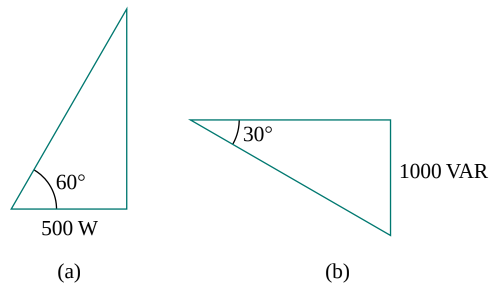

Figure 11.34 For Review Questions 11.7 and 11.8.

11.8 For the power triangle in Fig. 11.34(b), the apparent power is:

(a) 2000 VA (b) 1000 VAR
(c) 866 VAR (d) 500 VAR

11.9 A source is connected to three loads $\mathbf{Z}_1$, $\mathbf{Z}_2$, and $\mathbf{Z}_3$ in parallel. Which of these is not true?

(a) $P = P_1 + P_2 + P_3$ (b) $Q = Q_1 + Q_2 + Q_3$
(c) $S = S_1 + S_2 + S_3$ (d) $\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 + \mathbf{S}_3$

11.10 The instrument for measuring average power is the:

(a) voltmeter (b) ammeter
(c) wattmeter (d) varmeter
(e) kilowatt-hour meter

Answers: 11.1a, 11.2c, 11.3c, 11.4d, 11.5e, 11.6c, 11.7d, 11.8a, 11.9c, 11.10c.

PROBLEMS

Section 11.2 Instantaneous and Average Power

11.1 If $v(t) = 160\cos 50t$ V and $i(t) = -20\sin(50t - 30°)$ A, calculate the instantaneous power and the average power.

11.2 At $t = 2$ s, find the instantaneous power on each of the elements in the circuit of Fig. 11.35.

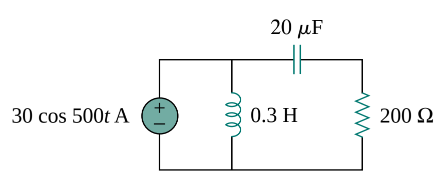

Figure 11.35 For Prob. 11.2.

11.3 Refer to the circuit depicted in Fig. 11.36. Find the average power absorbed by each element.

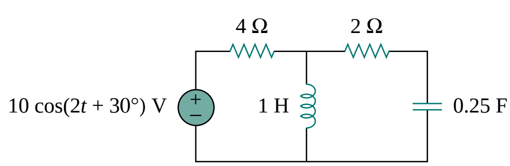

Figure 11.36 For Prob. 11.3.

11.4 Given the circuit in Fig. 11.37, find the average power absorbed by each of the elements.

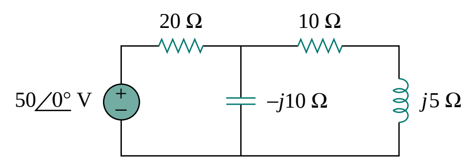

Figure 11.37 For Prob. 11.4.

11.5 Compute the average power absorbed by the 4-Ω resistor in the circuit of Fig. 11.38.

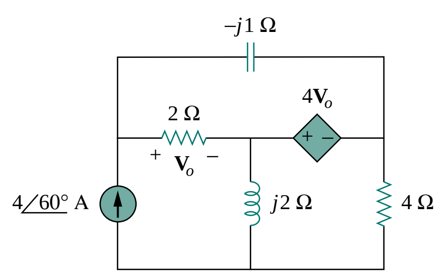

Figure 11.38 For Prob. 11.5.

11.6 Given the circuit of Fig. 11.39, find the average power absorbed by the 10-Ω resistor.

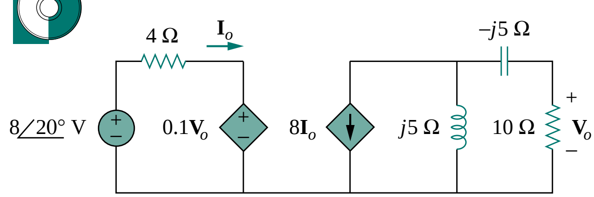

Figure 11.39 For Prob. 11.6.

11.7 In the circuit of Fig. 11.40, determine the average power absorbed by the 40-Ω resistor.

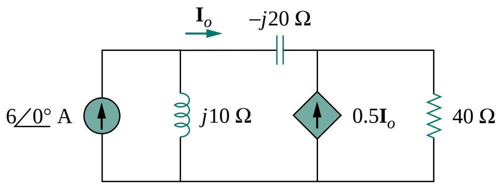

Figure 11.40 For Prob. 11.7.

11.8 Calculate the average power absorbed by each resistor in the op amp circuit of Fig. 11.41 if the rms value of v_s is 2 V.

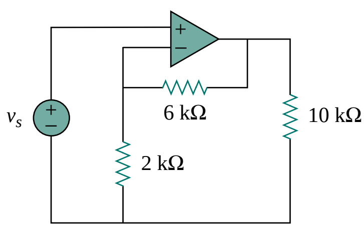

Figure 11.41 For Prob. 11.8.

11.9 In the op amp circuit in Fig. 11.42, find the total average power absorbed by the resistors.

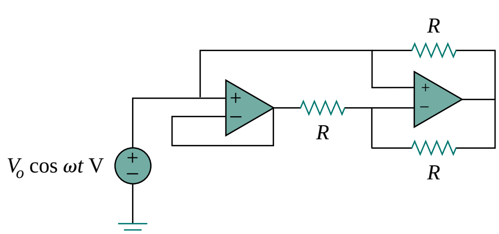

Figure 11.42 For Prob. 11.9.

11.10 For the network in Fig. 11.43, assume that the port impedance is

$$\mathbf{Z}_{ab} = \frac{R}{\sqrt{1 + \omega^2 R^2 C^2}} \angle -\tan^{-1} \omega RC$$

Find the average power consumed by the network when $R = 10$ kΩ, $C = 200$ nF, and $i = 2 \sin(377t + 22°)$ mA.

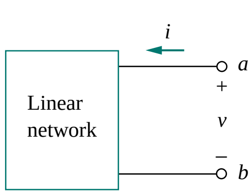

Figure 11.43 For Prob. 11.10.

Section 11.3 Maximum Average Power Transfer

11.11 For each of the circuits in Fig. 11.44, determine the value of load **Z** for maximum power transfer and the maximum average power transferred.

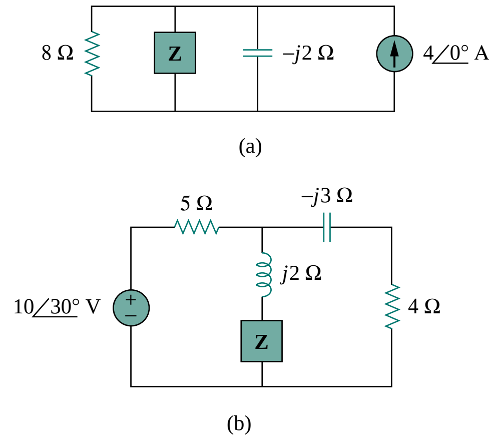

Figure 11.44 For Prob. 11.11.

11.12 For the circuit in Fig. 11.45, find:

(a) the value of the load impedance that absorbs the maximum average power

(b) the value of the maximum average power absorbed

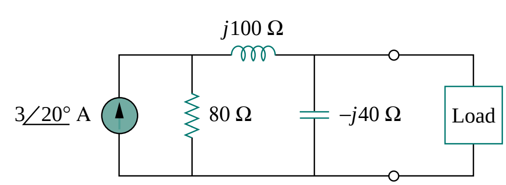

Figure 11.45 For Prob. 11.12.

11.13 In the circuit of Fig. 11.46, find the value of $\mathbf{Z}_L$ that will absorb the maximum power and the value of the maximum power.

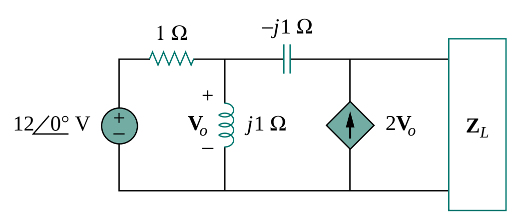

Figure 11.46 For Prob. 11.13.

11.14 Calculate the value of $\mathbf{Z}_L$ in the circuit of Fig. 11.47 in order for $\mathbf{Z}_L$ to receive maximum average power. What is the maximum average power received by $\mathbf{Z}$?

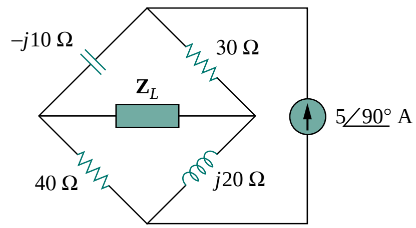

Figure 11.47 For Prob. 11.14.

11.15 Find the value of $\mathbf{Z}_L$ in the circuit of Fig. 11.48 for maximum power transfer.

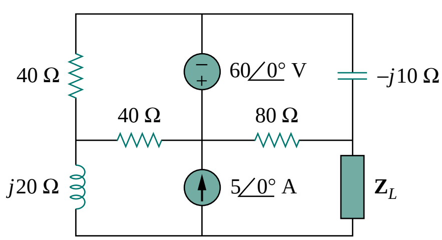

Figure 11.48 For Prob. 11.15.

11.16 The variable resistor R in the circuit of Fig. 11.49 is adjusted until it absorbs the maximum average power. Find R and the maximum average power absorbed.

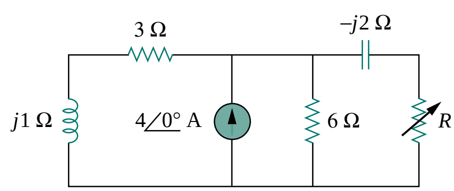

Figure 11.49 For Prob. 11.16.

11.17 The load resistance R_L in Fig. 11.50 is adjusted until it absorbs the maximum average power. Calculate the value of R_L and the maximum average power.

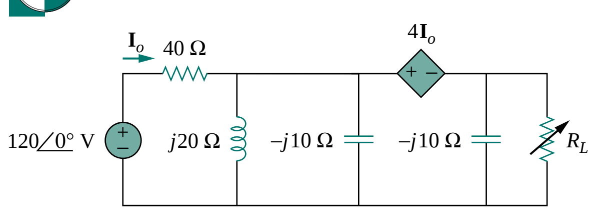

Figure 11.50 For Prob. 11.17.

11.18 Assuming that the load impedance is to be purely resistive, what load should be connected to terminals a-b of the circuits in Fig. 11.51 so that the maximum power is transferred to the load?

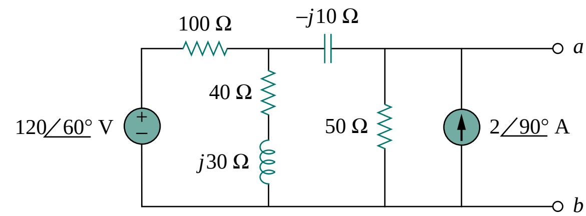

Figure 11.51 For Prob. 11.18.

Section 11.4 Effective or RMS Value

11.19 Find the rms value of the periodic signal in Fig. 11.52.

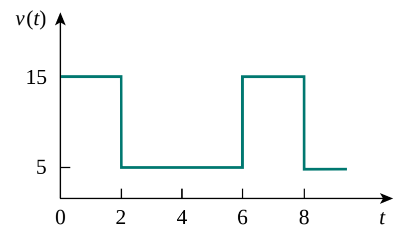

Figure 11.52 For Prob. 11.19.

11.20 Determine the rms value of the waveform in Fig. 11.53.

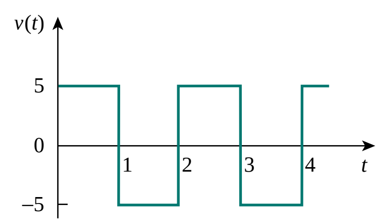

Figure 11.53 For Prob. 11.20.

11.21 Find the effective value of the voltage waveform in Fig. 11.54.

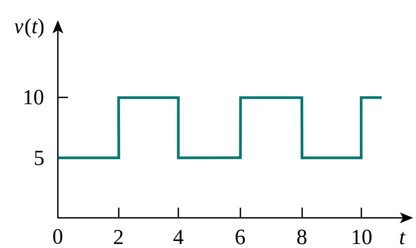

Figure 11.54 For Prob. 11.21.

11.22 Calculate the rms value of the current waveform of Fig. 11.55.

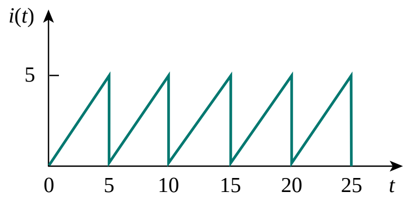

Figure 11.55 For Prob. 11.22.

11.23 Find the rms value of the voltage waveform of Fig. 11.56 as well as the average power absorbed by a 2-Ω resistor when the voltage is applied across the resistor.

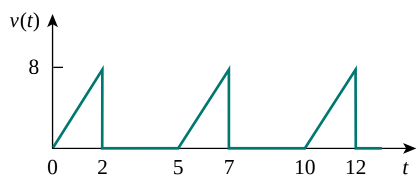

Figure 11.56 For Prob. 11.23.

11.24 Calculate the effective value of the current waveform in Fig. 11.57 and the average power delivered to a 12-Ω resistor when the current runs through the resistor.

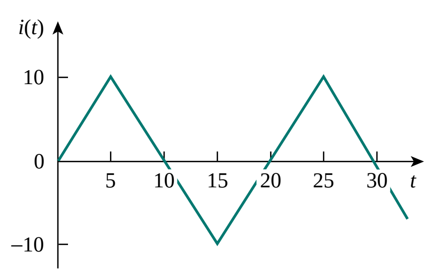

Figure 11.57 For Prob. 11.24.

11.25 Compute the rms value of the waveform depicted in Fig. 11.58.

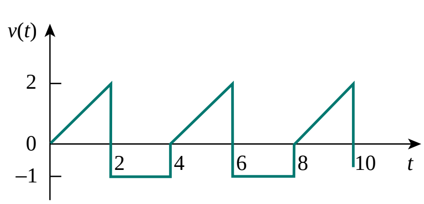

Figure 11.58 For Prob. 11.25.

11.26 Obtain the rms value of the current waveform shown in Fig. 11.59.

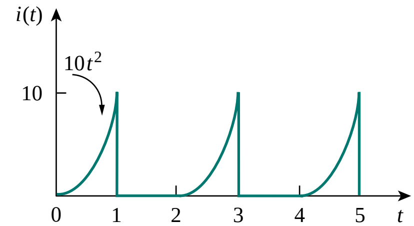

Figure 11.59 For Prob. 11.26.

11.27 Determine the effective value of the periodic waveform in Fig. 11.60.

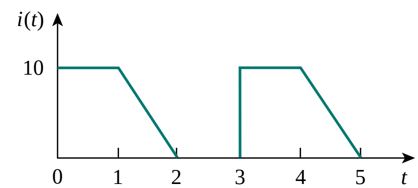

Figure 11.60 For Prob. 11.27.

11.28 One cycle of a periodic voltage waveform is depicted in Fig. 11.61. Find the effective value of the voltage.

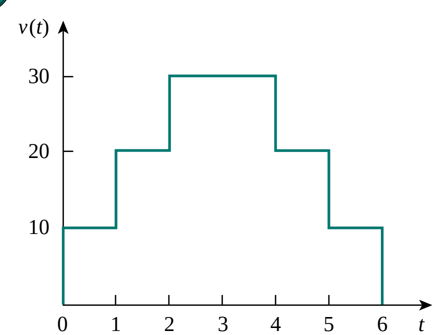

Figure 11.61 For Prob. 11.28.

Section 11.5 Apparent Power and Power Factor

11.29 A relay coil is connected to a 210-V, 50-Hz supply. If it has a resistance of 30 Ω and an inductance of 0.5 H, calculate the apparent power and the power factor.

11.30 A certain load comprises $12 - j8\ \Omega$ in parallel with $j4\ \Omega$. Determine the overall power factor.

11.31 Obtain the power factor for each of the circuits in Fig. 11.62. Specify each power factor as leading or lagging.

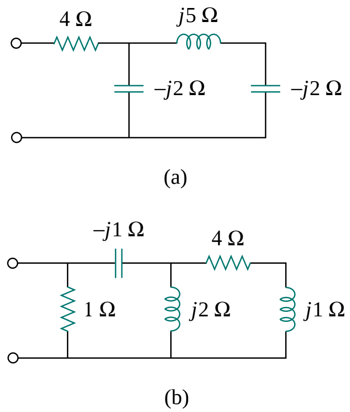

Figure 11.62 For Prob. 11.31.

Section 11.6 Complex Power

11.32 A load draws 5 kVAR at a power factor of 0.86 (leading) from a 220-V rms source. Calculate the peak current and the apparent power supplied to the load.

11.33 For the following voltage and current phasors, calculate the complex power, apparent power, real power, and reactive power. Specify whether the pf is leading or lagging.

(a) $\mathbf{V} = 220\angle 30^\circ$ V rms, $\mathbf{I} = 0.5\angle 60^\circ$ A rms

(b) $\mathbf{V} = 250\angle -10^\circ$ V rms, $\mathbf{I} = 6.2\angle -25^\circ$ A rms

(c) $\mathbf{V} = 120\angle 0^\circ$ V rms, $\mathbf{I} = 2.4\angle -15^\circ$ A rms

(d) $\mathbf{V} = 160\angle 45^\circ$ V rms, $\mathbf{I} = 8.5\angle 90^\circ$ A rms

11.34 For each of the following cases, find the complex power, the average power, and the reactive power:

(a) $v(t) = 112\cos(\omega t + 10^\circ)$ V, $i(t) = 4\cos(\omega t - 50^\circ)$ A

(b) $v(t) = 160\cos 377t$ V, $i(t) = 4\cos(377t + 45^\circ)$ A

(c) $\mathbf{V} = 80\angle 60^\circ$ V rms, $\mathbf{Z} = 50\angle 30^\circ$ Ω

(d) $\mathbf{I} = 10\angle 60^\circ$ V rms, $\mathbf{Z} = 100\angle 45^\circ$ Ω

11.35 Determine the complex power for the following cases:

(a) $P = 269$ W, $Q = 150$ VAR (capacitive)

(b) $Q = 2000$ VAR, pf $= 0.9$ (leading)

(c) $S = 600$ VA, $Q = 450$ VAR (inductive)

(d) $V_{rms} = 220$ V, $P = 1$ kW, $|\mathbf{Z}| = 40$ Ω (inductive)

11.36 Find the complex power for the following cases:

(a) $P = 4$ kW, pf $= 0.86$ (lagging)

(b) $S = 2$ kVA, $P = 1.6$ kW (capacitive)

(c) $\mathbf{V}_{rms} = 208\angle 20^\circ$ V, $\mathbf{I}_{rms} = 6.5\angle -50^\circ$ A

(d) $\mathbf{V}_{rms} = 120\angle 30^\circ$ V, $\mathbf{Z} = 40 + j60$ Ω

11.37 Obtain the overall impedance for the following cases:

(a) $P = 1000$ W, pf $= 0.8$ (leading), $V_{rms} = 220$ V

(b) $P = 1500$ W, $Q = 2000$ VAR (inductive), $I_{rms} = 12$ A

(c) $\mathbf{S} = 4500\angle 60^\circ$ VA, $\mathbf{V} = 120\angle 45^\circ$ V

11.38 For the entire circuit in Fig. 11.63, calculate:

(a) the power factor

(b) the average power delivered by the source

(c) the reactive power

(d) the apparent power

(e) the complex power

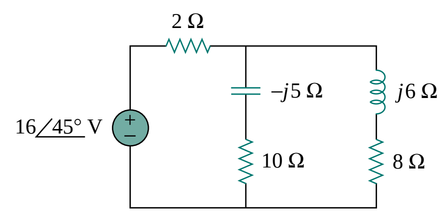

Figure 11.63 For Prob. 11.38.

Section 11.7 Conservation of AC Power

11.39 For the network in Fig. 11.64, find the complex power absorbed by each element.

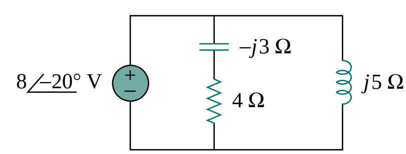

Figure 11.64 For Prob. 11.39.

11.40 Find the complex power absorbed by each of the five elements in the circuit of Fig. 11.65.

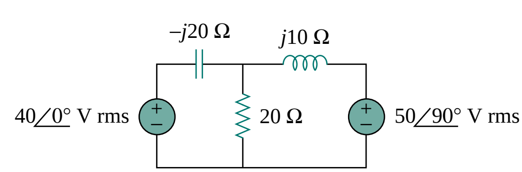

Figure 11.65 For Prob. 11.40.

11.41 Obtain the complex power delivered by the source in the circuit of Fig. 11.66.

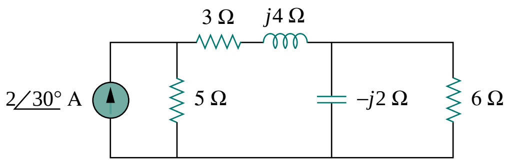

Figure 11.66 For Prob. 11.41.

11.42 For the circuit in Fig. 11.67, find the average, reactive, and complex power delivered by the dependent voltage source.

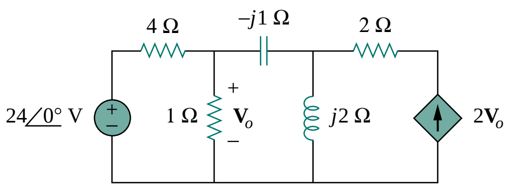

Figure 11.67 For Prob. 11.42.

11.43 Obtain the complex power delivered to the 10-kΩ resistor in Fig. 11.68 below.

11.44 Calculate the reactive power in the inductor and capacitor in the circuit of Fig. 11.69.

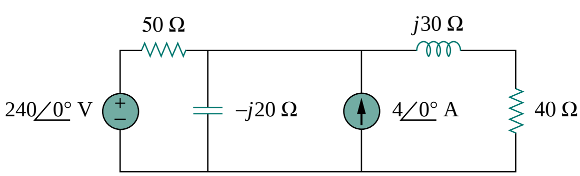

Figure 11.69 For Prob. 11.44.

11.45 For the circuit in Fig. 11.70, find $\mathbf{V}_o$ and the input power factor.

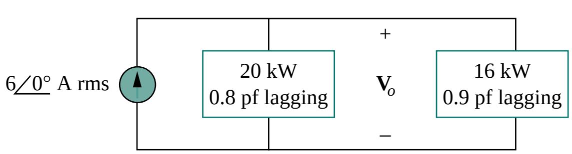

Figure 11.70 For Prob. 11.45.

11.46 Given the circuit in Fig. 11.71, find $\mathbf{I}_o$ and the overall complex power supplied.

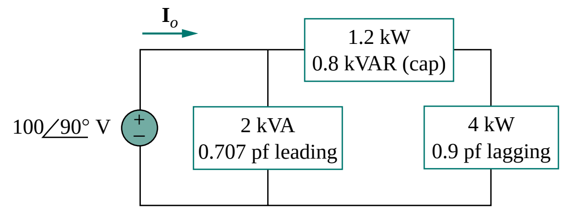

Figure 11.71 For Prob. 11.46.

11.47 For the circuit in Fig. 11.72, find $\mathbf{V}_s$.

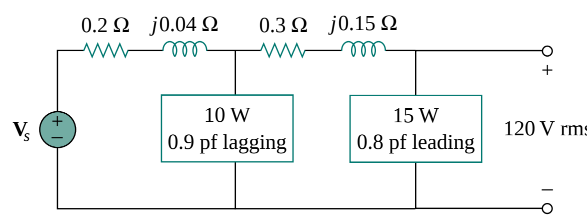

Figure 11.72 For Prob. 11.47.

11.48 Find $\mathbf{I}_o$ in the circuit of Fig. 11.73 on the bottom of the next page.

11.49 In the op amp circuit of Fig. 11.74, $v_s = 4\cos 10^4 t$ V. Find the average power delivered to the 50-kΩ resistor.

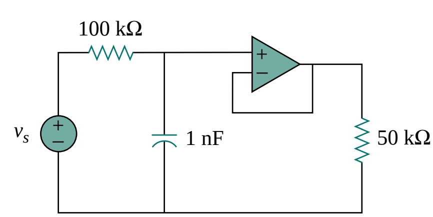

Figure 11.74 For Prob. 11.49.

11.50 Obtain the average power absorbed by the 6-kΩ resistor in the op amp circuit in Fig. 11.75.

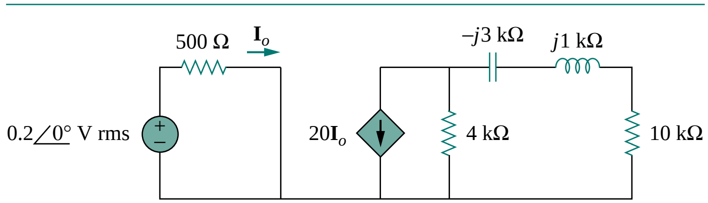

Figure 11.68 For Prob. 11.43.

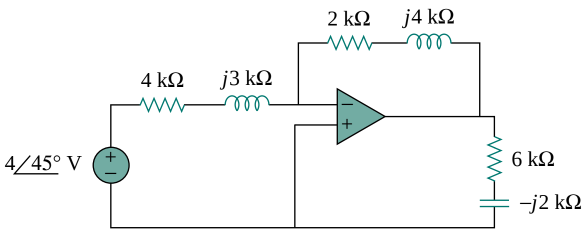

Figure 11.75 For Prob. 11.50.

11.51 Calculate the complex power delivered to each resistor and capacitor in the op amp circuit of Fig. 11.76. Let $v_s = 2\cos 10^3 t$ V.

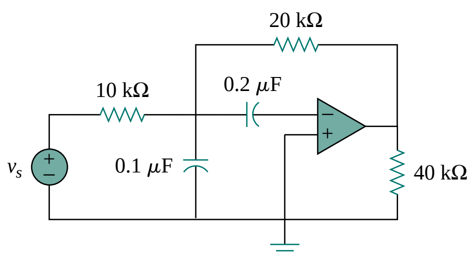

Figure 11.76 For Prob. 11.51.

11.52 Compute the complex power supplied by the current source in the series *RLC* circuit in Fig. 11.77.

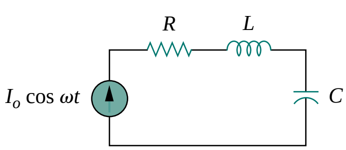

Figure 11.77 For Prob. 11.52.

Section 11.8 Power Factor Correction

11.53 Refer to the circuit shown in Fig. 11.78.

(a) What is the power factor?

(b) What is the average power dissipated?

(c) What is the value of the capacitance that will give a unity power factor when connected to the load?

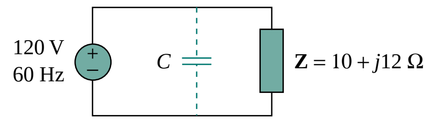

Figure 11.78 For Prob. 11.53.

11.54 An 880-VA, 220-V, 50-Hz load has a power factor of 0.8 lagging. What value of parallel capacitance will correct the load power factor to unity?

11.55 An 40-kW induction motor, with a lagging power factor of 0.76, is supplied by a 120-V rms 60-Hz sinusoidal voltage source. Find the capacitance needed in parallel with the motor to raise the power factor to:

(a) 0.9 lagging (b) 1.0.

11.56 A 240-V rms 60-Hz supply serves a load that is 10 kW (resistive), 15 kVAR (capacitive), and 22 kVAR (inductive). Find:

(a) the apparent power

(b) the current drawn from the supply

(c) the kVAR rating and capacitance required to improve the power factor to 0.96 lagging

(d) the current drawn from the supply under the new power-factor conditions

11.57 A 120-V rms 60-Hz source supplies two loads connected in parallel, as shown in Fig. 11.79.

(a) Find the power factor of the parallel combination.

(b) Calculate the value of the capacitance connected in parallel that will raise the power factor to unity.

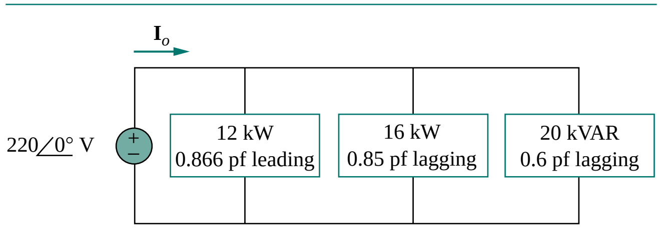

Figure 11.73 For Prob. 11.48.

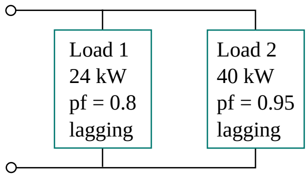

Figure 11.79 For Prob. 11.57.

11.58 Consider the power system shown in Fig. 11.80. Calculate:

(a) the total complex power

(b) the power factor

(c) the capacitance necessary to establish a unity power factor

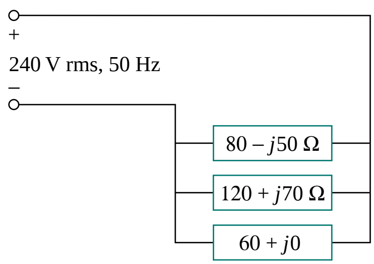

Figure 11.80 For Prob. 11.58.

Section 11.9 Applications

11.59 Obtain the wattmeter reading of the circuit in Fig. 11.81 below.

11.60 What is the reading of the wattmeter in the network of Fig. 11.82?

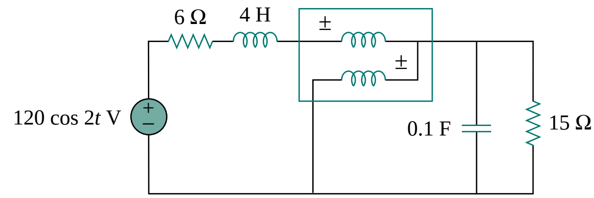

Figure 11.82 For Prob. 11.60.

11.61 Find the wattmeter reading of the circuit shown in Fig. 11.83 below.

11.62 The circuit of Fig. 11.84 portrays a wattmeter connected into an ac network.

(a) Find the load current.

(b) Calculate the wattmeter reading.

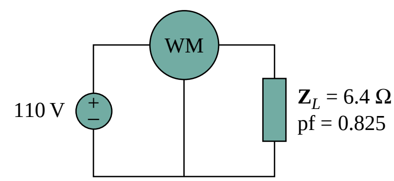

Figure 11.84 For Prob. 11.62.

11.63 The kilowatthour-meter of a home is read once a month. For a particular month, the previous and present readings are as follows:

Previous reading: 3246 kWh

Present reading: 4017 kWh

Calculate the electricity bill for that month based on the following residential rate schedule:

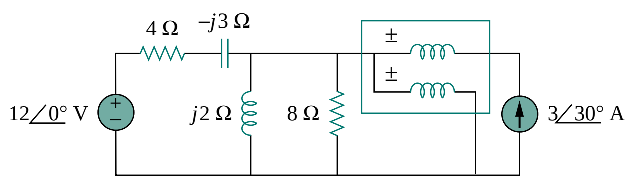

Figure 11.81 For Prob. 11.59.

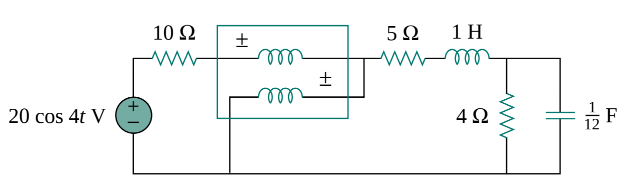

Figure 11.83 For Prob. 11.61.

Minimum monthly charge—$12.00
First 100 kWh per month at 16 cents/kWh
Next 200 kWh per month at 10 cents/kWh
Over 300 kWh per month at 6 cents/kWh

11.64 A consumer has an annual consumption of 1200 MWh with a maximum demand of 2.4 MVA. The maximum demand charge is $30 per kVA per annum, and the energy charge per kWh is 4 cents.

(a) Determine the annual cost of energy.

(b) Calculate the charge per kWh with a flat-rate tariff if the revenue to the utility company is to remain the same as for the two-part tariff.

COMPREHENSIVE PROBLEMS

11.65 A transmitter delivers maximum power to an antenna when the antenna is adjusted to represent a load of 75-Ω resistance in series with an inductance of 4 μH. If the transmitter operates at 4.12 MHz, find its internal impedance.

11.66 In a TV transmitter, a series circuit has an impedance of 3 kΩ and a total current of 50 mA. If the voltage across the resistor is 80 V, what is the power factor of the circuit?

11.67 A certain electronic circuit is connected to a 110-V ac line. The root-mean-square value of the current drawn is 2 A, with a phase angle of 55°.

(a) Find the true power drawn by the circuit.

(b) Calculate the apparent power.

11.68 An industrial heater has a nameplate which reads:

210 V 60 Hz 12 kVA 0.78 pf lagging

Determine:

(a) the apparent and the complex power

(b) the impedance of the heater

*__11.69__ A 2000-kW turbine-generator of 0.85 power factor operates at the rated load. An additional load of 300 kW at 0.8 power factor is added. What kVAR of capacitors is required to operate the turbine -generator but keep it from being overloaded?

11.70 The nameplate of an electric motor has the following information:

Line voltage: 220 V rms
Line current: 15 A rms
Line frequency: 60 Hz
Power: 2700 W

Determine the power factor (lagging) of the motor. Find the value of the capacitance C that must be connected across the motor to raise the pf to unity.

11.71 As shown in Fig. 11.85, a 550-V feeder line supplies an industrial plant consisting of a motor drawing 60 kW at 0.75 pf (inductive), a capacitor with a rating of 20 kVAR, and lighting drawing 20 kW.

(a) Calculate the total reactive power and apparent power absorbed by the plant.

(b) Determine the overall pf.

(c) Find the current in the feeder line.

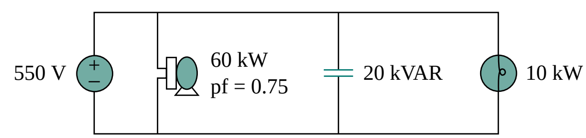

Figure 11.85 For Prob. 11.71.

11.72 A factory has the following four major loads:

- A motor rated at 5 hp, 0.8 pf lagging (1 hp = 0.7457 kW).
- A heater rated at 1.2 kW, 1.0 pf.
- Ten 120-W lightbulbs.
- A synchronous motor rated at 1.6 kVA, 0.6 pf leading.

(a) Calculate the total real and reactive power.

(b) Find the overall power factor.

11.73 A 1-MVA substation operates at full load at 0.7 power factor. It is desired to improve the power factor to 0.95 by installing capacitors. Assume that new substation and distribution facilities cost $120 per kVA installed, and capacitors cost $30 per kVA installed.

(a) Calculate the cost of capacitors needed.

(b) Find the savings in substation capacity released.

(c) Are capacitors economical for releasing the amount of substation capacity?

11.74 A coupling capacitor is used to block dc current from an amplifier as shown in Fig. 11.86(a). The amplifier and the capacitor act as the source, while the speaker is the load as in Fig. 11.86(b).

(a) At what frequency is maximum power transferred to the speaker?

(b) If $V_s = 4.6$ V rms, how much power is delivered to the speaker at that frequency?

*An asterisk indicates a challenging problem.

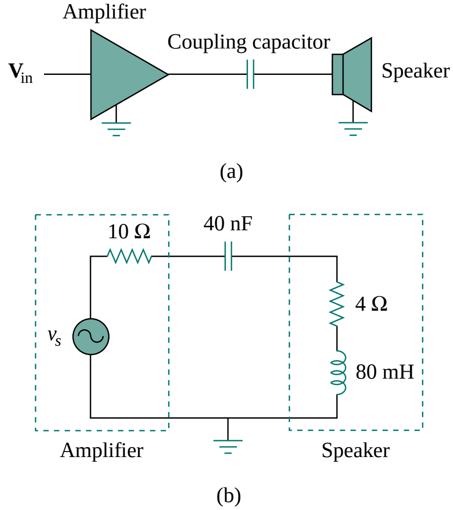

Figure 11.86 For Prob. 11.74.

11.75 A power amplifier has an output impedance of $40 + j8\ \Omega$. It produces a no-load output voltage of 146 V at 300 Hz.

(a) Determine the impedance of the load that achieves maximum power transfer.

(b) Calculate the load power under this matching condition.

11.76 A power transmission system is modeled as shown in Fig. 11.87. If $\mathbf{V}_s = 240\underline{/0^\circ}$ rms, find the average power absorbed by the load.

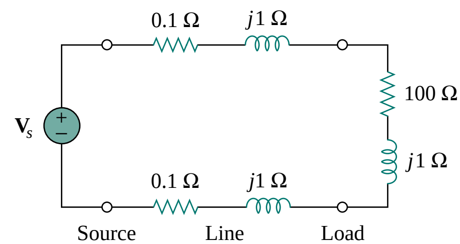

Figure 11.87 For Prob. 11.76.