1000\,t)$ is applied to a series *RLC* circuit. If $R$ = 400 Ω, $C$ = 5.00 $\mu$F, and $L$ = 0.500 H, what is the average power delivered to the circuit?

**G:** Comparing $\Delta v = (100\text{ V})\sin(1000\,t)$ with $\Delta v = \Delta V_{\max}\sin\omega t$, we see that

$\Delta V_{\max} = 100\text{ V}$ and $\omega = 1000\text{ s}^{-1}$

Only the resistor takes electric energy out of the circuit, but the capacitor and inductor will impede the current flow and therefore reduce the voltage across the resistor. Because of this impedance, the average power dissipated by the resistor must be less than the maximum power from the source:

$$\mathcal{P}_{\max} = \frac{(\Delta V_{\max})^2}{2R} = \frac{(100\text{ V})^2}{2(400\ \Omega)} = 12.5\text{ W}$$

**O:** The actual power dissipated by the resistor can be found from $\mathcal{P} = I_{rms}^2 R$, where $I_{rms} = \Delta V_{rms}/Z$.

**A:** $\Delta V_{rms} = \dfrac{100}{\sqrt{2}} = 70.7\text{ V}$

In order to calculate the impedance, we first need the capacitive and inductive reactances:

$$X_C = \frac{1}{\omega C} = \frac{1}{(1000\text{ s}^{-1})(5.00\times 10^{-6}\text{ F})} = 200\ \Omega \quad \text{and} \quad X_L = \omega L = (1000\text{ s}^{-1})(0.500\text{ H}) = 500\ \Omega$$

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

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{Z} = \frac{70.7\text{ V}}{500\ \Omega} = 0.141\text{ A} \quad \text{and} \quad \mathcal{P} = I_{\text{rms}}^2 R = (0.141\text{ A})^2(400\ \Omega) = 8.00\text{ W}$$

**L:** The power dissipated by the resistor is less than 12.5 W, so our answer appears to be reasonable. As with other *RLC* circuits, the power will be maximized at the resonance frequency where $X_L = X_C$ so that $Z = R$. Then the average power dissipated will simply be the 12.5 W we calculated first.

**33.30**

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \text{or} \quad (X_L - X_C) = \sqrt{Z^2 - R^2}$$

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

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

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

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

**33.31** (a) $\mathcal{P} = I_{rms}(\Delta V_{rms})\cos\phi = (9.00)(180)\cos(-37.0°) = 1.29 \times 10^3\ \text{W}$

$\mathcal{P} = I_{rms}^2 R$ so $1.29 \times 10^3 = (9.00)^2 R$ 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 $X_L - X_C = \boxed{-12.0\ \Omega}$

***33.32** $X_L = \omega L = 2\pi(60.0\ /\ \text{s})(0.0250\ \text{H}) = 9.42\ \Omega$

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

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

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

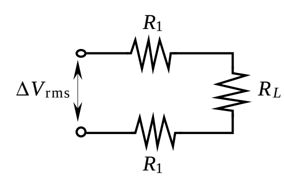
(c) We require $\phi = 0$. Thus, $X_L = X_C$: $9.42\ \Omega = \dfrac{1}{2\pi(60.0\ \text{s}^{-1})C}$

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

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

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

**33.33** Consider a two-wire transmission line:




$I_{rms} = \dfrac{\mathcal{P}}{\Delta V_{rms}} = \dfrac{100 \times 10^6\ \text{W}}{50.0 \times 10^3\ \text{V}} = 2.00 \times 10^3\ \text{A}$

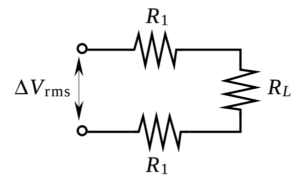
loss $= (0.0100)\mathcal{P} = I_{rms}^2 R_{line} = I_{rms}^2(2R_1)$

Thus, $R_1 = \dfrac{(0.0100)\mathcal{P}}{2I_{max}^2} = \dfrac{(0.0100)(100 \times 10^6\ \text{W})}{2(2.00 \times 10^3\ \text{A})^2} = 0.125\ \Omega$

But $R_1 = \dfrac{\rho \ell}{A}$ or $A = \dfrac{\pi d^2}{4} = \dfrac{\rho \ell}{R_1}$

Therefore $d = \sqrt{\dfrac{4\rho \ell}{\pi R_1}} = \sqrt{\dfrac{4(1.70 \times 10^{-8}\ \Omega \cdot \text{m})(100 \times 10^3\ \text{m})}{\pi(0.125\ \Omega)}} = 0.132\ \text{m} = \boxed{132\ \text{mm}}$

**33.34** Consider a two-wire transmission line:



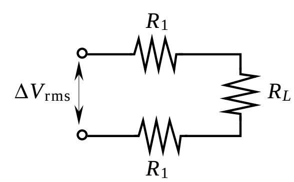

$$I_{rms} = \frac{\mathcal{P}}{\Delta V_{rms}} \quad \text{and} \quad \text{power loss} = I_{rms}^2 R_{line} = \frac{\mathcal{P}}{100}$$

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

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

and the diameter is $$2r = \boxed{\sqrt{\frac{800\rho \mathcal{P} d}{\pi (\Delta V_{rms})^2}}}$$

**33.35** 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




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

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

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

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

**33.36** At resonance, $$\frac{1}{2\pi f C} = 2\pi f L \quad \text{and} \quad \frac{1}{(2\pi f)^2 L} = C$$

The range of values for $C$ is $\boxed{46.5\text{ pF to }419\text{ pF}}$

**33.37** $$\omega_0 = 2\pi(99.7 \times 10^6) = 6.26 \times 10^8 \text{ rad / s} = \frac{1}{\sqrt{LC}}$$

$$C = \frac{1}{\omega_0^2 L} = \frac{1}{(6.26 \times 10^8)^2 (1.40 \times 10^{-6})} = \boxed{1.82\text{ pF}}$$

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

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

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

(c) From Equation 33.36, $Q = \frac{\omega_0 L}{R} = \boxed{22.4}$

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

**33.39** The resonance frequency is $\omega_0 = 1/\sqrt{LC}$. Thus, if $\omega = 2\omega_0$,

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

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

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

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

With the values specified for this circuit, this gives:

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

**33.40** The resonance frequency is $\omega_0 = 1/\sqrt{LC}$. Thus, if $\omega = 2\omega_0$,

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

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

and the energy dissipated in one period is

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

***33.41** For the circuit of problem 22, $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\left(160\times10^{-3}\text{ H}\right)\left(99.0\times10^{-6}\text{ F}\right)}} = 251 \text{ rad s}$

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

For the circuit of problem 23, $Q = \frac{\omega_0 L}{R} = \frac{L}{R\sqrt{LC}} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{150\ \Omega}\sqrt{\frac{460\times10^{-3}\text{ H}}{21.0\times10^{-6}\text{ F}}} = \boxed{0.987}$

The $\boxed{\text{circuit of problem 23}}$ has a sharper resonance.

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

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

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

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

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

**33.43** $\left(\Delta V_{\text{out}}\right)_{\max} = \frac{N_2}{N_1}\left(\Delta V_{\text{in}}\right)_{\max} = \left(\frac{2000}{350}\right)(170\text{ V}) = 971\text{ V}$

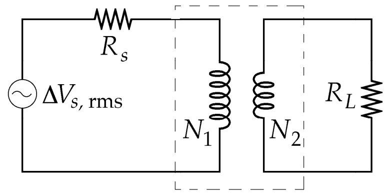
$$\left(\Delta V_{\text{out}}\right)_{\text{rms}} = \frac{(971\text{ V})}{\sqrt{2}} = \boxed{687\text{ V}}$$

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

(b) $I_{1,\text{rms}}\left(\Delta V_{1,\text{rms}}\right) = I_{2,\text{rms}}\left(\Delta V_{2,\text{rms}}\right)$ $I_{1,\text{rms}} = \frac{(1.50)(2200)}{110} = \boxed{30.0\text{ A}}$

(c) $0.950\, I_{1,\text{rms}}\left(\Delta V_{1,\text{rms}}\right) = I_{2,\text{rms}}\left(\Delta V_{2,\text{rms}}\right)$ $I_{1,\text{rms}} = \frac{(1.20)(2200)}{110(0.950)} = \boxed{25.3\text{ A}}$

**33.45** The rms voltage across the transformer primary is




$$\frac{N_1}{N_2}\left(\Delta V_{2,\text{rms}}\right)$$

so the source voltage is $\Delta V_{s,\text{rms}} = I_{1,\text{rms}} R_s + \frac{N_1}{N_2}\left(\Delta V_{2,\text{rms}}\right)$

The secondary current is $\frac{\left(\Delta V_{2,\text{rms}}\right)}{R_L}$, so the primary current is $\frac{N_2}{N_1}\frac{\left(\Delta V_{2,\text{rms}}\right)}{R_L} = I_{1,\text{rms}}$

Then $\Delta V_{s,\text{rms}} = \frac{N_2\left(\Delta V_{2,\text{rms}}\right)R_s}{N_1 R_L} + \frac{N_1\left(\Delta V_{2,\text{rms}}\right)}{N_2}$

and $R_s = \frac{N_1 R_L}{N_2\left(\Delta V_{2,\text{rms}}\right)}\left(\Delta V_{s,\text{rms}} - \frac{N_1\left(\Delta V_{2,\text{rms}}\right)}{N_2}\right) = \frac{5(50.0\ \Omega)}{2(25.0\ \text{V})}\left(80.0\ \text{V} - \frac{5(25.0\ \text{V})}{2}\right) = \boxed{87.5\ \Omega}$

**33.46** (a) $\Delta V_{2,\text{rms}} = \frac{N_2}{N_1}\left(\Delta V_{1,\text{rms}}\right)$ $\quad \frac{N_2}{N_1} = \frac{\Delta V_{2,\text{rms}}}{\Delta V_{1,\text{rms}}} = \frac{10.0\times 10^3\ \text{V}}{120\ \text{V}} = \boxed{83.3}$

(b) $I_{2,\text{rms}}\left(\Delta V_{2,\text{rms}}\right) = 0.900\, I_{1,\text{rms}}\left(\Delta V_{1,\text{rms}}\right)$

$I_{2,\text{rms}}\left(10.0\times 10^3\ \text{V}\right) = 0.900\left(\frac{120\ \text{V}}{24.0\ \Omega}\right)(120\ \text{V})$ $\qquad I_{2,\text{rms}} = \boxed{54.0\ \text{mA}}$

(c) $Z_2 = \frac{\Delta V_{2,\text{rms}}}{I_{2,\text{rms}}} = \frac{10.0\times 10^3\ \text{V}}{0.054\ \text{A}} = \boxed{185\ \text{k}\Omega}$

**33.47** (a) $R = (4.50\times 10^{-4}\ \Omega/\text{m})(6.44\times 10^5\ \text{m}) = 290\ \Omega$ and $I_{\text{rms}} = \frac{\mathcal{P}}{\Delta V_{\text{rms}}} = \frac{5.00\times 10^6\ \text{W}}{5.00\times 10^5\ \text{V}} = 10.0\ \text{A}$

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

(b) $\frac{\mathcal{P}_{\text{loss}}}{\mathcal{P}} = \frac{2.90\times 10^4}{5.00\times 10^6} = \boxed{5.80\times 10^{-3}}$

(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

$\frac{(4.50\times 10^3\ \text{V})^2}{2\cdot 2(290\ \Omega)} = 17.5\ \text{kW}$, far below the required 5000 kW

**33.48** For the filter circuit, $\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{X_C}{\sqrt{R^2 + X_C^2}}$

(a) At $f = 600$ Hz, $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(600 \text{ Hz})(8.00 \times 10^{-9} \text{ F})} = 3.32 \times 10^4\ \Omega$

and $\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{3.32 \times 10^4\ \Omega}{\sqrt{(90.0\ \Omega)^2 + (3.32 \times 10^4\ \Omega)^2}} \approx \boxed{1.00}$

(b) At $f = 600$ kHz, $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(600 \times 10^3 \text{ Hz})(8.00 \times 10^{-9} \text{ F})} = 33.2\ \Omega$

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

**33.49** For this RC high-pass filter, $\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{R}{\sqrt{R^2 + X_C^2}}$

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

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

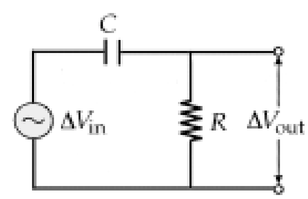
If this occurs at $f = 300$ Hz, the capacitance is

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

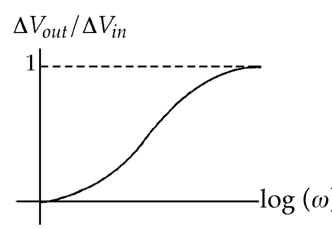
(b) With this capacitance and a frequency of 600 Hz,

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

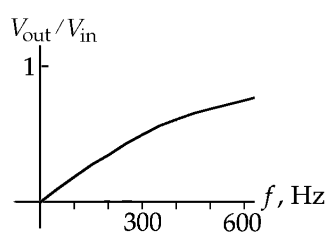
$$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{R}{\sqrt{R^2 + X_C^2}} = \frac{0.500\ \Omega}{\sqrt{(0.500\ \Omega)^2 + (0.433\ \Omega)^2}} = \boxed{0.756}$$



(a)



(b)



(c)

**Figures for Goal Solution**

**Goal Solution**

The $RC$ high-pass filter shown in Figure 33.22 has a resistance $R = 0.500\ \Omega$. (a) What capacitance gives an output signal that has one-half the amplitude of a 300-Hz input signal? (b) What is the gain ($\Delta V_{out} / \Delta V_{in}$) for a 600-Hz signal?

**G:** It is difficult to estimate the capacitance required without actually calculating it, but we might expect a typical value in the $\mu$F to pF range. The nature of a high-pass filter is to yield a larger gain at higher frequencies, so if this circuit is designed to have a gain of 0.5 at 300 Hz, then it should have a higher gain at 600 Hz. We might guess it is near 1.0 based on Figure (b) above.

**O:** The output voltage of this circuit is taken across the resistor, but the input sees the impedance of the resistor and the capacitor. Therefore, the gain will be the ratio of the resistance to the impedance.

**A:** $$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{R}{\sqrt{R^2 + (1/\omega C)^2}}$$

(a) When $\Delta V_{out} / \Delta V_{in} = 0.500$

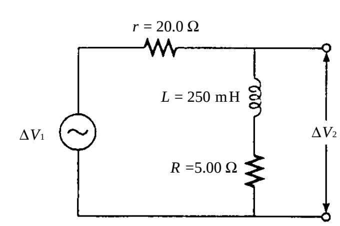
solving for $C$ gives $$C = \frac{1}{\omega R \sqrt{\left(\frac{\Delta V_{\text{in}}}{\Delta V_{\text{out}}}\right)^2 - 1}} = \frac{1}{(2\pi)(300\text{ Hz})(0.500\ \Omega)\sqrt{(2.00)^2 - 1}} = 613\ \mu\text{F}$$

(b) At 600 Hz, we have $\omega = (2\pi\text{ rad})(600\text{ s}^{-1})$

so $$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{0.500\ \Omega}{\sqrt{(0.500\ \Omega)^2 + \left(\frac{1}{(1200\pi\text{ rad / s})(613\ \mu\text{F})}\right)^2}} = 0.756$$

**L:** The capacitance value seems reasonable, but the gain is considerably less than we expected. Based on our calculation, we can modify the graph in Figure (b) to more transparently represent the characteristics of this high-pass filter, now shown in Figure (c). If this were an audio filter, it would reduce low frequency "humming" sounds while allowing high pitch sounds to pass through. A low pass filter would be needed to reduce high frequency "static" noise.

**33.50** $\Delta V_1 = I\sqrt{(r+R)^2 + X_L^2}$, and $\Delta V_2 = I\sqrt{R^2 + X_L^2}$

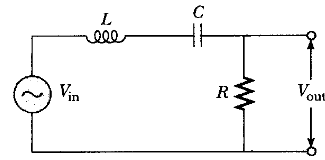



Thus, when $\Delta V_1 = 2\Delta V_2$ $\quad (r+R)^2 + X_L^2 = 4(R^2 + X_L^2)$

or $\quad (25.0\ \Omega)^2 + X_L^2 = 4(5.00\ \Omega)^2 + 4X_L^2$

which gives $\quad X_L = 2\pi f(0.250\text{ H}) = \sqrt{\frac{625 - 100}{3}}\ \Omega$ and $f = \boxed{8.42\text{ Hz}}$

***33.51** $\frac{\Delta V_{out}}{\Delta V_{in}} = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$




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

At 4000 Hz: $(8.00\ \Omega)^2 + \left[8000\pi L - \frac{1}{8000\pi C}\right]^2 = 4(8.00\ \Omega)^2$

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

For the high frequency half-voltage point, $8000\pi L - \frac{1}{8000\pi C} = +13.9\ \Omega$ [2]

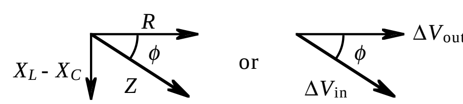
Solving Equations (1) and (2) simultaneously gives $C = \boxed{54.6\ \mu\text{F}}$ and $L = \boxed{580\ \mu\text{H}}$

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

(c) $X_L = X_C$ requires $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(5.80\times 10^{-4}\ \text{H})(5.46\times 10^{-5}\ \text{F})}} = \boxed{894\ \text{Hz}}$

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

so the phasor diagram is as shown:

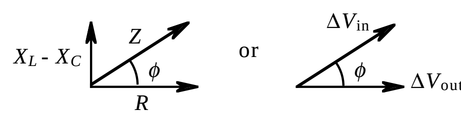



$\phi = -\cos^{-1}\left(\frac{R}{Z}\right) = -\cos^{-1}\left(\frac{1}{2}\right)$ so $\boxed{\Delta V_{out} \text{ leads } \Delta V_{in} \text{ by } 60.0°}$

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 4000 Hz, $\frac{\Delta V_{out}}{\Delta V_{in}} = \frac{R}{Z} = \frac{1}{2}$ and $X_L - X_C > 0$

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




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

(e) At 200 Hz and at 4 kHz, $\mathcal{P} = \frac{(\Delta V_{out,rms})^2}{R} = \frac{\left(\frac{1}{2}\Delta V_{in,rms}\right)^2}{R} = \frac{\frac{1}{2}\left(\frac{1}{2}\Delta V_{in,max}\right)^2}{R} = \frac{(10.0\ \text{V})^2}{8(8.00\ \Omega)} = \boxed{1.56\ \text{W}}$

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

(f) We take: $Q = \frac{\omega_0 L}{R} = \frac{2\pi f_0 L}{R} = \frac{2\pi(894\ \text{Hz})(5.80\times 10^{-4}\ \text{H})}{8.00\ \Omega} = \boxed{0.408}$

**33.52** For a high-pass filter,
$$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$$

$$\frac{(\Delta V_{\text{out}})_1}{(\Delta V_{\text{in}})_1} = \frac{R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} \quad \text{and} \quad \frac{(\Delta V_{\text{out}})_2}{(\Delta V_{\text{in}})_2} = \frac{R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$$

Now $(\Delta V_{\text{in}})_2 = (\Delta V_{\text{out}})_1$ so
$$\frac{(\Delta V_{\text{out}})_2}{(\Delta V_{\text{in}})_1} = \frac{R^2}{R^2 + \left(\frac{1}{\omega C}\right)^2} = \boxed{\frac{1}{1 + \left(\frac{1}{\omega RC}\right)^2}}$$

**33.53** Rewrite the circuit in terms of impedance as shown in Fig. (b).

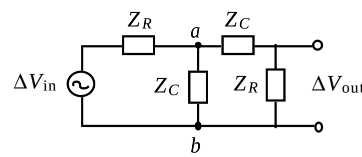


Figure (a)

Find:
$$\Delta V_{\text{out}} = \frac{Z_R}{Z_R + Z_C}\Delta V_{ab} \qquad [1]$$

From Figure (c),
$$\Delta V_{ab} = \frac{Z_C \parallel (Z_R + Z_C)}{Z_R + Z_C \parallel (Z_R + Z_C)}\Delta V_{\text{in}}$$

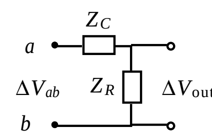


Figure (b)

So Eq. [1] becomes
$$\Delta V_{\text{out}} = \frac{Z_R[Z_C \parallel (Z_R + Z_C)]}{(Z_R + Z_C)[Z_R + Z_C \parallel (Z_R + Z_C)]}\Delta V_{\text{in}}$$

or
$$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{Z_R\left[\frac{1}{Z_C} + \frac{1}{Z_R + Z_C}\right]^{-1}}{(Z_R + Z_C)\left[Z_R + \left(\frac{1}{Z_C} + \frac{1}{Z_R + Z_C}\right)^{-1}\right]}$$

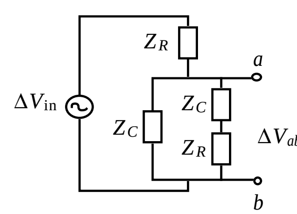
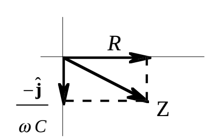


Figure (c)

$$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{Z_R Z_C}{Z_C(Z_C + Z_R) + Z_R(Z_R + 2Z_C)} = \frac{Z_R}{3Z_R + Z_C + (Z_R)^2 / Z_C}$$

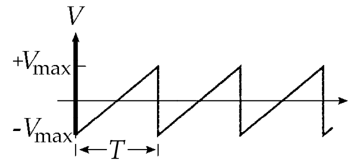
Now, $Z_R = R$ and $Z_C = \frac{-\mathrm{j}}{\omega C}$ where $\mathrm{j} = \sqrt{-1}$




$$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{R}{3R - \left(\frac{1}{\omega C}\right)\mathrm{j} + R^2\omega C\,\mathrm{j}}$$ where we used $\frac{1}{\mathrm{j}} = -\mathrm{j}$.

$$\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{R}{3R - \left(\frac{1}{\omega C} - R^2\omega C\right)\mathrm{j}} = \frac{R}{\sqrt{(3R)^2 + \left(\frac{1}{\omega C} - R^2\omega C\right)^2}} = \frac{1.00 \times 10^3}{\sqrt{(3.00 \times 10^3)^2 + (1592 - 628)^2}} = \boxed{0.317}$$

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




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

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

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

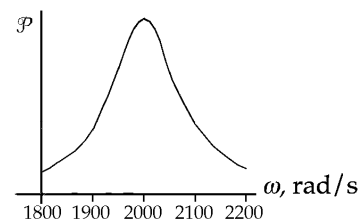
$$\Delta V_{\text{rms}} = \sqrt{\left[(\Delta v)^2\right]_{\text{ave}}} = \sqrt{\frac{(\Delta V_{\max})^2}{3}} = \boxed{\frac{\Delta V_{\max}}{\sqrt{3}}}$$

**33.55** $\omega_0 = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{(0.0500\text{ H})(5.00\times 10^{-6}\text{ F})}} = 2000\text{ s}^{-1}$

so the operating frequency of the circuit is $\omega = \dfrac{\omega_0}{2} = 1000\text{ s}^{-1}$

Using Equation 33.35, $\mathcal{P} = \dfrac{(\Delta V_{\text{rms}})^2 R\omega^2}{R^2\omega^2 + L^2\left(\omega^2 - \omega_0^2\right)^2}$

$$\mathcal{P} = \frac{(400)^2(8.00)(1000)^2}{(8.00)^2(1000)^2 + (0.0500)^2\left[(1.00 - 4.00)\times 10^6\right]^2} = \boxed{56.7\text{ W}}$$




$(Q \approx 12.5)$

**Figure for Goal Solution**

**Goal Solution**

A series *RLC* circuit consists of an 8.00-Ω resistor, a 5.00-μF capacitor, and a 50.0-mH inductor. A variable frequency source applies an emf of 400 V (rms) across the combination. Determine the power delivered to the circuit when the frequency is equal to one half the resonance frequency.

**G:** Maximum power is delivered at the resonance frequency, and the power delivered at other frequencies depends on the quality factor, $Q$. For the relatively small resistance in this circuit, we could expect a high $Q = \omega_0 L/R$. So at half the resonant frequency, the power should be a small fraction of the maximum power, $\mathcal{P}_{av,\max} = \Delta V_{rms}^2/R = (400\text{ V})^2/8\ \Omega = 20\text{ kW}$.

**O:** We must first calculate the resonance frequency in order to find half this frequency. Then the power delivered by the source must equal the power taken out by the resistor. This power can be found from $\mathcal{P}_{av} = I_{rms}^2 R$ where $I_{rms} = \Delta V_{rms} / Z$.

**A:** The resonance frequency is $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(0.0500 \text{ H})(5.00\times10^{-6} \text{ F})}} = 318 \text{ Hz}$

The operating frequency is $f = f_0 / 2 = 159 \text{ Hz}$. We can calculate the impedance at this frequency:

$X_L = 2\pi f L = 2\pi(159 \text{ Hz})(0.0500 \text{ H}) = 50.0\ \Omega$ and $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(159 \text{ Hz})(5.00\times10^{-6} \text{ F})} = 200\ \Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{8.00^2 + (50.0 - 200)^2}\ \Omega = 150\ \Omega$

So, $I_{rms} = \frac{\Delta V_{rms}}{Z} = \frac{400 \text{ V}}{150\ \Omega} = 2.66 \text{ A}$

The power delivered by the source is the power dissipated by the resistor:

$\mathcal{P}_{av} = I_{rms}{}^2 R = (2.66 \text{ A})^2(8.00\ \Omega) = 56.7 \text{ W}$

**L:** This power is only about 0.3% of the 20 kW peak power delivered at the resonance frequency. The significant reduction in power for frequencies away from resonance is a consequence of the relatively high $Q$-factor of about 12.5 for this circuit. A high $Q$ is beneficial if, for example, you want to listen to your favorite radio station that broadcasts at 101.5 MHz, and you do not want to receive the signal from another local station that broadcasts at 101.9 MHz.

**33.56** The resistance of the circuit is $R = \frac{\Delta V}{I} = \frac{12.0 \text{ V}}{0.630 \text{ A}} = 19.0\ \Omega$

The impedance of the circuit is $Z = \frac{\Delta V_{\text{rms}}}{I_{\text{rms}}} = \frac{24.0 \text{ V}}{0.570 \text{ A}} = 42.1\ \Omega$

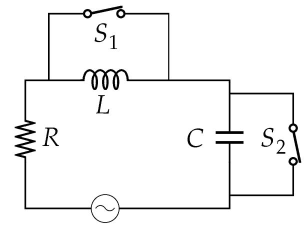
$Z^2 = R^2 + \omega^2 L^2$

$L = \frac{1}{\omega}\sqrt{Z^2 - R^2} = \frac{1}{377}\sqrt{(42.1)^2 - (19.0)^2} = \boxed{99.6 \text{ mH}}$

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

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

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




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

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

(c) $$\boxed{i(t) = \frac{\Delta V_{max}}{\sqrt{R^2 + \omega^2 L^2}} \cos[\omega t + \text{Arctan}(\omega L / R)]}$$

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

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

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

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

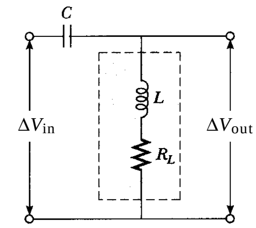
$$U_{max} = \frac{1}{2}C I_{max}^2 X_C{}^2 = \frac{1}{2}C\frac{(\Delta V_{max})^2}{R^2}\frac{1}{\omega_0{}^2 C^2} = \boxed{\frac{(\Delta V_{max})^2 L}{2R^2}}$$

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

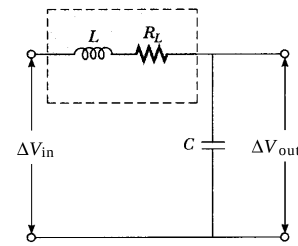
(h) Now $\omega = 2\omega_0 = \frac{2}{\sqrt{LC}}$

So $$\phi = \text{Arctan}\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right) = \text{Arctan}\left(\frac{2\sqrt{\frac{L}{C}} - \frac{1}{2}\sqrt{\frac{L}{C}}}{R}\right) = \boxed{\text{Arctan}\left(\frac{3}{2R}\sqrt{\frac{L}{C}}\right)}$$

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



Circuit (a)



Circuit (b)

**33.59** (a) As shown in part (b), **circuit (a) is a high-pass filter**

and **circuit (b) is a low-pass filter**.

(b) For circuit (a),

$$\frac{\Delta V_{out}}{\Delta V_{in}} = \frac{\sqrt{R_L^2 + X_L^2}}{\sqrt{R_L^2 + (X_L - X_C)^2}} = \boxed{\frac{\sqrt{R_L^2 + (\omega L)^2}}{\sqrt{R_L^2 + (\omega L - 1/\omega C)^2}}}$$

As $\omega \to 0$, $\frac{\Delta V_{out}}{\Delta V_{in}} \approx \omega R_L C \approx 0$

As $\omega \to \infty$, $\frac{\Delta V_{out}}{\Delta V_{in}} \approx 1$ (high-pass filter)

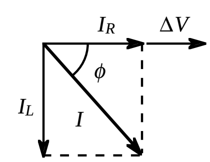
For circuit (b),

$$\frac{\Delta V_{out}}{\Delta V_{in}} = \frac{X_C}{\sqrt{R_L^2 + (X_L - X_C)^2}} = \boxed{\frac{1/\omega C}{\sqrt{R_L^2 + (\omega L - 1/\omega C)^2}}}$$

As $\omega \to 0$, $\frac{\Delta V_{out}}{\Delta V_{in}} \approx 1$

As $\omega \to \infty$, $\frac{\Delta V_{out}}{\Delta V_{in}} \approx \frac{1}{\omega^2 LC} \approx 0$ (low-pass filter)

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




(b) The total current will **lag** the applied voltage as seen in the phasor diagram at the right.

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

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

***33.61** 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

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

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

**33.62** $L = 2.00\text{ H},\ C = 10.0\times10^{-6}\text{ F},\ R = 10.0\ \Omega,\ \Delta v(t) = (100\sin\omega t)$

(a) The resonant frequency $\omega_0$ produces the maximum current and thus the maximum power dissipation in the resistor.

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(2.00)(10.0\times10^{-6})}} = \boxed{224\text{ rad/s}}$$

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

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

$$I_{\text{rms}}^2 R = \frac{1}{2}\left(I_{\text{rms}}^2\right)_{\max} R$$ or $$\frac{(\Delta V_{\text{rms}})^2}{Z^2}R = \frac{1}{2}\frac{(\Delta V_{\text{rms}})^2}{R^2}R$$

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

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

$$\left[(2.00)^2(10.0\times10^{-6})^2\right]\omega^4 - \left[2(2.00)(10.0\times10^{-6}) + (10.0)^2(10.0\times10^{-6})^2\right]\omega^2 + 1 = 0$$

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

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

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

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

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

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \boxed{36.8^\circ}$$ ($\Delta V$ leads $I$)

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

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

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

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

$$250 = \frac{(120)^2(40.0)}{(40.0)^2 + \left[2\pi f(0.185) - \dfrac{1}{2\pi f\left(65.0\times 10^{-6}\right)}\right]^2} \quad \text{and} \quad 250 = \frac{576\,000\, f^2}{1600 f^2 + \left(1.1624 f^2 - 2448.5\right)^2}$$

$$1 = \frac{2304\, f^2}{1600 f^2 + 1.3511 f^4 - 5692.3 f^2 + 5\,995\,300} \quad \text{so} \quad 1.3511 f^4 - 6396.3 f^2 + 5\,995\,300 = 0$$

$$f^2 = \frac{6396.3 \pm \sqrt{(6396.3)^2 - 4(1.3511)(5\,995\,300)}}{2(1.3511)} = 3446.5 \text{ or } 1287.4$$

$f = \boxed{58.7 \text{ Hz or } 35.9 \text{ Hz}}$

**33.65** (a) From Equation 33.39, $\dfrac{N_1}{N_2} = \dfrac{\Delta V_1}{\Delta V_2}$

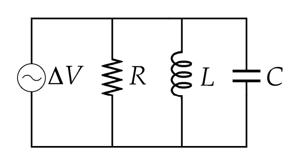
Let output impedance $Z_1 = \dfrac{\Delta V_1}{I_1}$ and the input impedance $Z_2 = \dfrac{\Delta V_2}{I_2}$

so that $\dfrac{N_1}{N_2} = \dfrac{Z_1 I_1}{Z_2 I_2}$ But from Eq. 33.40, $\dfrac{I_1}{I_2} = \dfrac{\Delta V_2}{\Delta V_1} = \dfrac{N_2}{N_1}$

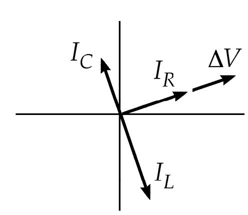
So, combining with the previous result we have $\boxed{\dfrac{N_1}{N_2} = \sqrt{\dfrac{Z_1}{Z_2}}}$

(b) $\dfrac{N_1}{N_2} = \sqrt{\dfrac{Z_1}{Z_2}} = \sqrt{\dfrac{8000}{8.00}} = \boxed{31.6}$

**33.66** $I_R = \dfrac{\Delta V_{\text{rms}}}{R}$; $I_L = \dfrac{\Delta V_{\text{rms}}}{\omega_L}$; $I_C = \dfrac{\Delta V_{\text{rms}}}{(\omega C)^{-1}}$

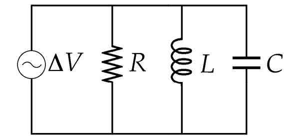


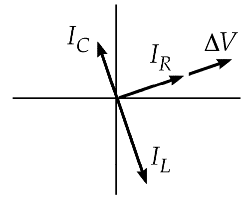

(a) $I_{\text{rms}} = \sqrt{I_R^2 + (I_C - I_L)^2} = \boxed{\Delta V_{\text{rms}} \sqrt{\left(\dfrac{1}{R^2}\right) + \left(\omega C - \dfrac{1}{\omega L}\right)^2}}$




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

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




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

$\Delta V_{\text{rms}} \to (\Delta V_{\text{rms}})_{\max}$ when $\omega C = \frac{1}{\omega L}$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f = \frac{1}{2\pi\sqrt{200\times10^{-3}\text{ H})(0.150\times10^{-6}\text{ F})}} = \boxed{919\text{ Hz}}$$

(b) $I_R = \frac{\Delta V_{\text{rms}}}{R} = \frac{120\text{ V}}{80.0\ \Omega} = \boxed{1.50\text{ A}}$

$$I_L = \frac{\Delta V_{\text{rms}}}{\omega L} = \frac{120\text{ V}}{(374\text{ s}^{-1})(0.200\text{ H})} = \boxed{1.60\text{ A}}$$

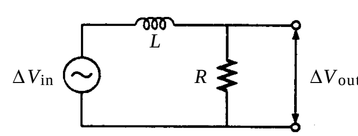
$$I_C = \Delta V_{\text{rms}}(\omega C) = (120\text{ V})(374\text{ s}^{-1})(0.150\times10^{-6}\text{ F}) = \boxed{6.73\text{ mA}}$$

(c) $I_{\text{rms}} = \sqrt{I_R^2 + (I_C - I_L)^2} = \sqrt{(1.50)^2 + (0.00673 - 1.60)^2} = \boxed{2.19\text{ A}}$

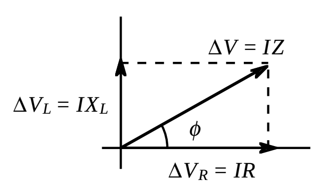
(d) $\phi = \tan^{-1}\left[\frac{I_C - I_L}{I_R}\right] = \tan^{-1}\left[\frac{0.00673 - 1.60}{1.50}\right] = \boxed{-46.7°}$

The $\boxed{\text{current is lagging the voltage}}$ .

**33.68** (a) $\tan\phi = \frac{\Delta V_L}{\Delta V_R} = \frac{I(\omega L)}{IR} = \frac{\omega L}{R}$




Thus, $R = \frac{\omega L}{\tan\phi} = \frac{(200\text{ s}^{-1})(0.500\text{ H})}{\tan(30.0°)} = \boxed{173\ \Omega}$




(b) $\frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \frac{\Delta V_R}{\Delta V_{\text{in}}} = \cos\phi$

$$\Delta V_{\text{out}} = (\Delta V_{\text{in}})\cos\phi = (10.0\text{ V})\cos 30.0° = \boxed{8.66\text{ V}}$$

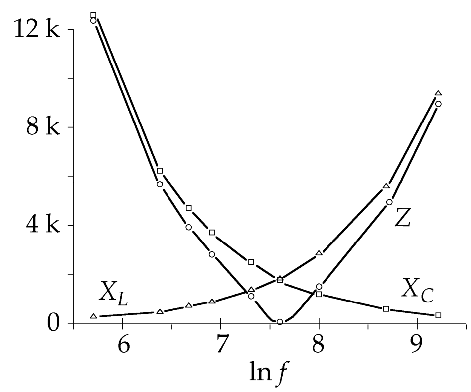
**33.69** (a) $X_L = X_C = 1884\ \Omega$ when $f = 2000$ Hz

$$L = \frac{X_L}{2\pi f} = \frac{1884\ \Omega}{4000\pi\ \text{rad/s}} = 0.150\ \text{H} \quad \text{and} \quad C = \frac{1}{(2\pi f)X_C} = \frac{1}{(4000\pi\ \text{rad/s})(1884\ \Omega)} = 42.2\ \text{nF}$$

$$X_L = 2\pi f(0.150\ \text{H}) \quad X_C = \frac{1}{(2\pi f)(4.22\times 10^{-8}\ \text{F})} \quad Z = \sqrt{(40.0\ \Omega)^2 + (X_L - X_C)^2}$$

| $f$ (Hz) | $X_L$ (Ω) | $X_C$ (Ω) | $Z$ (Ω) |
|---|---|---|---|
| 300 | 283 | 12600 | 12300 |
| 600 | 565 | 6280 | 5720 |
| 800 | 754 | 4710 | 3960 |
| 1000 | 942 | 3770 | 2830 |
| 1500 | 1410 | 2510 | 1100 |
| 2000 | 1880 | 1880 | 40 |
| 3000 | 2830 | 1260 | 1570 |
| 4000 | 3770 | 942 | 2830 |
| 6000 | 5650 | 628 | 5020 |
| 10000 | 9420 | 377 | 9040 |

(b)




**33.70** $\omega_0 = \dfrac{1}{\sqrt{LC}} = 1.00 \times 10^6$ rad/s

For each angular frequency, we find

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

then $I = (1.00\ \text{V}) / Z$

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

| $\omega/\omega_0$ | $\omega L$ (Ω) | $\dfrac{1}{\omega C}$ (Ω) | $Z$ (Ω) | $\mathsf{P} = I^2R$ (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 |

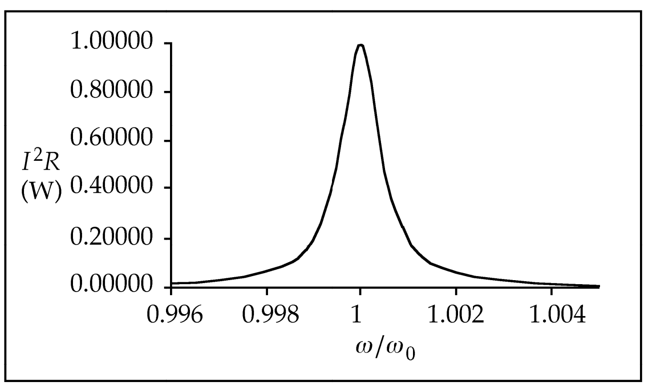
The full width at half maximum is:

$$\Delta f = \frac{\Delta\omega}{2\pi} = \frac{(1.0005 - 0.9995)\omega_0}{2\pi}$$

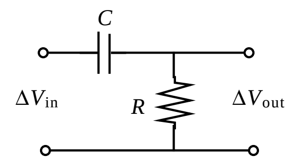
$$\Delta f = \frac{1.00\times 10^3\ \text{s}^{-1}}{2\pi} = 159\ \text{Hz}$$

while

$$\frac{R}{2\pi L} = \frac{1.00\ \Omega}{2\pi(1.00\times 10^{-3}\ \text{H})} = 159\ \text{Hz}$$



**33.71** $\dfrac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \dfrac{R}{\sqrt{R^2 + (1/\omega C)^2}} = \dfrac{R}{\sqrt{R^2 + (1/2\pi f C)^2}}$




(a) $\dfrac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} = \dfrac{1}{2}$ when $\dfrac{1}{\omega C} = R\sqrt{3}$

Hence, $f = \dfrac{\omega}{2\pi} = \dfrac{1}{2\pi RC\sqrt{3}} = \boxed{1.84\text{ kHz}}$

(b)