4.36 For the op-amp circuit shown in Fig. P4.36, find the average power absorbed by each element for the case that $v_s(t) = \cos \omega t$ V.

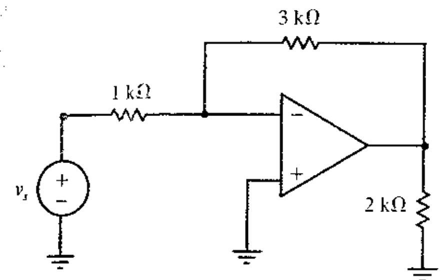

Fig. P4.36

4.37 For the op-amp circuit shown in Fig. P4.37, find the average power absorbed by each element for the case that $v_s(t) = \cos \omega t$ V.

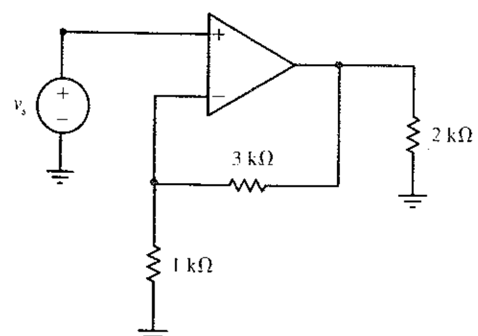

Fig. P4.37

4.38 Find the rms value of each function given in Fig. P4.38. (See p. 260.)

4.39 Find the rms value of the "half-wave rectified" sine wave that is shown in Fig. P4.39. [*Hint:* $\sin^2 x = \frac{1}{2}(1 - \cos 2x)$.]

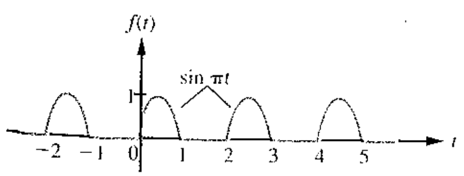

Fig. P4.39

4.40 Find the rms value of the "full-wave rectified" sine wave that is shown in Fig. P4.40. [*Hint:* $\sin^2 x = \frac{1}{2}(1 - \cos 2x)$.]

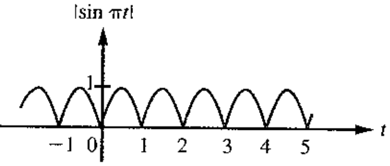

Fig. P4.40

4.41 The load shown in Fig. P4.41 operates at 60 Hz. (a) What are the pf and the pf angle of this load? (b) Is the pf leading or lagging? (c) To what value should the capacitor be changed to get a unity pf (pf = 1)?

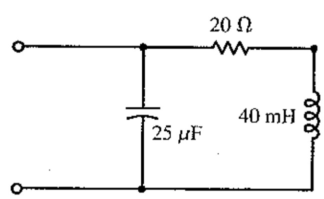

Fig. P4.41

4.42 A 115-V rms, 60-Hz electric hair dryer absorbs 500 W at a lagging pf of 0.95. What is the rms value of the current drawn by this dryer?

4.43 An electric motor which operates at 220 V rms, 20 A rms, 60 Hz, absorbs 2200 W. (a) What is the pf of the motor. (b) For the case that the pf is lagging, what value capacitor should be connected in parallel with the motor such that the resulting combination has a unity pf (pf = 1)?

4.44 An electric motor operating at 220 V rms, 60 Hz, draws a current of 20 A rms at a pf of 0.75 lagging. (a) What is the average power absorbed by the motor? (b) What value capacitor should be connected in parallel with the motor such that the resulting combination has a unity pf (pf = 1)?

4.45 Two loads, which are connected in parallel, operate at 230 V rms. One load absorbs 500 W at a pf of 0.8 lagging, and the other absorbs 1000 W at

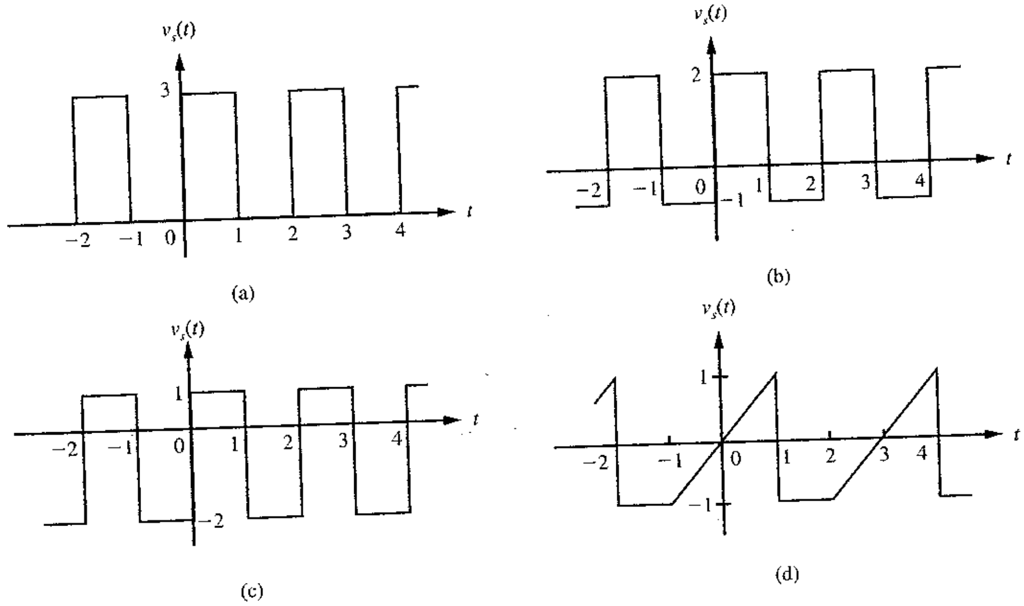

Fig. P4.38

a pf of 0.9 lagging. Find the pf of the combined load. Is this pf leading or lagging?

4.46 Three loads, which are connected in parallel, operate at 230 V rms. One load absorbs 500 W at a pf of 0.8 lagging. The second absorbs 1000 W at a pf of 0.9 lagging. The third absorbs 1500 W at a pf of 0.9 leading. Find the pf of the combined load. Is this pf leading or lagging?

4.47 The parallel connection of two 115-V rms loads absorbs 2000 W at a lagging pf of 0.95. Suppose that one load absorbs 1200 W at a pf of 0.8 lagging. What are the power absorbed and the pf of the second load?

4.48 A load, which operates at 220 V rms, draws 5 A rms at a lagging pf of 0.95. (a) Find the complex power absorbed by the load. (b) Find the average power absorbed by the load. (c) Find the reactive power absorbed by the load. (d) Find the apparent power absorbed by the load. (e) Find the impedance of the load.

4.49 Consider the circuit shown in Fig. P4.28. Suppose that $v_s(t) = 12\sqrt{2}\cos 3t$ V and $C = \frac{1}{6}$ F. Find the complex power absorbed by each element. Is complex power conserved?

4.50 Consider the circuit shown in Fig. P4.28. Suppose that $v_s(t) = 12\sqrt{2}\cos 3t$ V and $C = \frac{1}{6}$ F. Find the apparent power absorbed by each element. Is apparent power conserved?

4.51 Consider the circuit shown in Fig. P4.28. Suppose that $v_s(t) = 12\sqrt{2}\cos 3t$ V and $C = \frac{1}{6}$ F. Find the reactive power absorbed by each element. Is reactive power conserved?

4.52 For the circuit given in Fig. P4.24, when $\mathbf{V}_{s1} = 250\sqrt{2}\angle{-30°}$ V, $\mathbf{V}_{s2} = 250\sqrt{2}\angle{-90°}$ V, and $\mathbf{Z} = 78 - j45\ \Omega$, then $\mathbf{I}_1 = 6.8\angle{30°}$ A and $\mathbf{I}_2 = 6.8\angle{-90°}$ A. (a) Find the complex power absorbed by each impedance. (b) Find the complex power supplied by each source.

4.53 For the circuit given in Fig. P4.24, when $\mathbf{V}_{s1} = 250\sqrt{2}\angle{-30°}$ V, $\mathbf{V}_{s2} = 250\sqrt{2}\angle{-90°}$ V, and $\mathbf{Z} = 78 - j45\ \Omega$, then $\mathbf{I}_1 = 6.8\angle{30°}$ A and $\mathbf{I}_2 = 6.8\angle{-90°}$ A. (a) Find the apparent power absorbed by each impedance. (b) Find the apparent power supplied by each source.

4.54 For the circuit given in Fig. P4.24, when $\mathbf{V}_{s1} = 250\sqrt{2}\angle{-30°}$ V, $\mathbf{V}_{s2} = 250\sqrt{2}\angle{-90°}$ V, and $\mathbf{Z} = 78 - j45\ \Omega$, then $\mathbf{I}_1 = 6.8\angle{30°}$ A and $\mathbf{I}_2 = 6.8\angle{-90°}$ A. (a) Find the reactive power absorbed by each impedance. (b) Find the reactive power supplied by each source.

4.55 An R-ohm resistor has the voltage $v(t) = V\cos(\omega t + \phi_1)$ across it and it has the current $i(t) = I\cos(\omega t + \phi_2)$ through it. Show that the complex power absorbed by the resistor is given by

$$\mathbf{S}_R = \tfrac{1}{2}RI^2 = \tfrac{1}{2}V^2/R$$

4.56 An L-henry inductor has the voltage $v(t) = V\cos(\omega t + \phi_1)$ across it and it has the current $i(t) = I\cos(\omega t + \phi_2)$ through it. Show that the complex power absorbed by the inductor is given by

$$\mathbf{S}_L = \frac{j\omega LI^2}{2} = \frac{jV^2}{2\omega L}$$

4.57 An C-farad capacitor has the voltage $v(t) = V\cos(\omega t + \phi_1)$ across it and it has the current $i(t) = I\cos(\omega t + \phi_2)$ through it. Show that the complex power absorbed by the capacitor is given by

$$\mathbf{S}_C = \frac{-jI^2}{2\omega C} = \frac{-j\omega CV^2}{2}$$

4.58 For the single-phase, three-wire circuit shown in Fig. P4.58, suppose that $\mathbf{V}_s = 120\angle{0°}$ V rms. Find the average power supplied by each source if $\mathbf{Z}_1 = 60\ \Omega$, $\mathbf{Z}_2 = 80\ \Omega$, $\mathbf{Z}_3 = 40\ \Omega$, and $R_g = R_n = 0\ \Omega$.

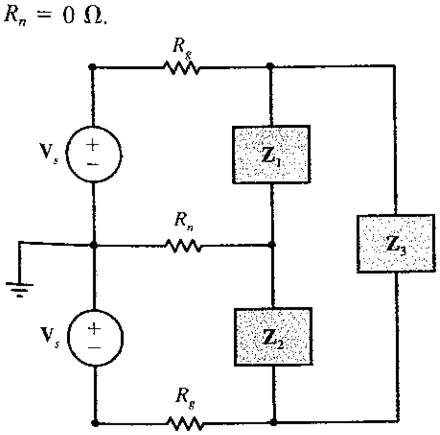

Fig. P4.58

4.59 For the single-phase, three-wire circuit shown in Fig. P4.58, suppose that $\mathbf{V}_s = 115\angle{0°}$ V rms. Find the average power supplied by each source if $\mathbf{Z}_1 = 60\ \Omega$, $\mathbf{Z}_2 = 80\ \Omega$, $\mathbf{Z}_3 = 40\ \Omega$, $R_g = 1\ \Omega$, and $R_n = 2\ \Omega$.

4.60 For the single-phase, three-wire circuit shown in Fig. P4.58, suppose that $R_g = R_n = 0\ \Omega$. For the case that $\mathbf{Z}_1$ absorbs 500 W at a lagging pf of 0.8, $\mathbf{Z}_2$ absorbs 1000 W at a lagging pf of 0.9, and $\mathbf{Z}_3$ absorbs 1500 W at a leading pf of 0.95, find the average power supplied by each source.

4.61 A balanced Y-Y three-phase circuit has 130-V rms phase voltages and a per-phase impedance of $\mathbf{Z} = 12 + j12\ \Omega$. Find the line currents and the total power absorbed by the load.

4.62 A balanced Y-Y three-phase circuit has 210-V rms, 60-Hz line voltages. Suppose that the load absorbs a total of 3 kW of power at a lagging pf of 0.85. (a) Find the per-phase impedance. (b) What value capacitors should be connected in parallel with the per-phase impedances to result in a unity pf (pf = 1)?

4.63 A balanced, three-phase Y-connected source, whose phase voltages are 115 V rms, has the unbalanced Y-connected load $\mathbf{Z}_{AN} = 3 + j4\ \Omega$, $\mathbf{Z}_{BN} = 10\ \Omega$, and $\mathbf{Z}_{CN} = 5 + j12\ \Omega$. Find the line currents and the total power absorbed by the load for the case that there is a neutral wire.

4.64 A balanced, three-phase Y-connected source, whose phase voltages are 120 V rms, has the unbalanced Y-connected load $\mathbf{Z}_{AN} = 10\ \Omega$, $\mathbf{Z}_{BN} = 20\ \Omega$, and $\mathbf{Z}_{CN} = 60\ \Omega$. Find the line currents and the total power absorbed by the load for the case that there is no neutral wire.

4.65 Suppose that the balanced Y-Δ three-phase circuit shown in Fig. 4.40 on p. 241 has a line voltage of 130 V rms and $\mathbf{Z} = 4\sqrt{2}\angle{45°}\ \Omega$. Find the line currents and the total power absorbed by the load.

4.66 A balanced, three-phase Y-connected source with 230-V rms line voltages has an unbalanced Δ-connected load whose impedances are $\mathbf{Z}_{AB} = 8\ \Omega$, $\mathbf{Z}_{BC} = 4 + j3\ \Omega$, and $\mathbf{Z}_{AC} = 12 - j5\ \Omega$. Find the line currents and the total power absorbed by the load.

4.67 Suppose that the balanced Y-Δ three-phase circuit shown in Fig. 4.40 on p. 241 has 210-V rms, 60-Hz line voltages. If the load absorbs a total of 3 kW of power at a lagging pf of 0.85, (a) find the per-phase impedance, and (b) what value capacitors should be connected in parallel with the per-phase impedances to result in a unity pf (pf = 1)?

4.68 A Δ-connected load has impedances $\mathbf{Z}_{AB} = 2\ \Omega$, $\mathbf{Z}_{BC} = 3\ \Omega$, and $\mathbf{Z}_{AC} = 5\ \Omega$. Find the equivalent Y-connected load.

4.69 A Δ-connected load has impedances $\mathbf{Z}_{AB} = 2 + j2\ \Omega$, $\mathbf{Z}_{BC} = 3 - j3\ \Omega$, and $\mathbf{Z}_{AC} = 1 + j1\ \Omega$. Find the equivalent Y-connected load.

4.70 A Y-connected load has impedances $\mathbf{Z}_A = 1\ \Omega$, $\mathbf{Z}_B = 0.6\ \Omega$, and $\mathbf{Z}_C = 1.5\ \Omega$. Find the equivalent Δ-connected load.

4.71 A Y-connected load has impedances $\mathbf{Z}_A = j2/3\ \Omega$, $\mathbf{Z}_B = 2\ \Omega$, and $\mathbf{Z}_C = 1\ \Omega$. Find the equivalent Δ-connected load.

4.72 A Y-connected load has admittances $\mathbf{Y}_A = 2\ \mho$, $\mathbf{Y}_B = 3\ \mho$, and $\mathbf{Y}_C = 5\ \mho$. Find the equivalent Δ-connected load.

4.73 A Y-connected load has admittances $\mathbf{Y}_A = 2 + j2\ \mho$, $\mathbf{Y}_B = 3 - j3\ \mho$, and $\mathbf{Y}_C = 1 + j1\ \mho$. Find the equivalent Δ-connected load.

4.74 For the load shown in Fig. 4.42*a* on p. 247, $\mathbf{Z}_Y = 3 + j4\ \Omega$ and $\mathbf{Z}_\Delta = 5 - j12\ \Omega$. Find the pf and the total power absorbed by the load for the case that the line voltage is 120 V rms.

4.75 A balanced, three-phase Δ-connected load has a per-phase impedance of $\mathbf{Z} = 36 + j36\ \Omega$. Find the readings for the two-wattmeter connection shown in Fig. 4.45 on p. 250 for the case that the line voltage of $130\sqrt{3}$ V rms is produced by a balanced Y-connected source.

4.76 A balanced Y-Y three-phase circuit has a line voltage of 210 V rms, a line current of 9.72 A rms, and a pf of 0.95 lagging. Find the wattmeter readings for the two-wattmeter method.

4.77 An unbalanced Y-connected load has rms line voltages $\mathbf{V}_{ab} = 208\angle 30^\circ$ V, $\mathbf{V}_{bc} = 208\angle -90^\circ$ V, $\mathbf{V}_{ca} = 208\angle -210^\circ$ V, rms line currents $\mathbf{I}_{aA} = 7.49\angle 16.1^\circ$ A, $\mathbf{I}_{bB} = 6.82\angle -142^\circ$ A, $\mathbf{I}_{cC} = 2.75\angle 131^\circ$ A. Find the wattmeter readings for the two-wattmeter method.

4.78 A balanced Y-Δ three-phase circuit has a line voltage of 225 V rms, a line current of 39.8 A rms, and a pf of 0.707 lagging. Find the wattmeter readings for the two-wattmeter method.

4.79 A balanced Y-Δ three-phase circuit has a line voltage of 210 V rms, a line current of 9.7 A rms, and a pf of 0.85 lagging. Find the wattmeter readings for the two-wattmeter method.

4.80 An unbalanced Δ-connected load has rms line voltages $\mathbf{V}_{ab} = 230\angle 30^\circ$ V, $\mathbf{V}_{bc} = 230\angle -90^\circ$ V, $\mathbf{V}_{ca} = 230\angle -210^\circ$ V, rms line currents $\mathbf{I}_{aA} = 44.2\angle 16^\circ$ A, $\mathbf{I}_{bB} = 73.3\angle -136^\circ$ A, $\mathbf{I}_{cC} = 40.4\angle 75.7^\circ$ A. Find the wattmeter readings for the two-wattmeter method.

4.81 The unbalanced Δ-connected load shown in Fig. 4.45 on p. 250 has rms line voltages $\mathbf{V}_{ab} = 220\angle 30^\circ$ V, $\mathbf{V}_{bc} = 220\angle -90^\circ$ V, $\mathbf{V}_{ca} = 220\angle -210^\circ$ V, rms phase currents $\mathbf{I}_{AB} = 11\angle 30^\circ$ A, $\mathbf{I}_{BC} = 5.5\angle -135^\circ$ A, $\mathbf{I}_{CA} = 22\angle 60^\circ$ A. (a) Find the impedances $\mathbf{Z}_{AB}$, $\mathbf{Z}_{BC}$, and $\mathbf{Z}_{AC}$. (b) Find the power absorbed by each impedance.

4.82 The unbalanced Δ-connected load shown in Fig. 4.45 on p. 250 has rms line voltages $\mathbf{V}_{ab} = 220\angle 30^\circ$ V, $\mathbf{V}_{bc} = 220\angle -90^\circ$ V, $\mathbf{V}_{ca} = 220\angle -210^\circ$ V, rms phase currents $\mathbf{I}_{AB} = 11\angle 30^\circ$ A, $\mathbf{I}_{BC} = 5.5\angle -135^\circ$ A, $\mathbf{I}_{CA} = 22\angle 60^\circ$ A. Find the wattmeter readings for the two-wattmeter method.

4.83 The unbalanced Δ-connected load shown in Fig. 4.45 on p. 250 has impedances $\mathbf{Z}_{AB} = 12 - j5\ \Omega$, $\mathbf{Z}_{BC} = 26\ \Omega$, $\mathbf{Z}_{AC} = 8 - j6\ \Omega$, and line voltages of 130 V rms that are produced by a balanced Y-connected source. Find the wattmeter readings for the two-wattmeter method.

4.84 Find the wattmeter readings for the circuit shown in Fig. P4.84.

4.85 Find the wattmeter readings for the circuit shown in Fig. P4.85.

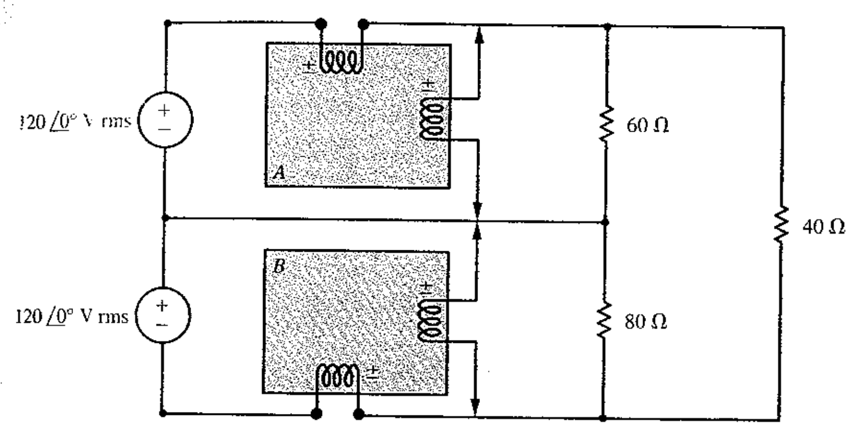

Fig. P4.84

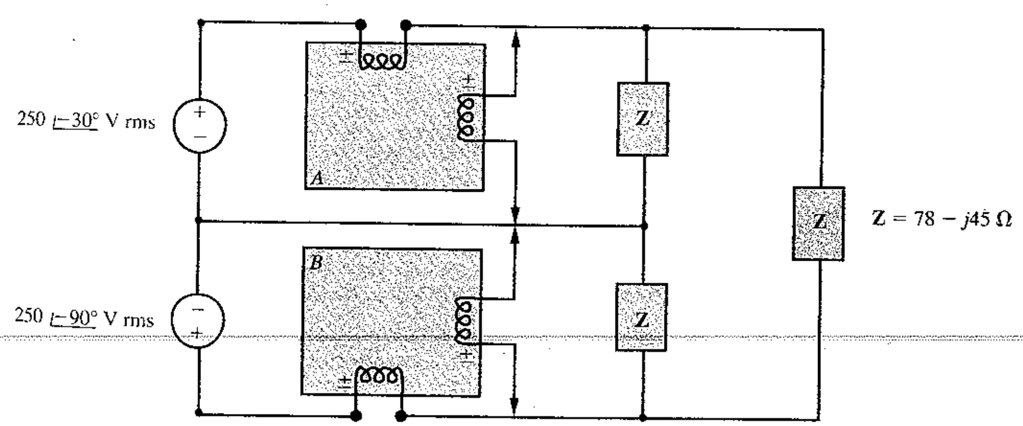

Fig. P4.85

7. If there are no cancellations of common poles and zeros, the poles of a network function indicate the form of the natural response.

8. A linear system can be simulated with integrators, adders, and scalers (i.e., with an analog computer).

9. Systems are often represented by block diagrams.

10. Feedback can improve system performance and can be used for purposes of control.

11. The Laplace transform is a linear transformation that can be used to solve linear differential equations or analyze linear circuits.

12. The inverse Laplace transform can be found by using a table of transforms and various transform properties, as well as partial-fraction expansions.

13. The impedance of an R-ohm resistor is R, of an L-henry inductor is Ls, and of a C-farad capacitor is $1/Cs$.

14. An inductor (or a capacitor) with a nonzero initial condition can be modeled by an independent source and an inductor (or capacitor) with a zero initial condition.

15. Circuit analysis using Laplace transforms results in complete (both forced and natural) responses.

Problems

5.1 Sketch the phase response ang($\mathbf{V}_2/\mathbf{V}_1$) versus ω for the high-pass filter given in Fig. 5.5 on p. 269.

5.2 For the circuit given in Fig. 5.5 on p. 269, replace the capacitor C with an inductor L, and sketch the phase response ang($\mathbf{V}_2/\mathbf{V}_1$) versus ω for the resulting low-pass filter.

5.3 Sketch the amplitude response of $\mathbf{V}_2/\mathbf{V}_1$ for the op-amp circuit shown in Fig. P5.3. Determine the half-power frequency. What type of filter is this circuit?

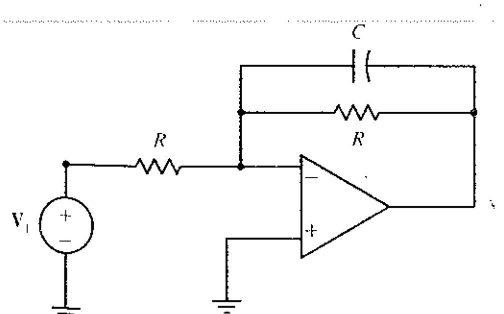

Fig. P5.3

5.4 Show that for the circuit given in Fig. P5.4 the voltage transfer function is

$$\mathbf{H}(j\omega) = \frac{\mathbf{V}_2}{\mathbf{V}_1} = \frac{R_2(1 + j\omega R_1 C_1)}{(R_1 + R_2) + j\omega R_1 R_2 (C_1 + C_2)}$$

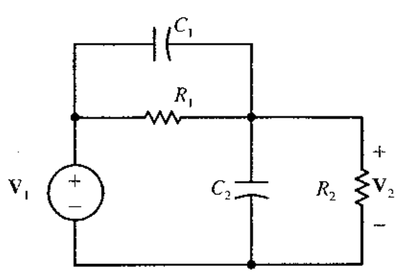

Fig. P5.4

5.5 For the circuit shown in Fig. P5.4, suppose that $R_1 = R_2 = R$ and $C_1 = C_2 = C$. Sketch the amplitude response and the phase response of $\mathbf{V}_2/\mathbf{V}_1$.

5.6 For the circuit shown in Fig. P5.4, suppose that $R_1 = R_2 = R$, $C_1 = C$ and $C_2 = 0$ F. Sketch the amplitude response of $\mathbf{V}_2/\mathbf{V}_1$. What is the half-power frequency?

5.7 For the circuit shown in Fig. P5.4, suppose that $R_1 = R_2 = R$, $C_1 = 0$ F and $C_2 = C$. Sketch the amplitude response of $\mathbf{V}_2/\mathbf{V}_1$. What is the half-power frequency?

5.8 For the op-amp circuit shown in Fig. P5.8, sketch the amplitude response of $\mathbf{V}_2/\mathbf{V}_1$, indicating the half-power frequency. What type of filter is this circuit?

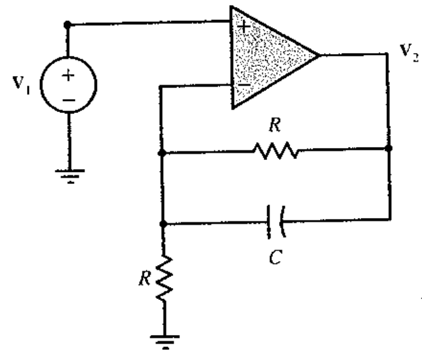

Fig. P5.8

5.9 Sketch the Bode plot—both the amplitude and phase responses—for (a) $\mathbf{H}(j\omega) = K$, where $K > 0$, (b) $\mathbf{H}(j\omega) = j\omega$, and (c) $\mathbf{H}(j\omega) = 1/j\omega$.

5.10 Use only the straight-line asymptotes to sketch the Bode plot—both the amplitude and phase responses—for

$$\mathbf{H}(j\omega) = \frac{(a + j\omega)}{a}$$

where $a > 0$. What is the corner frequency?

5.11 Use only the straight-line asymptotes to sketch the Bode plot—both the amplitude and phase responses—for

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

where $a > 0$. What is the corner frequency? What type of filter is this?

5.12 The transfer function

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

where $a > 0$, can be expressed as the product $\mathbf{H}(j\omega) = \mathbf{H}_1(j\omega)\mathbf{H}_2(j\omega)$, where $\mathbf{H}_1(j\omega) = j\omega/a$ and $\mathbf{H}_2(j\omega) = 1/(1 + j\omega/a)$. Use only the straight-line asymptotes to sketch the Bode plot—both the amplitude and phase responses—for $\mathbf{H}(j\omega)$ by adding the Bode plots for $\mathbf{H}_1(j\omega)$ and $\mathbf{H}_2(j\omega)$. What type of filter is this?

5.13 The transfer function

$$\mathbf{H}(j\omega) = \frac{1}{1 + j\omega 11 + (j\omega)^2 10} = \left(\frac{1}{1 + j\omega}\right)\left(\frac{1}{1 + j\omega 10}\right)$$

is expressed as the product $\mathbf{H}(j\omega) = \mathbf{H}_1(j\omega)\mathbf{H}_2(j\omega)$, where $\mathbf{H}_1(j\omega) = 1/(1 + j\omega)$ and $\mathbf{H}_2(j\omega) = 1/(1 + j\omega 10)$. Use only the straight-line asymptotes to sketch the Bode plot—both the amplitude and phase responses—for $\mathbf{H}(j\omega)$ by adding the Bode plots for $\mathbf{H}_1(j\omega)$ and $\mathbf{H}_2(j\omega)$. What type of filter is this?

5.14 The transfer function

$$\mathbf{H}(j\omega) = \frac{j\omega}{10 + j\omega 11 + (j\omega)^2} = \left(\frac{1}{1 + j\omega}\right)\left(\frac{j\omega}{10 + j\omega}\right)$$

is expressed as the product $\mathbf{H}(j\omega) = \mathbf{H}_1(j\omega)\mathbf{H}_2(j\omega)$, where $\mathbf{H}_1(j\omega) = 1/(1 + j\omega)$ and $\mathbf{H}_2(j\omega) = j\omega/(10 + j\omega)$. Use only the straight-line asymptotes to sketch the Bode plot—both the amplitude and phase responses—for $\mathbf{H}(j\omega)$ by adding the Bode plots for $\mathbf{H}_1(j\omega)$ and $\mathbf{H}_2(j\omega)$. What type of filter is this?

5.15 For the circuit given in Fig. P5.15, show that:

(a) $$\mathbf{H}_C(j\omega) = \frac{\mathbf{V}_C}{\mathbf{V}_1} = \frac{1/LC}{1/LC + j\omega R/L + (j\omega)^2}$$

(b) $$\mathbf{H}_L(j\omega) = \frac{\mathbf{V}_L}{\mathbf{V}_1} = \frac{(j\omega)^2}{1/LC + j\omega R/L + (j\omega)^2}$$

(c) $$\mathbf{H}_R(j\omega) = \frac{\mathbf{V}_R}{\mathbf{V}_1} = \frac{j\omega L/R}{1/LC + j\omega R/L + (j\omega)^2}$$

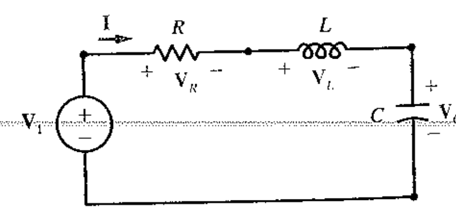

Fig. P5.15