REVIEW QUESTIONS

10.1 The voltage $\mathbf{V}_o$ across the capacitor in Fig. 10.43 is:

(a) $5\angle 0^\circ$ V (b) $7.071\angle 45^\circ$ V

(c) $7.071\angle -45^\circ$ V (d) $5\angle -45^\circ$ V

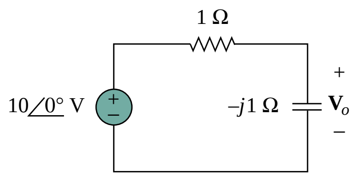

Figure 10.43 For Review Question 10.1.

10.2 The value of the current $\mathbf{I}_o$ in the circuit in Fig. 10.44 is:

(a) $4\angle 0^\circ$ A (b) $2.4\angle -90^\circ$ A

(c) $0.6\angle 0^\circ$ A (d) -1 A

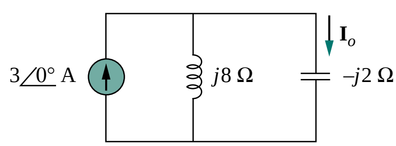

Figure 10.44 For Review Question 10.2.

10.3 Using nodal analysis, the value of $\mathbf{V}_o$ in the circuit of Fig. 10.45 is:

(a) -24 V (b) -8 V
(c) 8 V (d) 24 V

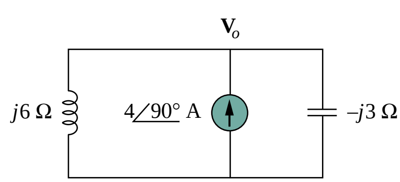

Figure 10.45 For Review Question 10.3.

10.4 In the circuit of Fig. 10.46, current $i(t)$ is:

(a) $10\cos t$ A (b) $10\sin t$ A (c) $5\cos t$ A
(d) $5\sin t$ A (e) $4.472\cos(t - 63.43^\circ)$ A

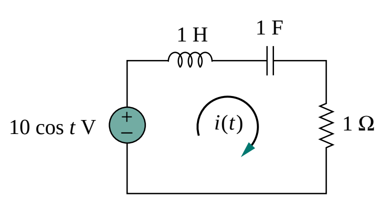

Figure 10.46 For Review Question 10.4.

10.5 Refer to the circuit in Fig. 10.47 and observe that the two sources do not have the same frequency. The current $i_x(t)$ can be obtained by:

(a) source transformation
(b) the superposition theorem
(c) *PSpice*

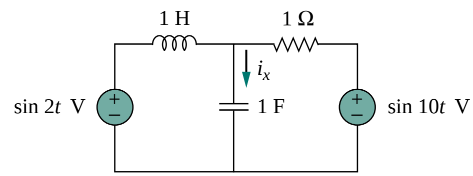

Figure 10.47 For Review Question 10.5.

10.6 For the circuit in Fig. 10.48, the Thevenin impedance at terminals *a*-*b* is:

(a) 1 Ω (b) $0.5 - j0.5$ Ω
(c) $0.5 + j0.5$ Ω (d) $1 + j2$ Ω
(e) $1 - j2$ Ω

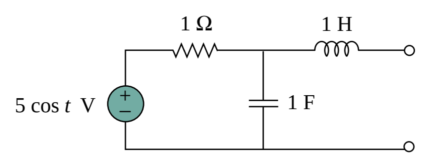

Figure 10.48 For Review Questions 10.6 and 10.7.

10.7 In the circuit of Fig. 10.48, the Thevenin voltage at terminals *a*-*b* is:

(a) $3.535\angle -45^\circ$ V (b) $3.535\angle 45^\circ$ V

(c) $7.071\angle -45^\circ$ V (d) $7.071\angle 45^\circ$ V

10.8 Refer to the circuit in Fig. 10.49. The Norton equivalent impedance at terminals *a*-*b* is:

(a) $-j4$ Ω (b) $-j2$ Ω
(c) $j2$ Ω (d) $j4$ Ω

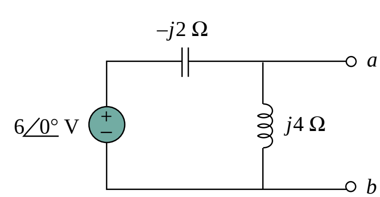

Figure 10.49 For Review Questions 10.8 and 10.9.

10.9 The Norton current at terminals *a-b* in the circuit of Fig. 10.49 is:

(a) $1\angle 0^\circ$ A (b) $1.5\angle -90^\circ$ A

(c) $1.5\angle 90^\circ$ A (d) $3\angle 90^\circ$ A

10.10 *PSpice* can handle a circuit with two independent sources of different frequencies.

(a) True (b) False

Answers: 10.1c, 10.2a, 10.3d, 10.4a, 10.5b, 10.6c, 10.7a, 10.8a, 10.9d, 10.10b.

PROBLEMS

Section 10.2 Nodal Analysis

10.1 Find v_o in the circuit in Fig. 10.50.

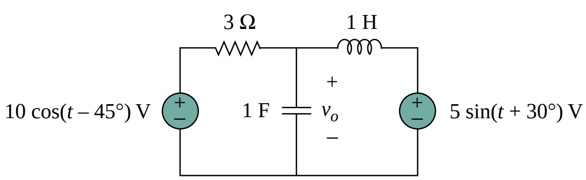

Figure 10.50 For Prob. 10.1.

10.2 For the circuit depicted in Fig. 10.51 below, determine i_o.

10.3 Determine v_o in the circuit of Fig. 10.52.

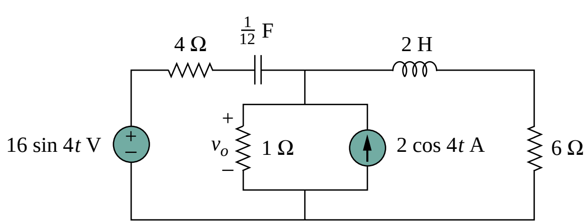

Figure 10.52 For Prob. 10.3.

10.4 Compute $v_o(t)$ in the circuit of Fig. 10.53.

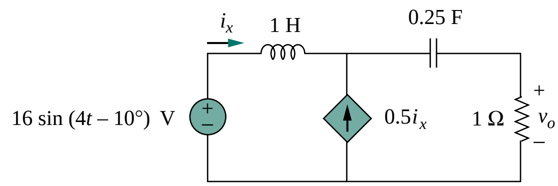

Figure 10.53 For Prob. 10.4.

10.5 Use nodal analysis to find v_o in the circuit of Fig. 10.54.

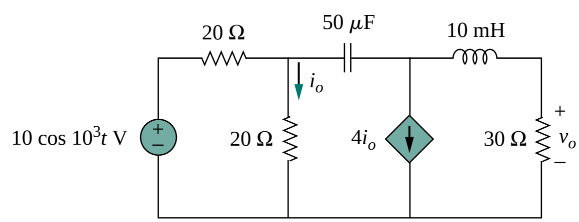

Figure 10.54 For Prob. 10.5.

10.6 Using nodal analysis, find $i_o(t)$ in the circuit in Fig. 10.55.

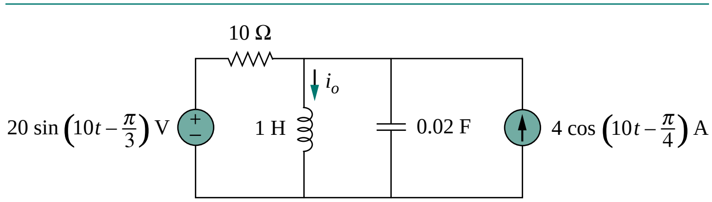

Figure 10.51 For Prob. 10.2.

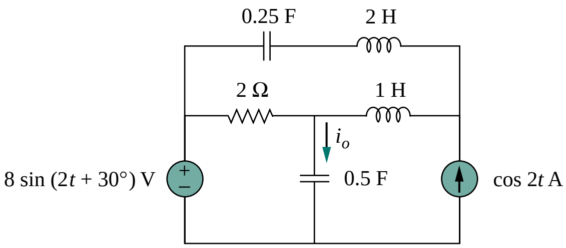

Figure 10.55 For Prob. 10.6.

10.7 By nodal analysis, find i_o in the circuit in Fig. 10.56.

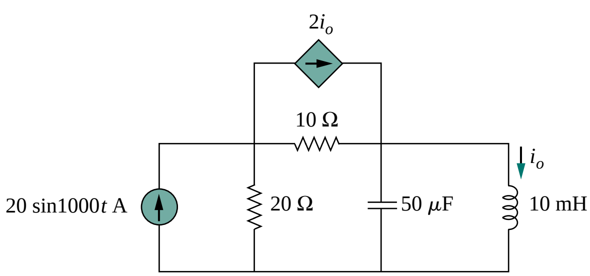

Figure 10.56 For Prob. 10.7.

10.8 Calculate the voltage at nodes 1 and 2 in the circuit of Fig. 10.57 using nodal analysis.

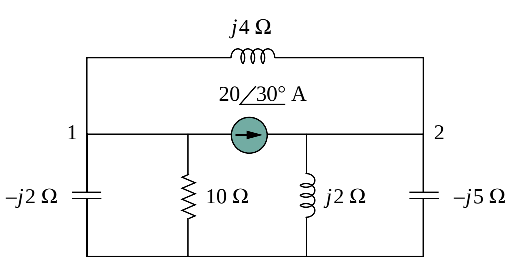

Figure 10.57 For Prob. 10.8.

10.9 Solve for the current **I** in the circuit of Fig. 10.58 using nodal analysis.

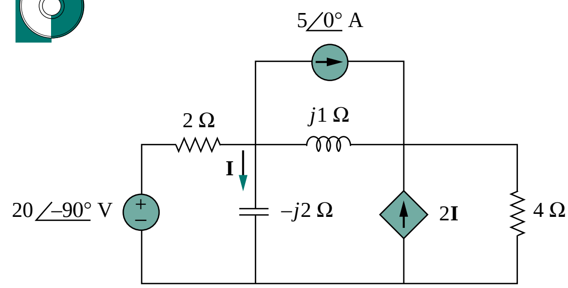

Figure 10.58 For Prob. 10.9.

10.10 Using nodal analysis, find $\mathbf{V}_1$ and $\mathbf{V}_2$ in the circuit of Fig. 10.59.

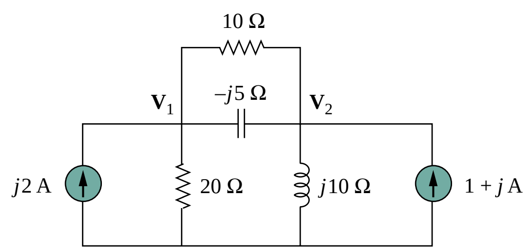

Figure 10.59 For Prob. 10.10.

10.11 By nodal analysis, obtain current $\mathbf{I}_o$ in the circuit in Fig. 10.60.

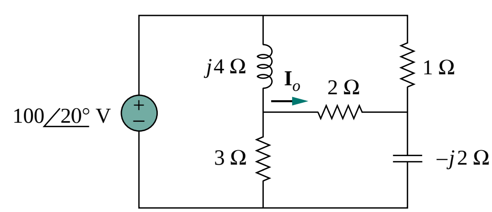

Figure 10.60 For Prob. 10.11.

10.12 Use nodal analysis to obtain $\mathbf{V}_o$ in the circuit of Fig. 10.61 below.

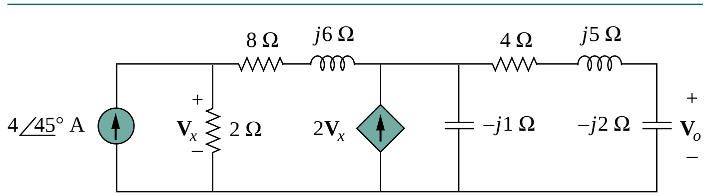

Figure 10.61 For Prob. 10.12.

10.13 Obtain $\mathbf{V}_o$ in Fig. 10.62 using nodal analysis.

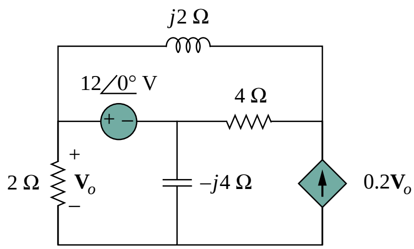

Figure 10.62 For Prob. 10.13.

10.14 Refer to Fig. 10.63. If $v_s(t) = V_m \sin \omega t$ and $v_o(t) = A \sin(\omega t + \phi)$, derive the expressions for A and ϕ.

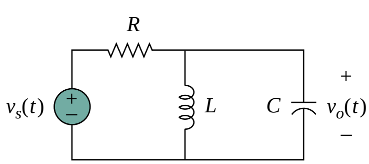

Figure 10.63 For Prob. 10.14.

10.15 For each of the circuits in Fig. 10.64, find $\mathbf{V}_o/\mathbf{V}_i$ for $\omega = 0$, $\omega \to \infty$, and $\omega^2 = 1/LC$.

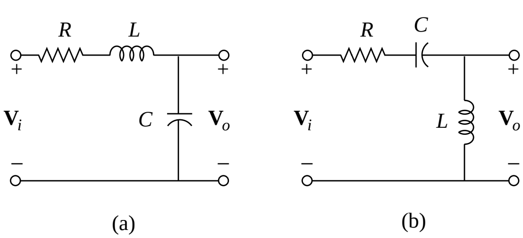

Figure 10.64 For Prob. 10.15.

10.16 For the circuit in Fig. 10.65, determine $\mathbf{V}_o/\mathbf{V}_s$.

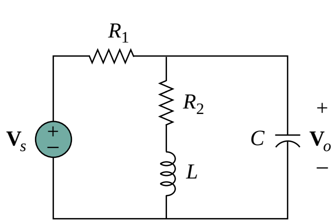

Figure 10.65 For Prob. 10.16.

Section 10.3 Mesh Analysis

10.17 Obtain the mesh currents $\mathbf{I}_1$ and $\mathbf{I}_2$ in the circuit of Fig. 10.66.

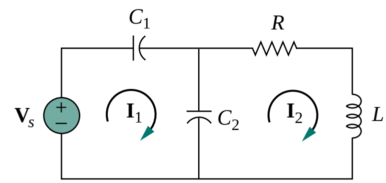

Figure 10.66 For Prob. 10.17.

10.18 Solve for i_o in Fig. 10.67 using mesh analysis.

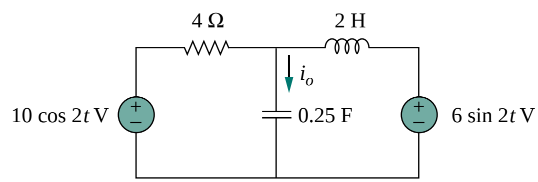

Figure 10.67 For Prob. 10.18.

10.19 Rework Prob. 10.5 using mesh analysis.

10.20 Using mesh analysis, find $\mathbf{I}_1$ and $\mathbf{I}_2$ in the circuit of Fig. 10.68.

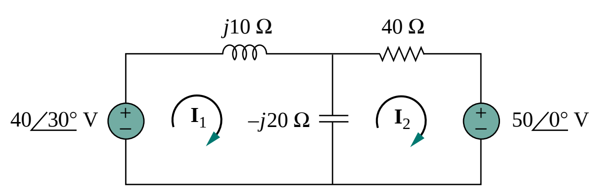

Figure 10.68 For Prob. 10.20.

10.21 By using mesh analysis, find $\mathbf{I}_1$ and $\mathbf{I}_2$ in the circuit depicted in Fig. 10.69.

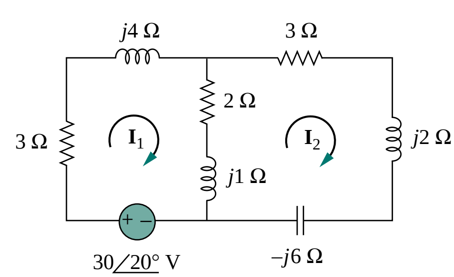

Figure 10.69 For Prob. 10.21.

10.22 Repeat Prob. 10.11 using mesh analysis.

10.23 Use mesh analysis to determine current $\mathbf{I}_o$ in the circuit of Fig. 10.70 below.

10.24 Determine $\mathbf{V}_o$ and $\mathbf{I}_o$ in the circuit of Fig. 10.71 using mesh analysis.

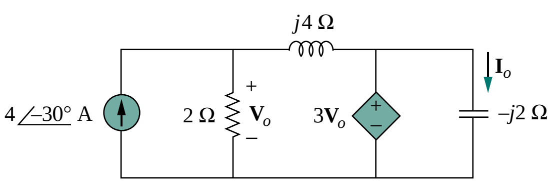

Figure 10.71 For Prob. 10.24.

10.25 Compute **I** in Prob. 10.9 using mesh analysis.

10.26 Use mesh analysis to find $\mathbf{I}_o$ in Fig. 10.28 (for Example 10.10).

10.27 Calculate $\mathbf{I}_o$ in Fig. 10.30 (for Practice Prob. 10.10) using mesh analysis.

10.28 Compute $\mathbf{V}_o$ in the circuit of Fig. 10.72 using mesh analysis.

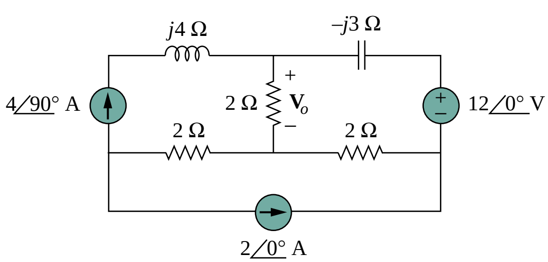

Figure 10.72 For Prob. 10.28.

10.29 Using mesh analysis, obtain $\mathbf{I}_o$ in the circuit shown in Fig. 10.73.

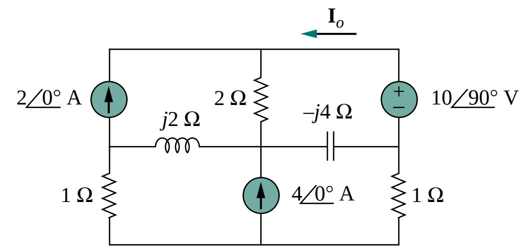

Figure 10.73 For Prob. 10.29.

Section 10.4 Superposition Theorem

10.30 Find i_o in the circuit shown in Fig. 10.74 using superposition.

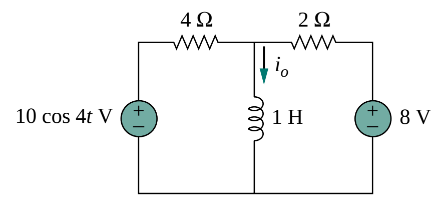

Figure 10.74 For Prob. 10.30.

10.31 Using the superposition principle, find i_x in the circuit of Fig. 10.75.

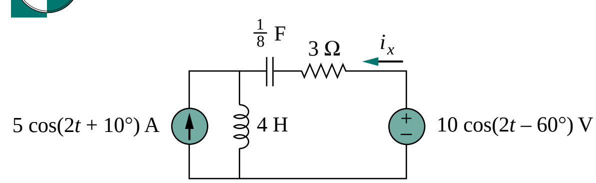

Figure 10.75 For Prob. 10.31.

10.32 Rework Prob. 10.2 using the superposition theorem.

10.33 Solve for $v_o(t)$ in the circuit of Fig. 10.76 using the superposition principle.

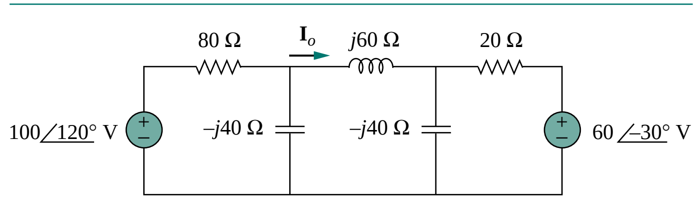

Figure 10.70 For Prob. 10.23.

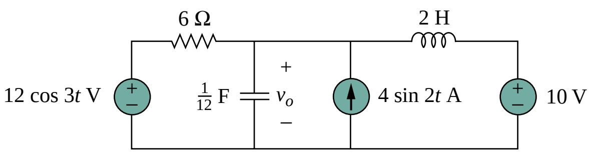

Figure 10.76 For Prob. 10.33.

10.34 Determine i_o in the circuit of Fig. 10.77.

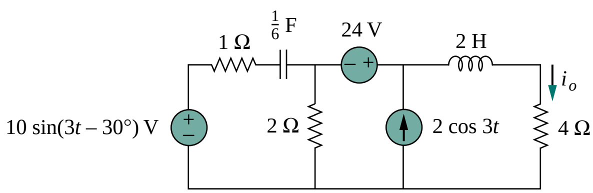

Figure 10.77 For Prob. 10.34.

10.35 Find i_o in the circuit in Fig. 10.78 using superposition.

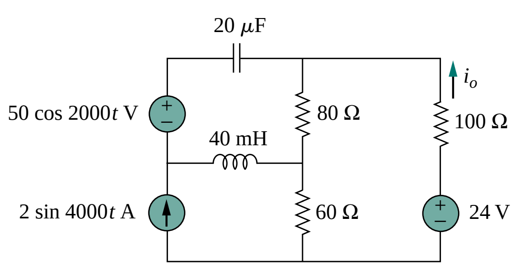

Figure 10.78 For Prob. 10.35.

Section 10.5 Source Transformation

10.36 Using source transformation, find i in the circuit of Fig. 10.79.

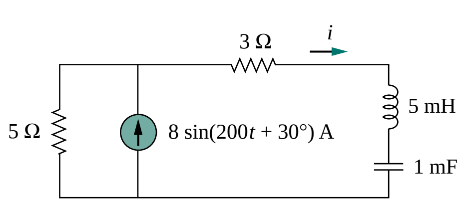

Figure 10.79 For Prob. 10.36.

10.37 Use source transformation to find v_o in the circuit in Fig. 10.80.

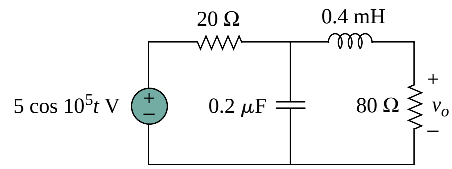

Figure 10.80 For Prob. 10.37.

10.38 Solve Prob. 10.20 using source transformation.

10.39 Use the method of source transformation to find $\mathbf{I}_x$ in the circuit of Fig. 10.81.

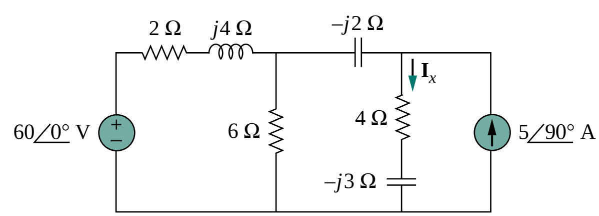

Figure 10.81 For Prob. 10.39.

10.40 Use the concept of source transformation to find $\mathbf{V}_o$ in the circuit of Fig. 10.82.

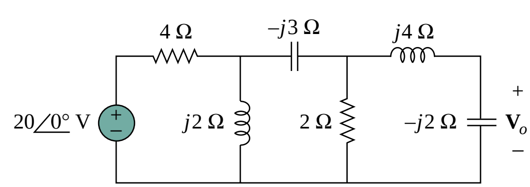

Figure 10.82 For Prob. 10.40.

Section 10.6 Thevenin and Norton Equivalent Circuits

10.41 Find the Thevenin and Norton equivalent circuits at terminals *a*-*b* for each of the circuits in Fig. 10.83.

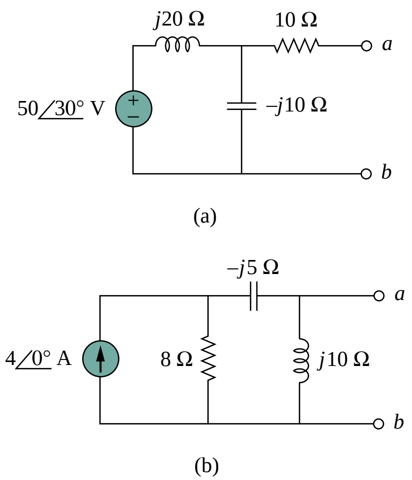

Figure 10.83 For Prob. 10.41.

10.42 For each of the circuits in Fig. 10.84, obtain Thevenin and Norton equivalent circuits at terminals *a*-*b*.

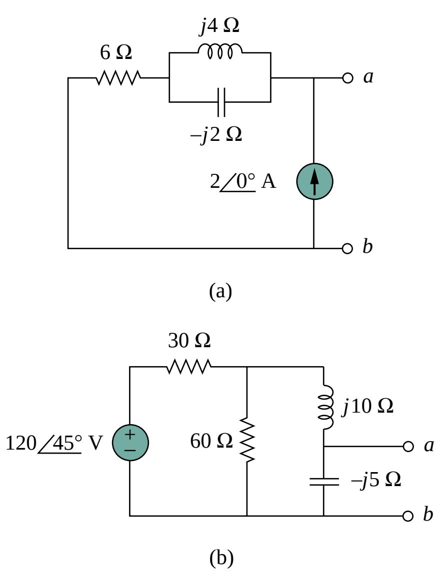

Figure 10.84 For Prob. 10.42.

10.43 Find the Thevenin and Norton equivalent circuits for the circuit shown in Fig. 10.85.

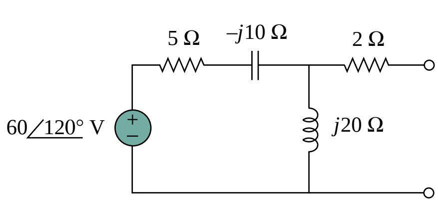

Figure 10.85 For Prob. 10.43.

10.44 For the circuit depicted in Fig. 10.86, find the Thevenin equivalent circuit at terminals *a*-*b*.

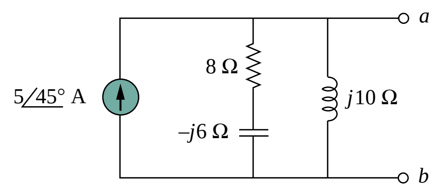

Figure 10.86 For Prob. 10.44.

10.45 Repeat Prob. 10.1 using Thevenin's theorem.

10.46 Find the Thevenin equivalent of the circuit in Fig. 10.87 as seen from:
(a) terminals *a*-*b* (b) terminals *c*-*d*

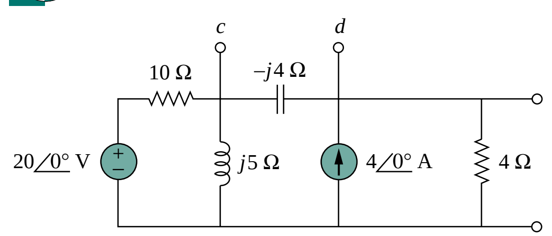

Figure 10.87 For Prob. 10.46.

10.47 Solve Prob. 10.3 using Thevenin's theorem.

10.48 Using Thevenin's theorem, find v_o in the circuit in Fig. 10.88.

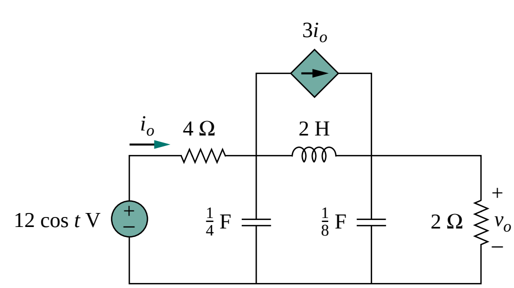

Figure 10.88 For Prob. 10.48.

10.49 Obtain the Norton equivalent of the circuit depicted in Fig. 10.89 at terminals *a*-*b*.

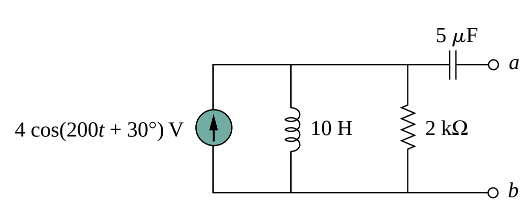

Figure 10.89 For Prob. 10.49.

10.50 For the circuit shown in Fig. 10.90, find the Norton equivalent circuit at terminals *a*-*b*.

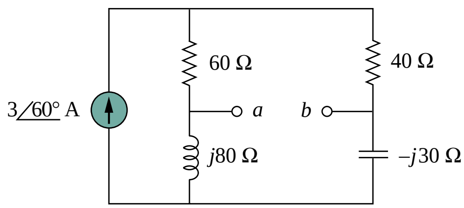

Figure 10.90 For Prob. 10.50.

10.51 Compute i_o in Fig. 10.91 using Norton's theorem.

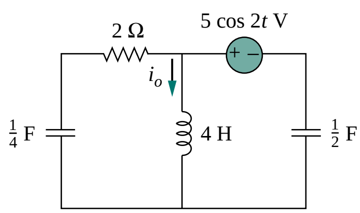

Figure 10.91 For Prob. 10.51.

10.52 At terminals *a*-*b*, obtain Thevenin and Norton equivalent circuits for the network depicted in Fig. 10.92. Take $\omega = 10$ rad/s.

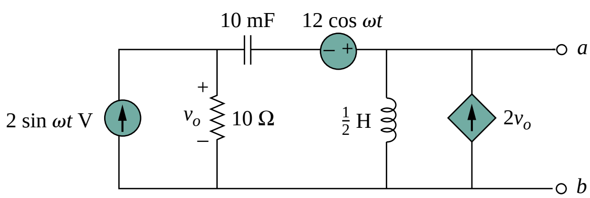

Figure 10.92 For Prob. 10.52.

Section 10.7 Op Amp AC Circuits

10.53 For the differentiator shown in Fig. 10.93, obtain $\mathbf{V}_o/\mathbf{V}_s$. Find $v_o(t)$ when $v_s(t) = V_m \sin \omega t$ and $\omega = 1/RC$.

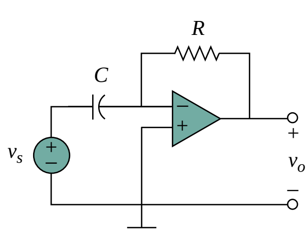

Figure 10.93 For Prob. 10.53.

10.54 The circuit in Fig. 10.94 is an integrator with a feedback resistor. Calculate $v_o(t)$ if $v_s = 2 \cos 4 \times 10^4 t$ V.

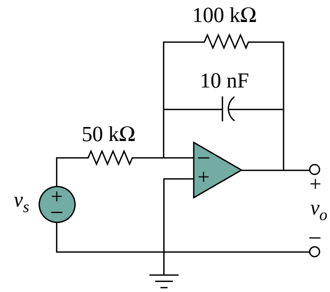

Figure 10.94 For Prob. 10.54.

10.55 Compute $i_o(t)$ in the op amp circuit in Fig. 10.95 if $v_s = 4 \cos 10^4 t$ V.

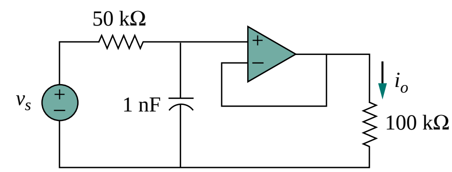

Figure 10.95 For Prob. 10.55.

10.56 If the input impedance is defined as $\mathbf{Z}_{\text{in}} = \mathbf{V}_s/\mathbf{I}_s$, find the input impedance of the op amp circuit in Fig. 10.96 when $R_1 = 10$ kΩ, $R_2 = 20$ kΩ, $C_1 = 10$ nF, $C_2 = 20$ nF, and $\omega = 5000$ rad/s.

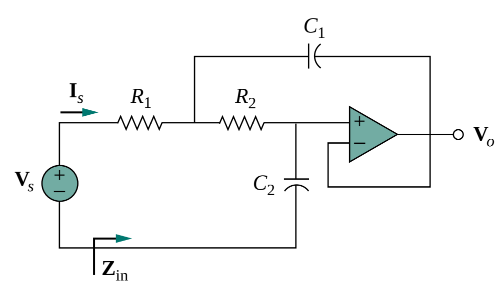

Figure 10.96 For Prob. 10.56.

10.57 Evaluate the voltage gain $\mathbf{A}_v = \mathbf{V}_o/\mathbf{V}_s$ in the op amp circuit of Fig. 10.97. Find $\mathbf{A}_v$ at $\omega = 0$, $\omega \to \infty$, $\omega = 1/R_1C_1$, and $\omega = 1/R_2C_2$.

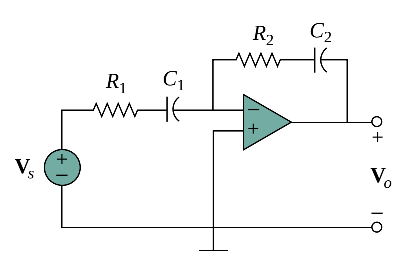

Figure 10.97 For Prob. 10.57.

10.58 In the op amp circuit of Fig. 10.98, find the closed-loop gain and phase shift if $C_1 = C_2 = 1$ nF, $R_1 = R_2 = 100$ kΩ, $R_3 = 20$ kΩ, $R_4 = 40$ kΩ, and $\omega = 2000$ rad/s.

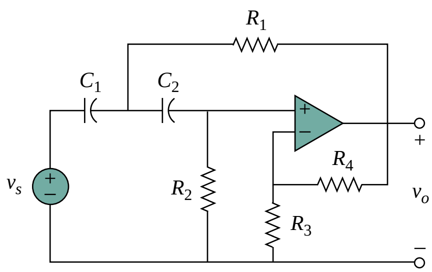

Figure 10.98 For Prob. 10.58.

10.59 Compute the closed-loop gain $\mathbf{V}_o/\mathbf{V}_s$ for the op amp circuit of Fig. 10.99.

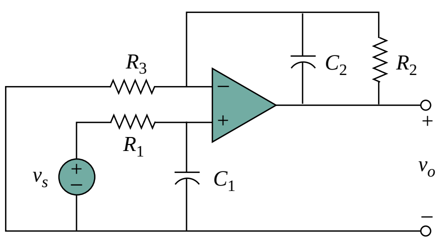

Figure 10.99 For Prob. 10.59.

10.60 Determine $v_o(t)$ in the op amp circuit in Fig. 10.100 below.

10.61 For the op amp circuit in Fig. 10.101, obtain $v_o(t)$.

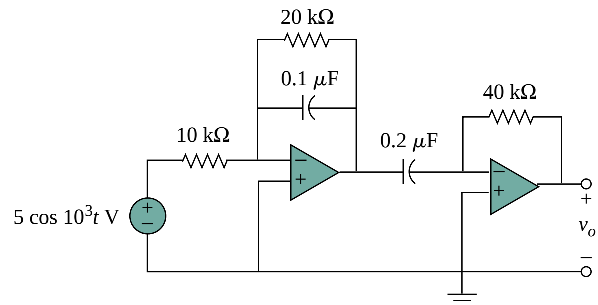

Figure 10.101 For Prob. 10.61.

10.62 Obtain $v_o(t)$ for the op amp circuit in Fig. 10.102 if $v_s = 4\cos(1000t - 60^\circ)$ V.

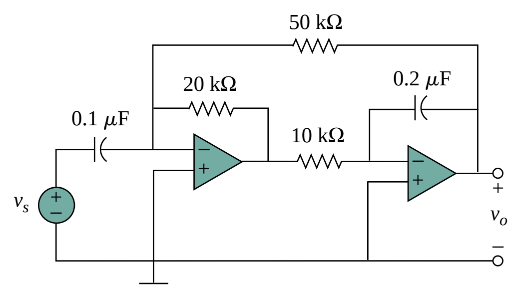

Figure 10.102 For Prob. 10.62.

Section 10.8 AC Analysis Using *PSpice*

10.63 Use *PSpice* to solve Example 10.10.

10.64 Solve Prob. 10.13 using *PSpice*.

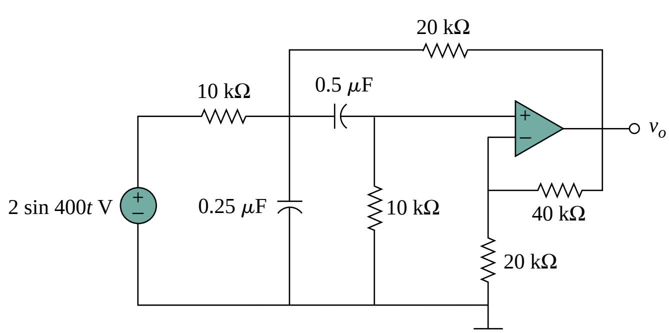

Figure 10.100 For Prob. 10.60.

10.65 Obtain $\mathbf{V}_o$ in the circuit of Fig. 10.103 using *PSpice*.

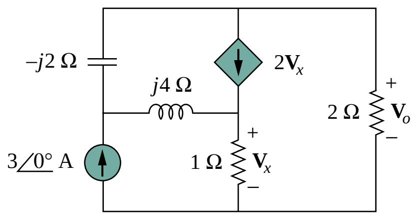

Figure 10.103 For Prob. 10.65.

10.66 Use *PSpice* to find $\mathbf{V}_1$, $\mathbf{V}_2$, and $\mathbf{V}_3$ in the network of Fig. 10.104.

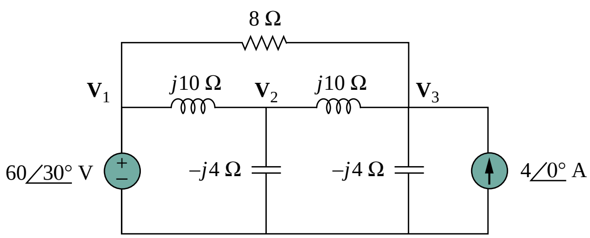

Figure 10.104 For Prob. 10.66.

10.67 Determine $\mathbf{V}_1$, $\mathbf{V}_2$, and $\mathbf{V}_3$ in the circuit of Fig. 10.105 using *PSpice*.

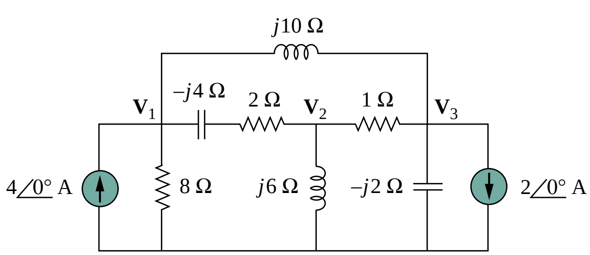

Figure 10.105 For Prob. 10.67.

10.68 Use *PSpice* to find v_o and i_o in the circuit of Fig. 10.106 below.

Section 10.9 Applications

10.69 The op amp circuit in Fig. 10.107 is called an *inductance simulator*. Show that the input impedance is given by

$$\mathbf{Z}_{\text{in}} = \frac{\mathbf{V}_{\text{in}}}{\mathbf{I}_{\text{in}}} = j\omega L_{\text{eq}}$$

where

$$L_{\text{eq}} = \frac{R_1 R_3 R_4}{R_2} C$$

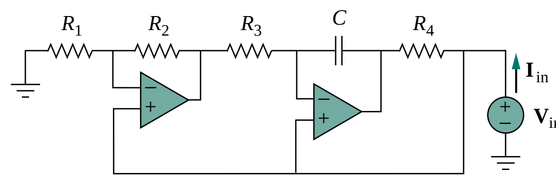

Figure 10.107 For Prob. 10.69.

10.70 Figure 10.108 shows a Wien-bridge network. Show that the frequency at which the phase shift between the input and output signals is zero is $f = \frac{1}{2}\pi RC$, and that the necessary gain is $\mathbf{A}_v = \mathbf{V}_o/\mathbf{V}_i = 3$ at that frequency.

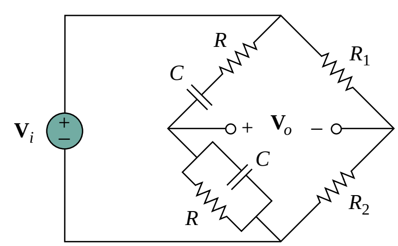

Figure 10.108 For Prob. 10.70.

10.71 Consider the oscillator in Fig. 10.109.

(a) Determine the oscillation frequency.

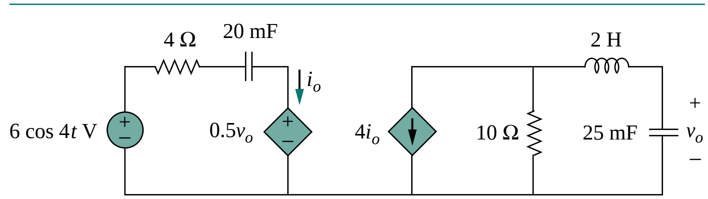

Figure 10.106 For Prob. 10.68.

(b) Obtain the minimum value of R for which oscillation takes place.

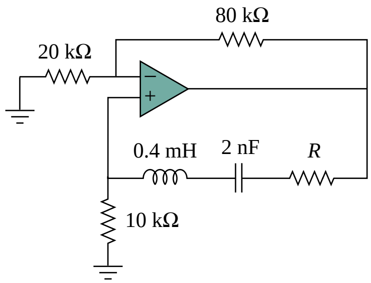

Figure 10.109 For Prob. 10.71.

10.72 The oscillator circuit in Fig. 10.110 uses an ideal op amp.

(a) Calculate the minimum value of R_o that will cause oscillation to occur.

(b) Find the frequency of oscillation.

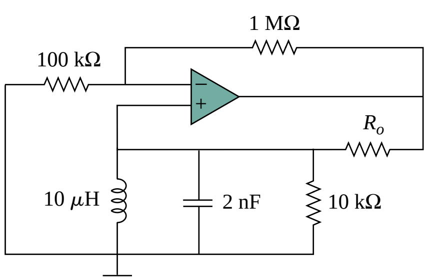

Figure 10.110 For Prob. 10.72.

10.73 Figure 10.111 shows a *Colpitts oscillator*. Show that the oscillation frequency is

$$f_o = \frac{1}{2\pi\sqrt{LC_T}}$$

where $C_T = C_1C_2/(C_1 + C_2)$. Assume $R_i \gg X_{C_2}$.

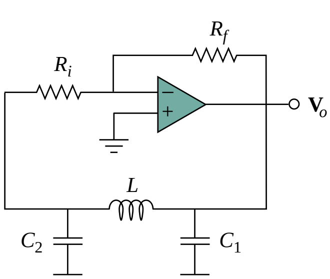

Figure 10.111 A Colpitts oscillator; for Prob. 10.73.

(*Hint:* Set the imaginary part of the impedance in the feedback circuit equal to zero.)

10.74 Design a Colpitts oscillator that will operate at 50 kHz.

10.75 Figure 10.112 shows a *Hartley oscillator*. Show that the frequency of oscillation is

$$f_o = \frac{1}{2\pi\sqrt{C(L_1 + L_2)}}$$

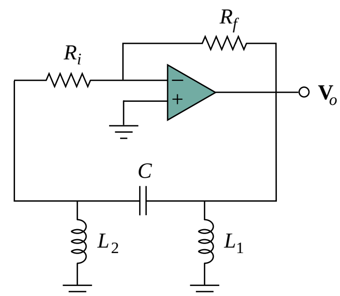

Figure 10.112 A Hartley oscillator; for Prob. 10.75.

10.76 Refer to the oscillator in Fig. 10.113.

(a) Show that

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{1}{3 + j(\omega L/R - R/\omega L)}$$

(b) Determine the oscillation frequency f_o.

(c) Obtain the relationship between R_1 and R_2 in order for oscillation to occur.

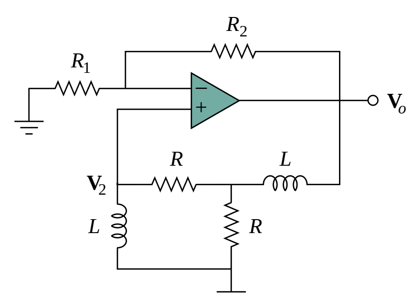

Figure 10.113 For Prob. 10.76.

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