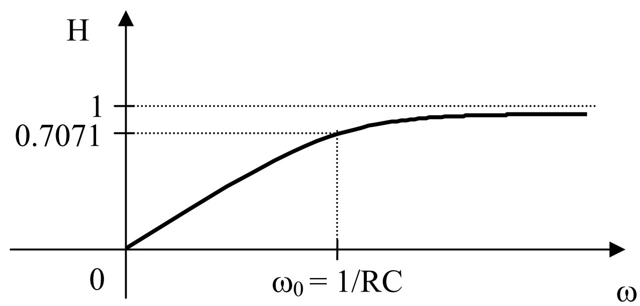
Chapter 14, Solution 1.

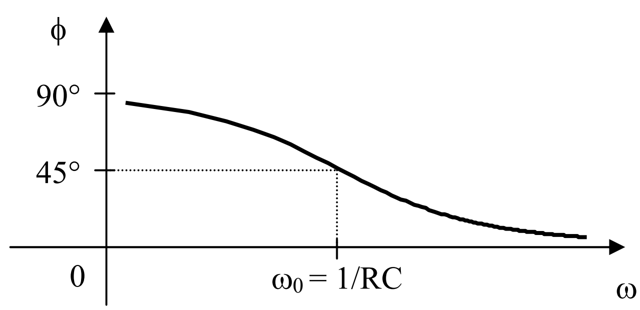
$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + 1/j\omega C} = \frac{j\omega RC}{1 + j\omega RC}$$

$$\underline{\mathbf{H}(\omega) = \frac{j\omega/\omega_0}{1 + j\omega/\omega_0}}, \qquad \text{where } \underline{\omega_0 = \frac{1}{RC}}$$

$$H = |\mathbf{H}(\omega)| = \frac{\omega/\omega_0}{\sqrt{1 + (\omega/\omega_0)^2}} \qquad \phi = \angle\mathbf{H}(\omega) = \frac{\pi}{2} - \tan^{-1}\left(\frac{\omega}{\omega_0}\right)$$

This is a highpass filter. The frequency response is the same as that for P.P.14.1 except that $\omega_0 = 1/RC$. Thus, the sketches of H and ϕ are shown below.



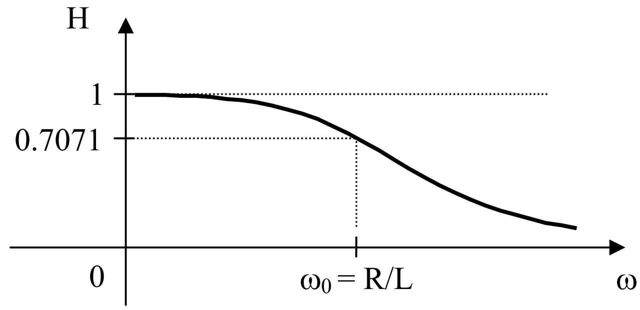


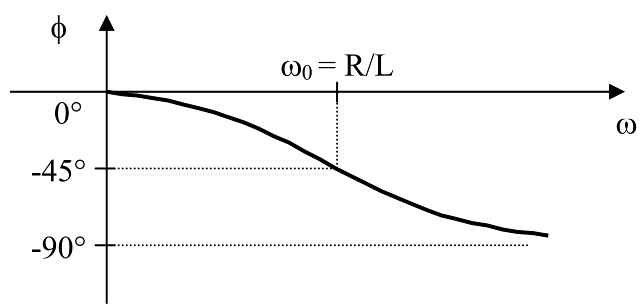
Chapter 14, Solution 2.

$$\mathbf{H}(\omega) = \frac{R}{R + j\omega L} = \frac{1}{1 + j\omega L/R} = \underline{\frac{\mathbf{1}}{\mathbf{1 + j\omega/\omega_0}}}, \qquad \text{where } \underline{\boldsymbol{\omega_0} = \frac{\mathbf{R}}{\mathbf{L}}}$$

$$H = \left|\mathbf{H}(\omega)\right| = \frac{1}{\sqrt{1 + (\omega/\omega_0)^2}} \qquad \phi = \angle\mathbf{H}(\omega) = -\tan^{-1}\left(\frac{\omega}{\omega_0}\right)$$

The frequency response is identical to the response in Example 14.1 except that $\omega_0 = R/L$. Hence the response is shown below.



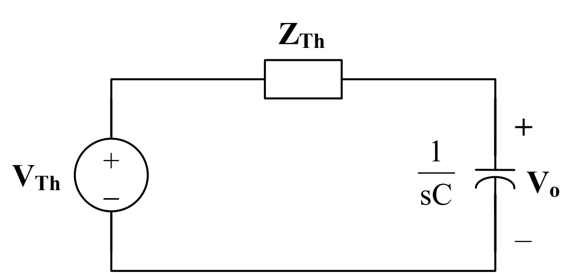


Chapter 14, Solution 3.

(a) The Thevenin impedance across the second capacitor where $\mathbf{V}_o$ is taken is

$$\mathbf{Z}_{Th} = R + R \,||\, 1/sC = R + \frac{R}{1 + sRC}$$

$$\mathbf{V}_{Th} = \frac{1/sC}{R + 1/sC}\mathbf{V}_i = \frac{\mathbf{V}_i}{1 + sRC}$$



$$\mathbf{V}_o = \frac{1/sC}{\mathbf{Z}_{Th} + 1/sC} \cdot \mathbf{V}_{Th} = \frac{\mathbf{V}_i}{(1+sRC)(1+sC\mathbf{Z}_{Th})}$$

$$\mathbf{H}(s) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1}{(1+sC\mathbf{Z}_{Th})(1+sRC)} = \frac{1}{(1+sRC)(1+sRC+sRC/(1+sRC))}$$

$$\mathbf{H}(s) = \underline{\frac{\mathbf{1}}{\mathbf{s^2R^2C^2 + 3sRC + 1}}}$$

(b) $\quad RC = (40\times10^3)(2\times10^{-6}) = 80\times10^{-3} = 0.08$

There are <u>no zeros</u> and the poles are at

$$s_1 = \frac{-0.383}{RC} = \underline{\mathbf{-4.787}}$$

$$s_2 = \frac{-2.617}{RC} = \underline{\mathbf{-32.712}}$$

Chapter 14, Solution 4.

(a) $\quad R \parallel \dfrac{1}{j\omega C} = \dfrac{R}{1+j\omega RC}$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\dfrac{R}{1+j\omega RC}}{j\omega L + \dfrac{R}{1+j\omega RC}} = \frac{R}{R + j\omega L(1+j\omega RC)}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{R}}{\mathbf{-\omega^2 RLC + R + j\omega L}}}$$

(b) $\quad \mathbf{H}(\omega) = \dfrac{R + j\omega L}{R + j\omega L + 1/j\omega C} = \dfrac{j\omega C(R + j\omega L)}{1 + j\omega C(R + j\omega L)}$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{-\omega^2 LC + j\omega RC}}{\mathbf{1 - \omega^2 LC + j\omega RC}}}$$

Chapter 14, Solution 5.

(a) $$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1/j\omega C}{R + j\omega L + 1/j\omega C}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{1}}{\mathbf{1 + j\omega RC - \omega^2 LC}}}$$

(b) $$R \parallel \frac{1}{j\omega C} = \frac{R}{1 + j\omega RC}$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{j\omega L}{j\omega L + R/(1 + j\omega RC)} = \frac{j\omega L\,(1 + j\omega RC)}{R + j\omega L\,(1 + j\omega RC)}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{j\omega L - \omega^2 RLC}}{\mathbf{R + j\omega L - \omega^2 RLC}}}$$

Chapter 14, Solution 6.

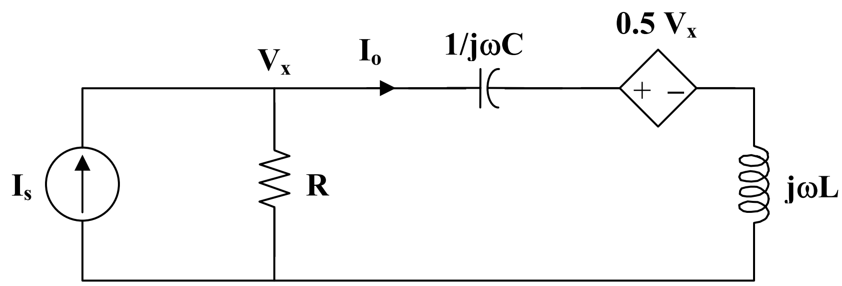
(a) Using current division,

$$\mathbf{H}(\omega) = \frac{\mathbf{I}_o}{\mathbf{I}_i} = \frac{R}{R + j\omega L + 1/j\omega C}$$

$$\mathbf{H}(\omega) = \frac{j\omega RC}{1 + j\omega RC - \omega^2 LC} = \frac{j\omega(20)(0.25)}{1 + j\omega(20)(0.25) - \omega^2(10)(0.25)}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{j\omega 5}}{\mathbf{1 + j\omega 5 - 2.5\omega^2}}}$$

(b) We apply nodal analysis to the circuit below.



$$\mathbf{I}_s = \frac{\mathbf{V}_x}{R} + \frac{\mathbf{V}_x - 0.5\mathbf{V}_x}{j\omega L + 1/j\omega C}$$

But $\quad \mathbf{I}_o = \dfrac{0.5\,\mathbf{V}_x}{j\omega L + 1/j\omega C} \longrightarrow \mathbf{V}_x = 2\,\mathbf{I}_o\,(j\omega L + 1/j\omega C)$

$$\frac{\mathbf{I}_s}{\mathbf{V}_x} = \frac{1}{R} + \frac{0.5}{j\omega L + 1/j\omega C}$$

$$\frac{\mathbf{I}_s}{2\,\mathbf{I}_o\,(j\omega L + 1/j\omega C)} = \frac{1}{R} + \frac{1}{2\,(j\omega L + 1/j\omega C)}$$

$$\frac{\mathbf{I}_s}{\mathbf{I}_o} = \frac{2\,(j\omega L + 1/j\omega C)}{R} + 1$$

$$\mathbf{H}(\omega) = \frac{\mathbf{I}_o}{\mathbf{I}_s} = \frac{1}{1 + 2\,(j\omega L + 1/j\omega C)/R} = \frac{j\omega RC}{j\omega RC + 2\,(1 - \omega^2 LC)}$$

$$\mathbf{H}(\omega) = \frac{j\omega}{j\omega + 2\,(1 - \omega^2\,0.25)}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{j\omega}}{\mathbf{2 + j\omega - 0.5\omega^2}}}$$

Chapter 14, Solution 7.

(a) $0.05 = 20\log_{10} H$

$2.5 \times 10^{-3} = \log_{10} H$

$H = 10^{2.5\times 10^{-3}} = \underline{\mathbf{1.005773}}$

(b) $-6.2 = 20\log_{10} H$

$-0.31 = \log_{10} H$

$H = 10^{-0.31} = \underline{\mathbf{0.4898}}$

(c) $104.7 = 20\log_{10} H$

$5.235 = \log_{10} H$

$H = 10^{5.235} = \underline{\mathbf{1.718 \times 10^5}}$

Chapter 14, Solution 8.

(a) $H = 0.05$

$H_{dB} = 20\log_{10} 0.05 = \underline{\mathbf{-26.02}}$, $\qquad \phi = \underline{\mathbf{0°}}$

(b) $H = 125$

$H_{dB} = 20\log_{10} 125 = \underline{\mathbf{41.94}}$, $\qquad \phi = \underline{\mathbf{0°}}$

(c) $\mathrm{H}(1) = \dfrac{j10}{2+j} = 4.472\angle 63.43°$

$H_{dB} = 20\log_{10} 4.472 = \underline{\mathbf{13.01}}$, $\qquad \phi = \underline{\mathbf{63.43°}}$

(d) $\mathrm{H}(1) = \dfrac{3}{1+j} + \dfrac{6}{2+j} = 3.9 - j1.7 = 4.254\angle -23.55°$

$H_{dB} = 20\log_{10} 4.254 = \underline{\mathbf{12.577}}$, $\qquad \phi = \underline{\mathbf{-23.55°}}$

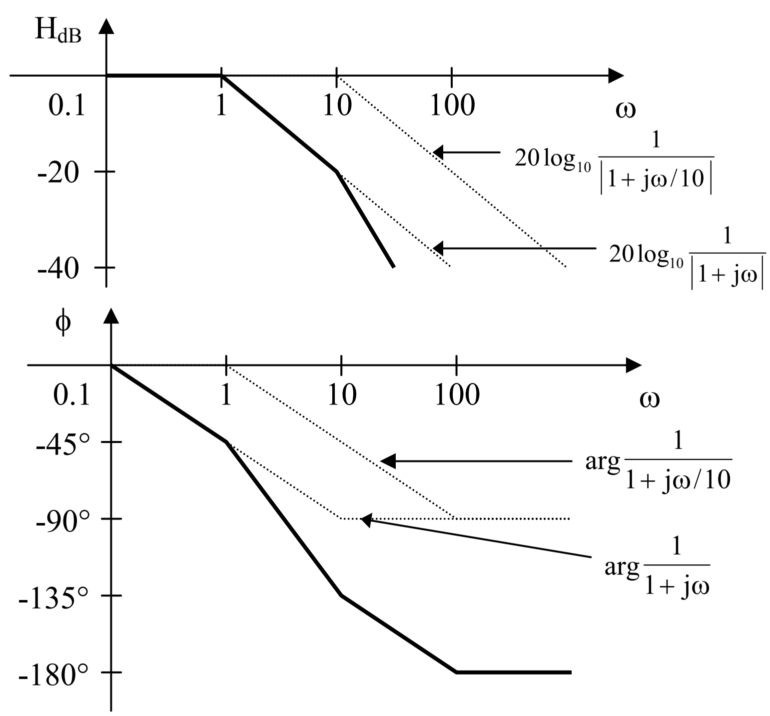
Chapter 14, Solution 9.

$$\mathbf{H}(\omega) = \frac{1}{(1+j\omega)(1+j\omega/10)}$$

$$H_{dB} = -20\log_{10}\left|1+j\omega\right| - 20\log_{10}\left|1+j\omega/10\right|$$

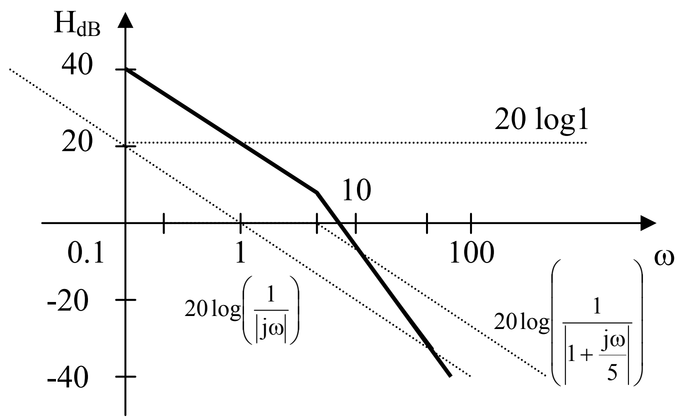
$$\phi = -\tan^{-1}(\omega) - \tan^{-1}(\omega/10)$$

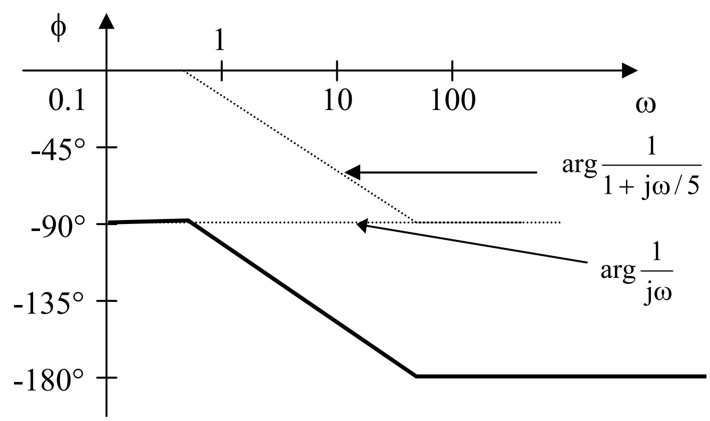
<u>The magnitude and phase plots are shown below</u>.



Chapter 14, Solution 10.

$$H(j\omega) = \frac{50}{j\omega(5 + j\omega)} = \frac{10}{1j\omega\left(1 + \frac{j\omega}{5}\right)}$$





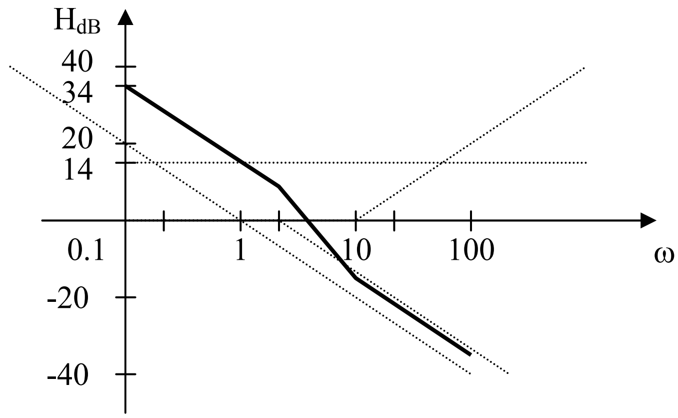
Chapter 14, Solution 11.

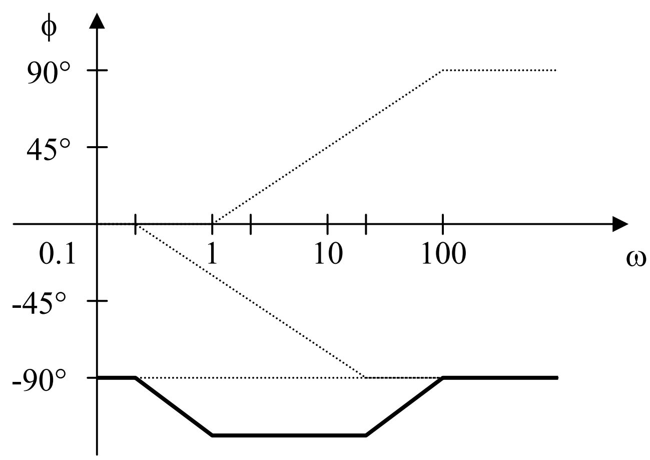
$$\mathbf{H}(\omega) = \frac{5(1 + j\omega/10)}{j\omega(1 + j\omega/2)}$$

$$H_{dB} = 20\log_{10} 5 + 20\log_{10}\left|1 + j\omega/10\right| - 20\log_{10}\left|j\omega\right| - 20\log_{10}\left|1 + j\omega/2\right|$$

$$\phi = -90° + \tan^{-1}\omega/10 - \tan^{-1}\omega/2$$

The magnitude and phase plots are shown below.

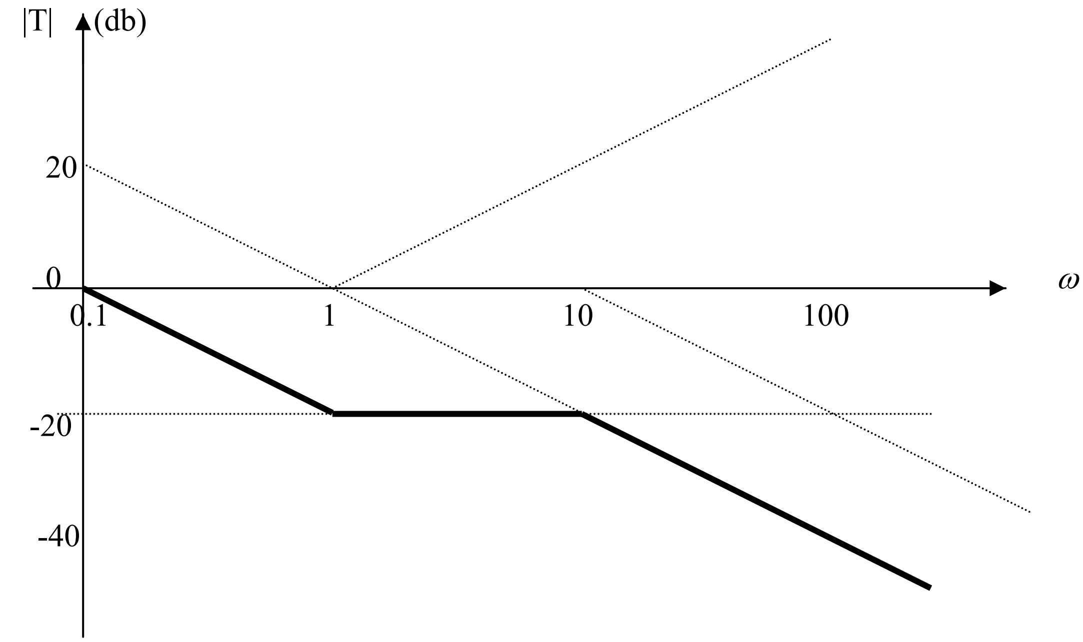


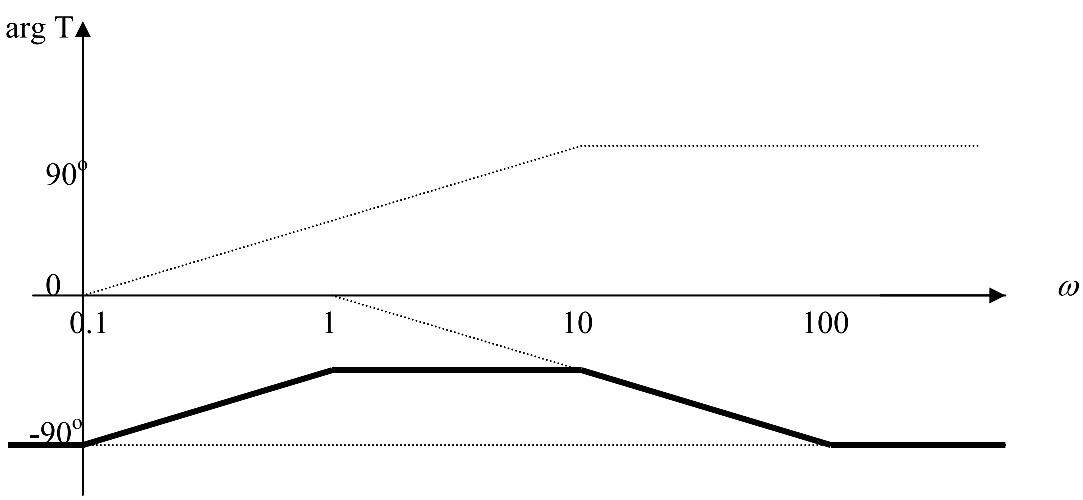


Chapter 14, Solution 12.

$$T(w) = \frac{0.1(1+j\omega)}{j\omega(1+j\omega/10)}, \qquad 20\log 0.1 = -20$$

The plots are shown below.



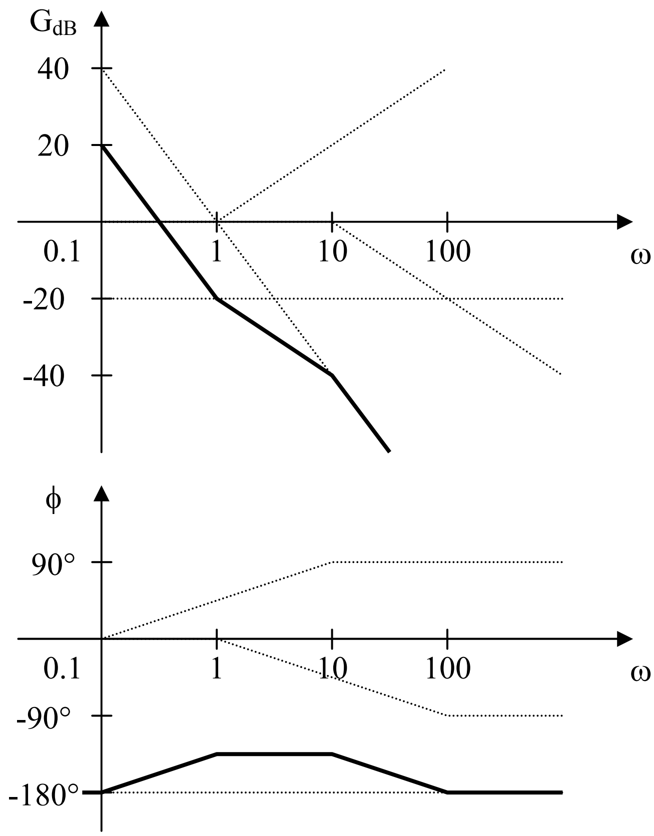


Chapter 14, Solution 13.

$$\mathbf{G}(\omega) = \frac{1 + j\omega}{(j\omega)^2 (10 + j\omega)} = \frac{(1/10)(1 + j\omega)}{(j\omega)^2 (1 + j\omega/10)}$$

$$G_{dB} = -20 + 20\log_{10}\left|1 + j\omega\right| - 40\log_{10}\left|j\omega\right| - 20\log_{10}\left|1 + j\omega/10\right|$$
$$\phi = -180° + \tan^{-1}\omega - \tan^{-1}\omega/10$$

__The magnitude and phase plots are shown below__.



Chapter 14, Solution 14.

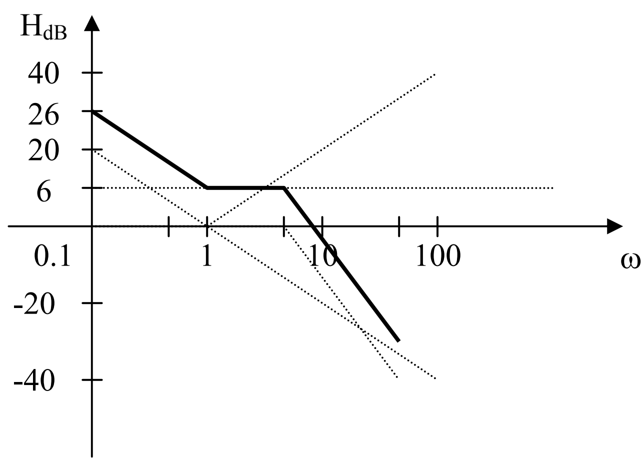
$$\mathbf{H}(\omega) = \frac{50}{25}\frac{1+j\omega}{j\omega\left(1+\frac{j\omega 10}{25}+\left(\frac{j\omega}{5}\right)^2\right)}$$

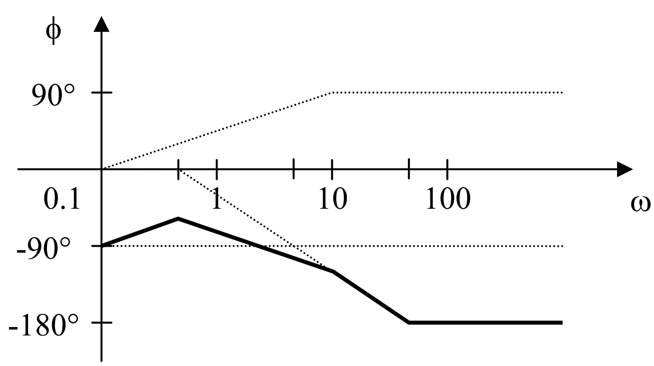
$$H_{dB} = 20\log_{10} 2 + 20\log_{10}\left|1+j\omega\right| - 20\log_{10}\left|j\omega\right|$$

$$-20\log_{10}\left|1+j\omega 2/5+(j\omega/5)^2\right|$$

$$\phi = -90° + \tan^{-1}\omega - \tan^{-1}\left(\frac{\omega 10/25}{1-\omega^2/5}\right)$$

<u>The magnitude and phase plots are shown below</u>.





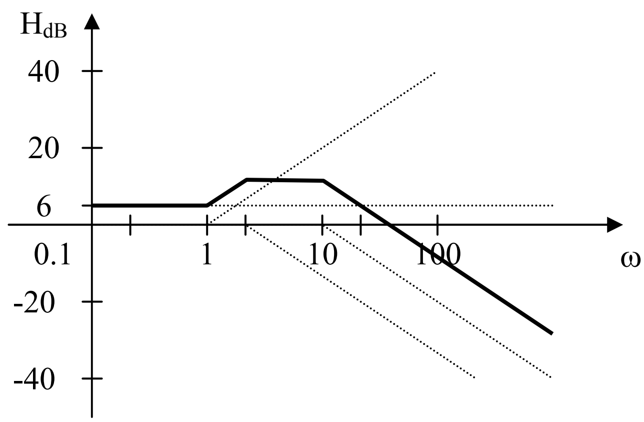
Chapter 14, Solution 15.

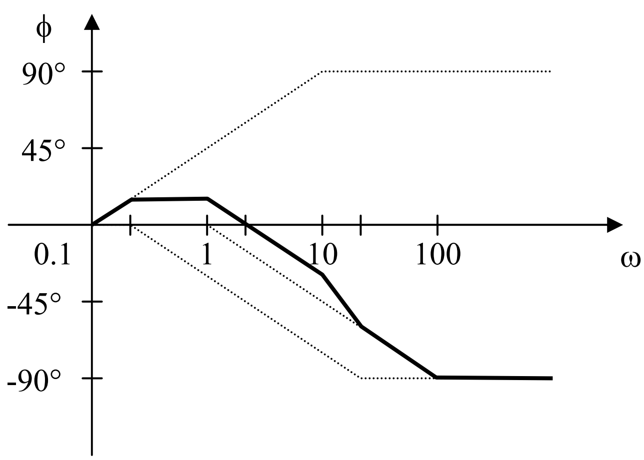
$$\mathbf{H}(\omega) = \frac{40(1+j\omega)}{(2+j\omega)(10+j\omega)} = \frac{2(1+j\omega)}{(1+j\omega/2)(1+j\omega/10)}$$

$$H_{dB} = 20\log_{10} 2 + 20\log_{10}\left|1+j\omega\right| - 20\log_{10}\left|1+j\omega/2\right| - 20\log_{10}\left|1+j\omega/10\right|$$

$$\phi = \tan^{-1}\omega - \tan^{-1}\omega/2 - \tan^{-1}\omega/10$$

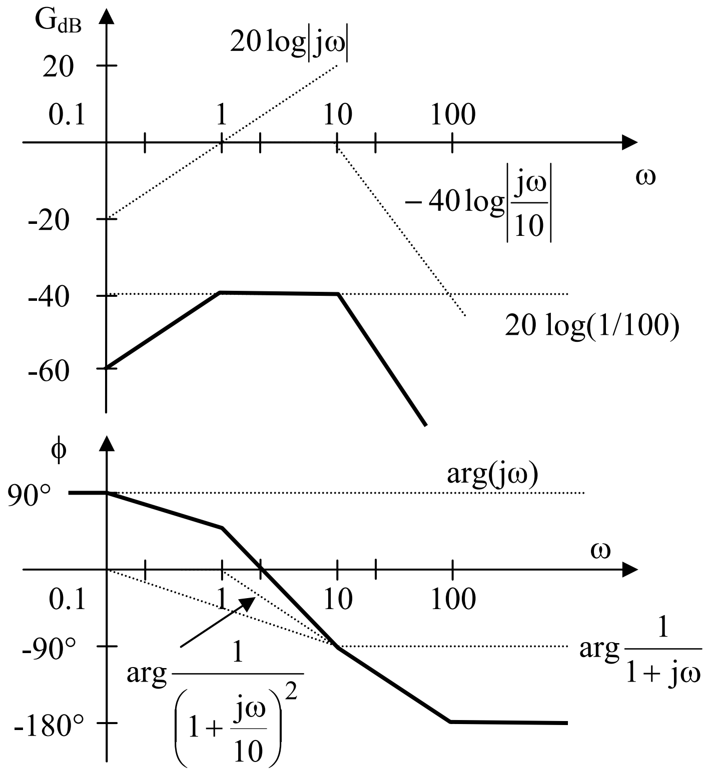
<u>**The magnitude and phase plots are shown below**</u>.





Chapter 14, Solution 16.

$$G(\omega) = \frac{j\omega}{100(1+j\omega)\left(1+\dfrac{j\omega}{10}\right)^2}$$



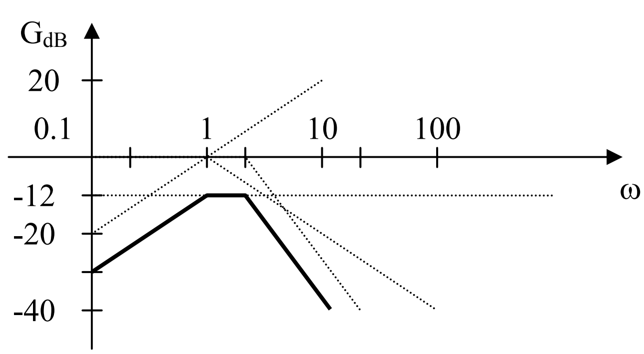
Chapter 14, Solution 17.

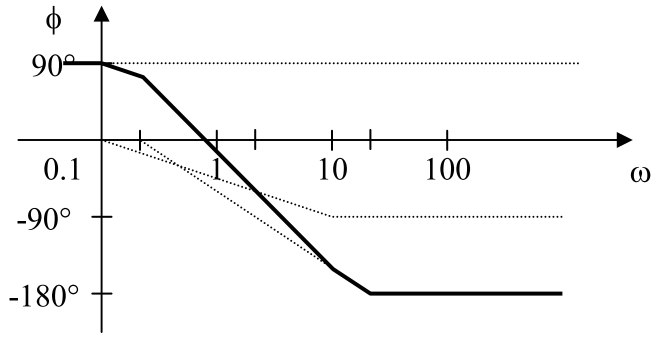
$$\mathbf{G}(\omega) = \frac{(1/4)\, j\omega}{(1 + j\omega)(1 + j\omega/2)^2}$$

$$G_{dB} = -20\log_{10} 4 + 20\log_{10}|\,j\omega\,| - 20\log_{10}|1 + j\omega| - 40\log_{10}|1 + j\omega/2\,|$$

$$\phi = -90° - \tan^{-1}\omega - 2\tan^{-1}\omega/2$$

<u>**The magnitude and phase plots are shown below**</u>.





Chapter 14, Solution 18.

$$\mathbf{G}(\omega) = \frac{4\,(1 + j\omega/2)^2}{50\,j\omega(1 + j\omega/5)(1 + j\omega/10)}$$

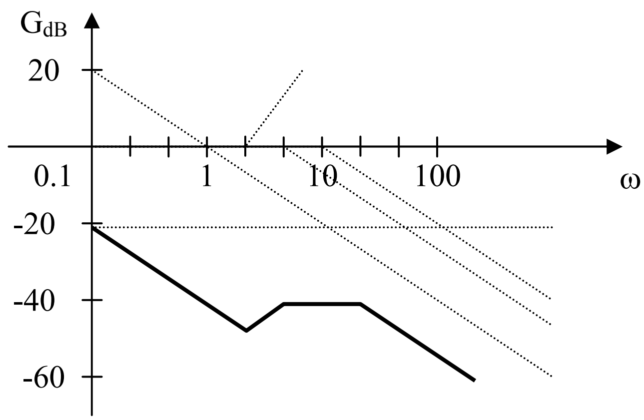
$$G_{dB} = 20\log_{10} 4/50 + 40\log_{10}\left|1 + j\omega/2\right| - 20\log_{10}\left|j\omega\right|$$

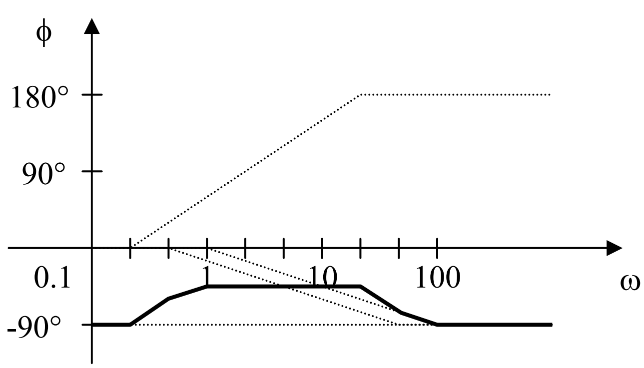
$$- 20\log_{10}\left|1 + j\omega/5\right| - 20\log_{10}\left|1 + j\omega/10\right|$$

where $20\log_{10} 4/50 = \text{-}21.94$

$$\phi = \text{-}90° + 2\tan^{-1}\omega/2 - \tan^{-1}\omega/5 - \tan^{-1}\omega/10$$

<u>The magnitude and phase plots are shown below</u>.





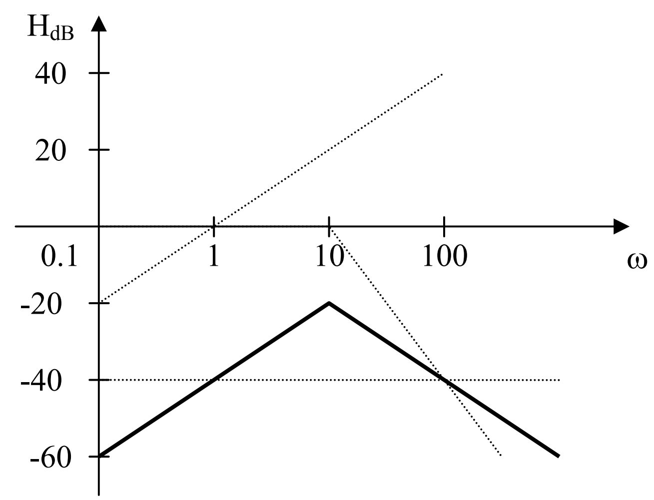
Chapter 14, Solution 19.

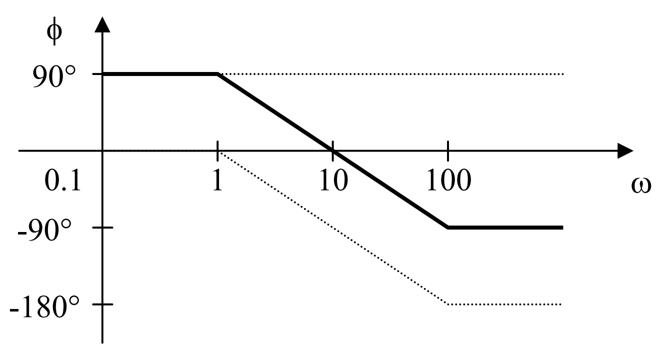
$$\mathbf{H}(\omega) = \frac{j\omega}{100(1 + j\omega/10 - \omega^2/100)}$$

$$H_{dB} = 20\log_{10}\left| j\omega \right| - 20\log_{10} 100 - 20\log_{10}\left| 1 + j\omega/10 - \omega^2/100 \right|$$

$$\phi = 90° - \tan^{-1}\left(\frac{\omega/10}{1 - \omega^2/100}\right)$$

<u>The magnitude and phase plots are shown below</u>.





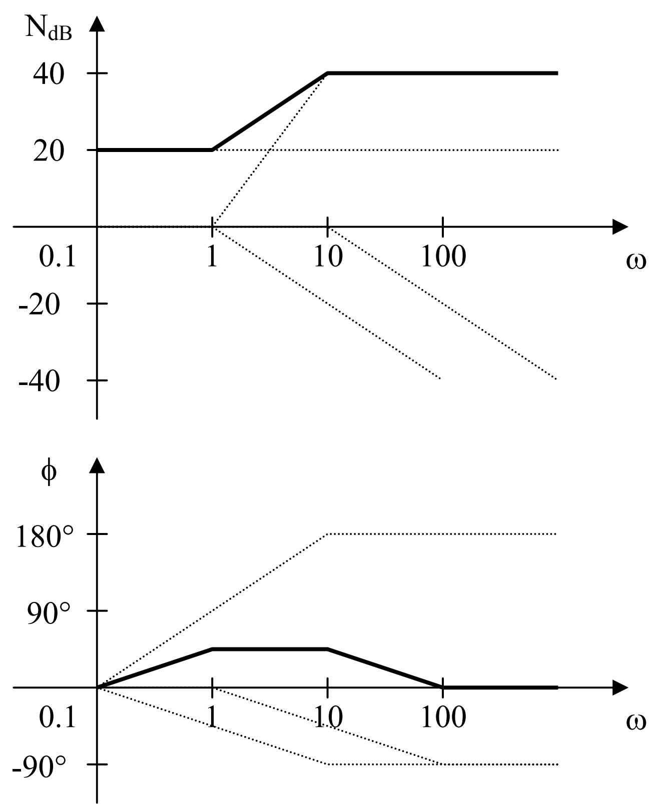
Chapter 14, Solution 20.

$$\mathbf{N}(\omega) = \frac{10(1 + j\omega - \omega^2)}{(1 + j\omega)(1 + j\omega/10)}$$

$$N_{dB} = 20 - 20\log_{10}\left|1 + j\omega\right| - 20\log_{10}\left|1 + j\omega/10\right| + 20\log_{10}\left|1 + j\omega - \omega^2\right|$$

$$\phi = \tan^{-1}\left(\frac{\omega}{1-\omega^2}\right) - \tan^{-1}\omega - \tan^{-1}\omega/10$$

<u>**The magnitude and phase plots are shown below**</u>.



Chapter 14, Solution 21.

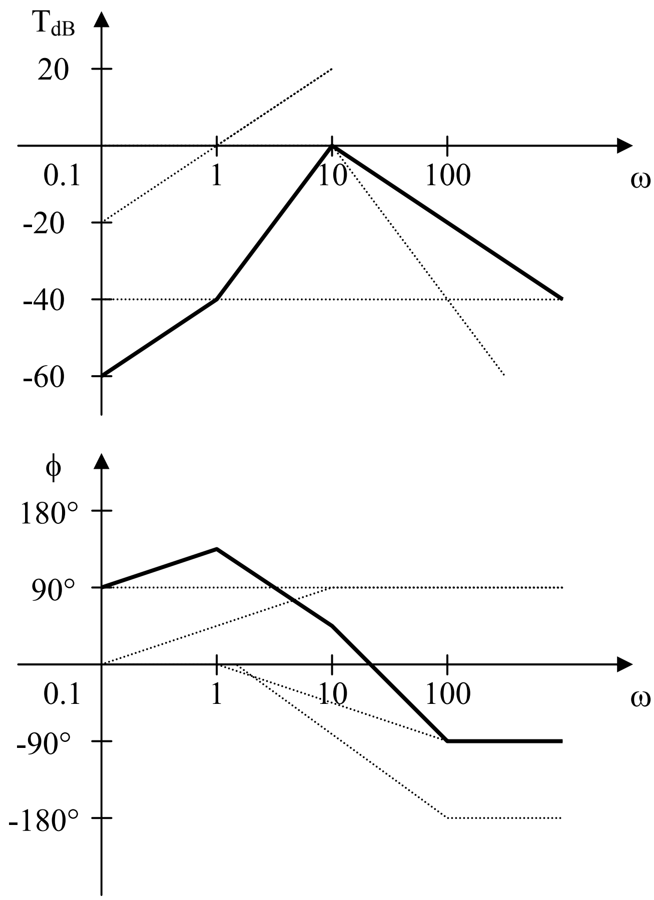
$$\mathbf{T}(\omega) = \frac{j\omega(1 + j\omega)}{100(1 + j\omega/10)(1 + j\omega/10 - \omega^2/100)}$$

$$T_{dB} = 20\log_{10}\left|j\omega\right| + 20\log_{10}\left|1 + j\omega\right| - 20\log_{10}100$$

$$- 20\log_{10}\left|1 + j\omega/10\right| - 20\log_{10}\left|1 + j\omega/10 - \omega^2/100\right|$$

$$\phi = 90° + \tan^{-1}\omega - \tan^{-1}\omega/10 - \tan^{-1}\left(\frac{\omega/10}{1 - \omega^2/100}\right)$$

<u>The magnitude and phase plots are shown below</u>.



Chapter 14, Solution 22.

$$20 = 20\log_{10} k \longrightarrow k = 10$$

A zero of slope $+20\ \mathrm{dB/dec}$ at $\omega = 2 \longrightarrow 1 + j\omega/2$

A pole of slope $-20\ \mathrm{dB/dec}$ at $\omega = 20 \longrightarrow \dfrac{1}{1 + j\omega/20}$

A pole of slope -20 dB/dec at $\omega = 100 \longrightarrow \dfrac{1}{1 + j\omega/100}$

Hence,

$$\mathbf{H}(\omega) = \frac{10(1 + j\omega/2)}{(1 + j\omega/20)(1 + j\omega/100)}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{10^4\,(2 + j\omega)}}{\mathbf{(20 + j\omega)(100 + j\omega)}}}$$

Chapter 14, Solution 23.

A zero of slope +20 dB/dec at the origin $\longrightarrow j\omega$

A pole of slope -20 dB/dec at $\omega = 1 \longrightarrow \dfrac{1}{1 + j\omega/1}$

A pole of slope -40 dB/dec at $\omega = 10 \longrightarrow \dfrac{1}{(1 + j\omega/10)^2}$

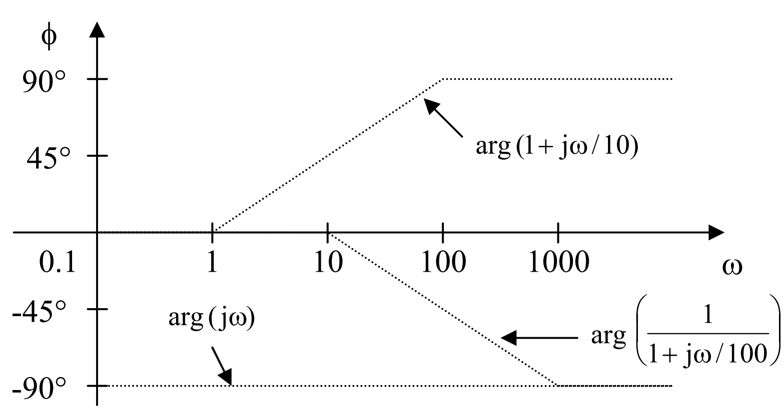
Hence,

$$\mathbf{H}(\omega) = \frac{j\omega}{(1 + j\omega)(1 + j\omega/10)^2}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{100\,j\omega}}{\mathbf{(1 + j\omega)(10 + j\omega)^2}}}$$

Chapter 14, Solution 24.

The phase plot is decomposed as shown below.



$$\mathbf{G}(\omega) = \frac{k'(1 + j\omega/10)}{j\omega(1 + j\omega/100)} = \frac{k'(10)(10 + j\omega)}{j\omega(100 + j\omega)}$$

where k' is a constant since $\arg k' = 0$.

Hence, $\mathbf{G}(\omega) = \underline{\dfrac{\mathbf{k\,(10 + j\omega)}}{\mathbf{j\omega(100 + j\omega)}}}$, where $\underline{\mathbf{k = 10k'}\ \textbf{is constant}}$

Chapter 14, Solution 25.

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(40 \times 10^{-3})(1 \times 10^{-6})}} = 5 \text{ krad/s}$$

$$\mathbf{Z}(\omega_0) = R = \underline{\mathbf{2\ k\Omega}}$$

$$\mathbf{Z}(\omega_0/4) = R + j\left(\frac{\omega_0}{4}L - \frac{4}{\omega_0 C}\right)$$

$$\mathbf{Z}(\omega_0/4) = 2000 + j\left(\frac{5 \times 10^3}{4} \cdot 40 \times 10^{-3} - \frac{4}{(5 \times 10^3)(1 \times 10^{-6})}\right)$$

$$\mathbf{Z}(\omega_0/4) = 2000 + j(50 - 4000/5)$$

$$\mathbf{Z}(\omega_0/4) = \underline{\mathbf{2 - j0.75\ k\Omega}}$$

$$\mathbf{Z}(\omega_0/2) = R + j\left(\frac{\omega_0}{2}L - \frac{2}{\omega_0 C}\right)$$

$$\mathbf{Z}(\omega_0/2) = 2000 + j\left(\frac{(5 \times 10^3)}{2}(40 \times 10^{-3}) - \frac{2}{(5 \times 10^3)(1 \times 10^{-6})}\right)$$

$$\mathbf{Z}(\omega_0/4) = 2000 + j(100 - 2000/5)$$

$$\mathbf{Z}(\omega_0/2) = \underline{\mathbf{2 - j0.3\ k\Omega}}$$

$$\mathbf{Z}(2\omega_0) = R + j\left(2\omega_0 L - \frac{1}{2\omega_0 C}\right)$$

$$\mathbf{Z}(2\omega_0) = 2000 + j\left((2)(5\times10^3)(40\times10^{-3}) - \frac{1}{(2)(5\times10^3)(1\times10^{-6})}\right)$$

$$\mathbf{Z}(2\omega_0) = \underline{\mathbf{2 + j0.3\ k\Omega}}$$

$$\mathbf{Z}(4\omega_0) = R + j\left(4\omega_0 L - \frac{1}{4\omega_0 C}\right)$$

$$\mathbf{Z}(4\omega_0) = 2000 + j\left((4)(5\times10^3)(40\times10^{-3}) - \frac{1}{(4)(5\times10^3)(1\times10^{-6})}\right)$$

$$\mathbf{Z}(4\omega_0) = \underline{\mathbf{2 + j0.75\ k\Omega}}$$

Chapter 14, Solution 26.

(a) $$f_o = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{5x10^{-9}x10x10^{-3}}} = \underline{22.51\,\text{kHz}}$$

(b) $$B = \frac{R}{L} = \frac{100}{10x10^{-3}} = \underline{10\,\text{krad/s}}$$

(c) $$Q = \frac{\omega_o L}{R} = \frac{1}{\sqrt{LC}}\frac{L}{R} = \frac{10^6}{\sqrt{50}}\frac{10x10^{-3}}{0.1x10^3} = \underline{14.142}$$

Chapter 14, Solution 27.

At resonance,

$$\mathbf{Z} = R = 10\,\Omega, \qquad \omega_0 = \frac{1}{\sqrt{LC}}$$

$$B = \frac{R}{L} \qquad \text{and} \qquad Q = \frac{\omega_0}{B} = \frac{\omega_0 L}{R}$$

Hence,

$$L = \frac{RQ}{\omega_0} = \frac{(10)(80)}{50} = 16\ \text{H}$$

$$C = \frac{1}{\omega_0^2 L} = \frac{1}{(50)^2(16)} = 25\ \mu F$$

$$B = \frac{R}{L} = \frac{10}{16} = 0.625\ \text{rad/s}$$

Therefore,

$R = \underline{\mathbf{10\ \Omega}}$, $L = \underline{\mathbf{16\ H}}$, $C = \underline{\mathbf{25\ \mu F}}$, $B = \underline{\mathbf{0.625\ rad/s}}$

Chapter 14, Solution 28.

Let $R = 10\ \Omega$.

$$L = \frac{R}{B} = \frac{10}{20} = 0.5\ H$$

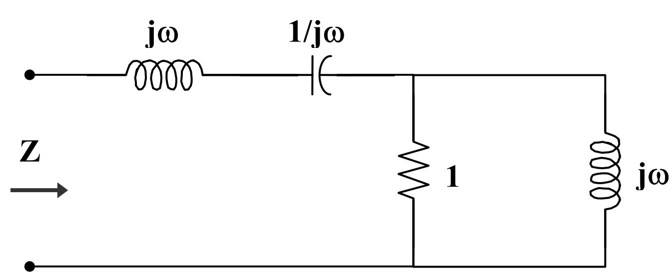
$$C = \frac{1}{\omega_0^2 L} = \frac{1}{(1000)^2(0.5)} = 2\ \mu F$$

$$Q = \frac{\omega_0}{B} = \frac{1000}{20} = 50$$

Therefore, if $R = 10\ \Omega$ then

$L = \underline{\mathbf{0.5\ H}}$, $C = \underline{\mathbf{2\ \mu F}}$, $Q = \underline{\mathbf{50}}$

Chapter 14, Solution 29.



$$\mathbf{Z} = j\omega + \frac{1}{j\omega} + \frac{j\omega}{1 + j\omega}$$

$$\mathbf{Z} = j\left(\omega - \frac{1}{\omega}\right) + \frac{\omega^2 + j\omega}{1+\omega^2}$$

Since $v(t)$ and $i(t)$ are in phase,

$$\mathrm{Im}(\mathbf{Z}) = 0 = \omega - \frac{1}{\omega} + \frac{\omega}{1+\omega^2}$$

$$\omega^4 + \omega^2 - 1 = 0$$

$$\omega^2 = \frac{-1 \pm \sqrt{1+4}}{2} = 0.618$$

$$\omega = \underline{\mathbf{0.7861\ rad/s}}$$

Chapter 14, Solution 30.

Select $R = 10\,\Omega$.

$$L = \frac{R}{\omega_0 Q} = \frac{10}{(10)(20)} = 0.05\text{ H} = 5\text{ mH}$$

$$C = \frac{1}{\omega_0^2 L} = \frac{1}{(100)(0.05)} = 0.2\text{ F}$$

$$B = \frac{1}{RC} = \frac{1}{(10)(0.2)} = 0.5\text{ rad/s}$$

Therefore, if $R = 10\,\Omega$ then

$$L = \underline{\mathbf{5\ mH}}, \quad C = \underline{\mathbf{0.2\ F}}, \quad B = \underline{\mathbf{0.5\ rad/s}}$$

Chapter 14, Solution 31.

$$X_L = \omega L \quad \longrightarrow \quad L = \frac{X_L}{\omega}$$

$$B = \frac{R}{L} = \frac{\omega R}{X_L} = \frac{2\pi x10x10^6 x5.6x10^3}{40x10^3} = \underline{8.796x10^6\text{ rad/s}}$$

Chapter 14, Solution 32.

Since $Q > 10$,

$$\omega_1 = \omega_0 - \frac{B}{2}, \qquad \omega_2 = \omega_0 + \frac{B}{2}$$

$$B = \frac{\omega_0}{Q} = \frac{6\times10^6}{120} = \underline{\mathbf{50\ krad/s}}$$

$$\omega_1 = 6 - 0.025 = \underline{\mathbf{5.975\times10^6\ rad/s}}$$

$$\omega_2 = 6 + 0.025 = \underline{\mathbf{6.025\times10^6\ rad/s}}$$

Chapter 14, Solution 33.

$$Q = \omega_o RC \quad \longrightarrow \quad C = \frac{Q}{2\pi f_o R} = \frac{80}{2\pi x 5.6x10^6 x 40x10^3} = \underline{56.84\ \ pF}$$

$$Q = \frac{R}{\omega_o L} \quad \longrightarrow \quad L = \frac{R}{2\pi f_o Q} = \frac{40x10^3}{2\pi x 5.6x10^6 x 80} = \underline{14.21\ \ \mu H}$$

Chapter 14, Solution 34.

(a) $$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8x10^{-3} x 60x10^{-6}}} = \underline{1.443\text{ krad/s}}$$

(b) $$B = \frac{1}{RC} = \frac{1}{5x10^3 x 60x10^{-6}} = \underline{3.33\text{ rad/s}}$$

(c) $$Q = \omega_o RC = 1.443x10^3 x 5x10^3 x 60x10^{-6} = \underline{432.9}$$

Chapter 14, Solution 35.

At resonance,

$$\mathbf{Y} = \frac{1}{R} \longrightarrow R = \frac{1}{Y} = \frac{1}{25\times10^{-3}} = \underline{\mathbf{40\ \Omega}}$$

$$Q = \omega_0 RC \longrightarrow C = \frac{Q}{\omega_0 R} = \frac{80}{(200\times10^3)(40)} = \underline{\mathbf{10\ \mu F}}$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \longrightarrow L = \frac{1}{\omega_0^2 C} = \frac{1}{(4\times10^{10})(10\times10^{-6})} = \underline{\mathbf{2.5\ \mu H}}$$

$$B = \frac{\omega_0}{Q} = \frac{200\times10^3}{80} = \underline{\mathbf{2.5\ krad/s}}$$

$$\omega_1 = \omega_0 - \frac{B}{2} = 200 - 2.5 = \underline{\mathbf{197.5\ krad/s}}$$

$$\omega_1 = \omega_0 + \frac{B}{2} = 200 + 2.5 = \underline{\mathbf{202.5\ krad/s}}$$

Chapter 14, Solution 36.

$$\omega_0 = \frac{1}{\sqrt{LC}} = 5000\ \text{rad/s}$$

$$\mathbf{Y}(\omega_0) = \frac{1}{R} \longrightarrow \mathbf{Z}(\omega_0) = R = \underline{\mathbf{2\ k\Omega}}$$

$$\mathbf{Y}(\omega_0/4) = \frac{1}{R} + j\left(\frac{\omega_0}{4}C - \frac{4}{\omega_0 L}\right) = 0.5 - j18.75\ \text{kS}$$

$$\mathbf{Z}(\omega_0/4) = \frac{1}{0.0005 - j0.01875} = \underline{\mathbf{1.4212 + j53.3\ \Omega}}$$

$$\mathbf{Y}(\omega_0/2) = \frac{1}{R} + j\left(\frac{\omega_0}{2}C - \frac{2}{\omega_0 L}\right) = 0.5 - j7.5\ \text{kS}$$

$$\mathbf{Z}(\omega_0/2) = \frac{1}{0.0005 - j0.0075} = \underline{\mathbf{8.85 + j132.74\ \Omega}}$$

$$\mathbf{Y}(2\omega_0) = \frac{1}{R} + j\left(2\omega_0 L - \frac{1}{2\omega_0 C}\right) = 0.5 + j7.5 \text{ kS}$$

$$\mathbf{Z}(2\omega_0) = \underline{\mathbf{8.85 - j132.74\ \Omega}}$$

$$\mathbf{Y}(4\omega_0) = \frac{1}{R} + j\left(4\omega_0 L - \frac{1}{4\omega_0 C}\right) = 0.5 + j18.75 \text{ kS}$$

$$\mathbf{Z}(4\omega_0) = \underline{\mathbf{1.4212 - j53.3\ \Omega}}$$

Chapter 14, Solution 37.

$$Z = j\omega L //(R + \frac{1}{j\omega C}) = \frac{j\omega L(R + \frac{1}{j\omega C})}{R + \frac{1}{j\omega C} + j\omega L} = \frac{\left(\frac{L}{C} + j\omega LR\right)\left(R + j(\omega L - \frac{1}{\omega C})\right)}{R^2 + (\omega L - \frac{1}{\omega C})^2}$$

$$\text{Im}(Z) = \frac{\omega LR^2 + \frac{L}{C}\left(\omega L - \frac{1}{\omega C}\right)}{R^2 + (\omega L - \frac{1}{\omega C})^2} = 0 \qquad \longrightarrow \qquad \omega^2(R^2C^2 + LC) = 1$$

Thus,

$$\underline{\omega = \frac{1}{\sqrt{LC + R^2C^2}}}$$

Chapter 14, Solution 38.

$$Y \frac{1}{R + j\omega L} + j\omega C = j\omega C + \frac{R - j\omega L}{R^2 + \omega^2 L^2}$$

At resonance, $\text{Im}(\mathbf{Y}) = 0$, i.e.

$$\omega_0 C - \frac{\omega_0 L}{R^2 + \omega_0^2 L^2} = 0$$

$$R^2 + \omega_0^2 L^2 = \frac{L}{C}$$

$$\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} = \sqrt{\frac{1}{(40\times10^{-3})(10\times10^{-6})} - \left(\frac{50}{40\times10^{-3}}\right)^2}$$

$$\omega_0 = \underline{\mathbf{4841\ rad/s}}$$

Chapter 14, Solution 39.

(a) $B = \omega_2 - \omega_1 = 2\pi(f_2 - f_1) = 2\pi(90-86)x10^3 = 8\pi krad/s$

$$\omega_o = \frac{1}{2}(\omega_1 + \omega_2) = 2\pi(88)x10^3 = 176\pi$$

$$B = \frac{1}{RC} \longrightarrow C = \frac{1}{BR} = \frac{1}{8\pi x10^3 x2x10^3} = \underline{19.89nF}$$

(b) $\omega_o = \dfrac{1}{\sqrt{LC}} \longrightarrow L = \dfrac{1}{\omega^2{}_o C} = \dfrac{1}{(176\pi)^2 x19.89x10^{-9}} = \underline{164.4H}$

(c) $\omega_o = 176\pi = \underline{552.9krad/s}$

(d) $B = 8\pi = \underline{25.13krad/s}$

(e) $Q = \dfrac{\omega_o}{B} = \dfrac{176\pi}{8\pi} = \underline{22}$

Chapter 14, Solution 40.

(a) L = 5 + 10 = 15 mH

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{15x10^{-3}x20x10^{-6}}} = \underline{\mathbf{1.8257\ k\ rad/sec}}$$

$$Q = \omega_0 RC = 1.8257x10^3 x25x10^3 x20x10^{-6} = \underline{\mathbf{912.8}}$$

$$B = \frac{1}{RC} = \frac{1}{25x10^3 20x10^{-6}} = \underline{\mathbf{2\ rad}}$$

(b) To increase B by 100% means that B' = 4.

$$C' = \frac{1}{RB'} = \frac{1}{25x10^3 x4} = \underline{\mathbf{10\ \mu F}}$$

Since $C' = \frac{C_1 C_2}{C_1 + C_2} = 10\mu F$ and $C_1 = 20\ \mu F$, we then obtain $C_2 = 20\ \mu F$.

Therefore, to increase the bandwidth, we merely **add another 20 μF in series with the first one**.

Chapter 14, Solution 41.

(a) This is a series RLC circuit.

$$R = 2 + 6 = 8\,\Omega, \qquad L = 1\,H, \qquad C = 0.4\,F$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.4}} = \underline{\mathbf{1.5811\ rad/s}}$$

$$Q = \frac{\omega_0 L}{R} = \frac{1.5811}{8} = \underline{\mathbf{0.1976}}$$

$$B = \frac{R}{L} = \underline{\mathbf{8\ rad/s}}$$

(b) This is a parallel RLC circuit.

$$3\ \mu F \text{ and } 6\ \mu F \longrightarrow \frac{(3)(6)}{3+6} = 2\ \mu F$$

$$C = 2\ \mu F, \qquad R = 2\ k\Omega, \qquad L = 20\ mH$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(2\times10^{-6})(20\times10^{-3})}} = \underline{\mathbf{5\ krad/s}}$$

$$Q = \frac{R}{\omega_0 L} = \frac{2\times10^3}{(5\times10^3)(20\times10^{-3})} = \underline{\mathbf{20}}$$

$$B = \frac{1}{RC} = \frac{1}{(2\times10^3)(2\times10^{-6})} = \underline{\mathbf{250\ krad/s}}$$

Chapter 14, Solution 42.

(a) $\mathbf{Z}_{in} = (1/j\omega C) \,||\, (R + j\omega L)$

$$\mathbf{Z}_{in} = \frac{\dfrac{R + j\omega L}{j\omega C}}{R + j\omega L + \dfrac{1}{j\omega C}} = \frac{R + j\omega L}{1 - \omega^2 LC + j\omega RC}$$

$$\mathbf{Z}_{in} = \frac{(R + j\omega L)(1 - \omega^2 LC - j\omega RC)}{(1 - \omega^2 LC)^2 + \omega^2 R^2 C^2}$$

At resonance, $\mathrm{Im}(\mathbf{Z}_{in}) = 0$, i.e.

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

$$\omega^2 LC = L - R^2 C$$

$$\omega_0 = \sqrt{\frac{L - R^2 C}{LC}} = \underline{\sqrt{\frac{\mathbf{1}}{\mathbf{C}} - \frac{\mathbf{R^2}}{\mathbf{L}}}}$$

(b) $\mathbf{Z}_{in} = j\omega L \,||\, (R + 1/j\omega C)$

$$\mathbf{Z}_{in} = \frac{j\omega L\,(R + 1/j\omega C)}{R + j\omega L + 1/j\omega C} = \frac{j\omega L\,(1 + j\omega RC)}{(1 - \omega^2 LC) + j\omega RC}$$

$$\mathbf{Z}_{in} = \frac{(-\omega^2 RLC + j\omega L)[(1 - \omega^2 LC) - j\omega RC]}{(1 - \omega^2 LC)^2 + \omega^2 R^2 C^2}$$

At resonance, $\mathrm{Im}(\mathbf{Z}_{in}) = 0$, i.e.

$$0 = \omega L\,(1 - \omega^2 LC) + \omega^3 R^2 C^2 L$$

$$\omega^2 (LC - R^2C^2) = 1$$

$$\omega_0 = \underline{\mathbf{\frac{1}{\sqrt{LC - R^2C^2}}}}$$

(c) $\mathbf{Z}_{in} = R \parallel (j\omega L + 1/j\omega C)$

$$\mathbf{Z}_{in} = \frac{R(j\omega L + 1/j\omega C)}{R + j\omega L + 1/j\omega C} = \frac{R(1 - \omega^2 LC)}{(1 - \omega^2 LC) + j\omega RC}$$

$$\mathbf{Z}_{in} = \frac{R(1 - \omega^2 LC)[(1 - \omega^2 LC) - j\omega RC]}{(1 - \omega^2 LC)^2 + \omega^2 R^2 C^2}$$

At resonance, $\text{Im}(\mathbf{Z}_{in}) = 0$, i.e.

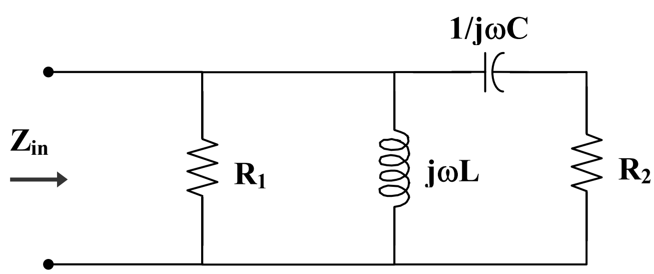
$$0 = R(1 - \omega^2 LC)\omega RC$$

$$1 - \omega^2 LC = 0$$

$$\omega_0 = \underline{\mathbf{\frac{1}{\sqrt{LC}}}}$$

Chapter 14, Solution 43.

Consider the circuit below.



(a) $\mathbf{Z}_{in} = (R_1 \parallel j\omega L) \parallel (R_2 + 1/j\omega C)$

$$\mathbf{Z}_{in} = \left(\frac{R_1 j\omega L}{R_1 + j\omega L}\right) \parallel \left(R_2 + \frac{1}{j\omega C}\right)$$

$$\mathbf{Z}_{in} = \frac{\dfrac{j\omega R_1 L}{R_1 + j\omega L} \cdot \left(R_2 + \dfrac{1}{j\omega C}\right)}{R_2 + \dfrac{1}{j\omega C} + \dfrac{jR_1\omega L}{R_1 + j\omega L}}$$

$$\mathbf{Z}_{in} = \frac{j\omega R_1 L\,(1 + j\omega R_2 C)}{(R_1 + j\omega L)(1 + j\omega R_2 C) - \omega^2 LCR_1}$$

$$\mathbf{Z}_{in} = \frac{-\omega^2 R_1 R_2 LC + j\omega R_1 L}{R_1 - \omega^2 LCR_1 - \omega^2 LCR_2 + j\omega(L + R_1 R_2 C)}$$

$$\mathbf{Z}_{in} = \frac{(-\omega^2 R_1 R_2 LC + j\omega R_1 L)[R_1 - \omega^2 LCR_1 - \omega^2 LCR_2 - j\omega(L + R_1 R_2 C)]}{(R_1 - \omega^2 LCR_1 - \omega^2 LCR_2)^2 + \omega^2 (L + R_1 R_2 C)^2}$$

At resonance, $\mathrm{Im}(\mathbf{Z}_{in}) = 0$, i.e.

$$0 = \omega^3 R_1 R_2 LC\,(L + R_1 R_2 C) + \omega R_1 L\,(R_1 - \omega^2 LCR_1 - \omega^2 LCR_2)$$
$$0 = \omega^3 R_1^2 R_2^2 LC^2 + R_1^2 \omega L - \omega^3 R_1^2 L^2 C$$
$$0 = \omega^2 R_2^2 C^2 + 1 - \omega^2 LC$$
$$\omega^2\,(LC - R_2^2 C^2) = 1$$

$$\omega_0 = \frac{1}{\sqrt{LC - R_2^2 C^2}}$$

$$\omega_0 = \frac{1}{\sqrt{(0.02)(9\times10^{-6}) - (0.1)^2 (9\times10^{-6})^2}}$$
$$\omega_0 = \underline{\mathbf{2.357\ krad/s}}$$

(b) At $\omega = \omega_0 = 2.357\ \text{krad/s}$,

$$j\omega L = j(2.357\times10^3)(20\times10^{-3}) = j47.14$$

$$R_1 \parallel j\omega L = \frac{j47.14}{1 + j47.14} = 0.9996 + j0.0212$$

$$R_2 + \frac{1}{j\omega C} = 0.1 + \frac{1}{j(2.357\times10^3)(9\times10^{-6})} = 0.1 - j47.14$$

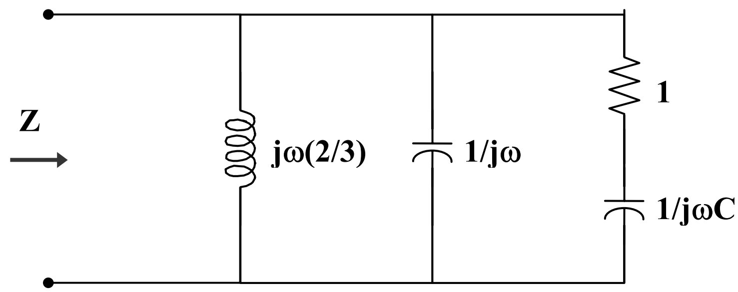
$$\mathbf{Z}_{in}(\omega_0) = (R_1 \parallel j\omega L) \parallel (R_2 + 1/j\omega C)$$

$$\mathbf{Z}_{in}(\omega_0) = \frac{(0.9996 + j0.0212)(0.1 - j47.14)}{(0.9996 + j0.0212) + (0.1 - j47.14)}$$

$$\mathbf{Z}_{in}(\omega_0) = \underline{\mathbf{1\,\Omega}}$$

Chapter 14, Solution 44.

We find the input impedance of the circuit shown below.



$$\frac{1}{\mathbf{Z}} = \frac{3}{j\omega 2} + j\omega + \frac{1}{1 + 1/j\omega C}, \qquad \omega = 1$$

$$\frac{1}{\mathbf{Z}} = \text{-}j1.5 + j + \frac{jC}{1 + jC} = \text{-}j0.5 + \frac{C^2 + jC}{1 + C^2}$$

$v(t)$ and $i(t)$ are in phase when **Z** is purely real, i.e.

$$0 = \text{-}0.5 + \frac{C}{1 + C^2} \longrightarrow (C - 1)^2 = 1 \qquad \text{or} \qquad C = \underline{\mathbf{1\,F}}$$

$$\frac{1}{\mathbf{Z}} = \frac{C^2}{1 + C^2} = \frac{1}{2} \longrightarrow \mathbf{Z} = 2\,\Omega$$

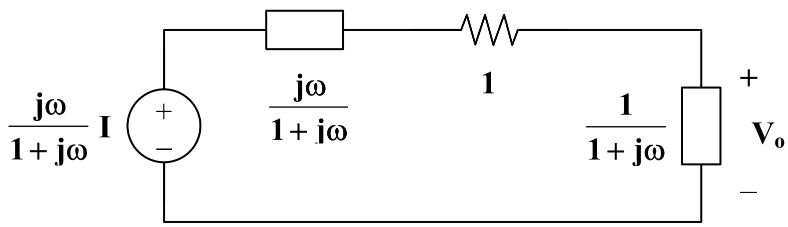
$$\mathbf{V} = \mathbf{Z}\,\mathbf{I} = (2)(10) = 20$$

$$v(t) = 20\sin(t)\ \text{V}, \qquad \text{i.e.} \qquad V_o = \underline{\mathbf{20\ V}}$$

Chapter 14, Solution 45.

(a) $1 \,\|\, j\omega = \dfrac{j\omega}{1+j\omega}, \qquad 1 \,\|\, \dfrac{1}{j\omega} = \dfrac{1/j\omega}{1+1/j\omega} = \dfrac{1}{1+j\omega}$

Transform the current source gives the circuit below.



$$\mathbf{V}_o = \frac{\dfrac{1}{1+j\omega}}{1+\dfrac{1}{1+j\omega}+\dfrac{j\omega}{1+j\omega}} \cdot \frac{j\omega}{1+j\omega}\,\mathbf{I}$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{I}} = \underline{\boldsymbol{\frac{j\omega}{2(1+j\omega)^2}}}$$

(b) $$\mathbf{H}(1) = \frac{1}{2(1+j)^2}$$

$$\left|\mathbf{H}(1)\right| = \frac{1}{2(\sqrt{2})^2} = \underline{\mathbf{0.25}}$$

Chapter 14, Solution 46.

(a) This is an RLC series circuit.

$$\omega_o = \frac{1}{\sqrt{LC}} \longrightarrow C = \frac{1}{\omega^2{}_o L} = \frac{1}{(2\pi x 15x10^3)^2 x10x10^{-3}} = \underline{11.26\text{nF}}$$

(b) $$Z = R,\ I = V/Z = 120/20 = \underline{\mathbf{6\ A}}$$

(c) $$Q = \frac{\omega_o L}{R} = \frac{2\pi x 15x10^3 x10x10^{-3}}{20} = 15\pi = \underline{47.12}$$

Chapter 14, Solution 47.

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + j\omega L} = \frac{1}{1 + j\omega L/R}$$

$H(0) = 1$ and $H(\infty) = 0$ showing that this circuit is a lowpass filter.

At the corner frequency, $\left|H(\omega_c)\right| = \dfrac{1}{\sqrt{2}}$, i.e.

$$\frac{1}{\sqrt{2}} = \frac{1}{\sqrt{1 + \left(\frac{\omega_c L}{R}\right)^2}} \longrightarrow 1 = \frac{\omega_c L}{R} \qquad \text{or} \qquad \omega_c = \frac{R}{L}$$

Hence,

$$\omega_c = \frac{R}{L} = 2\pi f_c$$

$$f_c = \frac{1}{2\pi} \cdot \frac{R}{L} = \frac{1}{2\pi} \cdot \frac{10 \times 10^3}{2 \times 10^{-3}} = \underline{\mathbf{796\ kHz}}$$

Chapter 14, Solution 48.

$$\mathbf{H}(\omega) = \frac{R \parallel \frac{1}{j\omega C}}{j\omega L + R \parallel \frac{1}{j\omega C}}$$

$$\mathbf{H}(\omega) = \frac{\frac{R/j\omega C}{R + 1/j\omega C}}{j\omega L + \frac{R/j\omega C}{R + 1/j\omega C}}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{R}}{\mathbf{R + j\omega L - \omega^2 RLC}}}$$

$H(0) = 1$ and $H(\infty) = 0$ showing that **<u>this circuit is a lowpass filter</u>**.

Chapter 14, Solution 49.

$$\text{At dc, } H(0) = \frac{4}{2} = 2.$$

Hence, $$\left| H(\omega) \right| = \frac{1}{\sqrt{2}} H(0) = \frac{2}{\sqrt{2}}$$

$$\frac{2}{\sqrt{2}} = \frac{4}{\sqrt{4 + 100\omega_c^2}}$$

$$4 + 100\omega_c^2 = 8 \longrightarrow \omega_c = 0.2$$

$$H(2) = \frac{4}{2 + j20} = \frac{2}{1 + j10}$$

$$\left| H(2) \right| = \frac{2}{\sqrt{101}} = 0.199$$

$$\text{In dB, } 20\log_{10}\left| H(2) \right| = \underline{\mathbf{-14.023}}$$

$$\arg H(2) = -\tan^{-1} 10 = \underline{\mathbf{-84.3^\circ}}$$

Chapter 14, Solution 50.

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{j\omega L}{R + j\omega L}$$

$H(0) = 0$ and $H(\infty) = 1$ showing that **<u>this circuit is a highpass filter</u>**.

$$\mathbf{H}(\omega_c) = \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{1 + \left(\dfrac{R}{\omega_c L}\right)^2}} \longrightarrow 1 = \frac{R}{\omega_c L}$$

or $$\omega_c = \frac{R}{L} = 2\pi f_c$$

$$f_c = \frac{1}{2\pi} \cdot \frac{R}{L} = \frac{1}{2\pi} \cdot \frac{200}{0.1} = \underline{\mathbf{318.3\ Hz}}$$

Chapter 14, Solution 51.

$$\mathbf{H}'(\omega) = \frac{j\omega RC}{1 + j\omega RC} = \frac{j\omega}{j\omega + 1/RC} \qquad \text{(from Eq. 14.52)}$$

This has a unity passband gain, i.e. $H(\infty) = 1$.

$$\frac{1}{RC} = \omega_c = 50$$

$$\mathbf{H}^{\wedge}(\omega) = 10\,\mathbf{H}'(\omega) = \frac{j10\omega}{50 + j\omega}$$

$$\mathbf{H}(\omega) = \underline{\boldsymbol{\frac{j10\omega}{50 + j\omega}}}$$

Chapter 14, Problem 52.

Design an *RL* lowpass filter that uses a 40-mH coil and has a cut-off frequency of 5 kHz.

Chapter 14, Solution 53.

$$\omega_c = \frac{R}{L} = 2\pi f_c$$

$$R = 2\pi f_c L = (2\pi)(10^5)(40 \times 10^{-3}) = \underline{\mathbf{25.13\ k\Omega}}$$

Chapter 14, Solution 54.

$$\omega_1 = 2\pi f_1 = 20\pi \times 10^3$$
$$\omega_2 = 2\pi f_2 = 22\pi \times 10^3$$

$$B = \omega_2 - \omega_1 = 2\pi \times 10^3$$

$$\omega_0 = \frac{\omega_2 + \omega_1}{2} = 21\pi \times 10^3$$

$$Q = \frac{\omega_0}{B} = \frac{21\pi}{2\pi} = \underline{11.5}$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \longrightarrow L = \frac{1}{\omega_0^2 C}$$

$$L = \frac{1}{(21\pi \times 10^3)^2 (80 \times 10^{-12})} = \underline{\mathbf{2.872\ H}}$$

$$B = \frac{R}{L} \longrightarrow R = BL$$

$$R = (2\pi \times 10^3)(2.872) = \underline{\mathbf{18.045\ k\Omega}}$$

Chapter 14, Solution 55.

$$\omega_c = 2\pi f_c = \frac{1}{RC} \longrightarrow R = \frac{1}{2\pi f_c C} = \frac{1}{2\pi x 2x10^3 x300x10^{-12}} = \underline{265.3k\Omega}$$

Chapter 14, Solution 56.

$$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(25 \times 10^{-3})(0.4 \times 10^{-6})}} = 10\ \text{krad/s}$$

$$B = \frac{R}{L} = \frac{10}{25 \times 10^{-3}} = 0.4\ \text{krad/s}$$

$$Q = \frac{10}{0.4} = \underline{\mathbf{25}}$$

$$\omega_1 = \omega_o - B/2 = 10 - 0.2 = 9.8\ \text{krad/s} \quad \text{or} \quad f_1 = \frac{9.8}{2\pi} = 1.56\ \text{kHz}$$

$$\omega_2 = \omega_o + B/2 = 10 + 0.2 = 10.2\ \text{krad/s} \quad \text{or} \quad f_2 = \frac{10.2}{2\pi} = 1.62\ \text{kHz}$$

Therefore,

$$\underline{\mathbf{1.56\ kHz < f < 1.62\ kHz}}$$

Chapter 14, Solution 57.

(a) From Eq 14.54,

$$\mathbf{H}(s) = \frac{R}{R + sL + \frac{1}{sC}} = \frac{sRC}{1 + sRC + s^2LC} = \frac{s\frac{R}{L}}{s^2 + s\frac{R}{L} + \frac{1}{LC}}$$

Since $B = \frac{R}{L}$ and $\omega_0 = \frac{1}{\sqrt{LC}}$,

$$\mathbf{H}(s) = \underline{\frac{\mathbf{sB}}{\mathbf{s^2 + sB + \omega_0^2}}}$$

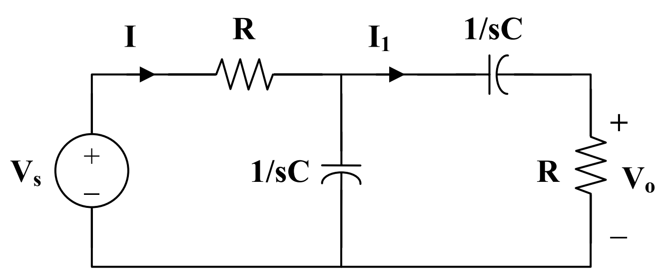
(b) From Eq. 14.56,

$$\mathbf{H}(s) = \frac{sL + \frac{1}{sC}}{R + sL + \frac{1}{sC}} = \frac{s^2 + \frac{1}{LC}}{s^2 + s\frac{R}{L} + \frac{1}{LC}}$$

$$\mathbf{H}(s) = \underline{\frac{\mathbf{s^2 + \omega_0^2}}{\mathbf{s^2 + sB + \omega_0^2}}}$$

Chapter 14, Solution 58.

(a) Consider the circuit below.



$$\mathbf{Z}(s) = R + \frac{1}{sC} \parallel \left(R + \frac{1}{sC}\right) = R + \frac{\frac{1}{sC}\left(R + \frac{1}{sC}\right)}{R + \frac{2}{sC}}$$

$$\mathbf{Z}(s) = R + \frac{1 + sRC}{sC(2 + sRC)}$$

$$\mathbf{Z}(s) = \frac{1 + 3sRC + s^2R^2C^2}{sC(2 + sRC)}$$

$$\mathbf{I} = \frac{\mathbf{V}_s}{\mathbf{Z}}$$

$$\mathbf{I}_1 = \frac{1/sC}{2/sC + R}\mathbf{I} = \frac{\mathbf{V}_s}{\mathbf{Z}(2 + sRC)}$$

$$\mathbf{V}_o = \mathbf{I}_1 R = \frac{R\,\mathbf{V}_s}{2 + sRC} \cdot \frac{sC(2 + sRC)}{1 + 3sRC + s^2R^2C^2}$$

$$\mathbf{H}(s) = \frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{sRC}{1 + 3sRC + s^2R^2C^2}$$

$$\mathbf{H}(s) = \frac{1}{3}\left[\frac{\frac{3}{RC}s}{s^2 + \frac{3}{RC}s + \frac{1}{R^2C^2}}\right]$$

Thus, $\omega_0^2 = \dfrac{1}{R^2C^2}$ or $\omega_0 = \dfrac{1}{RC} = \underline{\mathbf{1\ rad/s}}$

$$B = \frac{3}{RC} = \underline{\mathbf{3\ rad/s}}$$

(b) Similarly,

$$\mathbf{Z}(s) = sL + R \,\|\, (R + sL) = sL + \frac{R(R + sL)}{2R + sL}$$

$$\mathbf{Z}(s) = \frac{R^2 + 3sRL + s^2L^2}{2R + sL}$$

$$\mathbf{I} = \frac{\mathbf{V}_s}{\mathbf{Z}}, \qquad \mathbf{I}_1 = \frac{R}{2R + sL}\mathbf{I} = \frac{R\,\mathbf{V}_s}{\mathbf{Z}(2R + sL)}$$

$$\mathbf{V}_o = \mathbf{I}_1 \cdot sL = \frac{sLR\,\mathbf{V}_s}{2R + sL} \cdot \frac{2R + sL}{R^2 + 3sRL + s^2L^2}$$

$$\mathbf{H}(s) = \frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{sRL}{R^2 + 3sRL + s^2L^2} = \frac{\frac{1}{3}\left(\frac{3R}{L}s\right)}{s^2 + \frac{3R}{L}s + \frac{R^2}{L^2}}$$

Thus, $\omega_0 = \frac{R}{L} = \underline{\mathbf{1\ rad/s}}$

$$B = \frac{3R}{L} = \underline{\mathbf{3\ rad/s}}$$

Chapter 14, Solution 59.

(a) $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(0.1)(40 \times 10^{-12})}} = \underline{\mathbf{0.5 \times 10^6\ rad/s}}$

(b) $B = \frac{R}{L} = \frac{2 \times 10^3}{0.1} = 2 \times 10^4$

$$Q = \frac{\omega_0}{B} = \frac{0.5 \times 10^6}{2 \times 10^4} = 250$$

As a high Q circuit,

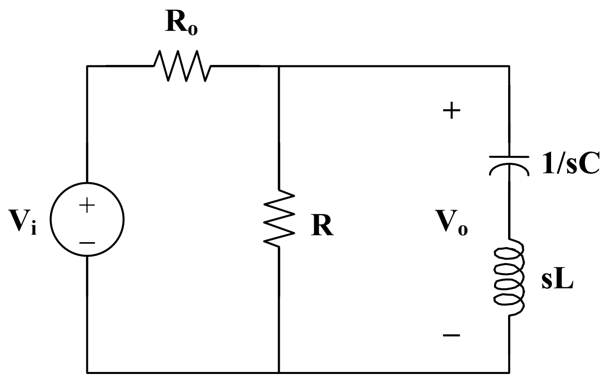
$$\omega_1 = \omega_0 - \frac{B}{2} = 10^4 (50 - 1) = \underline{\mathbf{490\ krad/s}}$$

$$\omega_2 = \omega_0 + \frac{B}{2} = 10^4 (50 + 1) = \underline{\mathbf{510\ krad/s}}$$

(c) As seen in part (b), $Q = \underline{\mathbf{250}}$

Chapter 14, Solution 60.

Consider the circuit below.



$$\mathbf{Z}(s) = R \,\|\, \left(sL + \frac{1}{sC}\right) = \frac{R\,(sL + 1/sC)}{R + sL + 1/sC}$$

$$\mathbf{Z}(s) = \frac{R\,(1 + s^2 LC)}{1 + sRC + s^2 LC}$$

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{Z}}{\mathbf{Z} + R_o} = \frac{R\,(1 + s^2 LC)}{R_o + sRR_oC + s^2 LCR_o + R + s^2 LCR}$$

$$\mathbf{Z}_{in} = R_o + \mathbf{Z} = R_o + \frac{R\,(1 + s^2 LC)}{1 + sRC + s^2 LC}$$

$$\mathbf{Z}_{in} = \frac{R_o + sRR_oC + s^2 LCR_o + R + s^2 LCR}{1 + sRC + s^2 LC}$$

$s = j\omega$

$$\mathbf{Z}_{in} = \frac{R_o + j\omega RR_oC - \omega^2 LCR_o + R - \omega^2 LCR}{1 - \omega^2 LC + j\omega RC}$$

$$\mathbf{Z}_{in} = \frac{(R_o + R - \omega^2 LCR_o - \omega^2 LCR + j\omega RR_oC)(1 - \omega^2 LC - j\omega RC)}{(1 - \omega^2 LC)^2 + (\omega RC)^2}$$

$\mathrm{Im}(\mathbf{Z}_{in}) = 0$ implies that

$$-\omega RC[R_o + R - \omega^2 LCR_o - \omega^2 LCR] + \omega RR_oC(1 - \omega^2 LC) = 0$$

$$R_o + R - \omega^2 LCR_o - \omega^2 LCR - R_o + \omega^2 LCR_o = 0$$
$$\omega^2 LCR = R$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(1\times10^{-3})(4\times10^{-6})}} = \underline{\mathbf{15.811\ krad/s}}$$

$$\mathbf{H} = \frac{R\,(1-\omega^2 LC)}{R_o + j\omega RR_oC + R - \omega^2 LCR_o - \omega^2 LCR}$$

$$H_{max} = H(0) = \frac{R}{R_o + R}$$

or $$H_{max} = H(\infty) = \lim_{\omega\to\infty} \frac{R\left(\dfrac{1}{\omega^2} - LC\right)}{\dfrac{R_o + R}{\omega^2} + j\dfrac{RR_oC}{\omega} - LC(R + R_o)} = \frac{R}{R + R_o}$$

At ω_1 and ω_2, $\left|\mathbf{H}\right| = \frac{1}{\sqrt{2}} H_{mzx}$

$$\frac{R}{\sqrt{2}(R_o + R)} = \left|\frac{R\,(1-\omega^2 LC)}{R_o + R - \omega^2 LC\,(R_o + R) + j\omega RR_oC}\right|$$

$$\frac{1}{\sqrt{2}} = \frac{(R_o + R)(1-\omega^2 LC)}{\sqrt{(\omega RR_oC)^2 + (R_o + R - \omega^2 LC(R_o + R))^2}}$$

$$\frac{1}{\sqrt{2}} = \frac{10\,(1-\omega^2\cdot 4\times10^{-9})}{\sqrt{(96\times10^{-6}\omega)^2 + (10-\omega^2\cdot 4\times10^{-8})^2}}$$

$$0 = \frac{10\,(1-\omega^2\cdot 4\times10^{-9})}{\sqrt{(96\times10^{-6}\omega)^2 + (10-\omega^2\cdot 4\times10^{-8})^2}} - \frac{1}{\sqrt{2}}$$

$$(10-\omega^2\cdot 4\times10^{-8})(\sqrt{2}) - \sqrt{(96\times10^{-6}\omega)^2 + (10-\omega^2\cdot 4\times10^{-8})^2} = 0$$

$$(2)(10-\omega^2\cdot 4\times10^{-8})^2 = (96\times10^{-6}\omega)^2 + (10-\omega^2\cdot 4\times10^{-8})^2$$

$$(96\times10^{-6}\omega)^2 - (10-\omega^2\cdot 4\times10^{-8})^2 = 0$$

$$1.6\times10^{-15}\omega^4 - 8.092\times10^{-7}\omega^2 + 100 = 0$$

$$\omega^4 - 5.058\times10^8 + 6.25\times10^{16} = 0$$

$$\omega^2 = \begin{cases} 2.9109\times10^8 \\ 2.1471\times10^8 \end{cases}$$

Hence,

$$\omega_1 = 14.653 \text{ krad/s}$$

$$\omega_2 = 17.061 \text{ krad/s}$$

$$B = \omega_2 - \omega_1 = 17.061 - 14.653 = \underline{\mathbf{2.408\ krad/s}}$$

Chapter 14, Solution 61.

(a) $$\mathbf{V}_+ = \frac{1/j\omega C}{R + 1/j\omega C}\mathbf{V}_i, \qquad \mathbf{V}_- = \mathbf{V}_o$$

Since $\mathbf{V}_+ = \mathbf{V}_-$,

$$\frac{1}{1 + j\omega RC}\mathbf{V}_i = \mathbf{V}_o$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \underline{\frac{\mathbf{1}}{\mathbf{1 + j\omega RC}}}$$

(b) $$\mathbf{V}_+ = \frac{R}{R + 1/j\omega C}\mathbf{V}_i, \qquad \mathbf{V}_- = \mathbf{V}_o$$

Since $\mathbf{V}_+ = \mathbf{V}_-$,

$$\frac{j\omega RC}{1 + j\omega RC}\mathbf{V}_i = \mathbf{V}_o$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \underline{\frac{\mathbf{j\omega RC}}{\mathbf{1 + j\omega RC}}}$$

Chapter 14, Solution 62.

This is a highpass filter.

$$\mathbf{H}(\omega) = \frac{j\omega RC}{1 + j\omega RC} = \frac{1}{1 - j/\omega RC}$$

$$\mathbf{H}(\omega) = \frac{1}{1 - j\omega_c/\omega}, \qquad \omega_c = \frac{1}{RC} = 2\pi(1000)$$

$$\mathbf{H}(\omega) = \frac{1}{1 - jf_c/f} = \frac{1}{1 - j1000/f}$$

(a) $$\mathbf{H}(f = 200\text{ Hz}) = \frac{1}{1 - j5} = \frac{\mathbf{V}_o}{\mathbf{V}_i}$$

$$|\mathbf{V}_o| = \frac{120\text{ mV}}{|1 - j5|} = \underline{\mathbf{23.53\ mV}}$$

(b) $$\mathbf{H}(f = 2\text{ kHz}) = \frac{1}{1 - j0.5} = \frac{\mathbf{V}_o}{\mathbf{V}_i}$$

$$|\mathbf{V}_o| = \frac{120\text{ mV}}{|1 - j0.5|} = \underline{\mathbf{107.3\ mV}}$$

(c) $$\mathbf{H}(f = 10\text{ kHz}) = \frac{1}{1 - j0.1} = \frac{\mathbf{V}_o}{\mathbf{V}_i}$$

$$|\mathbf{V}_o| = \frac{120\text{ mV}}{|1 - j0.1|} = \underline{\mathbf{119.4\ mV}}$$

Chapter 14, Solution 63.

For an active highpass filter,

$$H(s) = -\frac{sC_iR_f}{1 + sC_iR_i} \qquad (1)$$

But

$$H(s) = -\frac{10s}{1 + s/10} \qquad (2)$$

Comparing (1) and (2) leads to:

$$C_i R_f = 10 \quad \longrightarrow \quad R_f = \frac{10}{C_i} = \underline{10\text{M}\Omega}$$

$$C_i R_i = 0.1 \quad \longrightarrow \quad R_i = \frac{0.1}{C_i} = \underline{100\text{k}\Omega}$$

Chapter 14, Solution 64.

$$Z_f = R_f \parallel \frac{1}{j\omega C_f} = \frac{R_f}{1 + j\omega R_f C_f}$$

$$Z_i = R_i + \frac{1}{j\omega C_i} = \frac{1 + j\omega R_i C_i}{j\omega C_i}$$

Hence,

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{-\mathbf{Z}_f}{\mathbf{Z}_i} = \underline{\frac{\mathbf{-\,j\omega R_f C_i}}{\mathbf{(1 + j\omega R_f C_f)(1 + j\omega R_i C_i)}}}$$

<u>This is a bandpass filter</u>. $\mathbf{H}(\omega)$ is similar to the product of the transfer function of a lowpass filter and a highpass filter.

Chapter 14, Solution 65.

$$\mathbf{V}_+ = \frac{R}{R + 1/j\omega C}\mathbf{V}_i = \frac{j\omega RC}{1 + j\omega RC}\mathbf{V}_i$$

$$\mathbf{V}_- = \frac{R_i}{R_i + R_f}\mathbf{V}_o$$

Since $\mathbf{V}_+ = \mathbf{V}_-$,

$$\frac{R_i}{R_i + R_f}\mathbf{V}_o = \frac{j\omega RC}{1 + j\omega RC}\mathbf{V}_i$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \underline{\left(\mathbf{1} + \frac{\mathbf{R_f}}{\mathbf{R_i}}\right)\left(\frac{\mathbf{j\omega RC}}{\mathbf{1 + j\omega RC}}\right)}$$

It is evident that as $\omega \to \infty$, the gain is $\underline{\mathbf{1} + \frac{\mathbf{R_f}}{\mathbf{R_i}}}$ and that the corner frequency is $\underline{\frac{\mathbf{1}}{\mathbf{RC}}}$.

Chapter 14, Solution 66.

(a) **<u>Proof</u>**

(b) When $\underline{\mathbf{R_1 R_4 = R_2 R_3}}$,

$$\mathbf{H}(s) = \frac{R_4}{R_3 + R_4} \cdot \frac{s}{s + 1/R_2 C}$$

(c) When $\underline{\mathbf{R_3} \to \infty}$,

$$\mathbf{H}(s) = \frac{-1/R_1 C}{s + 1/R_2 C}$$

Chapter 14, Solution 67.

$$\text{DC gain} = \frac{R_f}{R_i} = \frac{1}{4} \longrightarrow R_i = 4R_f$$

$$\text{Corner frequency} = \omega_c = \frac{1}{R_f C_f} = 2\pi(500)\text{ rad/s}$$

If we select $R_f = 20\text{ k}\Omega$, then $R_i = 80\text{ k}\Omega$ and

$$C = \frac{1}{(2\pi)(500)(20 \times 10^3)} = 15.915\text{ nF}$$

Therefore, if $R_f = \underline{\mathbf{20\ k\Omega}}$, then $R_i = \underline{\mathbf{80\ k\Omega}}$ and $C = \underline{\mathbf{15.915\ nF}}$

Chapter 14, Solution 68.

$$\text{High frequency gain} = 5 = \frac{R_f}{R_i} \longrightarrow R_f = 5R_i$$

$$\text{Corner frequency} = \omega_c = \frac{1}{R_iC_i} = 2\pi(200) \text{ rad/s}$$

If we select $R_i = 20\text{ k}\Omega$, then $R_f = 100\text{ k}\Omega$ and

$$C = \frac{1}{(2\pi)(200)(20\times10^3)} = 39.8\text{ nF}$$

Therefore, if $R_i = \underline{\mathbf{20\ k\Omega}}$, then $R_f = \underline{\mathbf{100\ k\Omega}}$ and $C = \underline{\mathbf{39.8\ nF}}$

Chapter 14, Solution 69.

This is a highpass filter with $f_c = 2$ kHz.

$$\omega_c = 2\pi f_c = \frac{1}{RC}$$

$$RC = \frac{1}{2\pi f_c} = \frac{1}{4\pi\times10^3}$$

10^8 Hz may be regarded as high frequency. Hence the high-frequency gain is

$$\frac{-R_f}{R} = \frac{-10}{4} \qquad \text{or} \qquad R_f = 2.5R$$

If we let $R = \underline{\mathbf{10\ k\Omega}}$, then $R_f = \underline{\mathbf{25\ k\Omega}}$, and $C = \dfrac{1}{4000\pi\times10^4} = \underline{\mathbf{7.96\ nF}}$.

Chapter 14, Solution 70.

(a) $$\mathbf{H}(s) = \frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)} = \frac{Y_1 Y_2}{Y_1 Y_2 + Y_4 (Y_1 + Y_2 + Y_3)}$$

where $Y_1 = \dfrac{1}{R_1} = G_1,\ Y_2 = \dfrac{1}{R_2} = G_2,\ Y_3 = sC_1,\ Y_4 = sC_2$.

$$\mathbf{H}(s) = \underline{\frac{\mathbf{G_1 G_2}}{\mathbf{G_1 G_2 + sC_2 (G_1 + G_2 + sC_1)}}}$$

(b) $$H(0) = \frac{G_1 G_2}{G_1 G_2} = 1, \qquad H(\infty) = 0$$

showing that **<u>this circuit is a lowpass filter</u>**.

Chapter 14, Solution 71.

$R = 50\,\Omega,\ L = 40\text{ mH},\ C = 1\,\mu\text{F}$

$$L' = \frac{K_m}{K_f} L \longrightarrow 1 = \frac{K_m}{K_f} \cdot (40 \times 10^{-3})$$

$$25 K_f = K_m \tag{1}$$

$$C' = \frac{C}{K_m K_f} \longrightarrow 1 = \frac{10^{-6}}{K_m K_f}$$

$$10^6 K_f = \frac{1}{K_m} \tag{2}$$

Substituting (1) into (2),

$$10^6 K_f = \frac{1}{25 K_f}$$

$$K_f = \underline{\mathbf{0.2 \times 10^{-3}}}$$

$$K_m = 25 K_f = \underline{\mathbf{5 \times 10^{-3}}}$$

Chapter 14, Solution 72.

$$L'C' = \frac{LC}{K_f^2} \longrightarrow K_f^2 = \frac{LC}{L'C'}$$

$$K_f^2 = \frac{(4\times10^{-3})(20\times10^{-6})}{(1)(2)} = 4\times10^{-8}$$

$$K_f = \underline{\mathbf{2\times10^{-4}}}$$

$$\frac{L'}{C'} = \frac{L}{C}K_m^2 \longrightarrow K_m^2 = \frac{L'}{C'}\cdot\frac{C}{L}$$

$$K_m^2 = \frac{(1)(20\times10^{-6})}{(2)(4\times10^{-3})} = 2.5\times10^{-3}$$

$$K_m = \underline{\mathbf{5\times10^{-2}}}$$

Chapter 14, Solution 73.

$$R' = K_m R = (12)(800\times10^3) = \underline{\mathbf{9.6\ M\Omega}}$$

$$L' = \frac{K_m}{K_f}L = \frac{800}{1000}(40\times10^{-6}) = \underline{\mathbf{32\ \mu F}}$$

$$C' = \frac{C}{K_m K_f} = \frac{300\times10^{-9}}{(800)(1000)} = \underline{\mathbf{0.375\ pF}}$$

Chapter 14, Solution 74.

$$R'_1 = K_m R_1 = 3\text{x}100 = \underline{300\Omega}$$

$$R'_2 = K_m R_2 = 10\text{x}100 = \underline{1\,k\Omega}$$

$$L' = \frac{K_m}{K_f}L = \frac{10^2}{10^6}(2) = \underline{200\,\mu H}$$

$$C' = \frac{C}{K_m K_f} = \frac{\frac{1}{10}}{10^8} = \underline{1\,nF}$$

Chapter 14, Solution 75.

$$R' = K_m R = 20x10 = \underline{200\,\Omega}$$

$$L' = \frac{K_m}{K_f}L = \frac{10}{10^5}(4) = \underline{400\,\mu H}$$

$$C' = \frac{C}{K_m K_f} = \frac{1}{10x10^5} = \underline{1\,\mu F}$$

Chapter 14, Solution 76.

$$R' = K_m R = 50x10^3 \longrightarrow R = \frac{50x10^3}{10^3} = \underline{50\,\Omega}$$

$$L' = \frac{K_m}{K_f}L = 10\,\mu H \longrightarrow L = 10x10^{-6}x\frac{10^6}{10^3} = \underline{10\,mH}$$

$$C' = 40\,pF = \frac{C}{K_m K_f} \longrightarrow C = 40x10^{-12}x10^3x10^6 = \underline{40\ mF}$$

Chapter 14, Solution 77.

L and C are needed before scaling.

$$B = \frac{R}{L} \longrightarrow L = \frac{R}{B} = \frac{10}{5} = 2\text{ H}$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \longrightarrow C = \frac{1}{\omega_0^2 L} = \frac{1}{(1600)(2)} = 312.5\ \mu F$$

(a) $L' = K_m L = (600)(2) = \underline{\mathbf{1200\ H}}$

$$C' = \frac{C}{K_m} = \frac{3.125\times10^{-4}}{600} = \underline{\mathbf{0.5208\ \mu F}}$$

(b) $L' = \dfrac{L}{K_f} = \dfrac{2}{10^3} = \underline{\mathbf{2\ mH}}$

$C' = \dfrac{C}{K_f} = \dfrac{3.125 \times 10^{-4}}{10^3} = \underline{\mathbf{312.5\ nF}}$

(c) $L' = \dfrac{K_m}{K_f} L = \dfrac{(400)(2)}{10^5} = \underline{\mathbf{8\ mH}}$

$C' = \dfrac{C}{K_m K_f} = \dfrac{3.125 \times 10^{-4}}{(400)(10^5)} = \underline{\mathbf{7.81\ pF}}$

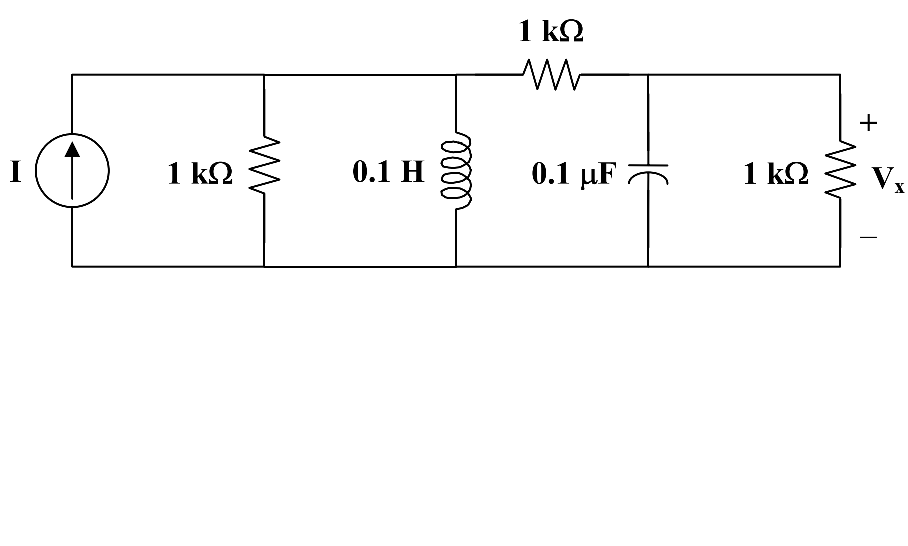
Chapter 14, Solution 78.

$R' = K_m R = (1000)(1) = 1\ k\Omega$

$L' = \dfrac{K_m}{K_f} L = \dfrac{10^3}{10^4}(1) = 0.1\ H$

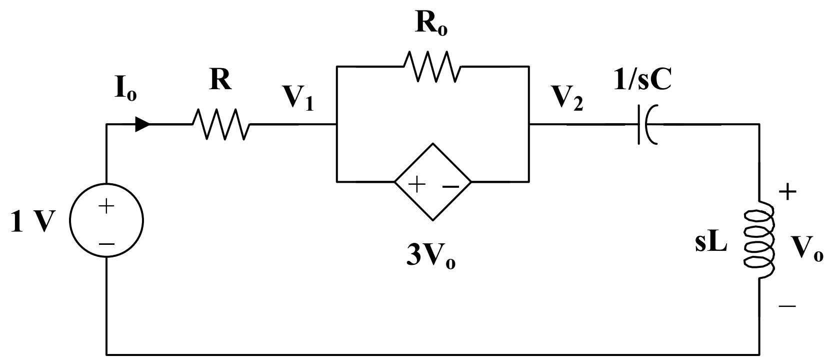
$C' = \dfrac{C}{K_m K_f} = \dfrac{1}{(10^3)(10^4)} = 0.1\ \mu F$

<u>The new circuit is shown below</u>.



Chapter 14, Solution 79.

(a) Insert a 1-V source at the input terminals.



There is a supernode.

$$\frac{1-\mathbf{V}_1}{R} = \frac{\mathbf{V}_2}{sL + 1/sC} \qquad (1)$$

But $\quad \mathbf{V}_1 = \mathbf{V}_2 + 3\mathbf{V}_o \longrightarrow \mathbf{V}_2 = \mathbf{V}_1 - 3\mathbf{V}_o \qquad (2)$

Also, $\quad \mathbf{V}_o = \dfrac{sL}{sL + 1/sC}\mathbf{V}_2 \longrightarrow \dfrac{\mathbf{V}_o}{sL} = \dfrac{\mathbf{V}_2}{sL + 1/sC} \qquad (3)$

Combining (2) and (3)

$$\mathbf{V}_2 = \mathbf{V}_1 - 3\mathbf{V}_o = \frac{sL + 1/sC}{sL}\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{s^2LC}{1 + 4s^2LC}\mathbf{V}_1 \qquad (4)$$

Substituting (3) and (4) into (1) gives

$$\frac{1-\mathbf{V}_1}{R} = \frac{\mathbf{V}_o}{sL} = \frac{sC}{1 + 4s^2LC}\mathbf{V}_1$$

$$1 = \mathbf{V}_1 + \frac{sRC}{1 + 4s^2LC}\mathbf{V}_1 = \frac{1 + 4s^2LC + sRC}{1 + 4s^2LC}\mathbf{V}_1$$

$$\mathbf{V}_1 = \frac{1 + 4s^2LC}{1 + 4s^2LC + sRC}$$

$$\mathbf{I}_o = \frac{1-\mathbf{V}_1}{R} = \frac{sRC}{R(1+4s^2LC+sRC)}$$

$$\mathbf{Z}_{in} = \frac{1}{\mathbf{I}_o} = \frac{1+sRC+4s^2LC}{sC}$$

$$\mathbf{Z}_{in} = 4sL + R + \frac{1}{sC} \qquad (5)$$

When $R = 5$, $L = 2$, $C = 0.1$,

$$\mathbf{Z}_{in}(s) = \underline{\mathbf{8s + 5 + \frac{10}{s}}}$$

At resonance,

$$\mathrm{Im}(\mathbf{Z}_{in}) = 0 = 4\omega L - \frac{1}{\omega C}$$

or $$\omega_0 = \frac{1}{2\sqrt{LC}} = \frac{1}{2\sqrt{(0.1)(2)}} = \underline{\mathbf{1.118\ rad/s}}$$

(b) After scaling,

$$R' \longrightarrow K_m R$$
$$4\,\Omega \longrightarrow 40\,\Omega$$
$$5\,\Omega \longrightarrow 50\,\Omega$$

$$L' = \frac{K_m}{K_f} L = \frac{10}{100}(2) = 0.2\ \text{H}$$

$$C' = \frac{C}{K_m K_f} = \frac{0.1}{(10)(100)} = 10^{-4}$$

From (5),

$$\mathbf{Z}_{in}(s) = \underline{\mathbf{0.8s + 50 + \frac{10^4}{s}}}$$

$$\omega_0 = \frac{1}{2\sqrt{LC}} = \frac{1}{2\sqrt{(0.2)(10^{-4})}} = \underline{\mathbf{111.8\ rad/s}}$$

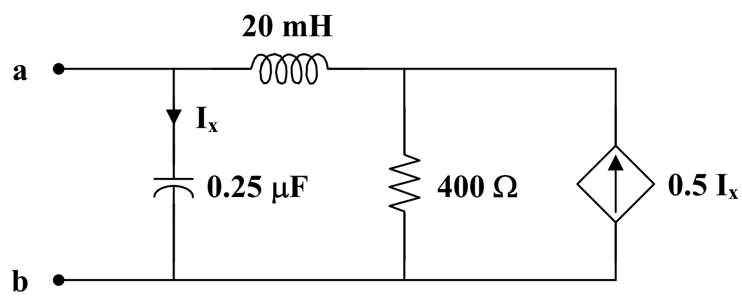
Chapter 14, Solution 80.

(a) $R' = K_m R = (200)(2) = 400\ \Omega$

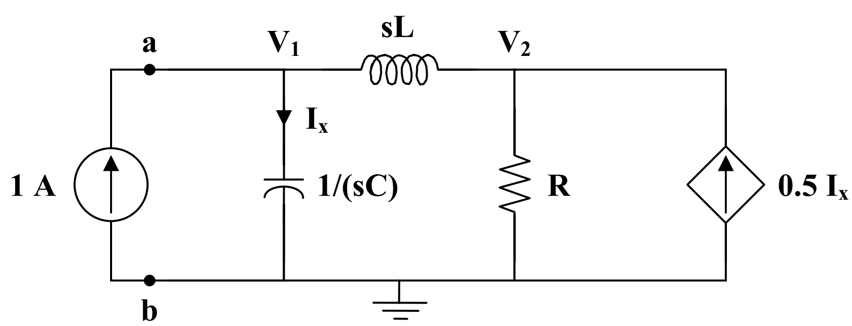
$$L' = \frac{K_m L}{K_f} = \frac{(200)(1)}{10^4} = 20 \text{ mH}$$

$$C' = \frac{C}{K_m K_f} = \frac{0.5}{(200)(10^4)} = 0.25\ \mu\text{F}$$

<u>The new circuit is shown below</u>.



(b) Insert a 1-A source at the terminals a-b.



At node 1,

$$1 = sC\mathbf{V}_1 + \frac{\mathbf{V}_1 - \mathbf{V}_2}{sL} \tag{1}$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{sL} + 0.5\mathbf{I}_x = \frac{\mathbf{V}_2}{R}$$

But, $\mathbf{I}_x = sC\,\mathbf{V}_1$.

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{sL} + 0.5sC\,\mathbf{V}_1 = \frac{\mathbf{V}_2}{R} \qquad (2)$$

Solving (1) and (2),

$$\mathbf{V}_1 = \frac{sL + R}{s^2LC + 0.5sCR + 1}$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{V}_1}{1} = \frac{sL + R}{s^2LC + 0.5sCR + 1}$$

At $\omega = 10^4$,

$$\mathbf{Z}_{Th} = \frac{(j10^4)(20\times10^{-3}) + 400}{(j10^4)^2(20\times10^{-3})(0.25\times10^{-6}) + 0.5(j10^4)(0.25\times10^{-6})(400) + 1}$$

$$\mathbf{Z}_{Th} = \frac{400 + j200}{0.5 + j0.5} = 600 - j200$$

$$\mathbf{Z}_{Th} = \underline{\mathbf{632.5\angle -18.435^\circ\ ohms}}$$

Chapter 14, Solution 81.

(a)

$$\frac{1}{Z} = G + j\omega C + \frac{1}{R + j\omega L} = \frac{(G + j\omega C)(R + j\omega L) + 1}{R + j\omega L}$$

which leads to $\quad Z = \dfrac{j\omega L + R}{-\omega^2 LC + j\omega(RC + LG) + GR + 1}$

$$Z(\omega) = \frac{j\dfrac{\omega}{C} + \dfrac{R}{LC}}{-\omega^2 + j\omega\left(\dfrac{R}{L} + \dfrac{G}{C}\right) + \dfrac{GR + 1}{LC}} \qquad (1)$$

We compare this with the given impedance:

$$Z(\omega) = \frac{1000(j\omega + 1)}{-\omega^2 + 2j\omega + 1 + 2500} \qquad (2)$$

Comparing (1) and (2) shows that

$$\frac{1}{C} = 1000 \longrightarrow C = 1\,\text{mF}, \quad R/L = 1 \longrightarrow R = L$$

$$\frac{R}{L} + \frac{G}{C} = 2 \longrightarrow G = C = 1\ \text{mS}$$

$$2501 = \frac{GR+1}{LC} = \frac{10^{-3}R+1}{10^{-3}R} \longrightarrow R = 0.4 = L$$

Thus,

R = **<u>0.4Ω</u>**, L = **<u>0.4 H</u>**, C = **<u>1 mF</u>**, G = **<u>1 mS</u>**

(b) By frequency-scaling, K_f =1000.

R' = **<u>0.4 Ω</u>**, G' = **<u>1 mS</u>**

$$L' = \frac{L}{K_f} = \frac{0.4}{10^3} = \underline{0.4\text{mH}}, \quad C' = \frac{C}{K_f} = \frac{10^{-3}}{10^{-3}} = \underline{1\mu\text{F}}$$

Chapter 14, Solution 82.

$$C' = \frac{C}{K_m K_f}$$

$$K_f = \frac{\omega_c'}{\omega} = \frac{200}{1} = 200$$

$$K_m = \frac{C}{C'} \cdot \frac{1}{K_f} = \frac{1}{10^{-6}} \cdot \frac{1}{200} = 5000$$

$R' = K_m R =$ **<u>5 kΩ</u>**, thus, $R_f' = 2R_i =$ **<u>10 kΩ</u>**

Chapter 14, Solution 83.

$$1\mu F \longrightarrow C' = \frac{1}{K_m K_f} C = \frac{10^{-6}}{100x10^5} = \underline{0.1\,pF}$$

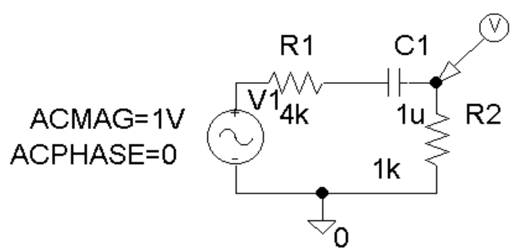
$$5\mu F \longrightarrow C' = \underline{0.5\,pF}$$

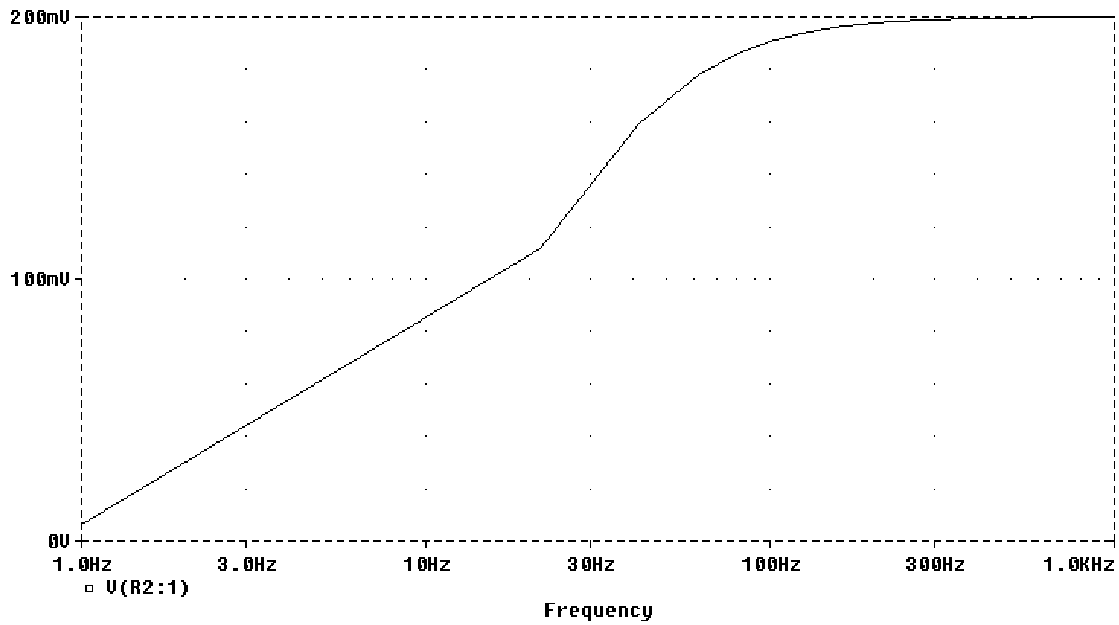
$$10\,k\Omega \longrightarrow R' = K_m R = 100x10\,k\Omega = \underline{1\,M\Omega}$$

$$20\,k\Omega \longrightarrow R' = \underline{2\,M\Omega}$$

Chapter 14, Solution 84.

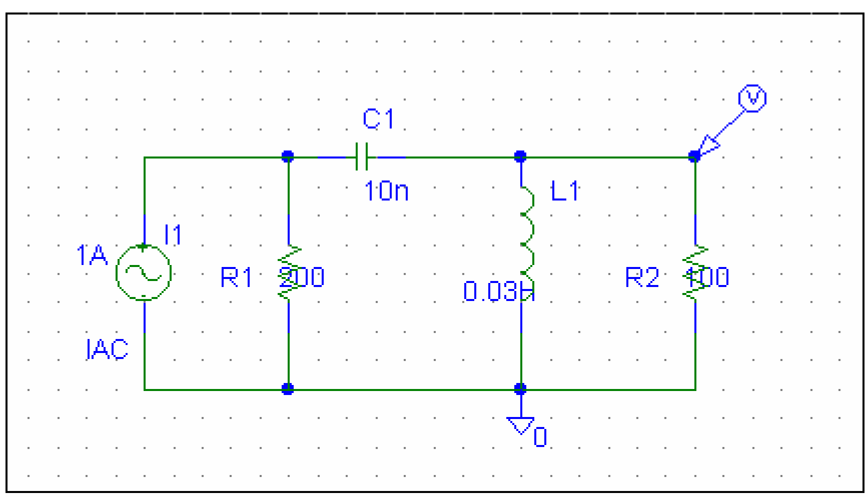
The schematic is shown below. A voltage marker is inserted to measure v_o. In the AC sweep box, we select Total Points = 50, Start Frequency = 1, and End Frequency = 1000. After saving and simulation, we obtain the magnitude and phase plots in the probe menu as shown below.

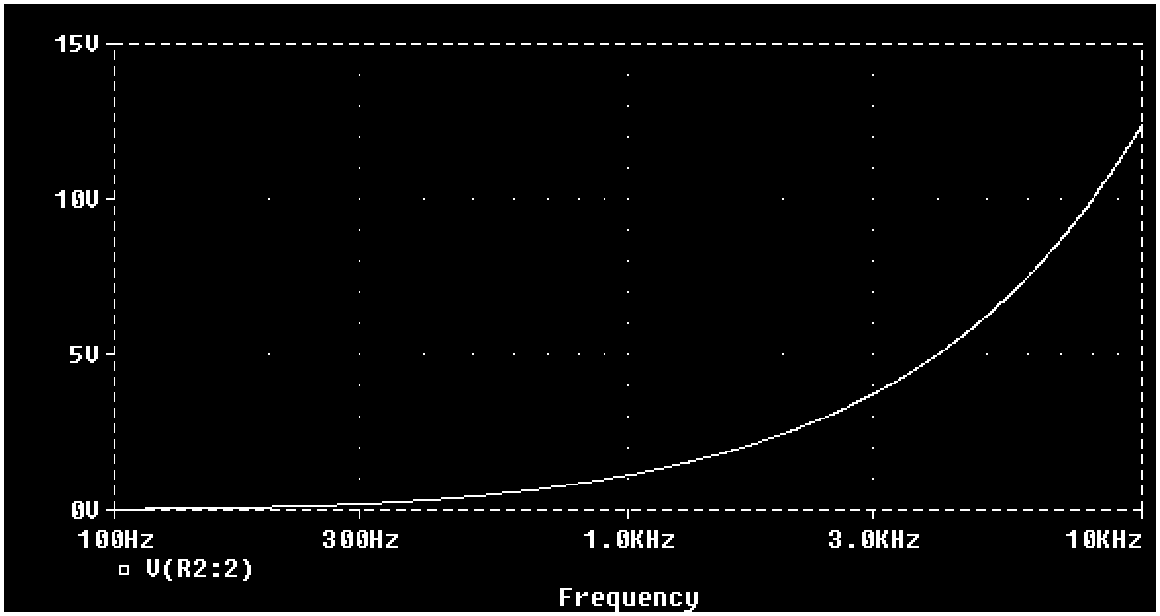


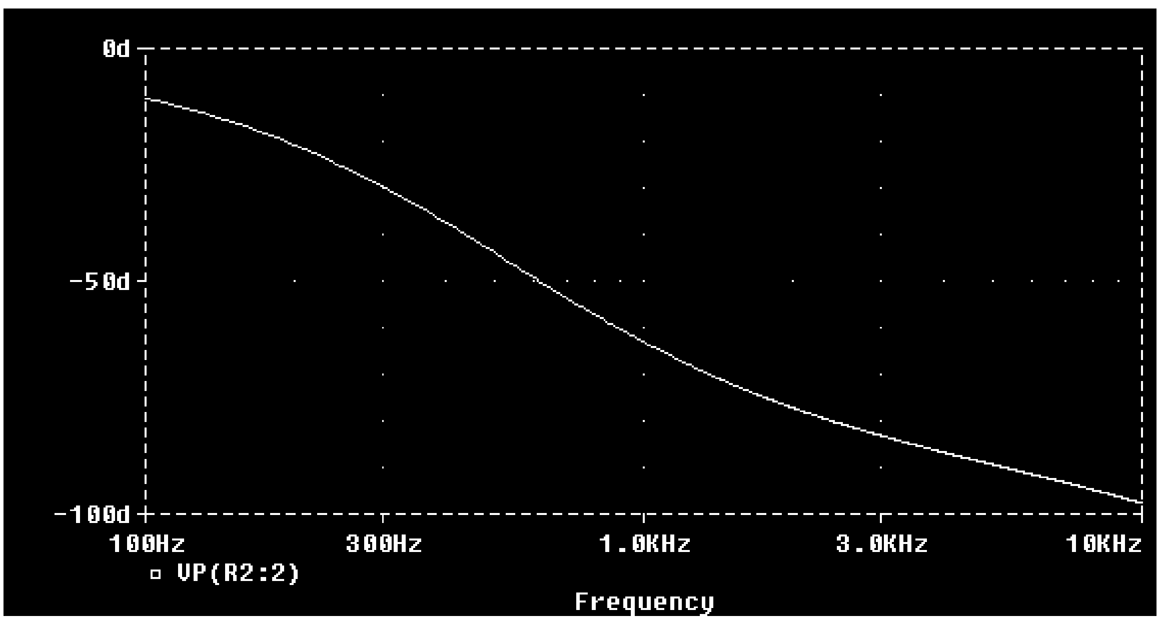


Chapter 14, Solution 85.

We let $I_s = 1\angle 0^o$ A so that $V_o / I_s = V_o$. The schematic is shown below. The circuit is simulated for $100 < f < 10$ kHz.

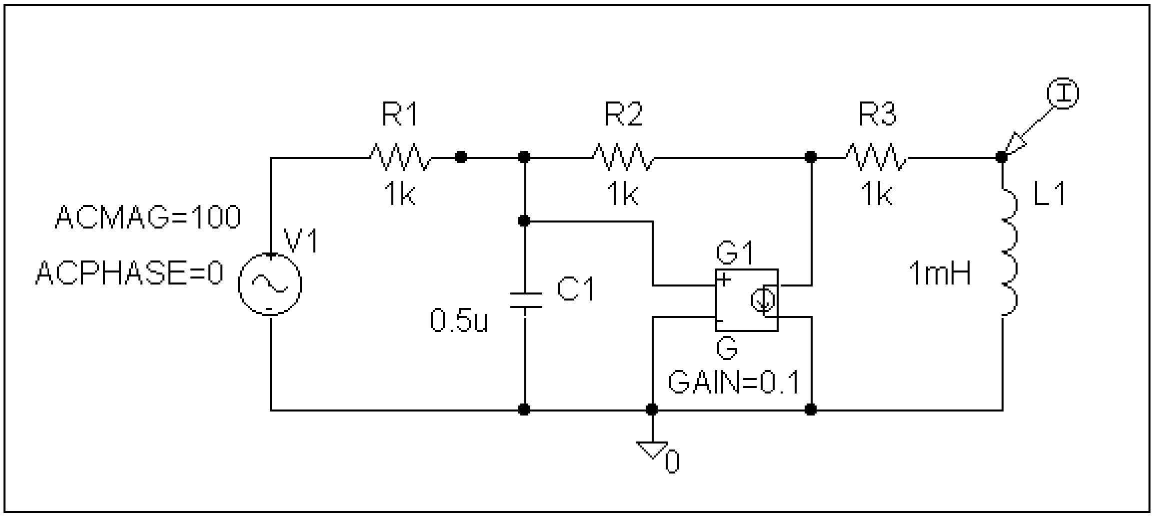


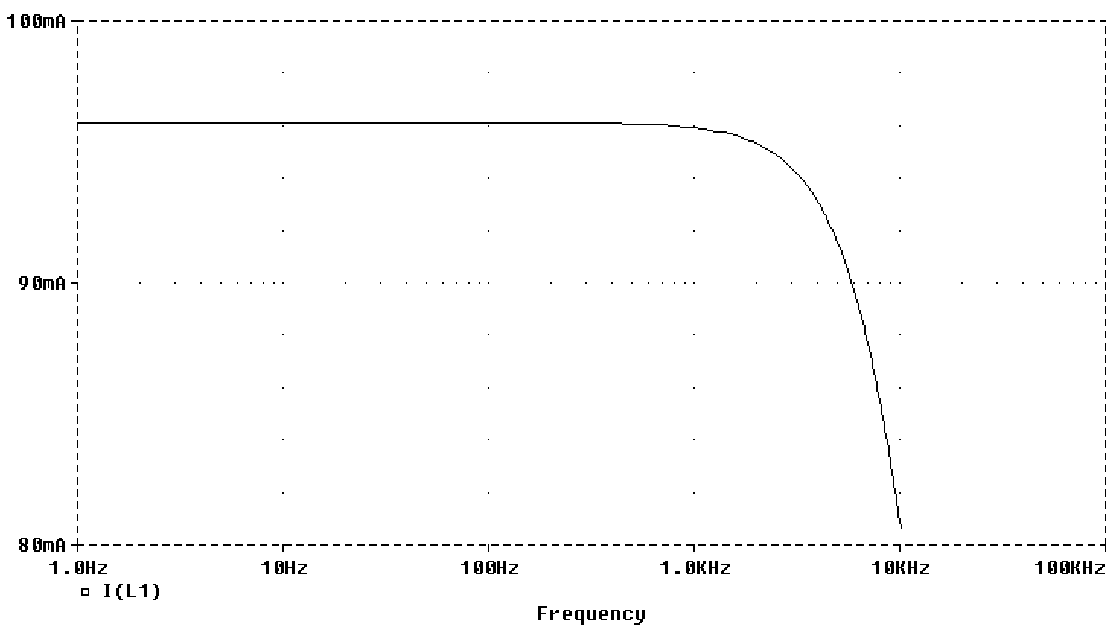


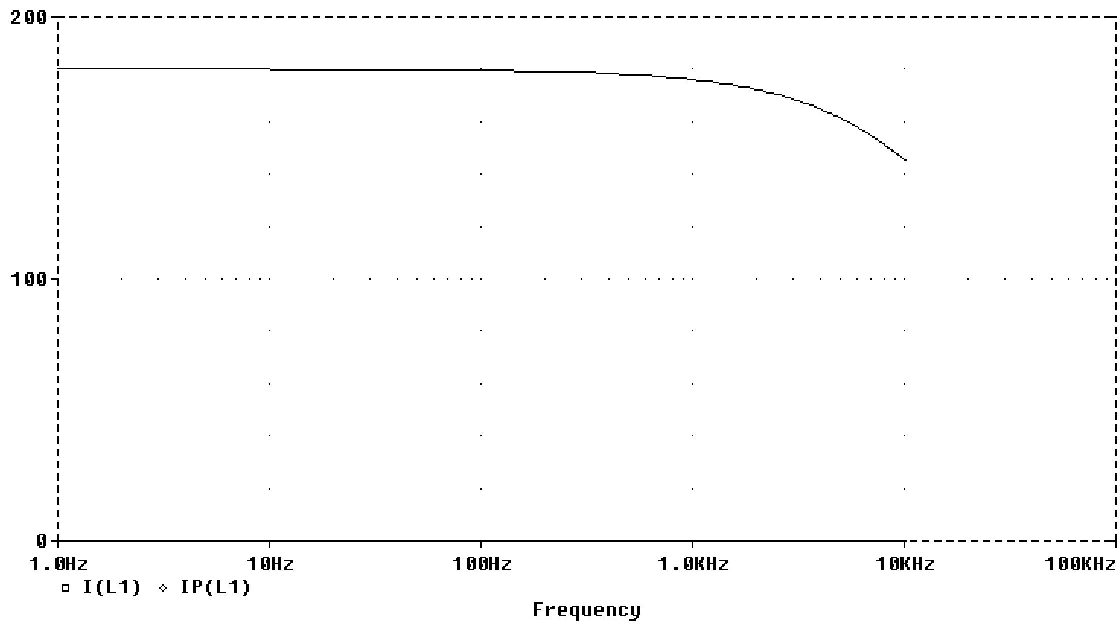


Chapter 14, Solution 86.

The schematic is shown below. A current marker is inserted to measure **I**. We set Total Points = 101, start Frequency = 1, and End Frequency = 10 kHz in the AC sweep box. After simulation, the magnitude and phase plots are obtained in the Probe menu as shown below.

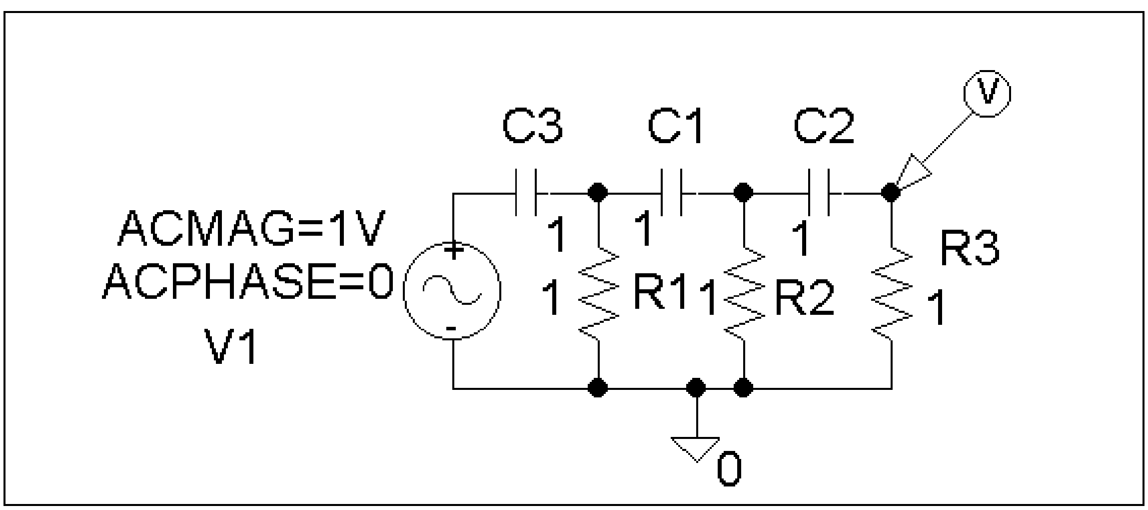

R1
1k
R2
1k
R3
1k
L1
1mH
ACMAG=100
ACPHASE=0
V1
G1
C1
0.5u
G
GAIN=0.1
0

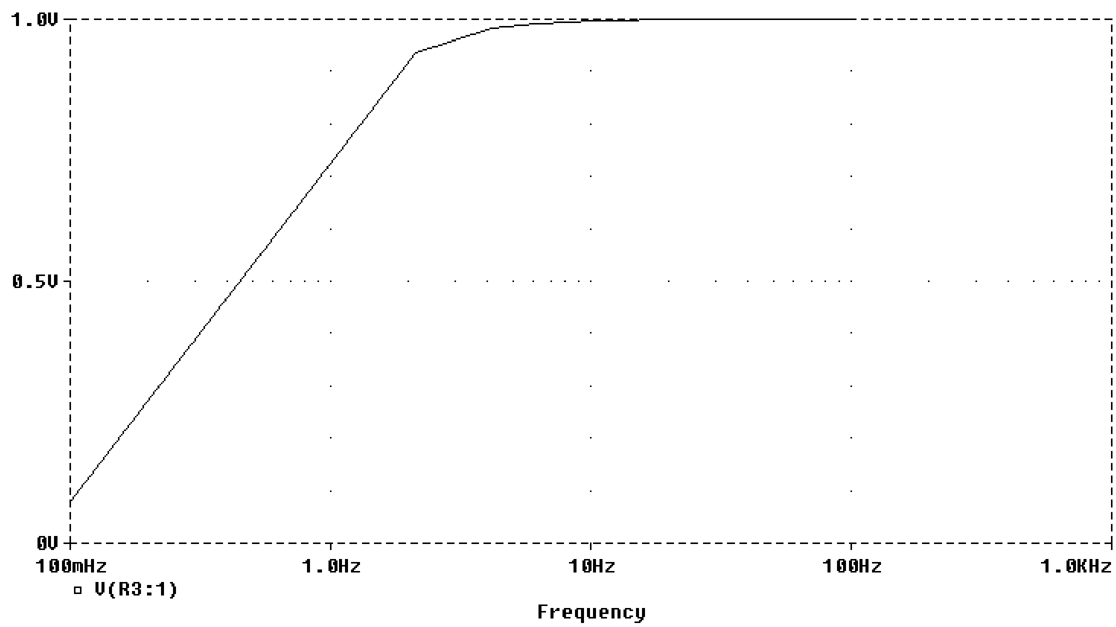

100mA
90mA
80mA
1.0Hz
10Hz
100Hz
1.0KHz
10KHz
100KHz
I(L1)
Frequency



Chapter 14, Solution 87.

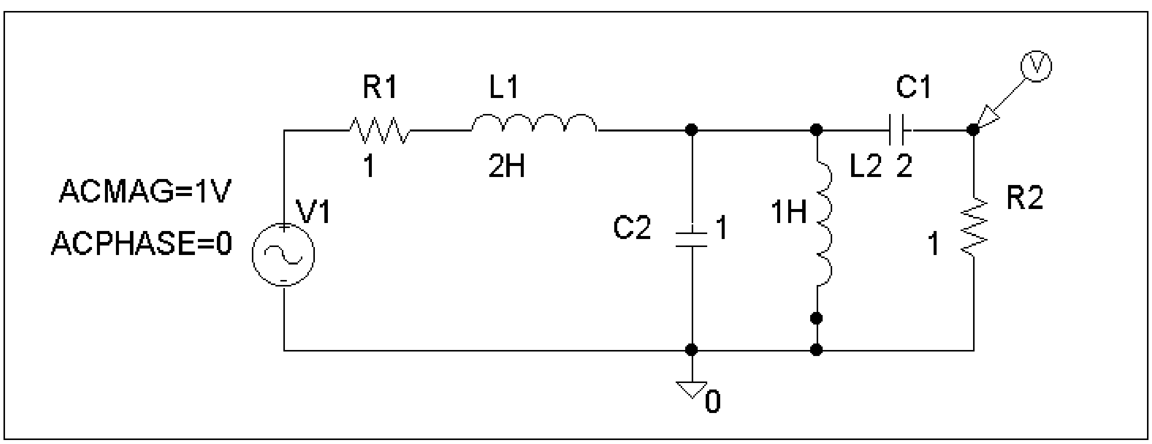
The schematic is shown below. I_n the AC Sweep box, we set Total Points = 50, Start Frequency = 1, and End Frequency = 100. After simulation, we obtain the magnitude response as shown below. It is evident from the response that the circuit represents a high-pass filter.

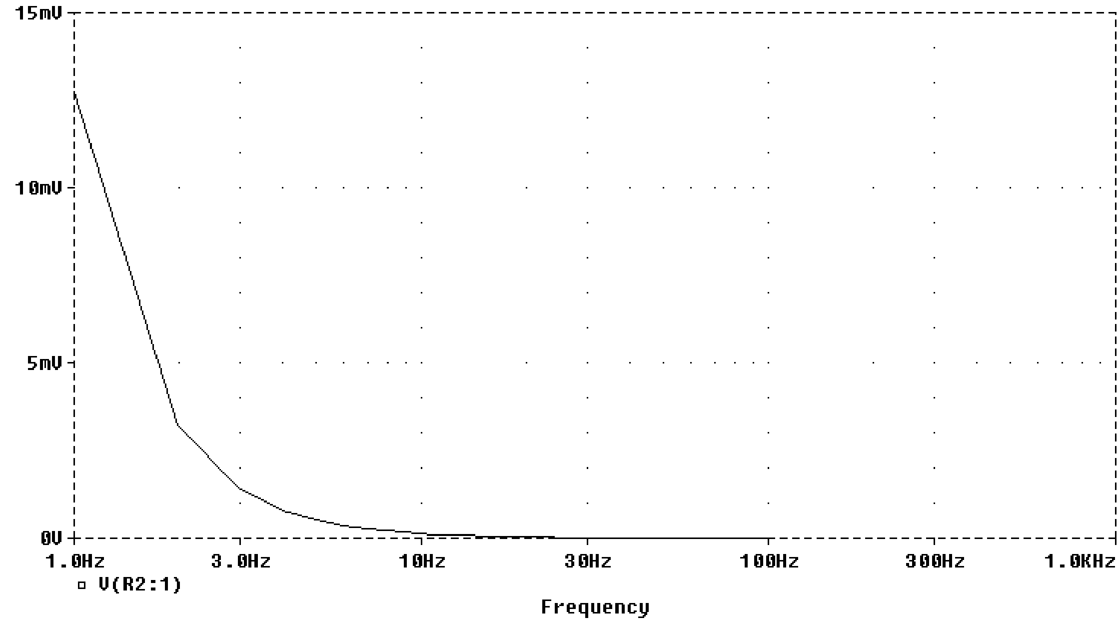


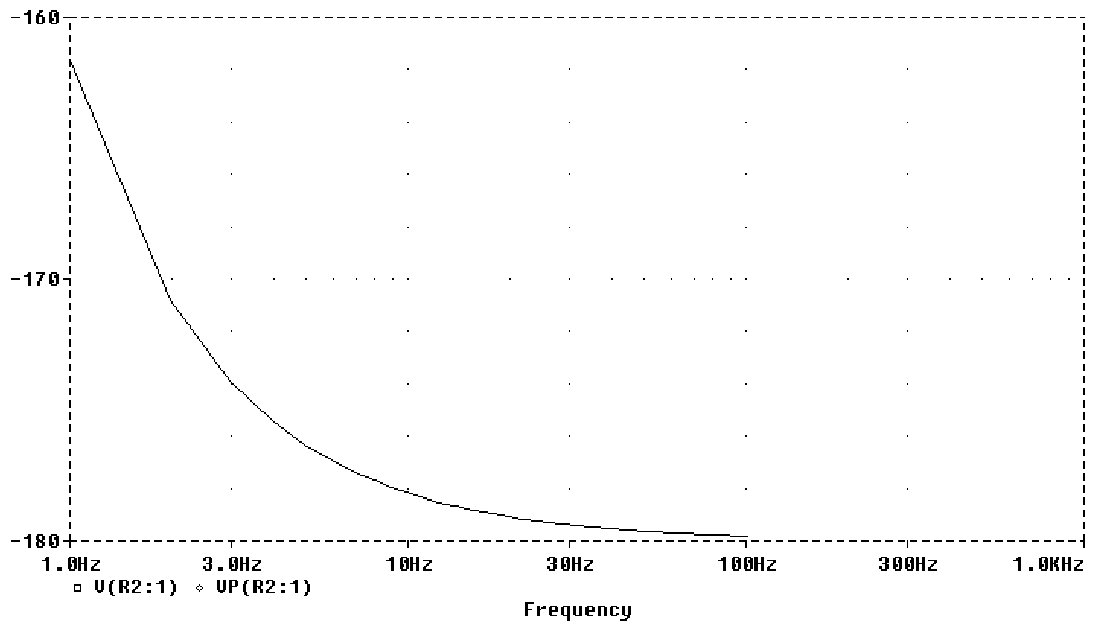


Chapter 14, Solution 88.

The schematic is shown below. We insert a voltage marker to measure V_o. In the AC Sweep box, we set Total Points = 101, Start Frequency = 1, and End Frequency = 100. After simulation, we obtain the magnitude and phase plots of V_o as shown below.

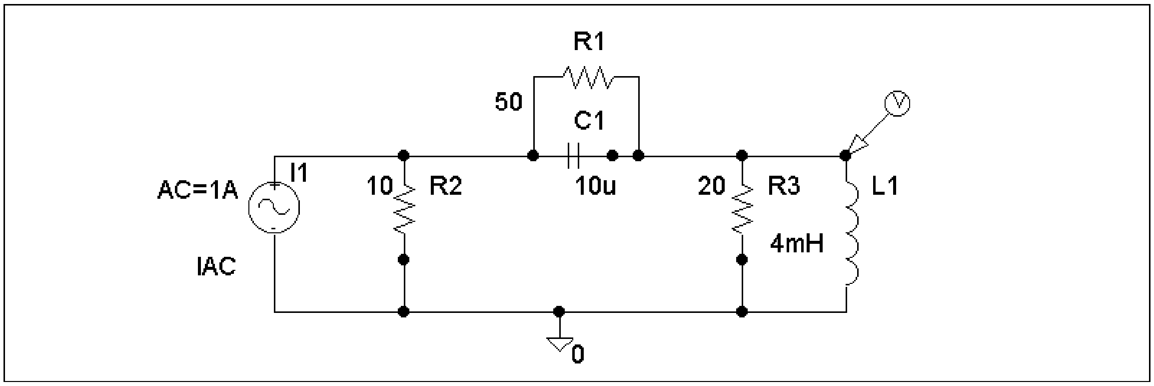


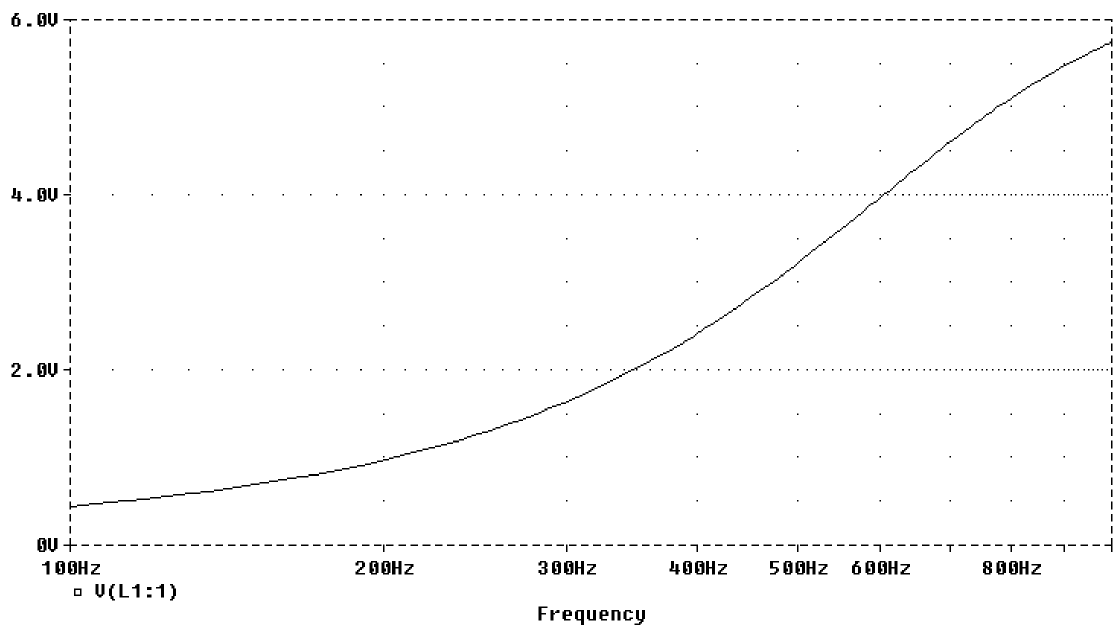




Chapter 14, Solution 89.

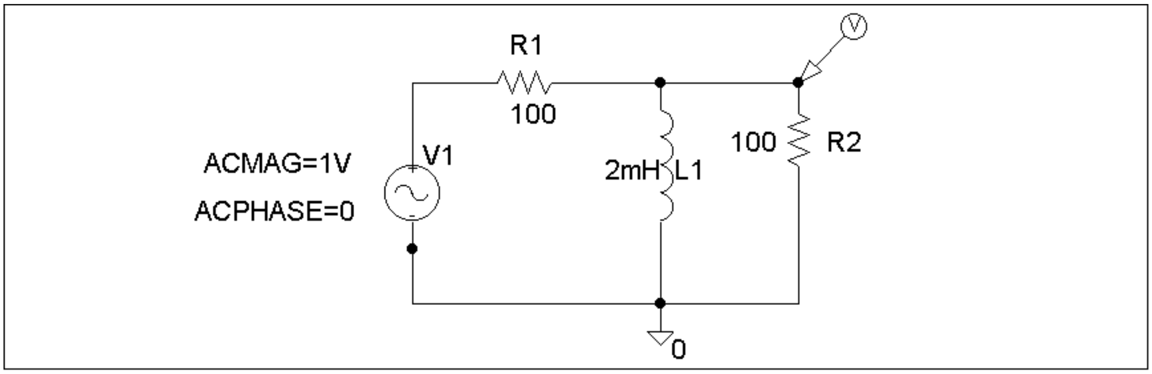
The schematic is shown below. In the AC Sweep box, we type Total Points = 101, Start Frequency = 100, and End Frequency = 1 k. After simulation, the magnitude plot of the response V_o is obtained as shown below.

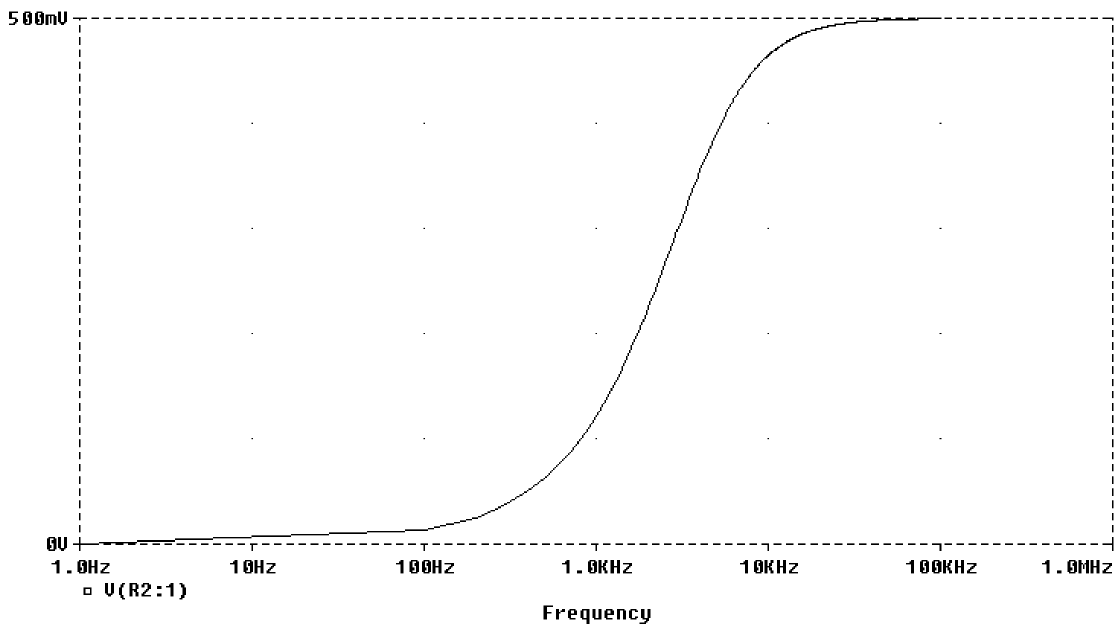




Chapter 14, Solution 90.

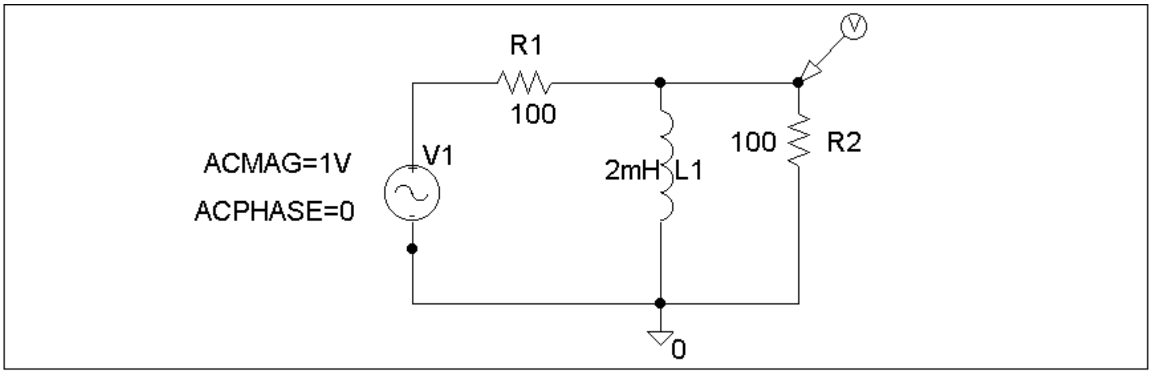
The schematic is shown below. In the AC Sweep box, we set Total Points = 1001, Start Frequency = 1, and End Frequency = 100k. After simulation, we obtain the magnitude plot of the response as shown below. The response shows that the circuit is a high-pass filter.

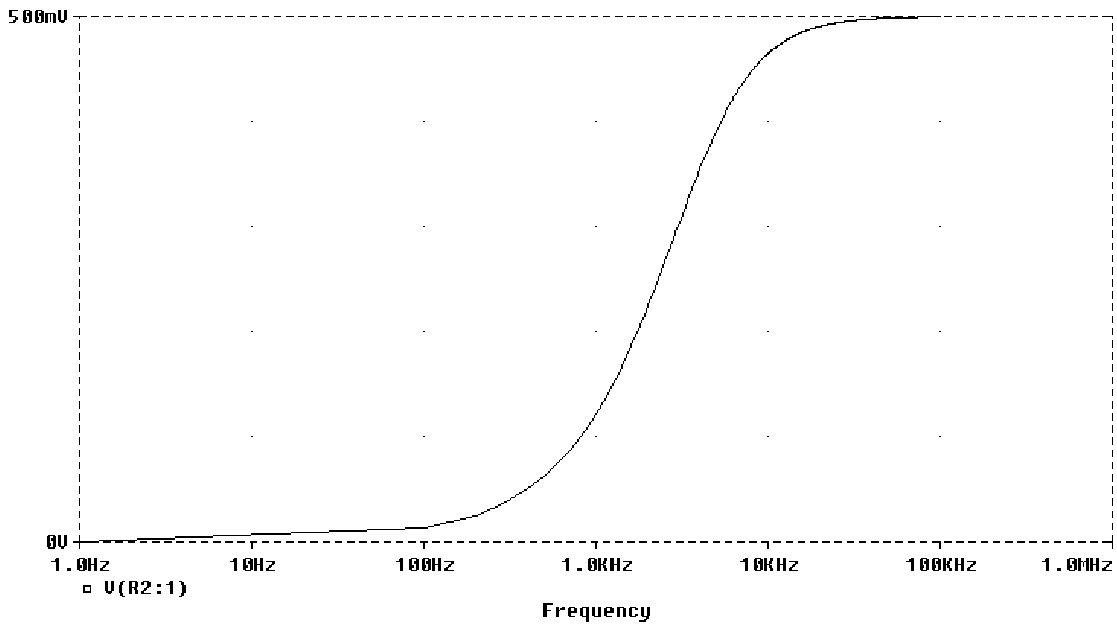




Chapter 14, Solution 91.

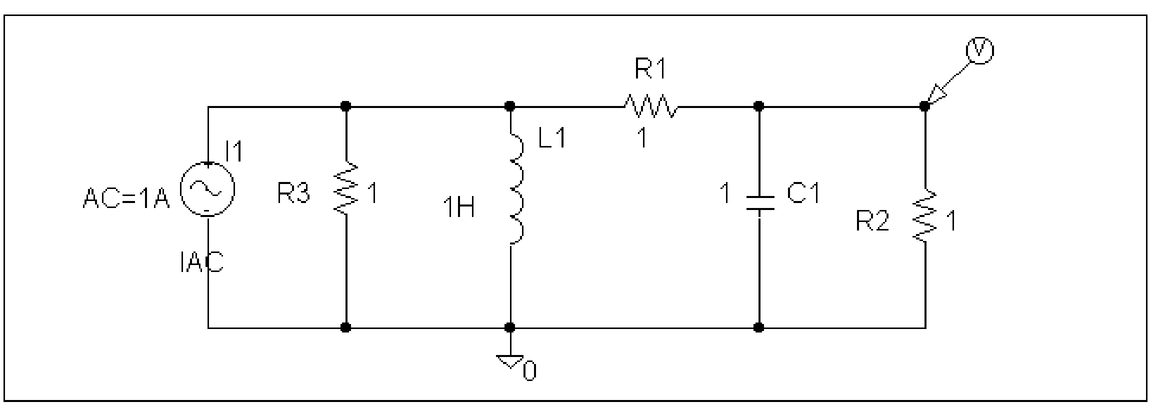
The schematic is shown below. In the AC Sweep box, we set
Total Points = 1001, Start Frequency = 1, and End Frequency = 100k. After simulation, we obtain the magnitude plot of the response as shown below. The response shows that the circuit is a high-pass filter.

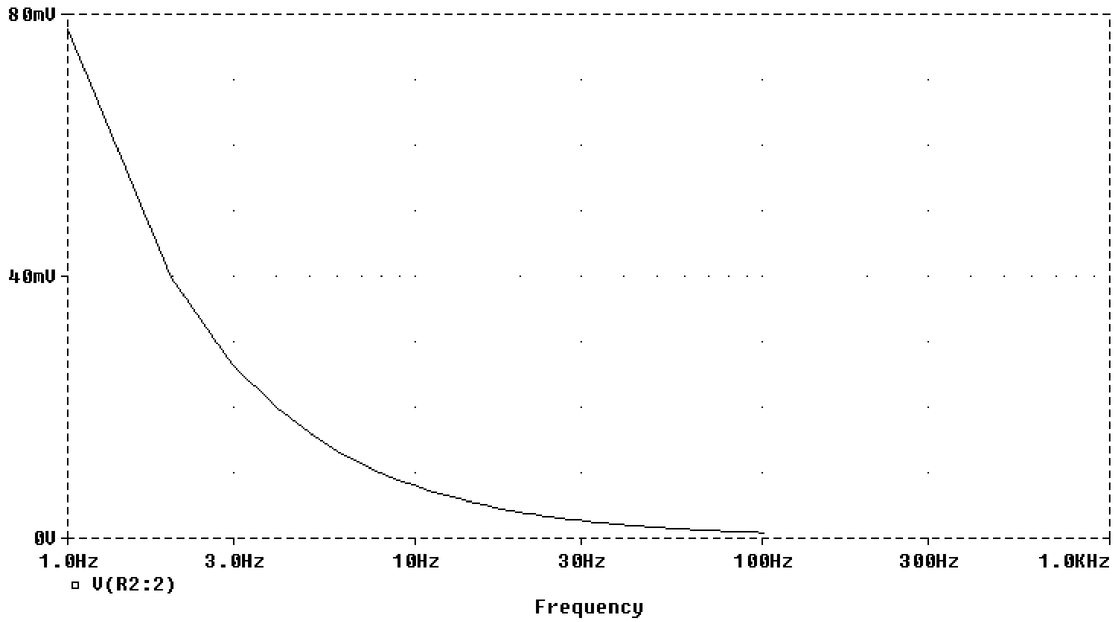




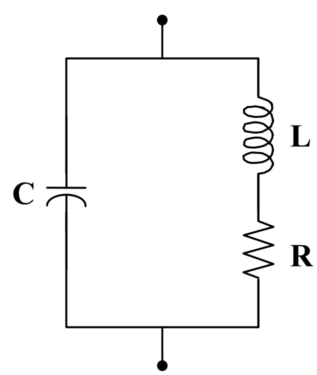
Chapter 14, Solution 92.

The schematic is shown below. We type Total Points = 101, Start Frequency = 1, and End Frequency = 100 in the AC Sweep box. After simulating the circuit, the magnitude plot of the frequency response is shown below.





Chapter 14, Solution 93.



$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$\frac{R}{L} = \frac{400}{240\times10^{-6}} = \frac{10^7}{6}, \qquad \frac{1}{LC} = \frac{1}{(240\times10^{-6})(120\times10^{-12})} = \frac{10^{16}}{288}$$

Since $\frac{R}{L} << \frac{1}{LC}$

$$f_0 \cong \frac{1}{2\pi\sqrt{LC}} = \frac{10^8}{24\pi\sqrt{2}} = \underline{\mathbf{938\ kHz}}$$

If R is reduced to 40 Ω, $\frac{R}{L} << \frac{1}{LC}$.

<u>The result remains the same</u>.

Chapter 14, Solution 94.

$$\omega_c = \frac{1}{RC}$$

We make R and C as small as possible. To achieve this, we connect 1.8 kΩ and 3.3 kΩ in parallel so that

$$R = \frac{1.8x3.3}{1.8 + 3.3} = 1.164\,k\Omega$$

We place the 10-pF and 30-pF capacitors in series so that

C = (10x30)/40 = 7.5 pF

Hence,

$$\omega_c = \frac{1}{RC} = \frac{1}{1.164x10^3 x7.5x10^{-12}} = \underline{114.55x10^6\ \text{rad/s}}$$

Chapter 14, Solution 95.

(a) $$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

When $C = 360\ \text{pF}$,

$$f_0 = \frac{1}{2\pi\sqrt{(240\times10^{-6})(360\times10^{-12})}} = 0.541\ \text{MHz}$$

When $C = 40\ \text{pF}$,

$$f_0 = \frac{1}{2\pi\sqrt{(240\times10^{-6})(40\times10^{-12})}} = 1.624\ \text{MHz}$$

Therefore, the frequency range is

$$\underline{\mathbf{0.541\ MHz < f_0 < 1.624\ MHz}}$$

(b) $$Q = \frac{2\pi f L}{R}$$

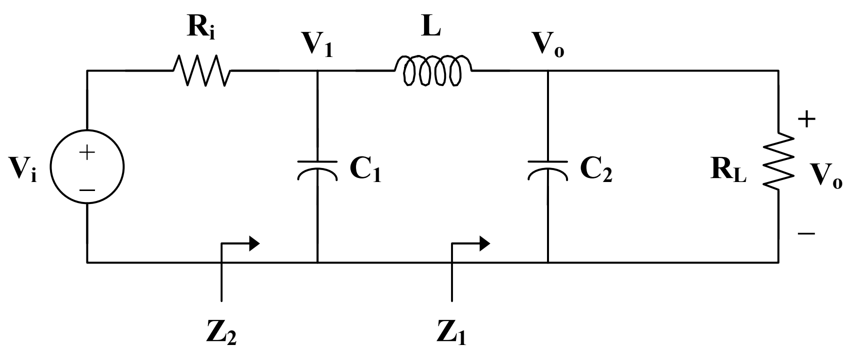
At $f_0 = 0.541\,\text{MHz}$,

$$Q = \frac{(2\pi)(0.541\times10^{6})(240\times10^{-6})}{12} = \underline{\mathbf{67.98}}$$

At $f_0 = 1.624\,\text{MHz}$,

$$Q = \frac{(2\pi)(1.624\times10^{6})(240\times10^{-6})}{12} = \underline{\mathbf{204.1}}$$

Chapter 14, Solution 96.



$$\mathbf{Z}_1 = R_L \parallel \frac{1}{sC_2} = \frac{R_L}{1 + sR_2C_2}$$

$$\mathbf{Z}_2 = \frac{1}{sC_1} \parallel (sL + \mathbf{Z}_1) = \frac{1}{sC_1} \parallel \left(\frac{sL + R_L + s^2R_LC_2L}{1 + sR_LC_2} \right)$$

$$\mathbf{Z}_2 = \frac{\dfrac{1}{sC_1} \cdot \dfrac{sL + R_L + s^2R_LC_2L}{1 + sR_LC_2}}{\dfrac{1}{sC_1} + \dfrac{sL + R_L + s^2R_LC_2L}{1 + sR_LC_2}}$$

$$\mathbf{Z}_2 = \frac{sL + R_L + s^2R_LLC_2}{1 + sR_LC_2 + s^2LC_1 + sR_LC_1 + s^3R_LLC_1C_2}$$

$$\mathbf{V}_1 = \frac{\mathbf{Z}_2}{\mathbf{Z}_2 + R_i}\mathbf{V}_i$$

$$\mathbf{V}_o = \frac{\mathbf{Z}_1}{\mathbf{Z}_1 + sL}\mathbf{V}_1 = \frac{\mathbf{Z}_2}{\mathbf{Z}_2 + R_2} \cdot \frac{\mathbf{Z}_1}{\mathbf{Z}_1 + sL}\mathbf{V}_i$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{Z}_2}{\mathbf{Z}_2 + R_2} \cdot \frac{\mathbf{Z}_1}{\mathbf{Z}_1 + sL}$$

where

$$\frac{\mathbf{Z}_2}{\mathbf{Z}_2 + R_2} =$$

$$\frac{sL + R_L + s^2 R_L L C_2}{sL + R_L + s^2 R_L L C_2 + R_i + sR_i R_L C_2 + s^2 R_i L C_1 + sR_i R_L C_1 + s^3 R_i R_L L C_1 C_2}$$

and $\quad \dfrac{\mathbf{Z}_1}{\mathbf{Z}_1 + sL} = \dfrac{R_L}{R_L + sL + s^2 R_L L C_2}$

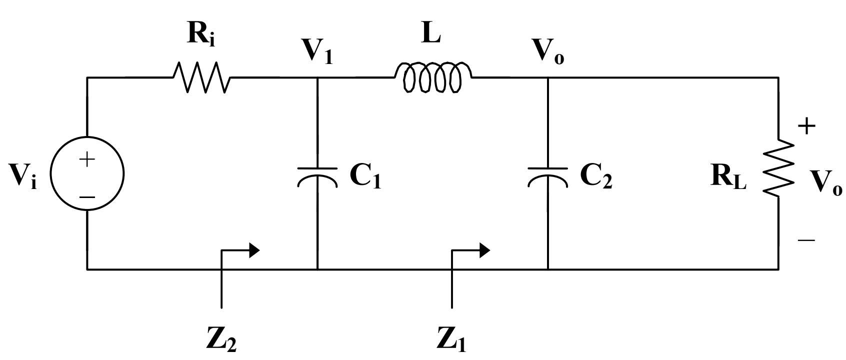
Therefore,

$$\frac{\mathbf{V}_o}{\mathbf{V}_i} =$$

$$\underline{\boldsymbol{\frac{R_L(sL + R_L + s^2 R_L L C_2)}{(sL + R_L + s^2 R_L L C_2 + R_i + sR_i R_L C_2 + s^2 R_i L C_1 + sR_i R_L C_1 + s^3 R_i R_L L C_1 C_2)(R_L + sL + s^2 R_L L C_2)}}}$$

where $s = j\omega$.

Chapter 14, Solution 97.



$$\mathbf{Z} = sL \parallel \left(R_L + \frac{1}{sC_2}\right) = \frac{sL(R_L + 1/sC_2)}{R_L + sL + 1/sC_2}, \qquad s = j\omega$$

$$\mathbf{V}_1 = \frac{\mathbf{Z}}{\mathbf{Z} + R_i + 1/sC_1}\mathbf{V}_i$$

$$\mathbf{V}_o = \frac{R_L}{R_L + 1/sC_2}\mathbf{V}_1 = \frac{R_L}{R_L + 1/sC_2} \cdot \frac{\mathbf{Z}}{\mathbf{Z} + R_i + 1/sC_1}\mathbf{V}_i$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R_L}{R_L + 1/sC_2} \cdot \frac{sL(R_L + 1/sC_2)}{sL(R_L + 1/sC_2) + (R_i + 1/sC_1)(R_L + sL + 1/sC_2)}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{s^3 L R_L C_1 C_2}}{\mathbf{(sR_i C_1 + 1)(s^2 L C_2 + sR_L C_2 + 1) + s^2 L C_1 (sR_L C_2 + 1)}}}$$

where $s = j\omega$.

Chapter 14, Solution 98.

$$B = \omega_2 - \omega_1 = 2\pi(f_2 - f_1) = 2\pi(454 - 432) = 44\pi$$

$$\omega_0 = 2\pi f_0 = QB = (20)(44\pi)$$

$$f_0 = \frac{(20)(44\pi)}{2\pi} = (20)(22) = \underline{\mathbf{440\ Hz}}$$

Chapter 14, Solution 99.

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$C = \frac{1}{2\pi f X_c} = \frac{1}{(2\pi)(2\times 10^6)(5\times 10^3)} = \frac{10^{-9}}{20\pi}$$

$$X_L = \omega L = 2\pi f L$$

$$L = \frac{X_L}{2\pi f} = \frac{300}{(2\pi)(2\times10^6)} = \frac{3\times10^{-4}}{4\pi}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{\frac{3\times10^{-4}}{4\pi}\cdot\frac{10^{-9}}{20\pi}}} = \underline{\mathbf{1.826\ MHz}}$$

$$B = \frac{R}{L} = (100)\left(\frac{4\pi}{3\times10^{-4}}\right) = \underline{\mathbf{4.188\times10^6\ rad/s}}$$

Chapter 14, Solution 100.

$$\omega_c = 2\pi f_c = \frac{1}{RC}$$

$$R = \frac{1}{2\pi f_c C} = \frac{1}{(2\pi)(20\times10^3)(0.5\times10^{-6})} = \underline{\mathbf{15.91\ \Omega}}$$

Chapter 14, Solution 101.

$$\omega_c = 2\pi f_c = \frac{1}{RC}$$

$$R = \frac{1}{2\pi f_c C} = \frac{1}{(2\pi)(15)(10\times10^{-6})} = \underline{\mathbf{1.061\ k\Omega}}$$

Chapter 14, Solution 102.

(a) When $R_s = 0$ and $R_L = \infty$, we have a low-pass filter.

$$\omega_c = 2\pi f_c = \frac{1}{RC}$$

$$f_c = \frac{1}{2\pi RC} = \frac{1}{(2\pi)(4\times10^3)(40\times10^{-9})} = \underline{\mathbf{994.7\ Hz}}$$

(b) We obtain R_{Th} across the capacitor.

$$R_{Th} = R_L \parallel (R + R_s)$$
$$R_{Th} = 5 \parallel (4+1) = 2.5\ \text{k}\Omega$$

$$f_c = \frac{1}{2\pi R_{Th} C} = \frac{1}{(2\pi)(2.5\times10^{3})(40\times10^{-9})}$$

$$f_c = \underline{\mathbf{1.59\ kHz}}$$

Chapter 14, Solution 103.

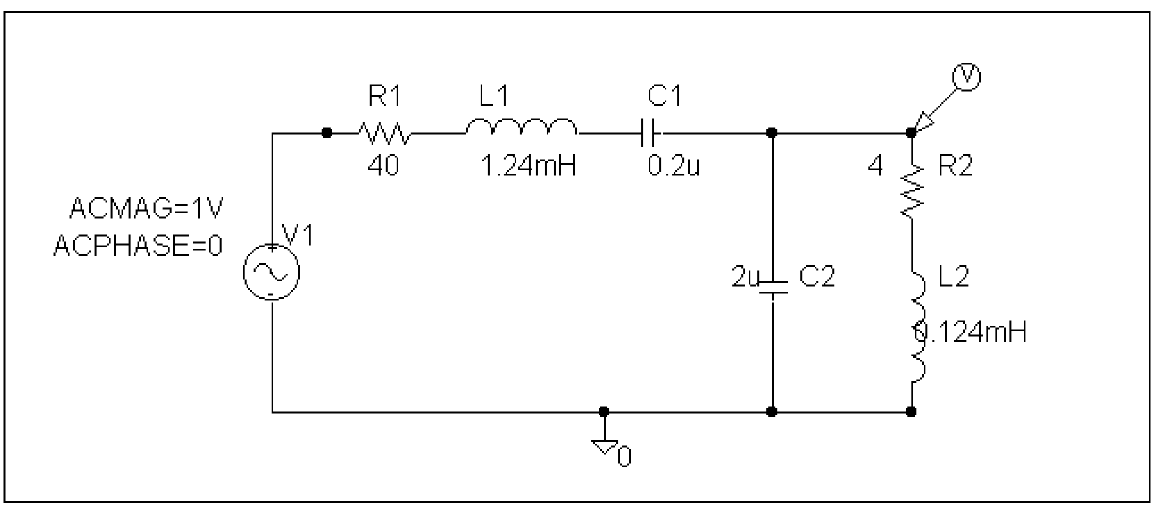
$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R_2}{R_2 + R_1 \parallel 1/sC}, \qquad s = j\omega$$

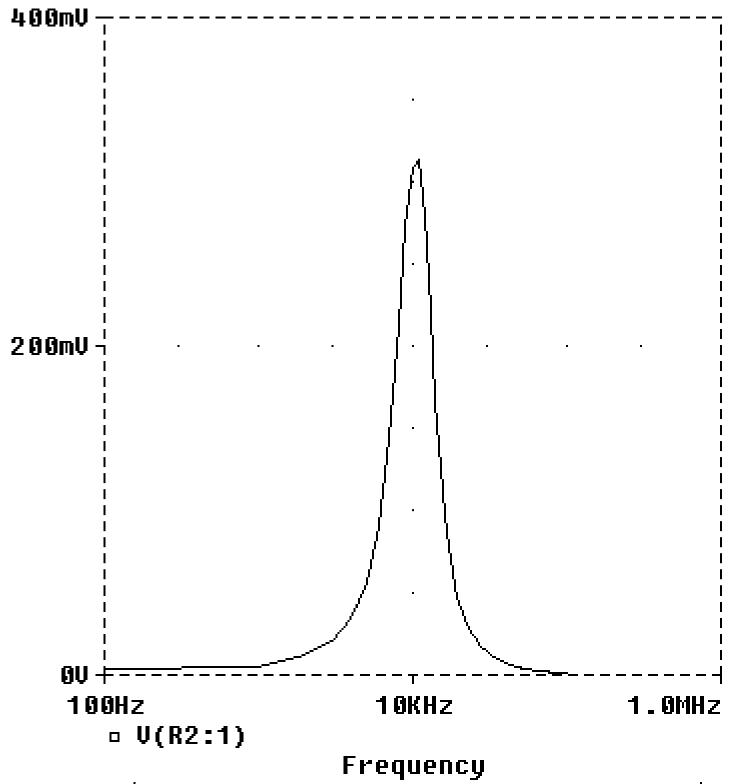
$$\mathbf{H}(\omega) = \frac{R_2}{R_2 + \dfrac{R_1(1/sC)}{R_1 + 1/sC}} = \frac{R_2(R_1 + 1/sC)}{R_2 + R_1(1/sC)}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{R_2(1 + sCR_1)}}{\mathbf{R_1 + sCR_2}}}$$

Chapter 14, Solution 104.

The schematic is shown below. We click <u>Analysis/Setup/AC Sweep</u> and enter Total Points = 1001, Start Frequency = 100, and End Frequency = 100 k. After simulation, we obtain the magnitude plot of the response as shown.




400mV
200mV
0V
100Hz
10KHz
1.0MHz
V(R2:1)
Frequency