Chapter 11, Problem 1.

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

Chapter 11, Solution 1.

$$v(t) = 160\cos(50t)$$
$$i(t) = \text{-}20\sin(50t - 30°) = 2\cos(50t - 30° + 180° - 90°)$$
$$i(t) = 20\cos(50t + 60°)$$

$$p(t) = v(t)\,i(t) = (160)(20)\cos(50t)\cos(50t + 60°)$$
$$p(t) = 1600\left[\cos(100t + 60°) + \cos(60°)\right] \text{ W}$$
$$p(t) = \underline{\mathbf{800 + 1600\cos(100t + 60°)\ W}}$$

$$P = \frac{1}{2}V_m I_m \cos(\theta_v - \theta_i) = \frac{1}{2}(160)(20)\cos(60°)$$
$$P = \underline{\mathbf{800\ W}}$$

Chapter 11, Problem 2.

Given the circuit in Fig. 11.35, find the average power supplied or absorbed by each element.

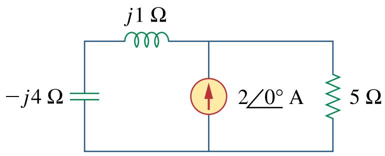
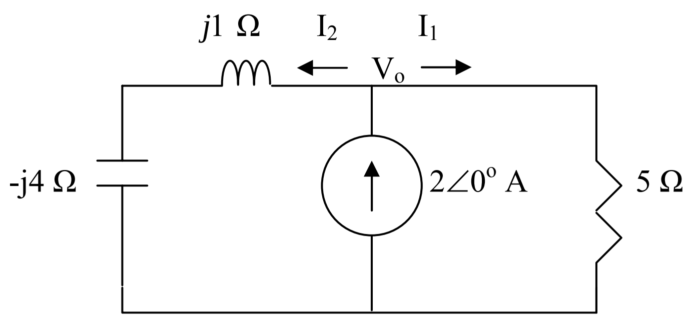


Figure 11.35
For Prob. 11.2.

Chapter 11, Solution 2.

Using current division,



$$I_1 = \frac{j1 - j4}{5 + j1 - j4}(2) = \frac{-j6}{5 - j3}$$

$$I_2 = \frac{5}{5 + j1 - j4}(2) = \frac{10}{5 - j3}$$

.

For the inductor and capacitor, the average power is zero. For the resistor,

$$P = \frac{1}{2}|I_1|^2 R = \frac{1}{2}(1.029)^2(5) = 2.647 \text{ W}$$

$$V_o = 5I_1 = -2.6471 - j4.4118$$

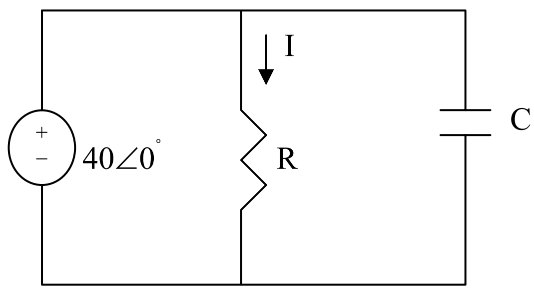
$$S = \frac{1}{2}V_o I^* = \frac{1}{2}(-2.6471 - j4.4118)x2 = -2.6471 - j4.4118$$

Hence the average power supplied by the current source is **2.647 W**.

Chapter 11, Problem 3.

A load consists of a 60-Ω resistor in parallel with a 90 μF capacitor. If the load is connected to a voltage source $v_s(t) = 40 \cos 2000t$, find the average power delivered to the load.

Chapter 11, Solution 3.



$$90\ \mu\text{F} \quad \longrightarrow \quad \frac{1}{j\omega C} = \frac{1}{j90x10^{-6}x2x10^{3}} = -j5.5556$$

$I = 40/60 = 0.6667\text{A}$ or $I_{rms} = 0.6667/1.4142 = 0.4714\text{A}$

The average power delivered to the load is the same as the average power absorbed by the resistor which is

$$P_{avg} = |I_{rms}|^2 60 = \underline{\mathbf{13.333\ W}}.$$

Chapter 11, Problem 4.

Find the average power dissipated by the resistances in the circuit of Fig. 11.36. Additionally, verify the conservation of power.

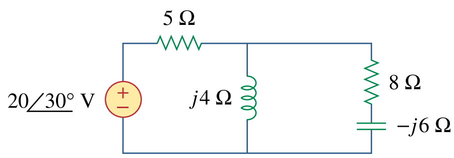
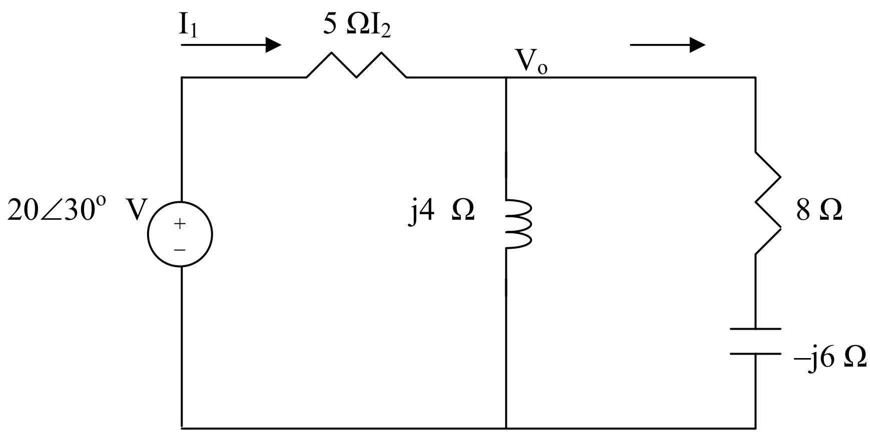


Figure 11.36
For Prob. 11.4.

Chapter 11, Solution 4.

We apply nodal analysis. At the main node,



$$\frac{20<30^o - V_o}{5} = \frac{V_o}{j4} + \frac{V_o}{8-j6} \longrightarrow V_o = 5.152 + j10.639$$

For the 5-Ω resistor,

$$I_1 = \frac{20<30^o - V_o}{5} = 2.438 < -3.0661^o \quad \text{A}$$

The average power dissipated by the resistor is

$$P_1 = \frac{1}{2}|I_1|^2 R_1 = \frac{1}{2}x2.438^2 x5 = \underline{14.86 \text{ W}}$$

For the 8-Ω resistor,

$$I_2 = \frac{V_o}{8-j} = 1.466 < 71.29^o$$

The average power dissipated by the resistor is

$$P_2 = \frac{1}{2}|I_2|^2 R_2 = \frac{1}{2}x1.466^2 x8 = \underline{8.5966 \text{ W}}$$

The complex power supplied is

$$S = \frac{1}{2}V_s I_1^* = \frac{1}{2}(20<30^o)(2.438<3.0661^o) = 20.43 + j13.30 \quad \text{VA}$$

Adding P_1 and P_2 gives the real part of S, showing the conservation of power.

Chapter 11, Problem 5.

Assuming that $v_s = 8\cos(2t - 40^\circ)$ V in the circuit of Fig. 11.37, find the average power delivered to each of the passive elements.

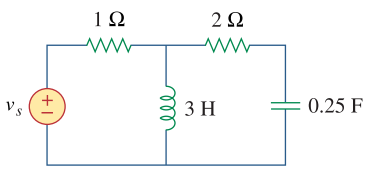
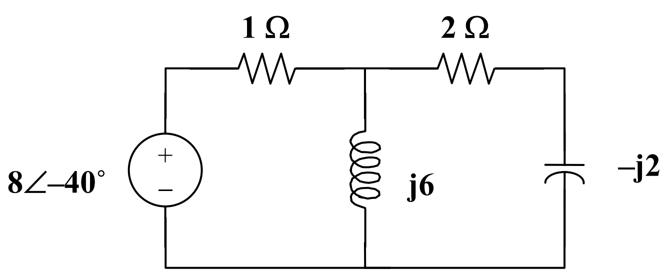


Figure 11.37
For Prob. 11.5.

Chapter 11, Solution 5.

Converting the circuit into the frequency domain, we get:



$$I_{1\Omega} = \frac{8\angle -40^\circ}{1 + \dfrac{j6(2 - j2)}{j6 + 2 - j2}} = 1.6828\angle -25.38^\circ$$

$$P_{1\Omega} = \frac{1.6828^2}{2}1 = \underline{1.4159\text{ W}}$$

$$P_{3H} = P_{0.25F} = \underline{\mathbf{0}}$$

$$|I_{2\Omega}| = \left|\frac{j6}{j6 + 2 - j2}1.6828\angle -25.38^\circ\right| = 2.258$$

$$P_{2\Omega} = \frac{2.258^2}{2}2 = \underline{5.097\text{ W}}$$

Chapter 11, Problem 6.

For the circuit in Fig. 11.38, $i_s = 6\cos 10^3 t$ A. Find the average power absorbed by the 50-Ω resistor.

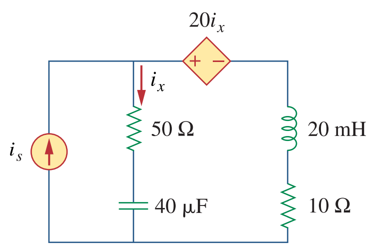


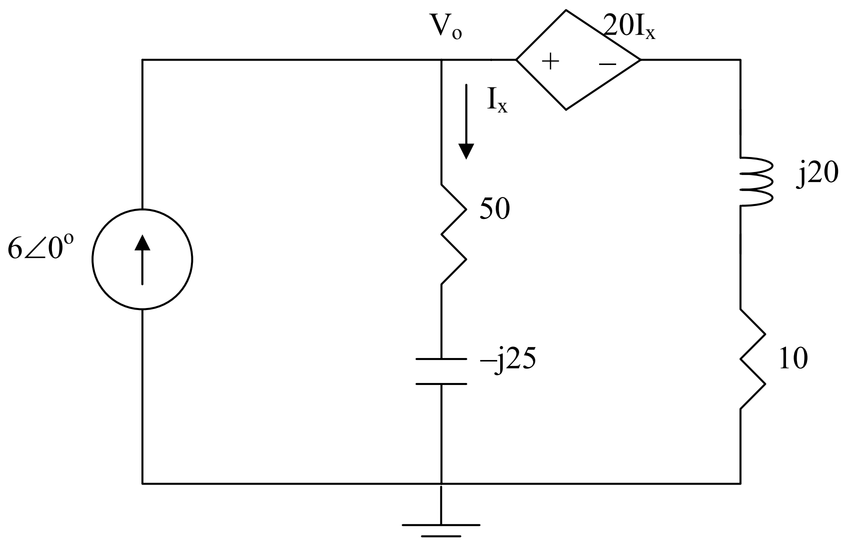
Figure 11.38
For Prob. 11.6.

Chapter 11, Solution 6.

$$20\text{ mH} \longrightarrow j\omega L = j10^3 x20x10^{-3} = j20$$

$$40\mu F \rightarrow \frac{1}{j\omega C} = \frac{1}{j10^3 x40x10^{-6}} = -j25$$

We apply nodal analysis to the circuit below.



$$-6 + \frac{V_o - 20I_x}{10 + j20} + \frac{V_o - 0}{50 - j25} = 0$$

But $I_x = \dfrac{V_o}{50 - j25}$. Substituting this and solving for V_o leads

$$\left(\frac{1}{10+j20} - \frac{20}{(10+j20)}\frac{1}{(50-j25)} + \frac{1}{50-j25}\right)V_o = 6$$

$$\left(\frac{1}{22.36\angle 63.43^\circ} - \frac{20}{(22.36\angle 63.43^\circ)(55.9\angle -26.57^\circ)} + \frac{1}{55.9\angle -26.57^\circ}\right)V_o = 6$$

$$(0.02 - j0.04 - 0.012802 + j0.009598 + 0.016 + j0.008)V_o = 6$$

$$(0.0232 - j0.0224)V_o = 6 \text{ or } V_o = 6/(0.03225\angle{-43.99^\circ} = 186.05\angle 43.99^\circ$$

For power, all we need is the magnitude of the rms value of I_x.

$|I_x| = 186.05/55.9 = 3.328$ and $|I_x|_{rms} = 3.328/1.4142 = 2.353$

We can now calculate the average power absorbed by the 50-Ω resistor.

$P_{avg} = (2.353)^2 x50 =$ **276.8 W**.

Chapter 11, Problem 7.

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

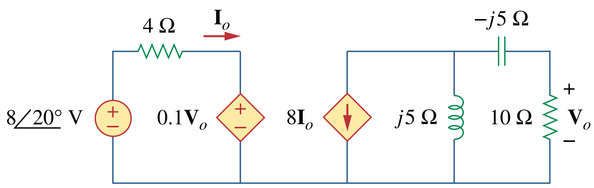


Figure 11.39
For Prob. 11.7.

Chapter 11, Solution 7.

Applying KVL to the left-hand side of the circuit,

$$8\angle 20° = 4\mathbf{I}_o + 0.1\mathbf{V}_o \qquad (1)$$

Applying KCL to the right side of the circuit,

$$8\mathbf{I}_o + \frac{\mathbf{V}_1}{j5} + \frac{\mathbf{V}_1}{10 - j5} = 0$$

But, $\mathbf{V}_o = \dfrac{10}{10 - j5}\mathbf{V}_1 \longrightarrow \mathbf{V}_1 = \dfrac{10 - j5}{10}\mathbf{V}_o$

Hence, $8\mathbf{I}_o + \dfrac{10 - j5}{j50}\mathbf{V}_o + \dfrac{\mathbf{V}_o}{10} = 0$

$$\mathbf{I}_o = j0.025\mathbf{V}_o \qquad (2)$$

Substituting (2) into (1),

$$8\angle 20° = 0.1\mathbf{V}_o(1 + j)$$

$$\mathbf{V}_o = \frac{80\angle 20°}{1 + j}$$

$$\mathbf{I}_1 = \frac{\mathbf{V}_o}{10} = \frac{8}{\sqrt{2}}\angle -25°$$

$$P = \frac{1}{2}|\mathbf{I}_1|^2 R = \left(\frac{1}{2}\right)\left(\frac{64}{2}\right)(10) = \underline{\mathbf{160W}}$$

Chapter 11, Problem 8.

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

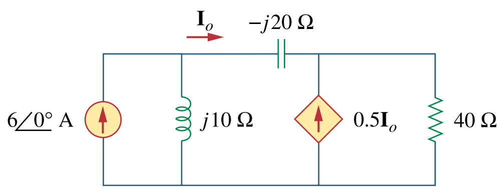
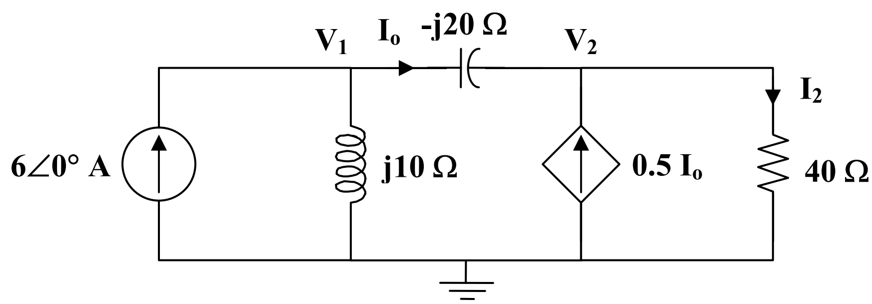


Figure 11.40
For Prob. 11.8.

Chapter 11, Solution 8.

We apply nodal analysis to the following circuit.



At node 1,

$$6 = \frac{\mathbf{V}_1}{j10} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j20} \quad \mathbf{V}_1 = j120 - \mathbf{V}_2 \qquad (1)$$

At node 2,

$$0.5\mathbf{I}_o + \mathbf{I}_o = \frac{\mathbf{V}_2}{40}$$

But, $\mathbf{I}_o = \dfrac{\mathbf{V}_1 - \mathbf{V}_2}{-j20}$

Hence, $\dfrac{1.5(\mathbf{V}_1 - \mathbf{V}_2)}{-j20} = \dfrac{\mathbf{V}_2}{40}$

$$3\mathbf{V}_1 = (3 - j)\mathbf{V}_2 \qquad (2)$$

Substituting (1) into (2),

$$j360 - 3\mathbf{V}_2 - 3\mathbf{V}_2 + j\mathbf{V}_2 = 0$$

$$\mathbf{V}_2 = \frac{j360}{6 - j} = \frac{360}{37}(-1 + j6)$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_2}{40} = \frac{9}{37}(-1 + j6)$$

$$P = \frac{1}{2}|\mathbf{I}_2|^2 R = \frac{1}{2}\left(\frac{9}{\sqrt{37}}\right)^2 (40) = \underline{\mathbf{43.78\ W}}$$

Chapter 11, Problem 9.

For the op amp circuit in Fig. 11.41, $\mathbf{V}_s = 10\angle 30°\,\text{V rms}$. Find the average power absorbed by the 20-kΩ resistor.

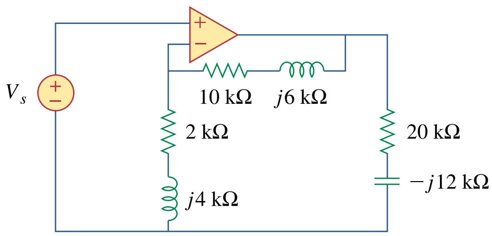


Figure 11.41
For Prob. 11.9.

Chapter 11, Solution 9.
This is a non-inverting op amp circuit. At the output of the op amp,

$$V_o = \left(1 + \frac{Z_2}{Z_1}\right)V_s = \left(1 + \frac{(10 + j6)x10^3}{(2 + j4)x10^3}\right)(8.66 + j5) = 20.712 + j28.124$$

The current through the 20-kς resistor is

$$I_o = \frac{V_o}{20k - j12k} = 0.1411 + j1.491\text{ mA}$$

$$P = |I_o|^2 R = (1.4975)^2 x10^{-6} x20x10^3 = \underline{44.85\text{ mW}}$$

Chapter 11, Problem 10.

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

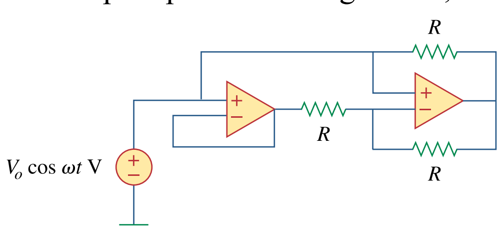


Figure 11.42
For Prob. 11.10.

Chapter 11, Solution 10.

No current flows through each of the resistors. Hence, for each resistor, P = $\underline{\mathbf{0\ W}}$. It should be noted that the input voltage will appear at the output of each of the op amps.

Chapter 11, Problem 11.

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 $R = 10\ \mathrm{k\Omega}$, $C = 200\ \mathrm{nF}$, and $i = 2 \sin(377t + 22°)$ mA.

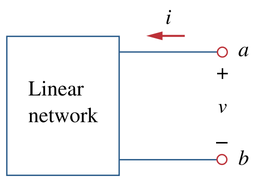


Figure 11.43
For Prob. 11.11.

Chapter 11, Solution 11.

$$\omega = 377, \qquad R = 10^4, \qquad C = 200 \times 10^{-9}$$
$$\omega RC = (377)(10^4)(200 \times 10^{-9}) = 0.754$$
$$\tan^{-1}(\omega RC) = 37.02°$$

$$Z_{ab} = \frac{10k}{\sqrt{1+(0.754)^2}} \angle -37.02° = 7.985 \angle -37.02°\ \mathrm{k\Omega}$$

$$i(t) = 2\sin(377t + 22°) = 2\cos(377t - 68°)\ \mathrm{mA}$$
$$I = 2\angle -68°$$

$$S = I_{rms}^2 Z_{ab} = \left(\frac{2 \times 10^{-3}}{\sqrt{2}}\right)^2 (7.985\angle -37.02°) \times 10^3$$
$$S = 15.97\angle -37.02°\ \mathrm{mVA}$$

$$P = |S| \cos(37.02) = \underline{\mathbf{12.751\ mW}}$$

Chapter 11, Problem 12.

For the circuit shown in Fig. 11.44, determine the load impedance **Z** for maximum power transfer (to **Z**). Calculate the maximum power absorbed by the load.

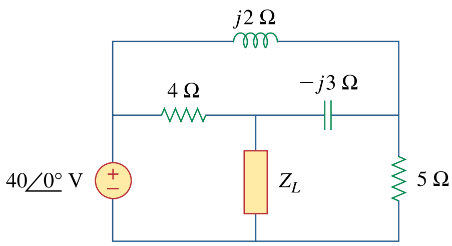
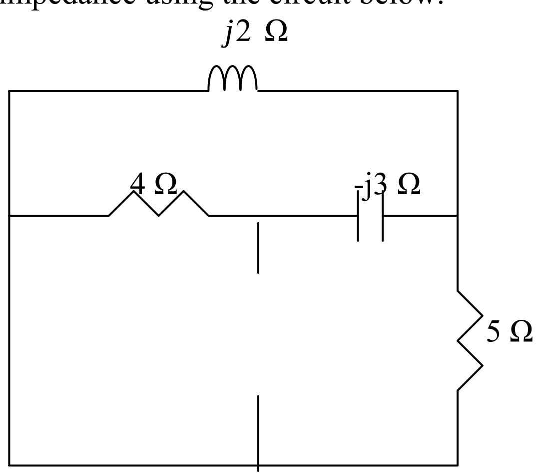


Figure 11.44
For Prob. 11.12.

Chapter 11, Solution 12.

We find the Thevenin impedance using the circuit below.



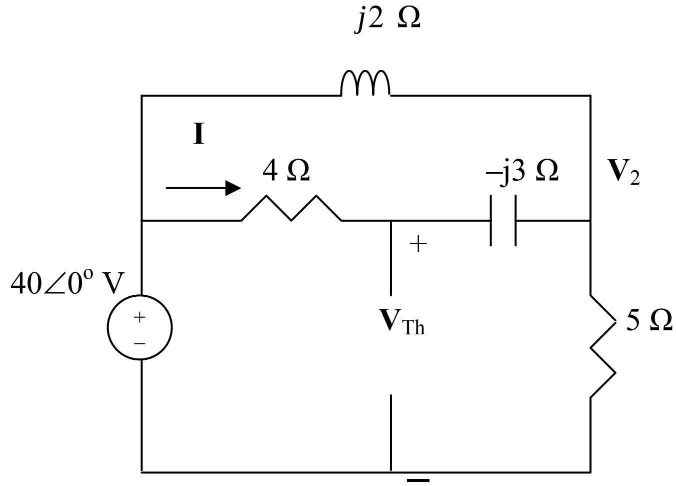
We note that the inductor is in parallel with the 5-Ω resistor and the combination is in series with the capacitor. That whole combination is in parallel with the 4-Ω resistor.

Thus,

$$Z_{Thev} = \frac{4\left(-j3+\dfrac{5xj2}{5+j2}\right)}{4-j3+\dfrac{5xj2}{5+j2}} = \frac{4(0.6896-j1.2758)}{4.69-j1.2758} = \frac{4(1.4502\angle-61.61°)}{4.86\angle-15.22°}$$
$$= 1.1936\angle-46.39°$$

$Z_{Thev} = 0.8233 - j0.8642$ or $Z_L =$ **<u>0.8233 + j0.8642Ω</u>**.

We obtain V_{Th} using the circuit below. We apply nodal analysis.



$$\frac{V_2-40}{4-j3}+\frac{V_2-40}{j2}+\frac{V_2-0}{5}=0$$
$$(0.16+j0.12-j0.5+0.2)V_2 = (0.16+j0.12-j0.5)40$$
$$(0.5235\angle-46.55°)V_2 = (0.4123\angle-67.17°)40$$

Thus, $V_2 = 31.5\angle{-20.62}^\circ V = 29.48 - j11.093V$

$I = (40 - V_2)/(4 - j3) = (40 - 29.48 + j11.093)/(4 - j3)$
$= 15.288\angle46.52^\circ/5\angle{-36.87}^\circ = 3.058\angle83.39^\circ = 0.352 + j3.038$

$V_{Thev} = 40 - 4I = 40 - 1.408 - j12.152 = 38.59 - j12.152V$
$= 40.46\angle{-17.479}^\circ V$

We can check our value of V_{Thev} by letting $V_1 = V_{Thev}$. Now we can use nodal analysis to solve for V_1.

At node 1,

$$\frac{V_1 - 40}{4} + \frac{V_1 - V_2}{-j3} + \frac{V_2 - 0}{5} = 0 \rightarrow (0.25 + j0.3333)V_1 + (0.2 - j0.3333)V_2 = 10$$

At node 2,

$$\frac{V_2 - V_1}{-j3} + \frac{V_2 - 40}{j2} = 0 \rightarrow -j0.3333V_1 + (-j0.1667)V_2 = -j20$$

```
>> Z=[(0.25+0.3333i),-0.3333i;-0.3333i,(0.2-0.1667i)]

Z =

  0.2500 + 0.3333i        0 - 0.3333i
       0 - 0.3333i   0.2000 - 0.1667i

>> I=[10;-20i]

I =

  10.0000
       0 -20.0000i

>> V=inv(Z)*I

V =

  38.5993 -12.1459i
  29.4890 -11.0952i
```

Please note, these values check with the ones obtained above.

To calculate the maximum power to the load,

$$|I_L|_{rms} = (40.46/(2x0.8233))/1.4141 = 17.376A$$

$$P_{avg} = (|I_L|_{rms})^2 0.8233 = \underline{\mathbf{248.58\ W}}.$$

Chapter 11, Problem 13.

The Thevenin impedance of a source is $\mathbf{Z}_{\text{Th}} = 120 + j60\,\Omega$, while the peak Thevenin voltage is $\mathbf{V}_{\text{Th}} = 110 + j0\text{ V}$. Determine the maximum available average power from the source.

Chapter 11, Solution 13.

For maximum power transfer to the load, $Z_L = 120 - j60\Omega$.

$I_{Lrms} = 110/(240\text{x}1.4142) = 0.3241\text{A}$

$$P_{avg} = |I_{Lrms}|^2 120 = \underline{\mathbf{12.605\ W}}.$$

Chapter 11, Problem 14.

It is desired to transfer maximum power to the load **Z** in the circuit of Fig. 11.45. Find **Z** and the maximum power. Let $i_s = 5\cos 40t$ A .

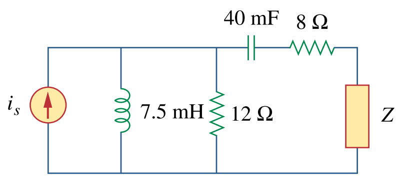


Figure 11.45
For Prob. 11.14.

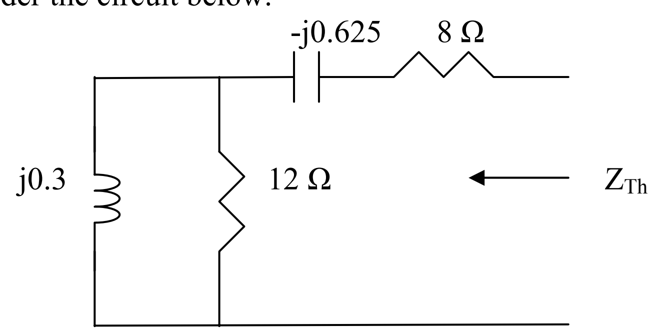
Chapter 11, Solution 14.

We find the Thevenin equivalent at the terminals of Z.

$$40\text{ mF} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j40x40x10^{-3}} = j0.625$$

$$7.5\text{ mH} \longrightarrow j\omega L = j40x7.5x10^{-3} = j0.3$$

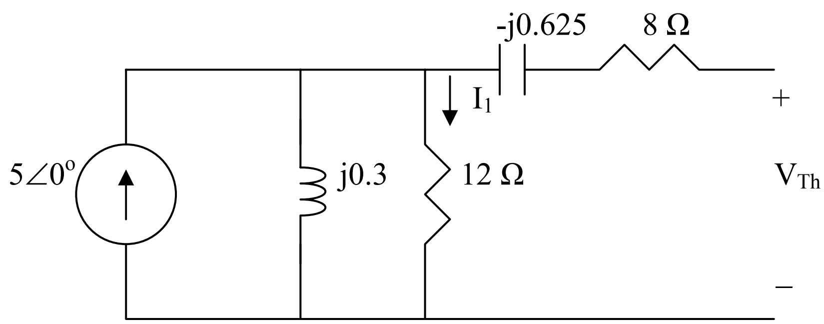
To find Z_{Th}, consider the circuit below.



$$Z_{Th} = 8 - j0.625 + 12 // j0.3 = 8 - j0.625 + \frac{12x0.3}{12 + 0.3} = 8.0075 - j0.3252$$

$$Z_L = (Z_{Thev})^* = \underline{\mathbf{8.008 + j0.3252\Omega}}.$$

To find V_{Th}, consider the circuit below.



By current division,

$$I_1 = 5(j0.3)/(12+j0.3) = 1.5\angle 90^\circ/12.004\angle 1.43^\circ = 0.12496\angle 88.57^\circ$$

$$= 0.003118 + j0.12492\text{A}$$

$$V_{\text{Thev rms}} = 12I_1/\sqrt{2} = 1.0603\angle 88.57^\circ\text{V}$$

$$I_{\text{Lrms}} = 1.0603\angle 88.57^\circ/2(8.008) = 66.2\angle 88.57^\circ\text{mA}$$

$$P_{avg} = |I_{\text{Lrms}}|^2 8.008 = \underline{\mathbf{35.09\ mW}}.$$

Chapter 11, Problem 15.

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.

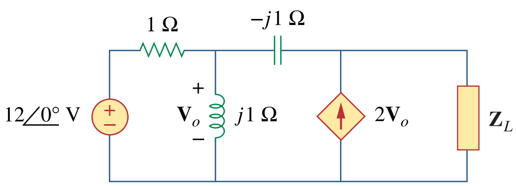
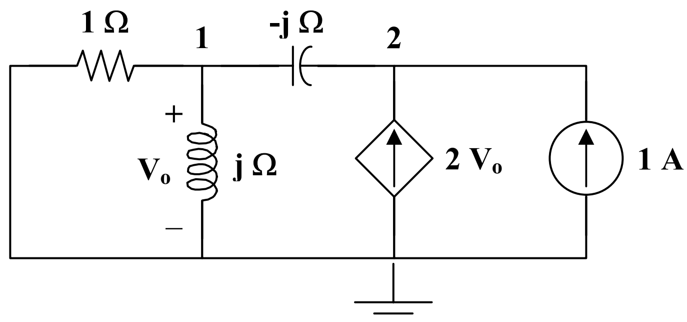


Figure 11.46
For Prob. 11.15.

Chapter 11, Solution 15.

To find $\mathbf{Z}_{Th}$, insert a 1-A current source at the load terminals as shown in Fig. (a).



(a)

At node 1,

$$\frac{\mathbf{V}_o}{1} + \frac{\mathbf{V}_o}{j} = \frac{\mathbf{V}_2 - \mathbf{V}_o}{-j} \longrightarrow \mathbf{V}_o = j\mathbf{V}_2 \qquad (1)$$

At node 2,

$$1 + 2\mathbf{V}_o = \frac{\mathbf{V}_2 - \mathbf{V}_o}{-j} \longrightarrow 1 = j\mathbf{V}_2 - (2 + j)\mathbf{V}_o \qquad (2)$$

Substituting (1) into (2),

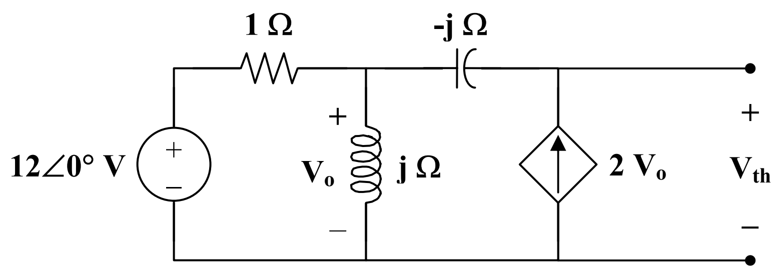
$$1 = j\mathbf{V}_2 - (2 + j)(j)\mathbf{V}_2 = (1 - j)\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{1}{1 - j}$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{V}_2}{1} = \frac{1 + j}{2} = 0.5 + j0.5$$

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = \underline{\mathbf{0.5 - j0.5\,\Omega}}$$

We now obtain $\mathbf{V}_{Th}$ from Fig. (b).



(b)

$$2\mathbf{V}_o + \frac{12 - \mathbf{V}_o}{1} = \frac{\mathbf{V}_o}{j}$$

$$\mathbf{V}_o = \frac{-12}{1 + j}$$

$$-\mathbf{V}_o - (-j \times 2\mathbf{V}_o) + \mathbf{V}_{Th} = 0$$

$$\mathbf{V}_{Th} = (1 - j2)\mathbf{V}_o = \frac{(-12)(1 - j2)}{1 + j}$$

$$P_{max} = \frac{|\mathbf{V}_{Th}|^2}{8R_L} = \frac{\left(\frac{12\sqrt{5}}{\sqrt{2}}\right)^2}{(8)(0.5)} = \underline{\mathbf{90\ W}}$$

Chapter 11, Problem 16.

For the circuit of Fig. 11.47, find the maximum power delivered to the load $\mathbf{Z}_L$.

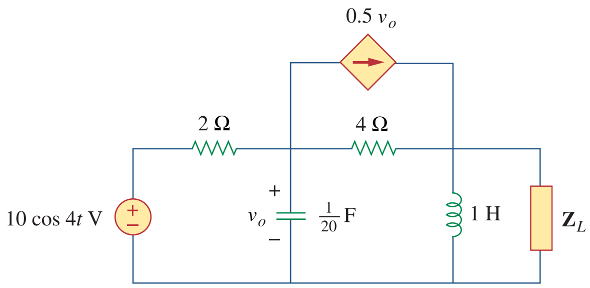
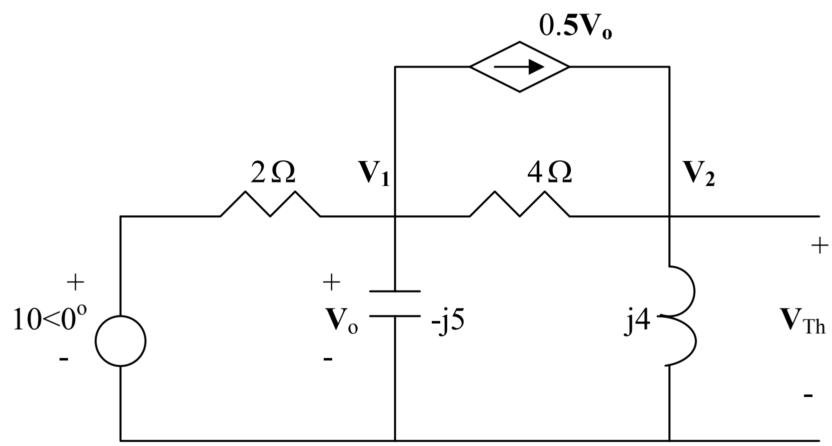


Figure 11.47
For Prob. 11.16.

Chapter 11, Solution 16.

$$\omega = 4, \quad 1\text{H} \longrightarrow j\omega L = j4, \quad 1/20\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j4x1/20} = -j5$$

We find the Thevenin equivalent at the terminals of Z_L. To find V_{Th}, we use the circuit shown below.



At node 1,

$$\frac{10 - V_1}{2} = \frac{V_1}{-j5} + 0.5V_1 + \frac{V_1 - V_2}{4} \longrightarrow 5 = V_1(1.25 + j0.2) - 0.25V_2 \qquad (1)$$

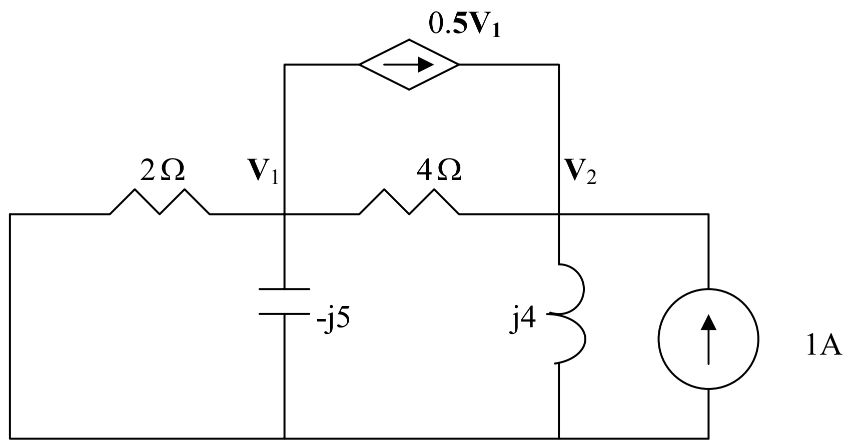
At node 2,

$$\frac{V_1 - V_2}{4} + 0.25V_1 = \frac{V_2}{j4} \longrightarrow 0 = 0.5V_1 + V_2(-0.25 + j0.25) \qquad (2)$$

Solving (1) and (2) leads to

$$V_{Th} = V_2 = 6.1947 + j7.0796 = 9.4072\angle 48.81^o$$

To obtain R_{Th}, consider the circuit shown below. We replace Z_L by a 1-A current source.



At node 1,

$$\frac{V_1}{2} + \frac{V_1}{-j5} + 0.25V_1 + \frac{V_1 - V_2}{4} = 0 \quad \longrightarrow \quad 0 = V_1(1 + j0.2) - 0.25V_2$$

(3)

At node 2,

$$1 + \frac{V_1 - V_2}{4} + 0.25V_1 = \frac{V_2}{j4} \quad \longrightarrow \quad -1 = 0.5V_1 + V_2(-0.25 + j0.25) \qquad (4)$$

Solving (1) and (2) gives

$$Z_{Th} = \frac{V_2}{1} = 1.9115 + j3.3274 = 3.8374\angle 60.12^o$$

$$P_{\max} = \frac{|V_{Th}|^2}{8R_{Th}} = \frac{9.4072^2}{8x1.9115} = \underline{5.787\ \text{W}}$$

Chapter 11, Problem 17.

Calculate the value of $\mathbf{Z}_L$ in the circuit of Fig. 11.48 in order for $\mathbf{Z}_L$ to receive maximum average power. What is the maximum average power received by $\mathbf{Z}_L$?

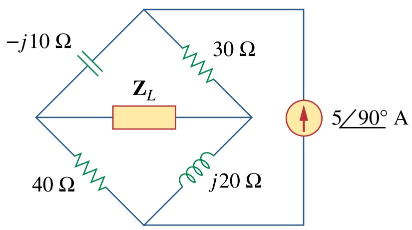
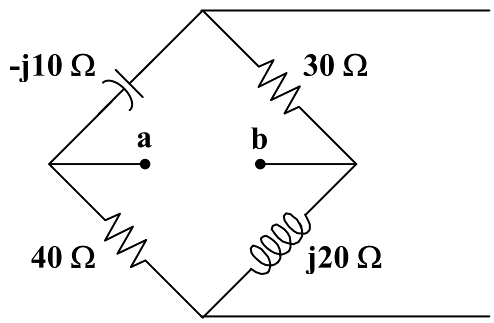


Figure 11.48
For Prob. 11.17.

Chapter 11, Solution 17.

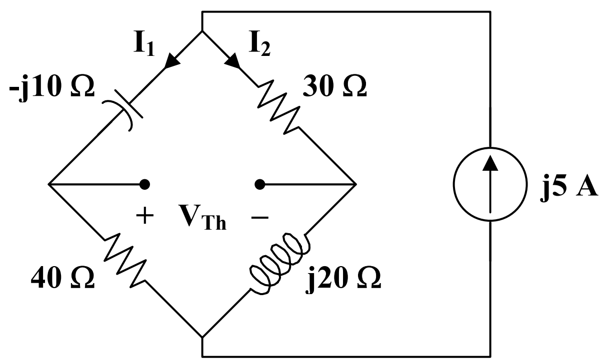
We find R_{Th} at terminals a-b following Fig. (a).



(a)

$$\mathbf{Z}_{Th} = -j10 + 30 \parallel j20 + 40 = \frac{(30 - j10)(40 + j20)}{70 + j10} = \underline{\mathbf{20\ \Omega}} = Z_L$$

We obtain $\mathbf{V}_{Th}$ from Fig. (b).



(b)

Using current division,

$$\mathbf{I}_1 = \frac{30 + j20}{70 + j10}(j5) = -1.1 + j2.3$$

$$\mathbf{I}_2 = \frac{40 - j10}{70 + j10}(j5) = 1.1 + j2.7$$

$$\mathbf{V}_{Th} = 30\mathbf{I}_2 + j10\mathbf{I}_1 = 10 + j70$$

$$P_{max} = \frac{\left|\mathbf{V}_{Th}\right|^2}{8R_L} = \frac{5000}{(8)(20)} = \underline{\mathbf{31.25\ W}}$$

Chapter 11, Problem 18.

Find the value of $\mathbf{Z}_L$ in the circuit of Fig. 11.49 for maximum power transfer.

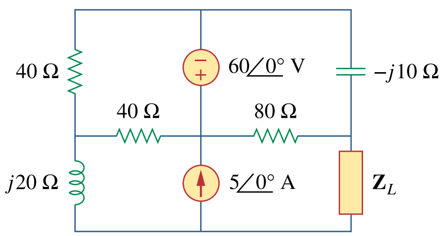
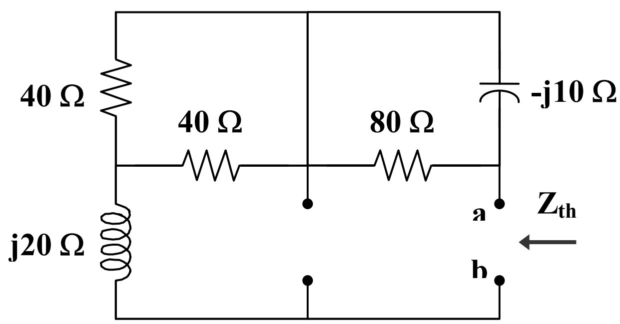


Figure 11.49
For Prob. 11.18.

Chapter 11, Solution 18.

We find $\mathbf{Z}_{Th}$ at terminals a-b as shown in the figure below.



$$\mathbf{Z}_{Th} = j20 + 40 \,||\, 40 + 80 \,||\, (-j10) = j20 + 20 + \frac{(80)(-j10)}{80 - j10}$$

$$\mathbf{Z}_{Th} = 21.23 + j10.154$$

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = \underline{\mathbf{21.23 - j10.15\,\Omega}}$$

Chapter 11, Problem 19.

The variable resistor *R* in the circuit of Fig. 11.50 is adjusted until it absorbs the maximum average power. Find *R* and the maximum average power absorbed.

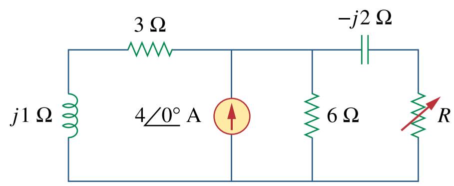


Figure 11.50
For Prob. 11.19.

Chapter 11, Solution 19.

At the load terminals,

$$\mathbf{Z}_{Th} = \text{-j}2 + 6 \,||\, (3 + \text{j}) = \text{-j}2 + \frac{(6)(3+\text{j})}{9+\text{j}}$$

$$\mathbf{Z}_{Th} = 2.049 - \text{j}1.561$$

$$R_L = \left| \mathbf{Z}_{Th} \right| = \underline{\mathbf{2.576\Omega}}$$

To get $\mathbf{V}_{Th}$, let $\mathbf{Z} = 6 \,||\, (3 + \text{j}) = 2.049 + \text{j}0.439$.

By transforming the current sources, we obtain

$$\mathbf{V}_{Th} = (4\angle 0°)\,\mathbf{Z} = 8.196 + \text{j}1.756$$

$$P_{max} = \left| \frac{8.382}{2.049 - \text{j}1.561 + 2.576} \right|^2 \frac{2.576}{2} = \underline{\mathbf{3.798\ W}}$$

Chapter 11, Problem 20.

The load resistance R_L in Fig. 11.51 is adjusted until it absorbs the maximum average power. Calculate the value of R_L and the maximum average power.

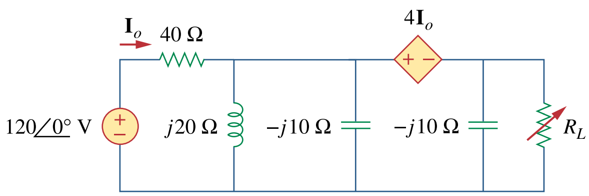
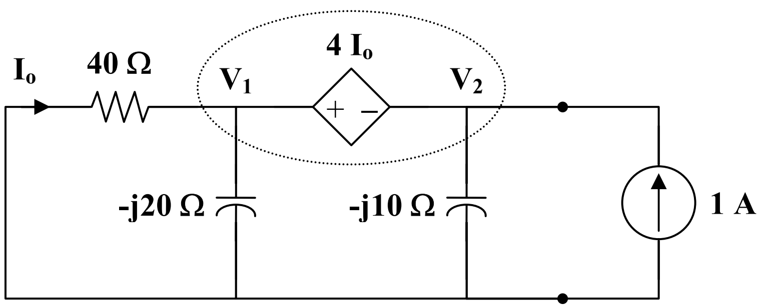


Figure 11.51
For Prob. 11.20.

Chapter 11, Solution 20.

Combine j20 Ω and -j10 Ω to get $j20 \parallel -j10 = -j20$.

To find $\mathbf{Z}_{Th}$, insert a 1-A current source at the terminals of R_L, as shown in Fig. (a).



(a)

At the supernode,

$$1 = \frac{\mathbf{V}_1}{40} + \frac{\mathbf{V}_1}{-j20} + \frac{\mathbf{V}_2}{-j10}$$

$$40 = (1 + j2)\,\mathbf{V}_1 + j4\,\mathbf{V}_2 \qquad (1)$$

Also, $\mathbf{V}_1 = \mathbf{V}_2 + 4\,\mathbf{I}_o$, where $\mathbf{I}_o = \frac{-\mathbf{V}_1}{40}$

$$1.1\,\mathbf{V}_1 = \mathbf{V}_2 \longrightarrow \mathbf{V}_1 = \frac{\mathbf{V}_2}{1.1} \qquad (2)$$

Substituting (2) into (1),

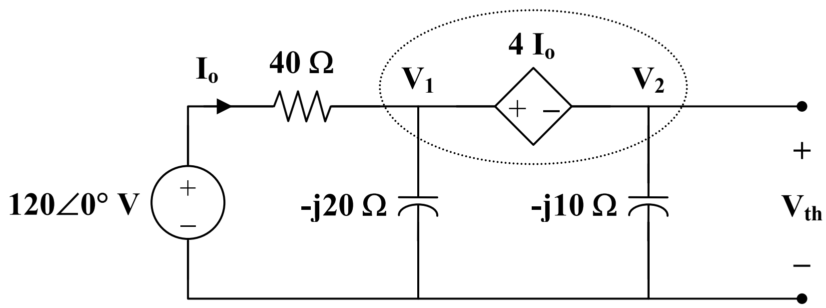
$$40 = (1 + j2)\left(\frac{\mathbf{V}_2}{1.1}\right) + j4\,\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{44}{1 + j6.4}$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{V}_2}{1} = 1.05 - j6.71\,\Omega$$

$$R_L = \left|\mathbf{Z}_{Th}\right| = \underline{\mathbf{6.792\,\Omega}}$$

To find $\mathbf{V}_{Th}$, consider the circuit in Fig. (b).



(b)

At the supernode,

$$\frac{120 - \mathbf{V}_1}{40} = \frac{\mathbf{V}_1}{-j20} + \frac{\mathbf{V}_2}{-j10}$$

$$120 = (1 + j2)\,\mathbf{V}_1 + j4\,\mathbf{V}_2 \qquad (3)$$

Also, $\mathbf{V}_1 = \mathbf{V}_2 + 4\,\mathbf{I}_o$, where $\mathbf{I}_o = \dfrac{120 - \mathbf{V}_1}{40}$

$$\mathbf{V}_1 = \frac{\mathbf{V}_2 + 12}{1.1} \qquad (4)$$

Substituting (4) into (3),

$$109.09 - j21.82 = (0.9091 + j5.818)\,\mathbf{V}_2$$

$$\mathbf{V}_{Th} = \mathbf{V}_2 = \frac{109.09 - j21.82}{0.9091 + j5.818} = 18.893\angle -92.43°$$

$$P_{max} = \left|\frac{18.893}{1.05 - j6.71 + 6.792}\right|^2 \frac{6.792}{2} = \underline{\mathbf{11.379\ W}}$$

Chapter 11, Problem 21.

Assuming that the load impedance is to be purely resistive, what load should be connected to terminals *a*-*b* of the circuits in Fig. 11.52 so that the maximum power is transferred to the load?

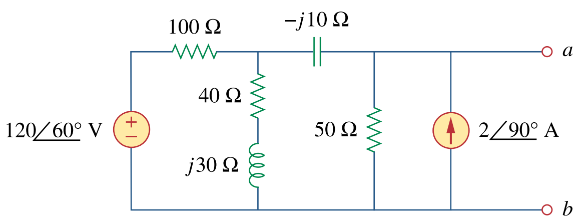
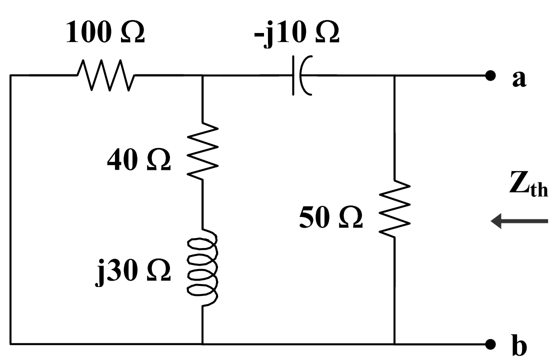


Figure 11.52
For Prob. 11.21.

Chapter 11, Solution 21.

We find $\mathbf{Z}_{Th}$ at terminals a-b, as shown in the figure below.



$$\mathbf{Z}_{Th} = 50 \,||\, [\,-j10 + 100 \,||\, (40 + j30)\,]$$

where $100 \,||\, (40 + j30) = \dfrac{(100)(40 + j30)}{140 + j30} = 31.707 + j14.634$

$$\mathbf{Z}_{Th} = 50 \,||\, (31.707 + j4.634) = \frac{(50)(31.707 + j4.634)}{81.707 + j4.634}$$

$$\mathbf{Z}_{Th} = 19.5 + j1.73$$

$$R_L = \left|\mathbf{Z}_{Th}\right| = \underline{\mathbf{19.58\ \Omega}}$$

Chapter 11, Problem 22.

Find the rms value of the offset sine wave shown in Fig. 11.53.

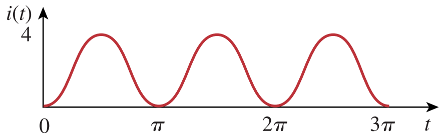


Figure 11.53
For Prob. 11.22.

Chapter 11, Solution 22.

$$i(t) = 4\sin t, \qquad 0 < t < \pi$$

$$I^2_{rms} = \frac{1}{\pi}\int_0^{\pi} 16\sin^2 t dt = \frac{16}{\pi}\left(\frac{t}{2} - \frac{\sin 2t}{4}\right)\Big|_0^{\pi} = \frac{16}{\pi}(\frac{\pi}{2} - 0) = 8$$

$I_{rms} = \sqrt{8} = \underline{2.828 \text{ A}}$

Chapter 11, Problem 23.

Determine the rms value of the voltage shown in Fig. 11.54.

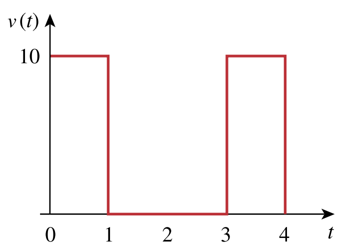


Figure 11.54
For Prob. 11.23.

Chapter 11, Solution 23.

$$V^2_{rms} = \frac{1}{T}\int_0^T v^2(t)dt = \frac{1}{3}\int_0^1 10^2 dt = \frac{100}{3}$$

$$V_{rms} = \underline{\mathbf{5.774 \text{ V}}}$$

Chapter 11, Problem 24.

Determine the rms value of the waveform in Fig. 11.55.

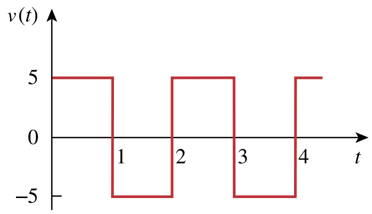


Figure 11.55
For Prob. 11.24.

Chapter 11, Solution 24.

$$T = 2, \qquad v(t) = \begin{cases} 5, & 0 < t < 1 \\ -5, & 1 < t < 2 \end{cases}$$

$$V_{rms}^2 = \frac{1}{2}\left[\int_0^1 5^2\ dt + \int_1^2 (-5)^2\ dt\right] = \frac{25}{2}[1+1] = 25$$

$$V_{rms} = \underline{\mathbf{5\ V}}$$

Chapter 11, Problem 25.

Find the rms value of the signal shown in Fig. 11.56.

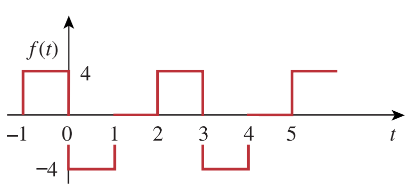


Figure 11.56
For Prob. 11.25.

Chapter 11, Solution 25.

$$f_{rms}^2 = \frac{1}{T}\int_0^T f^2(t)dt = \frac{1}{3}\left[\int_0^1 (-4)^2 dt + \int_1^2 0 dt + \int_2^3 4^2 dt\right]$$

$$= \frac{1}{3}[16 + 0 + 16] = \frac{32}{3}$$

$$f_{rms} = \sqrt{\frac{32}{3}} = \underline{3.266}$$

Chapter 11, Problem 26.

Find the effective value of the voltage waveform in Fig. 11.57.

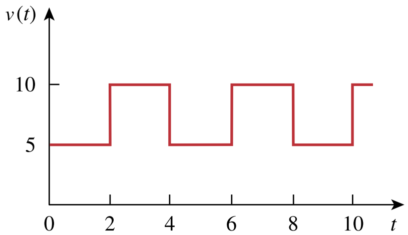


Figure 11.57
For Prob. 11.26.

Chapter 11, Solution 26.

$$T = 4, \qquad v(t) = \begin{cases} 5 & 0 < t < 2 \\ 10 & 2 < t < 4 \end{cases}$$

$$V_{rms}^2 = \frac{1}{4}\left[\int_0^2 5^2\, dt + \int_2^4 (10)^2\, dt\right] = \frac{1}{4}[50 + 200] = 62.5$$

$$V_{rms} = \underline{\mathbf{7.906\ V}}$$

Chapter 11, Problem 27.

Calculate the rms value of the current waveform of Fig. 11.58.

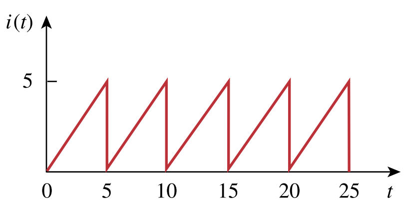


Figure 11.58
For Prob. 11.27.

Chapter 11, Solution 27.

$$T = 5, \qquad i(t) = t, \quad 0 < t < 5$$

$$I_{rms}^2 = \frac{1}{5}\int_0^5 t^2\, dt = \frac{1}{5}\cdot\frac{t^3}{3}\Big|_0^5 = \frac{125}{15} = 8.333$$

$$I_{rms} = \underline{\mathbf{2.887\ A}}$$

Chapter 11, Problem 28.

Find the rms value of the voltage waveform of Fig. 11.59 as well as the average power absorbed by a 2-Ω resistor when the voltage is applied across the resistor.

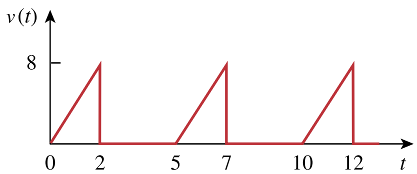


Figure 11.59
For Prob. 11.28.

Chapter 11, Solution 28.

$$V_{rms}^2 = \frac{1}{5}\left[\int_0^2 (4t)^2\ dt + \int_2^5 0^2\ dt\right]$$

$$V_{rms}^2 = \frac{1}{5}\cdot\frac{16t^3}{3}\Big|_0^2 = \frac{16}{15}(8) = 8.533$$

$$V_{rms} = \underline{\mathbf{2.92\ V}}$$

$$P = \frac{V_{rms}^2}{R} = \frac{8.533}{2} = \underline{\mathbf{4.267\ W}}$$

Chapter 11, Problem 29.

Calculate the effective value of the current waveform in Fig. 11.60 and the average power delivered to a 12-Ω resistor when the current runs through the resistor.

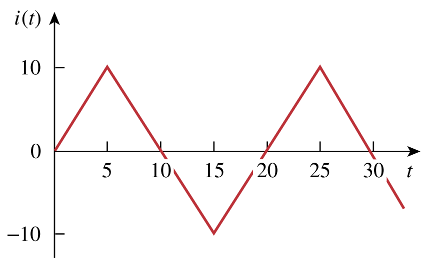


Figure 11.60
For Prob. 11.29.

Chapter 11, Solution 29.

$$T = 20, \qquad i(t) = \begin{cases} 20 - 2t & 5 < t < 15 \\ -40 + 2t & 15 < t < 25 \end{cases}$$

$$I_{eff}^2 = \frac{1}{20}\left[\int_5^{15} (20-2t)^2\, dt + \int_{15}^{25} (-40+2t)^2\, dt\right]$$

$$I_{eff}^2 = \frac{1}{5}\left[\int_5^{15} (100 - 20t + t^2)\, dt + \int_{15}^{25} (t^2 - 40t + 400)\, dt\right]$$

$$I_{eff}^2 = \frac{1}{5}\left[\left(100t - 10t^2 + \frac{t^3}{3}\right)\Bigg|_5^{15} + \left(\frac{t^3}{3} - 20t^2 + 400t\right)\Bigg|_{15}^{25}\right]$$

$$I_{eff}^2 = \frac{1}{5}[83.33 + 83.33] = 33.332$$

$$I_{eff} = \underline{\mathbf{5.773\ A}}$$

$$P = I_{eff}^2 R = \underline{\mathbf{400\ W}}$$

Chapter 11, Problem 30.

Compute the rms value of the waveform depicted in Fig. 11.61.

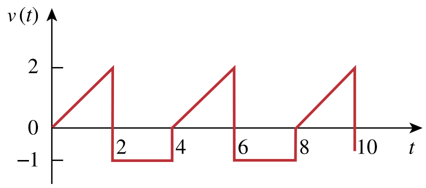


Figure 11.61
For Prob. 11.30.

Chapter 11, Solution 30.

$$v(t) = \begin{cases} t & 0 < t < 2 \\ -1 & 2 < t < 4 \end{cases}$$

$$V_{rms}^2 = \frac{1}{4}\left[\int_0^2 t^2\ dt + \int_2^4 (-1)^2\ dt\right] = \frac{1}{4}\left[\frac{8}{3} + 2\right] = 1.1667$$

$$V_{rms} = \underline{\mathbf{1.08\ V}}$$

Chapter 11, Problem 31.

Find the rms value of the signal shown in Fig. 11.62.

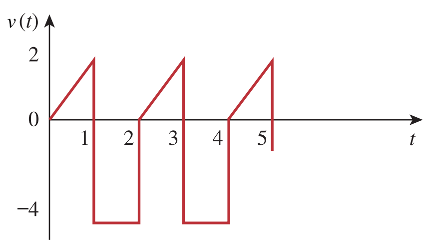


Figure 11.62
For Prob. 11.31.

Chapter 11, Solution 31.

$$V^2{}_{rms} = \frac{1}{2}\int_0^2 v(t)dt = \frac{1}{2}\left[\int_0^1 (2t)^2\,dt + \int_1^2 (-4)^2\,dt\right] = \frac{1}{2}\left[\frac{4}{3} + 16\right] = 8.6667$$

$$V_{rms} = \underline{2.944\ V}$$

Chapter 11, Problem 32.

Obtain the rms value of the current waveform shown in Fig. 11.63.

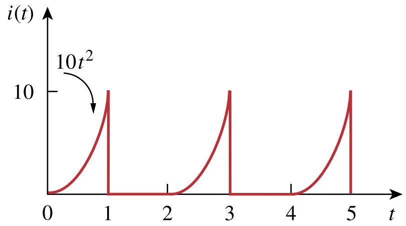


Figure 11.63
For Prob. 11.32.

Chapter 11, Solution 32.

$$I_{rms}^2 = \frac{1}{2}\left[\int_0^1 (10t^2)^2\ dt + \int_1^2 0\ dt\right]$$

$$I_{rms}^2 = 50\int_0^1 t^4\ dt = 50 \cdot \frac{t^5}{5}\Big|_0^1 = 10$$

$$I_{rms} = \underline{\mathbf{3.162\ A}}$$

Chapter 11, Problem 33.

Determine the rms value for the waveform in Fig. 11.64.

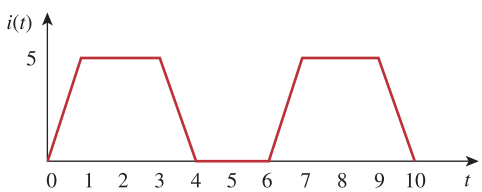


Figure 11.64
For Prob. 11.33.

Chapter 11, Solution 33.

$$I_{rms}^2 = \frac{1}{T}\int_0^T i^2(t)dt = \frac{1}{6}\left[\int_0^1 25t^2 dt + \int_1^3 25dt + \int_3^4 (-5t+20)^2 dt\right]$$

$$I_{rms}^2 = \frac{1}{6}\left[25\frac{t^3}{3}\Big|_0^1 + 25(3-1) + (25\frac{t^3}{3} - 100t^2 + 400t)\Big|_3^4\right] = 11.1056$$

$$\underline{I_{rms} = 3.3325\ \text{A}} = \underline{\mathbf{3.332\ A}}$$

Chapter 11, Problem 34.

Find the effective value of $f(t)$ defined in Fig. 11.65.

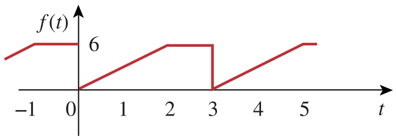


Figure 11.65
For Prob. 11.34.

Chapter 11, Solution 34.

$$f_{rms}^2 = \frac{1}{T}\int_0^T f^2(t)dt = \frac{1}{3}\left[\int_0^2 (3t)^2 dt + \int_2^3 6^2 dt\right]$$

$$= \frac{1}{3}\left[\left.\frac{9t^3}{3}\right|_0^2 + 36\right] = 20$$

$$f_{rms} = \sqrt{20} = \underline{4.472}$$

Chapter 11, Problem 35.

One cycle of a periodic voltage waveform is depicted in Fig. 11.66. Find the effective value of the voltage. Note that the cycle starts at $t = 0$ and ends at $t = 6$ s.

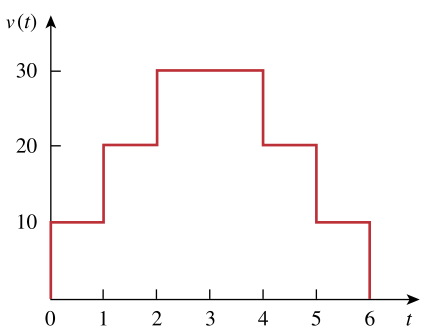


Figure 11.66
For Prob. 11.35.

Chapter 11, Solution 35.

$$V_{rms}^2 = \frac{1}{6}\left[\int_0^1 10^2\ dt + \int_1^2 20^2\ dt + \int_2^4 30^2\ dt + \int_4^5 20^2\ dt + \int_5^6 10^2\ dt\right]$$

$$V_{rms}^2 = \frac{1}{6}[100 + 400 + 1800 + 400 + 100] = 466.67$$

$$V_{rms} = \underline{\mathbf{21.6\ V}}$$

Chapter 11, Problem 36.

Calculate the rms value for each of the following functions:

(a) $i(\text{t}) = 10$ A (b) $v(\text{t}) = 4 + 3\cos 5t$ V

(c) $i(\text{t}) = 8 - 6\sin 2t$ A (d) $v(\text{t}) = 5\sin t + 4\cos t$ V

Chapter 11, Solution 36.

(a) $I_{rms} = \underline{10\text{ A}}$

(b) $V^2{}_{rms} = 4^2 + \left(\frac{3}{\sqrt{2}}\right)^2 \longrightarrow V_{rms} = \sqrt{16 + \frac{9}{2}} = \underline{4.528\text{ V}}$ (checked)

(c) $I_{rms} = \sqrt{64 + \frac{36}{2}} = \underline{9.055\text{ A}}$

$V_{rms} = \sqrt{\frac{25}{2} + \frac{16}{2}} = \underline{4.528\text{ V}}$

Chapter 11, Problem 37.

Calculate the rms value of the sum of these three currents:

$i_1 = 8$, $i_2 = 4\sin(t + 10^o)$, $i_3 = 6\cos(2t + 30^o)$ A

Chapter 11, Solution 37.

$$i = i_1 + i_2 + i_3 = 8 + 4\sin(t + 10^o) + 6\cos(2t + 30^o)$$

$$I_{rms} = \sqrt{I^2{}_{1rms} + I^2{}_{2rms} + I^2{}_{3rms}} = \sqrt{64 + \frac{16}{2} + \frac{36}{2}} = \sqrt{90} = \underline{9.487\text{ A}}$$

Chapter 11, Problem 38.

For the power system in Fig. 11.67, find: (a) the average power, (b) the reactive power, (c) the power factor. Note that 220 V is an rms value.

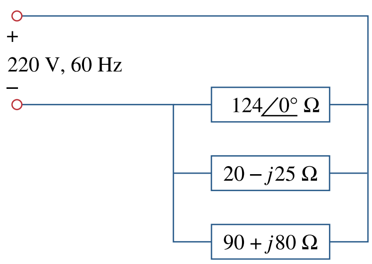


Figure 11.67
For Prob. 11.38.

Chapter 11, Solution 38.

$$S_1 = \frac{V^2}{Z_1^*} = \frac{220^2}{124} = 390.32$$

$$S_2 = \frac{V^2}{Z_2^*} = \frac{220^2}{20 + j25} = 944.4 - j1180.5$$

$$S_3 = \frac{V^2}{Z_3^*} = \frac{220^2}{90 - j80} = 300 + j267.03$$

$$S = S_1 + S_2 + S_3 = 1634.7 - j913.47 = 1872.6 < -29.196^o \text{ VA}$$

(a) P = Re(S) = **1634.7 W**

(b) Q = Im (S) = **913.47 VA (leading)**

(c) pf = cos (29.196^o) = **0.8732**

Chapter 11, Problem 39.

An ac motor with impedance $\mathbf{Z}_L = 4.2 + j3.6\ \Omega$ is supplied by a 220-V, 60-Hz source. (a) Find pf, P, and Q. (b) Determine the capacitor required to be connected in parallel with the motor so that the power factor is corrected to unity.

Chapter 11, Solution 39.

(a) $Z_L = 4.2 + j3.6 = 5.5317\angle 40.6^o$

pf = cos 40.6 = <u>0.7592</u>

$$S = \frac{V_{rms}^2}{Z^*} = \frac{220^2}{5.5317\angle -40.6^o} = 6.643 + j5.694 \text{ kVA}$$

P = 6.643 kW

Q = 5.695 kVAR

(b) $$C = \frac{P(\tan\theta_1 - \tan\theta_2)}{\omega V_{rms}^2} = \frac{6.643x10^3(\tan 40.6^o - \tan 0^o)}{2\pi x60x220^2} = \underline{312\ \mu\text{F}},$$

{It is important to note that this capacitor will see a peak voltage of 220$\sqrt{2}$ = 311.08V, this means that the specifications on the capacitor must be at least this or greater!}

Chapter 11, Problem 40.

A load consisting of induction motors is drawing 80 kW from a 220-V, 60-Hz power line at a pf of 0.72 lagging. Find the capacitance of a capacitor required to raise the pf to 0.92.

Chapter 11, Solution 40.

$$pf1 = 0.72 = \cos\theta_1 \quad \longrightarrow \quad \theta_1 = 43.94^0$$
$$pf2 = 0.92 = \cos\theta_2 \quad \longrightarrow \quad \theta_2 = 23.07^0$$

$$C = \frac{P(\tan\theta_1 - \tan\theta_2)}{\omega V_{rms}^2} = \frac{80x10^3(0.9637 - 0.4259)}{2\pi x60x(220)^2} = \underline{2.4\text{ mF}},$$

{Again, we need to note that this capacitor will be exposed to a peak voltage of 311.08V and must be rated to at least this level, preferably higher!}

Chapter 11, Problem 41.

Obtain the power factor for each of the circuits in Fig. 11.68. Specify each power factor as leading or lagging.

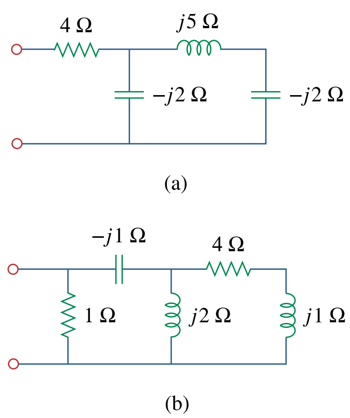


Figure 11.68
For Prob. 11.41.

Chapter 11, Solution 41.

(a) $$-j2 \,||\, (j5 - j2) = -j2 \,||\, -j3 = \frac{(-j2)(-j3)}{j} = -j6$$

$$\mathbf{Z}_T = 4 - j6 = 7.211\angle -56.31°$$

$$\text{pf} = \cos(-56.31°) = \underline{\mathbf{0.5547 \quad (leading)}}$$

(b) $$j2 \,||\, (4 + j) = \frac{(j2)(4 + j)}{4 + j3} = 0.64 + j1.52$$

$$\mathbf{Z} = 1 \,||\, (0.64 + j1.52 - j) = \frac{0.64 + j0.44}{1.64 + j0.44} = 0.4793\angle 21.5°$$

$$\text{pf} = \cos(21.5°) = \underline{\mathbf{0.9304 \quad (lagging)}}$$

Chapter 11, Problem 42.

A 110-V rms, 60-Hz source is applied to a load impedance **Z**. The apparent power entering the load is 120 VA at a power factor of 0.707 lagging.

(a) Calculate the complex power.
(b) Find the rms current supplied to the load.
(c) Determine **Z**.
(d) Assuming that $\mathbf{Z} = R + j\omega L$, find the values of R and L.

Chapter 11, Solution 42.

(a) S=120, $\quad pf = 0.707 = \cos\theta \quad \longrightarrow \quad \theta = 45^o$

$$S = S\cos\theta + jS\sin\theta = \underline{84.84 + j84.84 \text{ VA}}$$

(b) $S = V_{rms} I_{rms} \quad \longrightarrow \quad I_{rms} = \dfrac{S}{V_{rms}} = \dfrac{120}{110} = \underline{1.091 \text{ A rms}}$

(c) $S = I_{rms}^2 Z \quad \longrightarrow \quad Z = \dfrac{S}{I_{rms}^2} = \underline{71.278 + j71.278\ \Omega}$

(d) If Z = R + jϖL, then $\quad$ R = **$\underline{71.278\ \Omega}$**

$$\omega L = 2\pi fL = 71.278 \quad \longrightarrow \quad L = \frac{71.278}{2\pi x 60} = \underline{0.1891 \text{ H}}$$

Chapter 11, Problem 43.

The voltage applied to a 10-Ω resistor is

$v(t) = 5 + 3\cos(t + 10°) + \cos(2t + 30°)$ V

(a) Calculate the rms value of the voltage.
(b) Determine the average power dissipated in the resistor.

Chapter 11, Solution 43.

(a) $V_{rms} = \sqrt{V^2{}_{1rms} + V^2{}_{2rms} + V^2{}_{3rms}} = \sqrt{25 + \dfrac{9}{2} + \dfrac{1}{2}} = \sqrt{30} = \underline{5.477 \text{ V}}$

(b) $P = \dfrac{V^2{}_{rms}}{R} = 30/10 = \underline{3 \text{ W}}$

Chapter 11, Problem 44.

Find the complex power delivered by v_s to the network in Fig. 11.69.
Let $v_s = 100 \cos 2000t$ V.

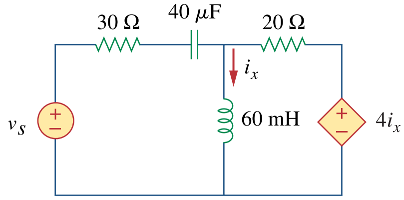


Figure 11.69
For Prob. 11.44.

Chapter 11, Solution 44.

$$40\mu F \quad \longrightarrow \quad \frac{1}{j\omega C} = \frac{1}{j2000x40x10^{-6}} = -j12.5$$

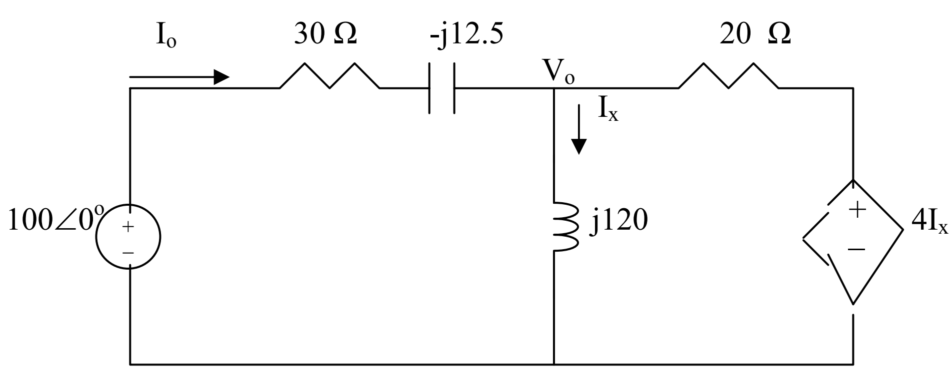
$$60mH \quad \longrightarrow \quad j\omega L = j2000x60x10^{-3} = j120$$

We apply nodal analysis to the circuit shown below.

$$\frac{100-V_o}{30-j12.5} + \frac{4I_x - V_o}{20} = \frac{V_o}{j120}$$

But $\quad I_x = \frac{V_o}{j120}$. Solving for V_o leads to

$$V_o = 2.9563 + j1.126$$



$$I_o = \frac{100-V_o}{30-j12.5} = 2.7696 + j1.1165$$

$$S = \frac{1}{2}V_s I_o^* = \frac{1}{2}(100)(2.7696 - j.1165) = \underline{138.48 - j55.825 \ \text{VA}}$$

Chapter 11, Problem 45.

The voltage across a load and the current through it are given by

$v(\text{t}) = 20 + 60 \cos 100t$ V
$i(\text{t}) = 1 - 0.5 \sin 100t$ A

Find:

(a) the rms values of the voltage and of the current
(b) the average power dissipated in the load

Chapter 11, Solution 45.

(a) $V^2_{rms} = 20^2 + \dfrac{60^2}{2} = 2200 \quad \longrightarrow \quad V_{rms} = \underline{46.9 \text{ V}}$

$$I_{rms} = \sqrt{1^2 + \frac{0.5^2}{2}} = \sqrt{1.125} = \underline{1.061 A}$$

(b) p(t) = v(t)i(t) = 20 + 60cos100t – 10sin100t – 30(sin100t)(cos100t); clearly the average power = **<u>20W</u>**.

Chapter 11, Problem 46.

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) $\mathbf{V} = 220\angle 30° \text{ V rms}, \mathbf{I} = 0.5\angle 60° \text{ A rms}$

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

(c) $\mathbf{V} = 80\angle 0° \text{ V rms}, \mathbf{I} = 2.4\angle -15° \text{ A rms}$

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

Chapter 11, Solution 46.

(a) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (220\angle 30°)(0.5\angle -60°) = 110\angle -30°$

$\mathbf{S} = \underline{\mathbf{95.26 - j55\ VA}}$

Apparent power = $\underline{\mathbf{110\ VA}}$

Real power = $\underline{\mathbf{95.26\ W}}$

Reactive power = $\underline{\mathbf{55\ VAR}}$

pf is **leading** because current leads voltage

(b) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (250\angle -10°)(6.2\angle 25°) = 1550\angle 15°$

$\mathbf{S} = \underline{\mathbf{1497.2 + j401.2\ VA}}$

Apparent power = $\underline{\mathbf{1550\ VA}}$

Real power = $\underline{\mathbf{1497.2\ W}}$

Reactive power = $\underline{\mathbf{401.2\ VAR}}$

pf is **lagging** because current lags voltage

(c) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (120\angle 0°)(2.4\angle 15°) = 288\angle 15°$

$\mathbf{S} = \underline{\mathbf{278.2 + j74.54\ VA}}$

Apparent power = $\underline{\mathbf{288\ VA}}$

Real power = $\underline{\mathbf{278.2\ W}}$

Reactive power = $\underline{\mathbf{74.54\ VAR}}$

pf is **lagging** because current lags voltage

(d) $\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = (160\angle 45°)(8.5\angle -90°) = 1360\angle -45°$

$\mathbf{S} = \underline{\mathbf{961.7 - j961.7\ VA}}$

Apparent power = $\underline{\mathbf{1360\ VA}}$

Real power = $\underline{\mathbf{961.7\ W}}$

Reactive power = $\underline{\mathbf{-961.7\ VAR}}$

pf is **leading** because current leads voltage

Chapter 11, Problem 47.

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

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

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

(c) $\mathbf{V} = 80\angle 60°$ V rms, $\mathbf{Z} = 50\angle 30°\ \Omega$

(d) $\mathbf{I} = 10\angle 60°$ A rms, $\mathbf{Z} = 100\angle 45°\ \Omega$

Chapter 11, Solution 47.

(a) $\mathbf{V} = 112\angle 10°, \qquad \mathbf{I} = 4\angle -50°$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\mathbf{I}^{*} = 224\angle 60° = \underline{\mathbf{112 + j194\ VA}}$$

Average power = $\underline{\mathbf{112\ W}}$

Reactive power = $\underline{\mathbf{194\ VAR}}$

(b) $\mathbf{V} = 160\angle 0°, \qquad \mathbf{I} = 4\angle 45°$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\mathbf{I}^{*} = 320\angle -45° = \underline{\mathbf{226.3 - j226.3}}$$

Average power = $\underline{\mathbf{226.3\ W}}$
Reactive power = $\underline{\mathbf{-226.3\ VAR}}$

(c) $$\mathbf{S} = \frac{|\mathbf{V}|^2}{\mathbf{Z}^{*}} = \frac{(80)^2}{50\angle -30°} = 128\angle 30° = \underline{\mathbf{110.85 + j64}}$$

Average power = $\underline{\mathbf{110.85\ W}}$
Reactive power = $\underline{\mathbf{64\ VAR}}$

(d) $$\mathbf{S} = |\mathbf{I}|^2\mathbf{Z} = (100)(100\angle 45°) = \underline{\mathbf{7.071 + j7.071\ kVA}}$$

Average power = $\underline{\mathbf{7.071\ kW}}$

Reactive power = $\underline{\mathbf{7.071\ kVAR}}$

Chapter 11, Problem 48.

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,
$|\mathbf{Z}| = 40\ \Omega$ (inductive)

Chapter 11, Solution 48.

(a) $$\mathbf{S} = P - jQ = \underline{\mathbf{269 - j150\ VA}}$$

(b) $$pf = \cos\theta = 0.9 \longrightarrow \theta = 25.84°$$

$$Q = S\sin\theta \longrightarrow S = \frac{Q}{\sin\theta} = \frac{2000}{\sin(25.84°)} = 4588.31$$

$$P = S\cos\theta = 4129.48$$

$$\mathbf{S} = \underline{\mathbf{4129 - j2000\ VA}}$$

(c) $$Q = S\sin\theta \longrightarrow \sin\theta = \frac{Q}{S} = \frac{450}{600} = 0.75$$

$$\theta = 48.59, \qquad pf = 0.6614$$

$$P = S\cos\theta = (600)(0.6614) = 396.86$$

$$\mathbf{S} = \underline{\mathbf{396.9 + j450\ VA}}$$

(d) $$S = \frac{|\mathbf{V}|^2}{|\mathbf{Z}|} = \frac{(220)^2}{40} = 1210$$

$$P = S\cos\theta \longrightarrow \cos\theta = \frac{P}{S} = \frac{1000}{1210} = 0.8264$$

$$\theta = 34.26°$$

$$Q = S\sin\theta = 681.25$$

$$\mathbf{S} = \underline{\mathbf{1000 + j681.2\ VA}}$$

Chapter 11, Problem 49.

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) $\mathbf{V}_{\text{rms}} = 208\angle 20°$ V, $\mathbf{I}_{\text{rms}} = 6.5\angle -50°$ A
(d) $\mathbf{V}_{\text{rms}} = 120\angle 30°$ V, $\mathbf{Z} = 40 + j60\,\Omega$

Chapter 11, Solution 49.

(a)
$$\mathbf{S} = 4 + j\frac{4}{0.86}\sin(\cos^{-1}(0.86))\text{ kVA}$$
$$\mathbf{S} = \underline{\mathbf{4 + j2.373\ kVA}}$$

(b)
$$\text{pf} = \frac{P}{S} = \frac{1.6}{2}0.8 = \cos\theta \longrightarrow \sin\theta = 0.6$$

$$\mathbf{S} = 1.6 - j2\sin\theta = \underline{\mathbf{1.6 - j1.2\ kVA}}$$

(c)
$$\mathbf{S} = \mathbf{V}_{\text{rms}}\,\mathbf{I}^{*}_{\text{rms}} = (208\angle 20°)(6.5\angle 50°)\text{ VA}$$
$$\mathbf{S} = 1.352\angle 70° = \underline{\mathbf{0.4624 + j1.2705\ kVA}}$$

(d)
$$\mathbf{S} = \frac{|\mathbf{V}|^2}{\mathbf{Z}^*} = \frac{(120)^2}{40 - j60} = \frac{14400}{72.11\angle -56.31°}$$
$$\mathbf{S} = 199.7\angle 56.31° = \underline{\mathbf{110.77 + j166.16\ VA}}$$

Chapter 11, Problem 50.

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) $\mathbf{S} = 4500\angle 60°$ VA, $\mathbf{V} = 120\angle 45°$ V

Chapter 11, Solution 50.

(a) $$\mathbf{S} = \mathrm{P} - \mathrm{jQ} = 1000 - \mathrm{j}\frac{1000}{0.8}\sin(\cos^{-1}(0.8))$$
$$\mathbf{S} = 1000 - \mathrm{j}750$$

But, $$\mathbf{S} = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{Z}^*}$$
$$\mathbf{Z}^* = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{S}} = \frac{(220)^2}{1000 - \mathrm{j}750} = 30.98 + \mathrm{j}23.23$$
$$\mathbf{Z} = \underline{\mathbf{30.98 - j23.23\ \Omega}}$$

(b) $$\mathbf{S} = |\mathbf{I}_{rms}|^2 \mathbf{Z}$$
$$\mathbf{Z} = \frac{\mathbf{S}}{|\mathbf{I}_{rms}|^2} = \frac{1500 + \mathrm{j}2000}{(12)^2} = \underline{\mathbf{10.42 + j13.89\ \Omega}}$$

(c) $$\mathbf{Z}^* = \frac{|\mathbf{V}_{rms}|^2}{\mathbf{S}} = \frac{|\mathbf{V}|^2}{2\mathbf{S}} = \frac{(120)^2}{(2)(4500\angle 60°)} = 1.6\angle -60°$$
$$\mathbf{Z} = 1.6\angle 60° = \underline{\mathbf{0.8 + j1.386\ \Omega}}$$

Chapter 11, Problem 51.

For the entire circuit in Fig. 11.70, 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

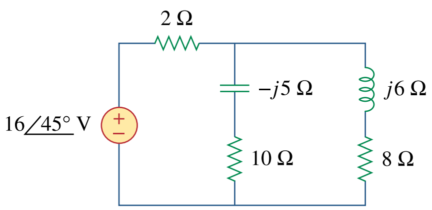


Figure 11.70
For Prob. 11.51.

Chapter 11, Solution 51.

(a) $\mathbf{Z}_T = 2 + (10 - j5) \,||\, (8 + j6)$

$$\mathbf{Z}_T = 2 + \frac{(10 - j5)(8 + j6)}{18 + j} = 2 + \frac{110 + j20}{18 + j}$$

$$\mathbf{Z}_T = 8.152 + j0.768 = 8.188\angle 5.382°$$

$$\text{pf} = \cos(5.382°) = \underline{\mathbf{0.9956 \quad (lagging)}}$$

(b)
$$\mathbf{S} = \frac{1}{2}\mathbf{V}\mathbf{I}^* = \frac{|\mathbf{V}|^2}{2\mathbf{Z}^*} = \frac{(16)^2}{(2)(8.188\angle -5.382°)}$$

$$\mathbf{S} = 15.63\angle 5.382°$$

$$P = S\cos\theta = \underline{\mathbf{15.56\ W}}$$

(c) $Q = S\sin\theta = \underline{\mathbf{1.466\ VAR}}$

(d) $S = |\mathbf{S}| = \underline{\mathbf{15.63\ VA}}$

(e) $\mathbf{S} = 15.63\angle 5.382° = \underline{\mathbf{15.56 + j1.466\ VA}}$

Chapter 11, Problem 52.

In the circuit of Fig. 11.71, device *A* receives 2 kW at 0.8 pf lagging, device *B* receives 3 kVA at 0.4 pf leading, while device *C* is inductive and consumes 1 kW and receives 500 VAR.

(a) Determine the power factor of the entire system.

(b) Find **I** given that $\mathbf{V}_s = 120\angle 45° \text{ V rms}$.

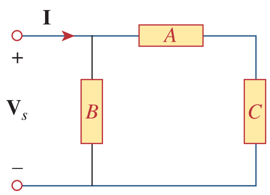


Figure 11.71
For Prob. 11.52.

Chapter 11, Solution 52.

$$S_A = 2000 + j\frac{2000}{0.8}0.6 = 2000 + j1500$$
$$S_B = 3000x0.4 - j3000x0.9165 = 1200 - j2749$$
$$S_C = 1000 + j500$$
$$S = S_A + S_B + S_C = 4200 - j749$$

(a) $\quad pf = \dfrac{4200}{\sqrt{4200^2 + 749^2}} = \underline{0.9845 \text{ leading.}}$

(b) $\quad S = V_{rms}I_{rms}^* \longrightarrow I_{rms}^* = \dfrac{4200 - j749}{120\angle 45°} = 35.55\angle -55.11°$

$I_{rms} = \underline{\mathbf{35.55\angle 55.11° \ A}}.$

Chapter 11, Problem 53.

In the circuit of Fig. 11.72, load *A* receives 4 kVA at 0.8 pf leading. Load *B* receives 2.4 kVA at 0.6 pf lagging. Box *C* is an inductive load that consumes 1 kW and receives 500 VAR.

(a) Determine **I**.
(b) Calculate the power factor of the combination.

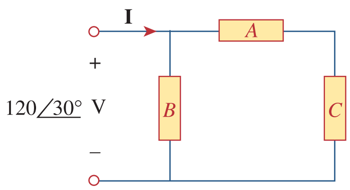


Figure 11.72
For Prob. 11.53.

Chapter 11, Solution 53.

$$S = S_A + S_B + S_C = 4000(0.8–j0.6) + 2400(0.6+j0.8) + 1000 + j500$$

$$= 5640 + j20 = 5640\angle 0.2^\circ$$

(a)

$$I^*_{rms} = \frac{S_B}{V_{rms}} + \frac{S_A + S_C}{V_{rms}} = \frac{S}{V_{rms}} = \frac{5640\angle 0.2^\circ}{\frac{120\angle 30^\circ}{\sqrt{2}}} = 66.46\angle -29.8^\circ$$

$$I = \sqrt{2}x66.46\angle 29.88^\circ = \underline{93.97\angle 29.8^\circ\,A}$$

(b) $\quad pf = \cos(0.2^\circ) \approx$ **<u>1.0 lagging</u>**.

Chapter 11, Problem 54.

For the network in Fig. 11.73, find the complex power absorbed by each element.

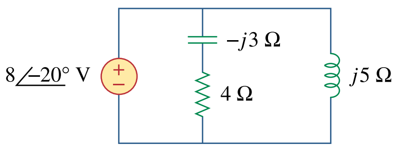


Figure 11.73
For Prob. 11.54.

Chapter 11, Solution 54.

Consider the circuit shown below.

$$\mathbf{I}_1 = \frac{8\angle -20^\circ}{4 - j3} = 1.6\angle 16.87^\circ$$

$$\mathbf{I}_2 = \frac{8\angle -20^\circ}{j5} = 1.6\angle -110^\circ$$

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 = (-0.5472 - j1.504) + (1.531 + j0.4643)$$
$$\mathbf{I} = 0.9839 - j1.04 = 1.432\angle -46.58^\circ$$

For the source,

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\,\mathbf{I}^* = \frac{1}{2}(8\angle -20^\circ)(1.432\angle 46.58^\circ)$$
$$\mathbf{S} = 5.728\angle 26.58^\circ = \underline{\mathbf{5.12 + j2.56\ VA}}$$

For the capacitor,

$$\mathbf{S} = \frac{1}{2}\left|\mathbf{I}_1\right|^2 \mathbf{Z}_c = \frac{1}{2}(1.6)^2(-j3) = \underline{\mathbf{-\ j3.84\ VA}}$$

For the resistor,

$$\mathbf{S} = \frac{1}{2}\left|\mathbf{I}_1\right|^2 \mathbf{Z}_R = \frac{1}{2}(1.6)^2(4) = \underline{\mathbf{5.12\ VA}}$$

For the inductor,

$$\mathbf{S} = \frac{1}{2}\left|\mathbf{I}_2\right|^2 \mathbf{Z}_L = \frac{1}{2}(1.6)^2(j5) = \underline{\mathbf{j6.4\ VA}}$$

Chapter 11, Problem 55.

Find the complex power absorbed by each of the five elements in the circuit of Fig. 11.74.

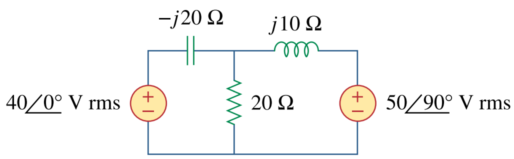
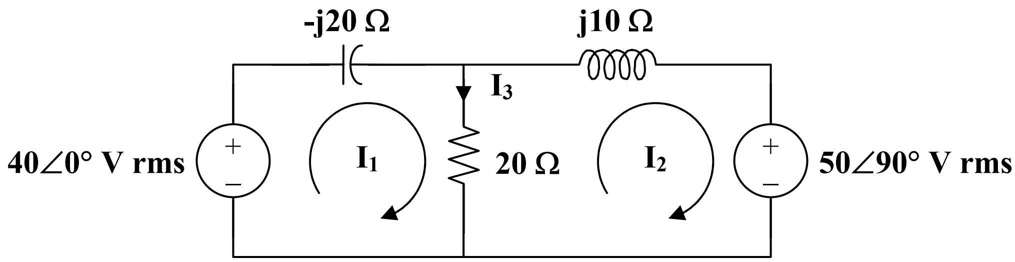


Figure 11.74
For Prob. 11.55.

Chapter 11, Solution 55.

We apply mesh analysis to the following circuit.



For mesh 1,

$$40 = (20 - j20)\,I_1 - 20\,I_2$$

$$2 = (1 - j)\,I_1 - I_2 \qquad (1)$$

For mesh 2,

$$-j50 = (20 + j10)\,I_2 - 20\,I_1$$

$$-j5 = -2\,I_1 + (2 + j)\,I_2 \qquad (2)$$

Putting (1) and (2) in matrix form,

$$\begin{bmatrix} 2 \\ -j5 \end{bmatrix} = \begin{bmatrix} 1-j & -1 \\ -2 & 2+j \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$\Delta = 1 - j, \qquad \Delta_1 = 4 - j3, \qquad \Delta_2 = -1 - j5$$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{4 - j3}{1 - j} = \frac{1}{2}(7 + j) = 3.535\angle 8.13°$$

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{-1 - j5}{1 - j} = 2 - j3 = 3.605\angle -56.31°$$

$$I_3 = I_1 - I_2 = (3.5 + j0.5) - (2 - j3) = 1.5 + j3.5 = 3.808\angle 66.8°$$

For the 40-V source,

$$\mathbf{S} = -\mathbf{V}\,\mathbf{I}_1^* = -(40)\left(\frac{1}{2}\cdot(7 - j)\right) = \underline{\mathbf{-140 + j20\ VA}}$$

For the capacitor,

$$\mathbf{S} = \left|\mathbf{I}_1\right|^2 \mathbf{Z}_c = \underline{\mathbf{-j250\ VA}}$$

For the resistor,

$$\mathbf{S} = \left|\mathbf{I}_3\right|^2 R = \underline{\mathbf{290\ VA}}$$

For the inductor,

$$\mathbf{S} = \left|\mathbf{I}_2\right|^2 \mathbf{Z}_L = \underline{\mathbf{j130\ VA}}$$

For the j50-V source,

$$\mathbf{S} = \mathbf{V}\,\mathbf{I}_2^* = (j50)(2 + j3) = \underline{\mathbf{-150 + j100\ VA}}$$

Chapter 11, Problem 56.

Obtain the complex power delivered by the source in the circuit of Fig. 11.75.

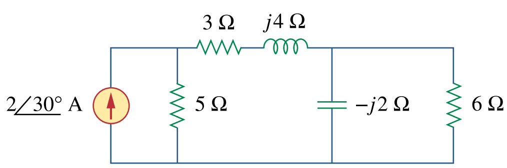
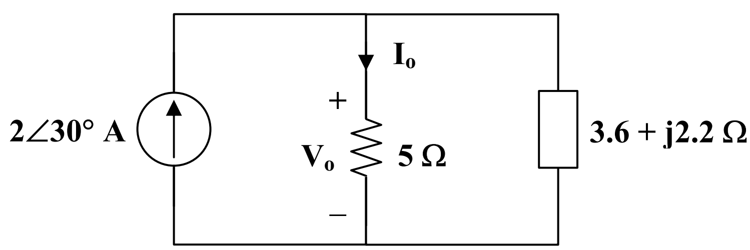


Figure 11.75
For Prob. 11.56.

Chapter 11, Solution 56.

$$- j2 \parallel 6 = \frac{(6)(-j2)}{6 - j2} = 0.6 - j1.8$$
$$3 + j4 + (-j2) \parallel 6 = 3.6 + j2.2$$

The circuit is reduced to that shown below.



$$\mathbf{I}_o = \frac{3.6 + j2.2}{8.6 + j2.2}(2\angle 30°) = 0.95\angle 47.08°$$

$$\mathbf{V}_o = 5\mathbf{I}_o = 4.75\angle 47.08°$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}_o\mathbf{I}_s^* = \frac{1}{2}\cdot(4.75\angle 47.08°)(2\angle -30°)$$
$$\mathbf{S} = 4.75\angle 17.08° = \underline{\mathbf{4.543 + j1.396\ VA}}$$

Chapter 11, Problem 57.

PS ML For the circuit in Fig. 11.76, find the average, reactive, and complex power delivered by the dependent current source.

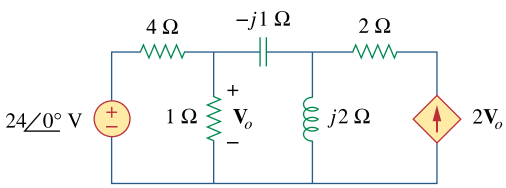
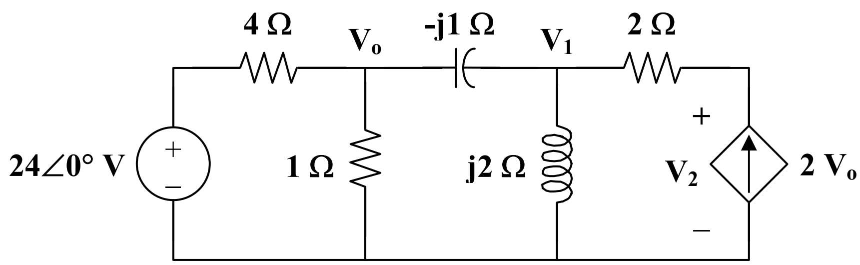


Figure 11.76
For Prob. 11.57.

Chapter 11, Solution 57.

Consider the circuit as shown below.



At node o,

$$\frac{24 - \mathbf{V}_o}{4} = \frac{\mathbf{V}_o}{1} + \frac{\mathbf{V}_o - \mathbf{V}_1}{-j}$$

$$24 = (5 + j4)\,\mathbf{V}_o - j4\,\mathbf{V}_1 \qquad (1)$$

At node 1,

$$\frac{\mathbf{V}_o - \mathbf{V}_1}{-j} + 2\,\mathbf{V}_o = \frac{\mathbf{V}_1}{j2}$$

$$\mathbf{V}_1 = (2 - j4)\,\mathbf{V}_o \qquad (2)$$

Substituting (2) into (1),

$$24 = (5 + j4 - j8 - 16)\,\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{-24}{11 + j4}, \qquad \mathbf{V}_1 = \frac{(-24)(2 - j4)}{11 + j4}$$

The voltage across the dependent source is

$$\mathbf{V}_2 = \mathbf{V}_1 + (2)(2\,\mathbf{V}_o) = \mathbf{V}_1 + 4\,\mathbf{V}_o$$

$$\mathbf{V}_2 = \frac{-24}{11 + j4} \cdot (2 - j4 + 4) = \frac{(-24)(6 - j4)}{11 + j4}$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}_2\,\mathbf{I}^* = \frac{1}{2}\mathbf{V}_2\,(2\,\mathbf{V}_o^*)$$

$$\mathbf{S} = \frac{(-24)(6 - j4)}{11 + j4} \cdot \frac{-24}{11 - j4} = \left(\frac{576}{137}\right)(6 - j4)$$

$$\mathbf{S} = \underline{\mathbf{25.23 - j16.82\ VA}}$$

Chapter 11, Problem 58.

ML Obtain the complex power delivered to the 10-kΩ resistor in Fig. 11.77 below.

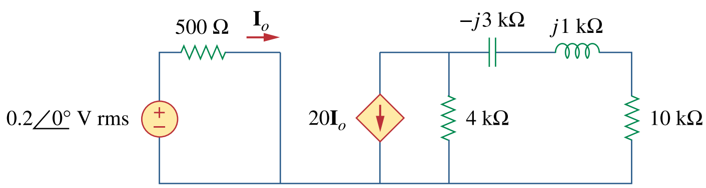
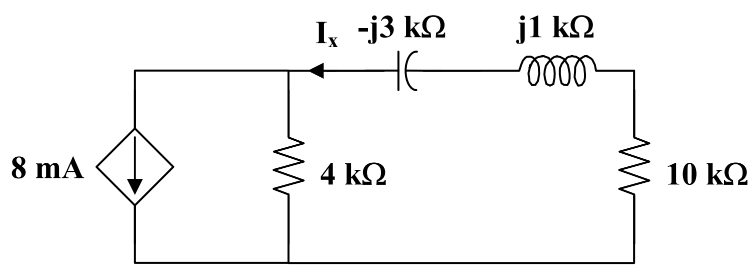


Figure 11.77
For Prob. 11.58.

Chapter 11, Solution 58.



From the left portion of the circuit,

$$\mathbf{I}_o = \frac{0.2}{500} = 0.4 \text{ mA}$$

$$20\mathbf{I}_o = 8 \text{ mA}$$

From the right portion of the circuit,

$$\mathbf{I}_x = \frac{4}{4 + 10 + j - j3}(8 \text{ mA}) = \frac{16}{7 - j} \text{ mA}$$

$$\mathbf{S} = \left|\mathbf{I}_x\right|^2 R = \frac{(16 \times 10^{-3})^2}{50} \cdot (10 \times 10^3)$$

$$\mathbf{S} = \underline{\mathbf{51.2\ mVA}}$$

Chapter 11, Problem 59.

ML Calculate the reactive power in the inductor and capacitor in the circuit of Fig. 11.78.

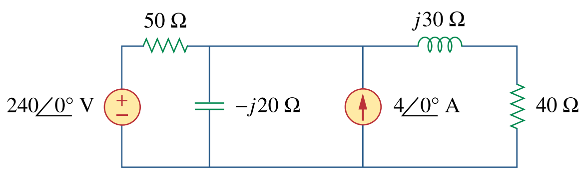


Figure 11.78
For Prob. 11.59.

Chapter 11, Solution 59.

Let $\mathbf{V}_o$ represent the voltage across the current source and then apply nodal analysis to the circuit and we get:

$$4 + \frac{240 - \mathbf{V}_o}{50} = \frac{\mathbf{V}_o}{-j20} + \frac{\mathbf{V}_o}{40 + j30}$$

$$88 = (0.36 + j0.38)\,\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{88}{0.36 + j0.38} = 168.13\angle -46.55°$$

$$\mathbf{I}_1 = \frac{\mathbf{V}_o}{-j20} = 8.41\angle 43.45°$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_o}{40 + j30} = 3.363\angle -83.42°$$

Reactive power in the inductor is

$$\mathbf{S} = \frac{1}{2}\left|\mathbf{I}_2\right|^2 \mathbf{Z}_L = \frac{1}{2}\cdot(3.363)^2(j30) = \underline{\mathbf{j169.65\ VAR}}$$

Reactive power in the capacitor is

$$\mathbf{S} = \frac{1}{2}\left|\mathbf{I}_1\right|^2 \mathbf{Z}_c = \frac{1}{2}\cdot(8.41)^2(-j20) = \underline{\mathbf{-\ j707.3\ VAR}}$$

Chapter 11, Problem 60.

For the circuit in Fig. 11.79, find $\mathbf{V}_o$ and the input power factor.

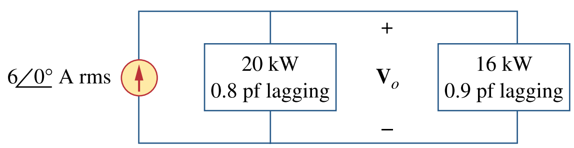


Figure 11.79
For Prob. 11.60.

Chapter 11, Solution 60.

$$S_1 = 20 + j\frac{20}{0.8}\sin(\cos^{-1}(0.8)) = 20 + j15$$

$$S_2 = 16 + j\frac{16}{0.9}\sin(\cos^{-1}(0.9)) = 16 + j7.749$$

$$S = S_1 + S_2 = 36 + j22.749 = 42.585\angle 32.29°$$

But $\quad S = V_o I^* = 6V_o$

$$V_o = \frac{S}{6} = \underline{\mathbf{7.098\angle 32.29°}}$$

$$pf = \cos(32.29°) = \underline{\mathbf{0.8454 \quad (lagging)}}$$

Chapter 11, Problem 61.

Given the circuit in Fig. 11.80, find $\mathbf{I}_o$ and the overall complex power supplied.

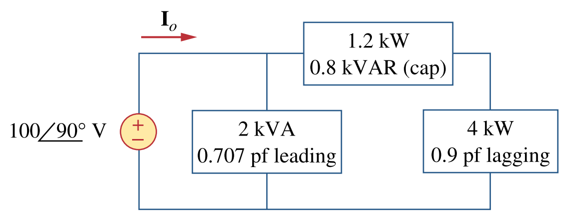
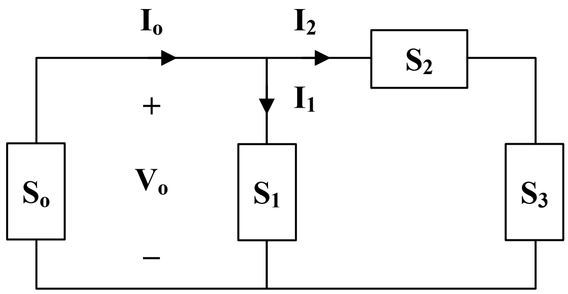


Figure 11.80
For Prob. 11.61.

Chapter 11, Solution 61.

Consider the network shown below.



$$\mathbf{S}_2 = 1.2 - j0.8 \text{ kVA}$$

$$\mathbf{S}_3 = 4 + j\frac{4}{0.9}\sin(\cos^{-1}(0.9)) = 4 + j1.937 \text{ kVA}$$

Let $\mathbf{S}_4 = \mathbf{S}_2 + \mathbf{S}_3 = 5.2 + j1.137 \text{ kVA}$

But $\mathbf{S}_4 = \frac{1}{2}\mathbf{V}_o\mathbf{I}_2^*$

$$\mathbf{I}_2^* = \frac{2\mathbf{S}_4}{\mathbf{V}_o} = \frac{(2)(5.2 + j1.137)\times 10^3}{100\angle 90°} = 22.74 - j104$$

$$\mathbf{I}_2 = 22.74 + j104$$

Similarly, $\mathbf{S}_1 = \sqrt{2} - j\frac{\sqrt{2}}{0.707}\sin(\cos^{-1}(0.707)) = \sqrt{2}(1 - j) \text{ kVA}$

But $\mathbf{S}_1 = \frac{1}{2}\mathbf{V}_o\mathbf{I}_1^*$

$$\mathbf{I}_1^* = \frac{2\mathbf{S}_1}{V_o} = \frac{(2.8284 - j2.8284)\times 10^3}{j100} = -28.284 - j28.284$$

$$\mathbf{I}_1 = -28.28 + j28.28$$

$$\mathbf{I}_o = \mathbf{I}_1 + \mathbf{I}_2 = -5.54 + j132.28 = \underline{132.4\angle 92.4°\text{A}}$$

$$\mathbf{S}_o = \frac{1}{2}V_o I_o^*$$

$$\mathbf{S}_o = \frac{1}{2}\cdot(100\angle 90°)(132.4\angle -92.4°) \text{ VA}$$

$$\mathbf{S}_o = \underline{\mathbf{6.62\angle{-2.4}° \text{ kVA}}}$$

Chapter 11, Problem 62.

For the circuit in Fig. 11.81, find $\mathbf{V}_s$.

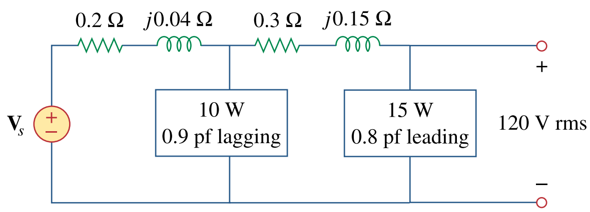
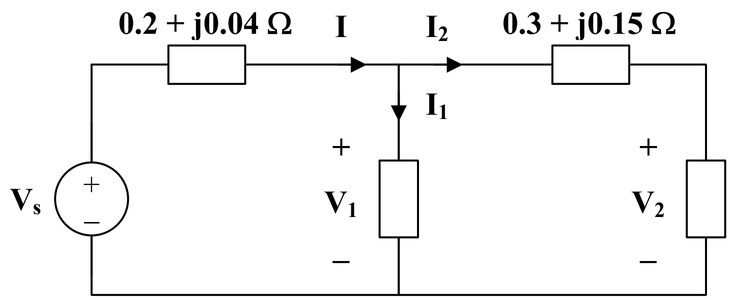


Figure 11.81
For Prob. 11.62.

Chapter 11, Solution 62.

Consider the circuit below.



$$\mathbf{S}_2 = 15 - j\frac{15}{0.8}\sin(\cos^{-1}(0.8)) = 15 - j11.25$$

But $\mathbf{S}_2 = \mathbf{V}_2\,\mathbf{I}_2^*$

$$\mathbf{I}_2^* = \frac{\mathbf{S}_2}{\mathbf{V}_2} = \frac{15 - j11.25}{120}$$

$$\mathbf{I}_2 = 0.125 + j0.09375$$

$$\mathbf{V}_1 = \mathbf{V}_2 + \mathbf{I}_2\,(0.3 + j0.15)$$

$$\mathbf{V}_1 = 120 + (0.125 + j0.09375)(0.3 + j0.15)$$

$$\mathbf{V}_1 = 120.02 + j0.0469$$

$$\mathbf{S}_1 = 10 + j\frac{10}{0.9}\sin(\cos^{-1}(0.9)) = 10 + j4.843$$

But $\mathbf{S}_1 = \mathbf{V}_1\,\mathbf{I}_1^*$

$$\mathbf{I}_1^* = \frac{\mathbf{S}_1}{\mathbf{V}_1} = \frac{11.111\angle 25.84°}{120.02\angle 0.02°}$$

$$\mathbf{I}_1 = 0.093\angle -25.82° = 0.0837 - j0.0405$$

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 = 0.2087 + j0.053$$

$$\mathbf{V}_s = \mathbf{V}_1 + \mathbf{I}\,(0.2 + j0.04)$$

$$\mathbf{V}_s = (120.02 + j0.0469) + (0.2087 + j0.053)(0.2 + j0.04)$$

$$\mathbf{V}_s = 120.06 + j0.0658$$

$$\mathbf{V}_s = \underline{\mathbf{120.06\angle 0.03°\ V}}$$

Chapter 11, Problem 63.

Find $\mathbf{I}_o$ in the circuit of Fig. 11.82.

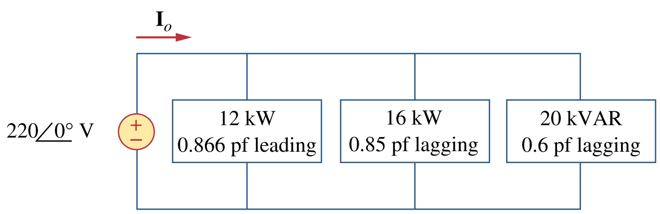


Figure 11.82
For Prob. 11.63.

Chapter 11, Solution 63.

Let $\quad \mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 + \mathbf{S}_3$.

$$\mathbf{S}_1 = 12 - j\frac{12}{0.866}\sin(\cos^{-1}(0.866)) = 12 - j6.929$$

$$\mathbf{S}_2 = 16 + j\frac{16}{0.85}\sin(\cos^{-1}(0.85)) = 16 + j9.916$$

$$\mathbf{S}_3 = \frac{(20)(0.6)}{\sin(\cos^{-1}(0.6))} + j20 = 15 + j20$$

$$\mathbf{S} = 43 + j22.987 = \frac{1}{2}\mathbf{V}\,\mathbf{I}_o^*$$

$$\mathbf{I}_o^* = \frac{2\mathbf{S}}{\mathbf{V}} = \frac{2(43 + j22.99)\text{x}10^3}{220} = 390.9 + j209 = 443.3\angle 28.13°$$

$$\mathbf{I}_o = \underline{\mathbf{443.3\angle{-28.13}°\,A}}$$

Chapter 11, Problem 64.

Determine $\mathbf{I}_s$ in the circuit of Fig. 11.83, if the voltage source supplies 2.5 kW and 0.4 kVAR (leading).

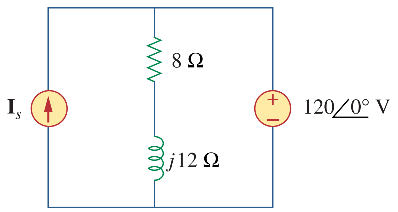
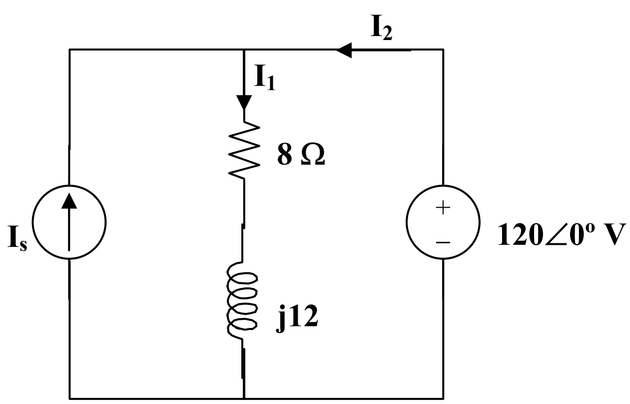


Figure 11.83
For Prob. 11.64.

Chapter 11, Solution 64.



$$I_s + I_2 = I_1 \text{ or } I_s = I_1 - I_2$$

$$I_1 = \frac{120}{8 + j12} = 4.615 - j6.923$$

But, $$S = VI_2^* \longrightarrow I_2^* = \frac{S}{V} = \frac{2500 - j400}{120} = 20.83 - j3.333$$

$$\text{or } I_2 = 20.83 + j3.333$$

$$I_s = I_1 - I_2 = -16.22 - j10.256 = \underline{\mathbf{19.19\angle{-147.69^\circ}\ A}}.$$

Chapter 11, Problem 65.

In the op amp circuit of Fig. 11.84, $v_s = 4\cos 10^4 t$ V.~norm~&] Find the average power delivered to the 50-kΩ resistor.

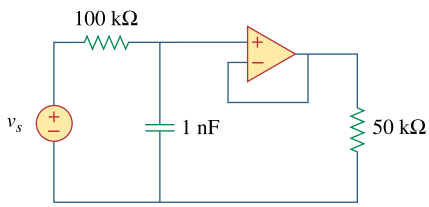


Figure 11.84
For Prob. 11.65.

Chapter 11, Solution 65.

$$C = 1\text{ nF} \longrightarrow \frac{1}{j\omega C} = \frac{-j}{10^4 \times 10^{-9}} = -j100\text{ k}\Omega$$

At the noninverting terminal,

$$\frac{4\angle 0° - \mathbf{V}_o}{100} = \frac{\mathbf{V}_o}{-j100} \longrightarrow \mathbf{V}_o = \frac{4}{1+j}$$

$$\mathbf{V}_o = \frac{4}{\sqrt{2}}\angle -45°$$

$$v_o(t) = \frac{4}{\sqrt{2}}\cos(10^4 t - 45°)$$

$$P = \frac{V_{rms}^2}{R} = \left(\frac{4}{\sqrt{2}} \cdot \frac{1}{\sqrt{2}}\right)^2 \left(\frac{1}{50 \times 10^3}\right) \text{W}$$

$$P = \underline{\mathbf{80\ \mu W}}$$

Chapter 11, Problem 66.

Obtain the average power absorbed by the 6-kΩ resistor in the op amp circuit in Fig. 11.85.

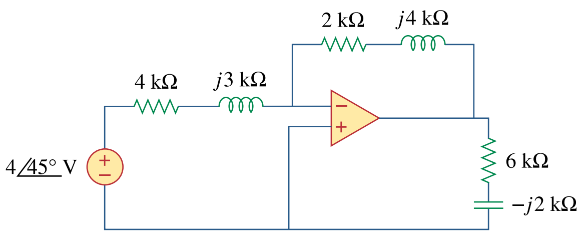


Figure 11.85
For Prob. 11.66.

Chapter 11, Solution 66.

As an inverter,

$$\mathbf{V}_o = \frac{-\mathbf{Z}_f}{\mathbf{Z}_i}\mathbf{V}_s = \frac{-(2+j4)}{4+j3}\cdot(4\angle 45°)$$

$$\mathbf{I}_o = \frac{\mathbf{V}_o}{6-j2}\ \text{mA} = \frac{-(2+j4)(4\angle 45°)}{(6-j2)(4+j3)}\ \text{mA}$$

The power absorbed by the 6-kΩ resistor is

$$P = \frac{1}{2}\left|\mathbf{I}_o\right|^2 R = \frac{1}{2}\cdot\left(\frac{\sqrt{20}\times 4}{\sqrt{40}\times 5}\right)^2 \times 10^{-6}\times 6\times 10^3$$

$$P = \underline{\mathbf{0.96\ mW}}$$

Chapter 11, Problem 67.

For the op amp circuit in Fig. 11.86, calculate:

(a) the complex power delivered by the voltage source
(b) the average power dissipated in the 12-Ω resistor

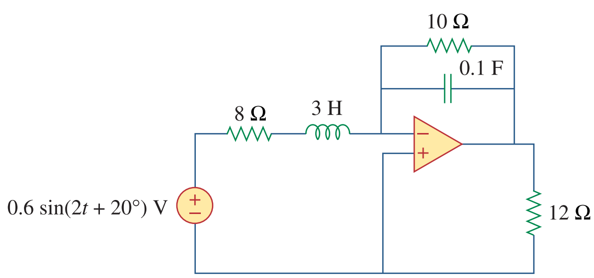


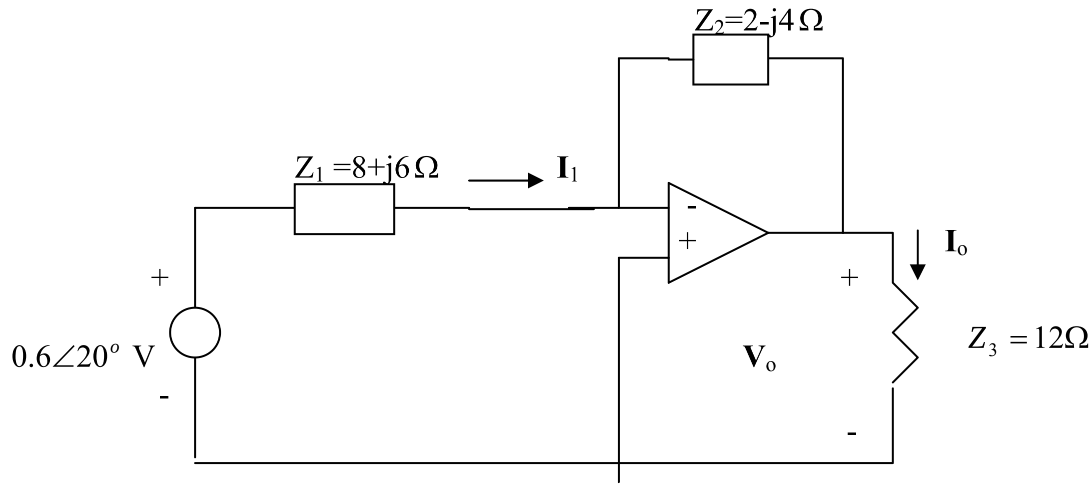
Figure 11.86
For Prob. 11.67.

Chapter 11, Solution 67.

$$\omega = 2, \quad 3\text{H} \longrightarrow j\omega L = j6, \quad 0.1\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j2x0.1} = -j5$$

$$10 // (-j5) = \frac{-j50}{10 - j5} = 2 - j4$$

The frequency-domain version of the circuit is shown below.



(a) $$I_1 = \frac{0.6\angle 20^o - 0}{8 + j6} = \frac{0.5638 + j0.2052}{8 + j6} = 0.06\angle -16.87^o$$

$$S = \frac{1}{2} V_s I^*{}_1 = (0.3\angle 20^o)(0.06\angle +16.87^o) = \underline{14.4 + j10.8\,\text{mVA}} = \underline{18\angle 36.86^o \text{ mVA}}$$

(b) $$V_o = -\frac{Z_2}{Z_1} V_s, \qquad I_o = \frac{V_o}{Z_3} = -\frac{(2 - j4)}{12(8 + j6)}(0.6\angle 20^o) = 0.0224\angle 99.7^o$$

$$P = \frac{1}{2} | I_o |^2 R = 0.5(0.0224)^2 (12) = \underline{2.904\,\text{mW}}$$

Chapter 11, Problem 68.

Compute the complex power supplied by the current source in the series *RLC* circuit in Fig. 11.87.

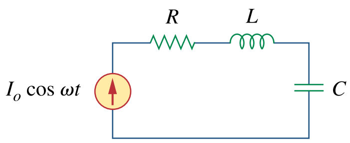


Figure 11.87
For Prob. 11.68.

Chapter 11, Solution 68.

Let $\quad \mathbf{S} = \mathbf{S}_R + \mathbf{S}_L + \mathbf{S}_c$

where $\quad \mathbf{S}_R = P_R + jQ_R = \frac{1}{2} I_o^2 R + j0$

$$\mathbf{S}_L = P_L + jQ_L = 0 + j\frac{1}{2} I_o^2 \omega L$$

$$\mathbf{S}_c = P_c + jQ_c = 0 - j\frac{1}{2} I_o^2 \cdot \frac{1}{\omega C}$$

Hence, $\quad \underline{\mathbf{S} = \frac{1}{2} \mathbf{I}_o^2 \left[\mathbf{R} + \mathbf{j}\left(\omega \mathbf{L} - \frac{1}{\omega \mathbf{C}} \right) \right]}$

Chapter 11, Problem 69.

Refer to the circuit shown in Fig. 11.88.

(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?

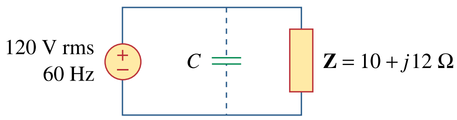


Figure 11.88
For Prob. 11.69.

Chapter 11, Solution 69.

(a) Given that $\mathbf{Z} = 10 + j12$

$$\tan\theta = \frac{12}{10} \longrightarrow \theta = 50.19°$$

$$\text{pf} = \cos\theta = \underline{\mathbf{0.6402}}$$

(b)
$$\mathbf{S} = \frac{|\mathbf{V}|^2}{2\mathbf{Z}^*} = \frac{(120)^2}{(2)(10 - j12)} = 295.12 + j354.09$$

The average power absorbed $= P = \text{Re}(\mathbf{S}) = \underline{\mathbf{295.1\ W}}$

(c) For unity power factor, $\theta_1 = 0°$, which implies that the reactive power due to the capacitor is $Q_c = 354.09$

But $\quad Q_c = \dfrac{V^2}{2X_c} = \dfrac{1}{2}\omega C V^2$

$$C = \frac{2Q_c}{\omega V^2} = \frac{(2)(354.09)}{(2\pi)(60)(120)^2} = \underline{\mathbf{130.4\ \mu F}}$$

Chapter 11, Problem 70.

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?

Chapter 11, Solution 70.

$$pf = \cos\theta = 0.8 \quad \longrightarrow \quad \sin\theta = 0.6$$
$$Q = S\sin\theta = (880)(0.6) = 528$$

If the power factor is to be unity, the reactive power due to the capacitor is

$$Q_c = Q = 528 \text{ VAR}$$

$$\text{But} \quad Q = \frac{V_{rms}^2}{X_c} = \frac{1}{2}\omega C V^2 \quad \longrightarrow \quad C = \frac{2Q_c}{\omega V^2}$$

$$C = \frac{(2)(528)}{(2\pi)(50)(220)^2} = \underline{\mathbf{69.45\ \mu F}}$$

Chapter 11, Problem 71.

Three loads are connected in parallel to a $120\angle 0°$ V rms source. Load 1 absorbs 60 kVAR at pf = 0.85 lagging, load 2 absorbs 90 kW and 50 kVAR leading, and load 3 absorbs 100 kW at pf = 1. (a) Find the equivalent impedance. (b) Calculate the power factor of the parallel combination. (c) Determine the current supplied by the source.

Chapter 11, Solution 71.

(a) For load 1,

$Q_1 = 60$ kVAR, pf = 0.85 or $\theta_1 = 31.79°$

$Q_1 = S_1 \sin\theta_1 = 60k$ or $S_1 = 113.89k$ and $P_1 = 113.89\cos(31.79) = 96.8$kW

$\mathbf{S}_1 = 96.8 + j60$ kVA

For load 2, $\mathbf{S}_2 = 90 - j50$ kVA

For load 3, $\mathbf{S}_3 = 100$ kVA

Hence,

$\mathbf{S} = \mathbf{S_1} + \mathbf{S_2} + \mathbf{S_3} = 286.8 + j10\text{kVA} = 287\angle 2°\text{kVA}$

But $\quad \mathbf{S} = (V_{rms})^2/Z^*$ or $Z^* = 120^2/287\angle 2°k = 0.05017\angle -2°$

Thus, $\quad Z = \underline{\mathbf{0.05017\angle 2°\ \Omega}}$ or $\underline{\mathbf{0.05014 + j0.0017509\Omega}}$.

(b) From above, pf = cos2° = $\underline{\mathbf{0.9994}}$.

(c) $I_{rms} = V_{rms}/Z = 120/0.05017\angle 2° = \underline{\mathbf{2.392\angle -2°kA}}$ or $\underline{\mathbf{2.391 - j0.08348kA}}$.

Chapter 11, Problem 72.

Two loads connected in parallel draw a total of 2.4 kW at 0.8 pf lagging from a 120-V rms, 60-Hz line. One load absorbs 1.5 kW at a 0.707 pf lagging. Determine: (a) the pf of the second load, (b) the parallel element required to correct the pf to 0.9 lagging for the two loads.

Chapter 11, Solution 72.

(a) $P = S\cos\theta_1 \quad\longrightarrow\quad S = \dfrac{P}{\cos\theta_1} = \dfrac{2.4}{0.8} = 3.0 \text{ kVA}$

$pf = 0.8 = \cos\theta_1 \quad\longrightarrow\quad \theta_1 = 36.87^o$

$Q = S\sin\theta_1 = 3.0\sin 36.87^o = 1.8 \text{ kVAR}$

Hence, $S = 2.4 + j1.8$ kVA

$S_1 = \dfrac{P_1}{\cos\theta} = \dfrac{1.5}{0.707} = 2.122 \text{ kVA}$

$pf = 0.707 = \cos\theta \quad\longrightarrow\quad \theta = 45^o$

$Q_1 = P_1 = 1.5 \text{ kVAR} \quad\longrightarrow\quad S_1 = 1.5 + j1.5 \text{ kVA}$

Since, $S = S_1 + S_2 \quad\longrightarrow\quad S_2 = S - S_1 = (2.4 + j1.8) - (1.5 + j1.5) = 0.9 + j0.3 \text{ kVA}$

$S_2 = 0.9497 < 18.43^o$

pf = cos 18.43° = $\underline{0.9487}$

(b) $pf = 0.9 = \cos\theta_2 \quad\longrightarrow\quad \theta_2 = 25.84^o$

$$C = \frac{P(\tan\theta_1 - \tan\theta_2)}{\omega V_{rms}^2} = \frac{2400(\tan 36.87 - \tan 25.84)}{2\pi x 60 x (120)^2} = \underline{117.5\ \mu\text{F}}$$

Chapter 11, Problem 73.

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

Chapter 11, Solution 73.

(a) $\mathbf{S} = 10 - j15 + j22 = 10 + j7 \text{ kVA}$

$S = |\mathbf{S}| = \sqrt{10^2 + 7^2} = \underline{\mathbf{12.21\ kVA}}$

(b) $\mathbf{S} = \mathbf{V}\mathbf{I}^* \longrightarrow \mathbf{I}^* = \dfrac{\mathbf{S}}{\mathbf{V}} = \dfrac{10{,}000 + j7{,}000}{240}$

$\mathbf{I} = 41.667 - j29.167 = \underline{\mathbf{50.86\angle -35^\circ\ A}}$

(c) $\theta_1 = \tan^{-1}\left(\dfrac{7}{10}\right) = 35^\circ, \qquad \theta_2 = \cos^{-1}(0.96) = 16.26^\circ$

$Q_c = P_1[\tan\theta_1 - \tan\theta_2] = 10[\tan(35^\circ) - \tan(16.26^\circ)]$
$Q_c = \underline{\mathbf{4.083\ kVAR}}$

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{4083}{(2\pi)(60)(240)^2} = \underline{\mathbf{188.03\ \mu F}}$$

(d) $\mathbf{S}_2 = P_2 + jQ_2, \qquad P_2 = P_1 = 10 \text{ kW}$

$Q_2 = Q_1 - Q_c = 7 - 4.083 = 2.917 \text{ kVAR}$

$\mathbf{S}_2 = 10 + j2.917 \text{ kVA}$
But $\mathbf{S}_2 = \mathbf{V}\mathbf{I}_2^*$

$\mathbf{I}_2^* = \dfrac{\mathbf{S}_2}{\mathbf{V}} = \dfrac{10{,}000 + j2917}{240}$
$\mathbf{I}_2 = 41.667 - j12.154 = \underline{\mathbf{43.4\angle -16.26^\circ\ A}}$

Chapter 11, Problem 74.

A 120-V rms 60-Hz source supplies two loads connected in parallel, as shown in Fig. 11.89.

(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.

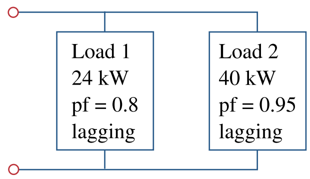


Figure 11.89
For Prob. 11.74.

Chapter 11, Solution 74.

(a) $\theta_1 = \cos^{-1}(0.8) = 36.87°$

$$S_1 = \frac{P_1}{\cos\theta_1} = \frac{24}{0.8} = 30 \text{ kVA}$$

$Q_1 = S_1 \sin\theta_1 = (30)(0.6) = 18 \text{ kVAR}$

$\mathbf{S}_1 = 24 + j18 \text{ kVA}$

$\theta_2 = \cos^{-1}(0.95) = 18.19°$

$$S_2 = \frac{P_2}{\cos\theta_2} = \frac{40}{0.95} = 42.105 \text{ kVA}$$

$Q_2 = S_2 \sin\theta_2 = 13.144 \text{ kVAR}$

$\mathbf{S}_2 = 40 + j13.144 \text{ kVA}$

$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 = 64 + j31.144 \text{ kVA}$

$$\theta = \tan^{-1}\left(\frac{31.144}{64}\right) = 25.95°$$

$\text{pf} = \cos\theta = \underline{\mathbf{0.8992}}$

(b) $\theta_2 = 25.95°, \qquad \theta_1 = 0°$

$Q_c = P[\tan\theta_2 - \tan\theta_1] = 64[\tan(25.95°) - 0] = 31.144 \text{ kVAR}$

$$C = \frac{Q_c}{\omega V_{rms}^2} = \frac{31{,}144}{(2\pi)(60)(120)^2} = \underline{\mathbf{5.74\ mF}}$$

Chapter 11, Problem 75.

Consider the power system shown in Fig. 11.90. Calculate:

(a) the total complex power
(b) the power factor

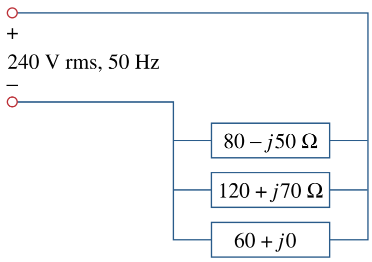


Figure 11.90
For Prob. 11.75.

Chapter 11, Solution 75.

(a) $$\mathbf{S}_1 = \frac{|\mathbf{V}|^2}{\mathbf{Z}_1^*} = \frac{(240)^2}{80 + j50} = \frac{5760}{8 + j5} = 517.75 - j323.59 \text{ VA}$$

$$\mathbf{S}_2 = \frac{(240)^2}{120 - j70} = \frac{5760}{12 - j7} = 358.13 + j208.91 \text{ VA}$$

$$\mathbf{S}_3 = \frac{(240)^2}{60} = 960 \text{ VA}$$

$$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 + \mathbf{S}_3 = \underline{1835.9 - j114.68 \text{ VA}}$$

(b) $$\theta = \tan^{-1}\left(\frac{114.68}{1835.88}\right) = 3.574°$$

$$\text{pf} = \cos\theta = \underline{\mathbf{0.998}} \text{ \{leading\}}$$

(c) Since the circuit already has a leading power factor, near unity, no compensation is necessary.

Chapter 11, Problem 76.

Obtain the wattmeter reading of the circuit in Fig. 11.91.

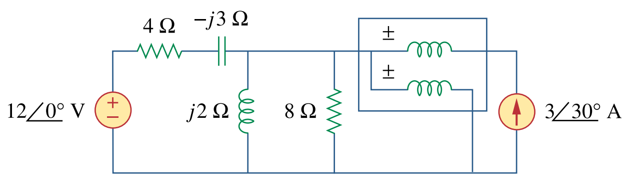
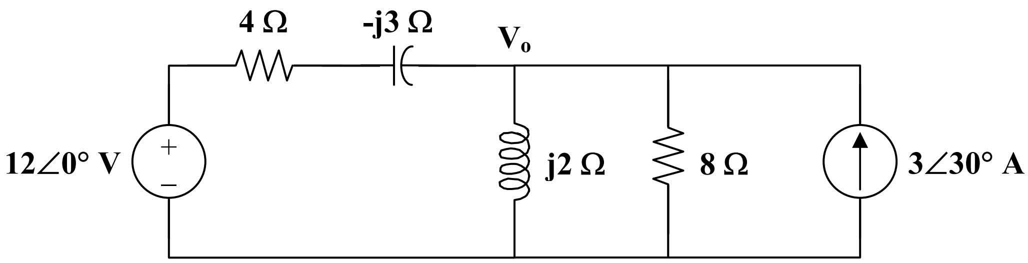


Figure 11.91
For Prob. 11.76.

Chapter 11, Solution 76.

The wattmeter reads the real power supplied by the current source. Consider the circuit below.



$$3\angle 30^\circ + \frac{12 - \mathbf{V}_o}{4 - j3} = \frac{\mathbf{V}_o}{j2} + \frac{\mathbf{V}_o}{8}$$

$$\mathbf{V}_o = \frac{36.14 + j23.52}{2.28 - j3.04} = 0.7547 + j11.322 = 11.347\angle 86.19^\circ$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}_o\,\mathbf{I}_o^* = \frac{1}{2}\cdot(11.347\angle 86.19^\circ)(3\angle -30^\circ)$$

$$\mathbf{S} = 17.021\angle 56.19^\circ$$

$$\mathrm{P} = \mathrm{Re}(\mathbf{S}) = \underline{\mathbf{9.471\ W}}$$

Chapter 11, Problem 77.

What is the reading of the wattmeter in the network of Fig. 11.92?

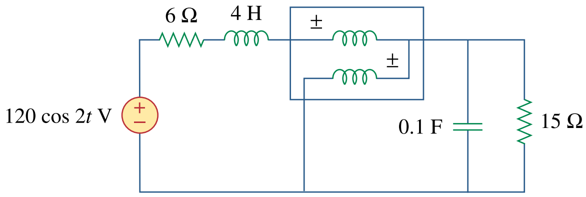


Figure 11.92
For Prob. 11.77.

Chapter 11, Solution 77.

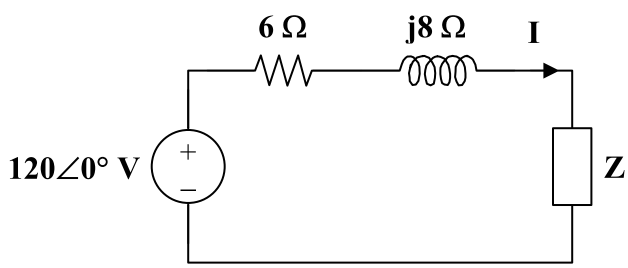
The wattmeter measures the power absorbed by the parallel combination of 0.1 F and 150 Ω.

$$120\cos(2t) \longrightarrow 120\angle 0°, \qquad \omega = 2$$

$$4\text{ H} \longrightarrow j\omega L = j8$$

$$0.1\text{ F} \longrightarrow \frac{1}{j\omega C} = \text{-j5}$$

Consider the following circuit.



$$\mathbf{Z} = 15 \,||\, (\text{-j5}) = \frac{(15)(\text{-j5})}{15 - j5} = 1.5 - j4.5$$

$$\mathbf{I} = \frac{120}{(6 + j8) + (1.5 - j4.5)} = 14.5\angle\text{-}25.02°$$

$$\mathbf{S} = \frac{1}{2}\mathbf{V}\,\mathbf{I}^* = \frac{1}{2}\left|\mathbf{I}\right|^2 \mathbf{Z} = \frac{1}{2}\cdot(14.5)^2(1.5 - j4.5)$$

$$\mathbf{S} = 157.69 - j473.06\text{ VA}$$

The wattmeter reads

$$P = \text{Re}(\mathbf{S}) = \underline{\mathbf{157.69\ W}}$$

Chapter 11, Problem 78.

Find the wattmeter reading of the circuit shown in Fig. 11.93.

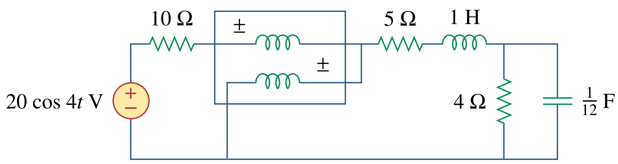


Figure 11.93
For Prob. 11.78.

Chapter 11, Solution 78.

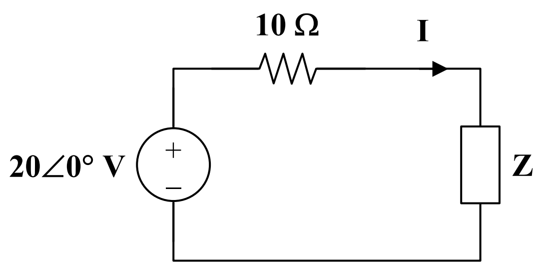
The wattmeter reads the power absorbed by the element to its right side.

$$2\cos(4t) \longrightarrow 2\angle 0°, \qquad \omega = 4$$

$$1\text{ H} \longrightarrow j\omega L = j4$$

$$\frac{1}{12}\text{ F} \longrightarrow \frac{1}{j\omega C} = \text{-j3}$$

Consider the following circuit.



$$\mathbf{Z} = 5 + j4 + 4 \,||\, \text{-j3} = 5 + j4 + \frac{(4)(\text{-j3})}{4 - j3}$$

$$\mathbf{Z} = 6.44 + j2.08$$

$$\mathbf{I} = \frac{20}{16.44 + j2.08} = 1.207\angle\text{-}7.21°$$

$$\mathbf{S} = \frac{1}{2}\left|\mathbf{I}\right|^2 \mathbf{Z} = \frac{1}{2}\cdot(1.207)^2(6.44 + j2.08)$$

$$P = \text{Re}(\mathbf{S}) = \underline{\mathbf{4.691\ W}}$$

Chapter 11, Problem 79.

Determine the wattmeter reading of the circuit in Fig. 11.94.

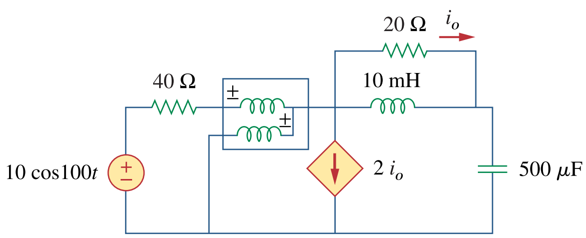


Figure 11.94
For Prob. 11.79.

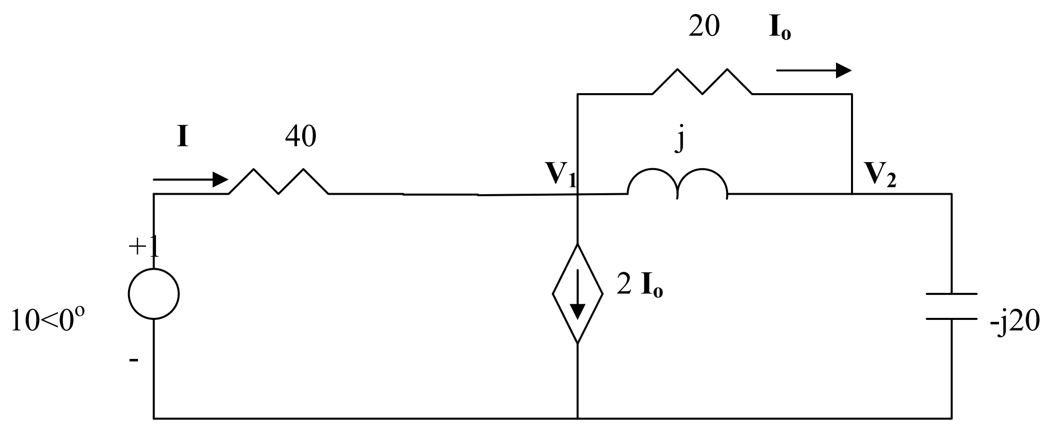
Chapter 11, Solution 79.

The wattmeter reads the power supplied by the source and partly absorbed by the 40-Ω resistor.

$\omega = 100,$

$$10\,\text{mH} \longrightarrow j100\text{x}10\text{x}10^{-3} = j, \quad 500\mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j100\text{x}500\text{x}10^{-6}} = -j20$$

The frequency-domain circuit is shown below.



At node 1,

$$\frac{10 - V_1}{40} = 2I_o + \frac{V_1 - V_2}{j} + \frac{V_1 - V_2}{20} = \frac{3(V_1 - V_2)}{20} + \frac{V_1 - V_2}{j} \longrightarrow \qquad (1)$$

$$10 = (7 - j40)V_1 + (-6 + j40)V_2$$

At node 2,

$$\frac{V_1 - V_2}{j} + \frac{V_1 - V_2}{20} = \frac{V_2}{-j20} \longrightarrow 0 = (20 + j)V_1 - (19 + j)V_2 \qquad (2)$$

Solving (1) and (2) yields $V_1 = 1.5568 - j4.1405$

$$I = \frac{10 - V_1}{40} = 0.2111 + j0.1035, \quad S = \frac{1}{2}V_1 I^* = -0.04993 - j0.5176$$

$$P = \text{Re}(S) = \underline{\mathbf{50\ mW}}.$$

Chapter 11, Problem 80.

The circuit of Fig. 11.95 portrays a wattmeter connected into an ac network.

(a) Find the load current.
(b) Calculate the wattmeter reading.

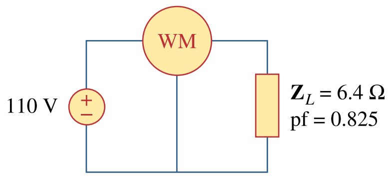


Figure 11.95
For Prob. 11.80.

Chapter 11, Solution 80.

(a) $$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{Z}} = \frac{110}{6.4} = \underline{\mathbf{17.19\ A}}$$

(b) $$\mathbf{S} = \frac{\mathbf{V}^2}{\mathbf{Z}} = \frac{(110)^2}{6.4} = 1890.625$$

$$\cos\theta = \text{pf} = 0.825 \longrightarrow \theta = 34.41°$$

$$\text{P} = \text{S}\cos\theta = 1559.76 \cong \underline{\mathbf{1.6\ kW}}$$

Chapter 11, Problem 81.

A 120-V rms, 60-Hz electric hair dryer consumes 600 W at a lagging pf of 0.92. Calculate the rms-valued current drawn by the dryer.

Chapter 11, Solution 81.

P = 600 W, $pf = 0.92 \longrightarrow \theta = 23.074^o$

$$P = S\cos\theta \longrightarrow S = \frac{P}{0.92} = 652.17\ \text{VA}$$

S = P+jQ = 600 + j652.17sin23.09° = 600 +j255.6

But $S = V_{rms}I^*_{rms}$.

$$I^*_{rms} = \frac{S}{V_{rms}} = \frac{600 + j255.6}{120}$$

$$\text{I}_{\text{rms}} = 5 - \text{j}2.13 = \underline{\mathbf{5.435\angle{-23.07}°A}}.$$

Chapter 11, Problem 82.

A 240-V rms 60-Hz source supplies a parallel combination of a 5-kW heater and a 30-kVA induction motor whose power factor is 0.82. Determine:

(a) the system apparent power
(b) the system reactive power
(c) the kVA rating of a capacitor required to adjust the system power factor to 0.9 lagging
(d) the value of the capacitor required

Chapter 11, Solution 82.

(a) $P_1 = 5{,}000, \qquad Q_1 = 0$

$$P_2 = 30{,}000x0.82 = 24{,}600, \qquad Q_2 = 30{,}000\sin(\cos^{-1} 0.82) = 17{,}171$$

$$\overline{S} = \overline{S}_1 + \overline{S}_2 = (P_1 + P_2) + j(Q_1 + Q_2) = 29{,}600 + j17{,}171$$

$$S = |\overline{S}| = \underline{34.22\text{ kV}}\text{A}$$

(b) $$Q = \underline{\mathbf{17.171\ kVAR}}$$

(c) $pf = \frac{P}{S} = \frac{29{,}600}{34{,}220} = 0.865$

$$\begin{aligned} Q_c &= P(\tan\theta_1 - \tan\theta_2) \\ &= 29{,}600\left[\tan(\cos^{-1} 0.865) - \tan(\cos^{-1} 0.9)\right] = \underline{2833\text{ VAR}} \end{aligned}$$

(c) $$C = \frac{Q_c}{\omega V^2_{rms}} = \frac{2833}{2\pi x 60 x 240^2} = \underline{130.46\mu\text{ F}}$$

Chapter 11, Problem 83.

Oscilloscope measurements indicate that the voltage across a load and the current through it are, respectively, $210\angle 60° \text{ V}$ and $8\angle 25° \text{ A}$. Determine:

(a) the real power
(b) the apparent power
(c) the reactive power
(d) the power factor

Chapter 11, Solution 83.

(a) $\overline{S} = \frac{1}{2}VI^* = \frac{1}{2}(210\angle 60^o)(8\angle -25^o) = 840\angle 35^o$

$$P = S\cos\theta = 840\cos 35^o = \underline{688.1 \text{ W}}$$

(b) S = **840 VA**

(c) $Q = S\sin\theta = 840\sin 35^o = \underline{481.8 \text{ VAR}}$

(d) $pf = P/S = \cos 35^o = \underline{0.8191 \text{ (lagging)}}$

Chapter 11, Problem 84.

e⊘d

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.

Chapter 11, Solution 84.

(a) Maximum demand charge $= 2{,}400 \times 30 = \$72{,}000$

Energy cost $= \$0.04 \times 1{,}200 \times 10^3 = \$48{,}000$

Total charge = **$120,000**

(b) To obtain \$120,000 from 1,200 MWh will require a flat rate of

$$\frac{\$120{,}000}{1{,}200 \times 10^3} \text{ per kWh} = \mathbf{\$0.10 \text{ per kWh}}$$

Chapter 11, Problem 85.

A regular household system of a single-phase three-wire circuit allows the operation of both 120-V and 240-V, 60-Hz appliances. The household circuit is modeled as shown in Fig. 11.96. Calculate:

(a) the currents $\mathbf{I}_1$, $\mathbf{I}_2$, and $\mathbf{I}_n$
(b) the total complex power supplied
(c) the overall power factor of the circuit

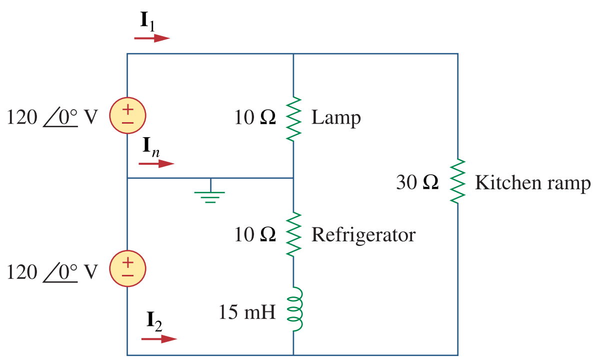
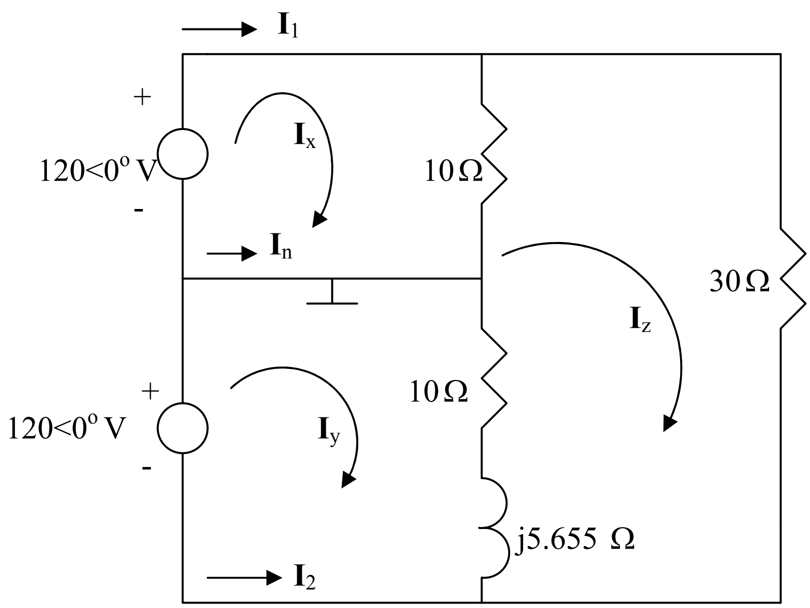


Figure 11.96
For Prob. 11.85.

Chapter 11, Solution 85.

(a) 15 mH $\longrightarrow$ $j2\pi x60x15x10^{-3} = j5.655$

We apply mesh analysis as shown below.



For mesh x,

$120 = 10\,\mathbf{I}_x - 10\,\mathbf{I}_z$ (1)

For mesh y,

$120 = (10+j5.655)\,\mathbf{I}_y - (10+j5.655)\,\mathbf{I}_z$ (2)

For mesh z,

$0 = -10\,\mathbf{I}_x - (10+j5.655)\,\mathbf{I}_y + (50+j5.655)\,\mathbf{I}_z$ (3)

Solving (1) to (3) gives

$\mathbf{I}_x = 20$, $\mathbf{I}_y = 17.09 - j5.142$, $\mathbf{I}_z = 8$

Thus,

$\mathbf{I}_1 = \mathbf{I}_x = \underline{20\text{ A}}$

$\mathbf{I}_2 = -\mathbf{I}_y = -17.09 + j5.142 = \underline{17.85\angle 163.26^o\ \text{A}}$

$\mathbf{I}_n = \mathbf{I}_y - \mathbf{I}_x = -2.91 - j5.142 = \underline{5.907\angle -119.5^o\ \text{A}}$

(b) $\overline{S_1} = (120)I^{\bullet}{}_x = 120x20 = 2400, \qquad \overline{S_2} = (120)I^{\bullet}{}_y = 2051 + j617$

$\overline{S} = \overline{S_1} + \overline{S_2} = \underline{4451 + j617\text{ VA}}$

(c) pf = P/S = 4451/4494 = **<u>0.9904</u>** (lagging)

Chapter 11, Problem 86.

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.

Chapter 11, Solution 86.

For maximum power transfer

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* \longrightarrow \mathbf{Z}_i = \mathbf{Z}_{Th} = \mathbf{Z}_L^*$$

$$\mathbf{Z}_L = R + j\omega L = 75 + j(2\pi)(4.12\times10^{6})(4\times10^{-6})$$
$$\mathbf{Z}_L = 75 + j103.55\ \Omega$$

$$\mathbf{Z}_i = \underline{\mathbf{75 - j103.55\ \Omega}}$$

Chapter 11, Problem 87.

In a TV transmitter, a series circuit has an impedance of $3\text{k}\Omega$ and a total current of 50 mA. If the voltage across the resistor is 80 V, what is the power factor of the circuit?

Chapter 11, Solution 87.

$$\mathbf{Z} = R \pm jX$$

$$\mathbf{V}_R = \mathbf{I}R \longrightarrow R = \frac{\mathbf{V}_R}{\mathbf{I}} = \frac{80}{50\times10^{-3}} = 1.6\ \text{k}\Omega$$

$$|\mathbf{Z}|^2 = R^2 + X^2 \longrightarrow X^2 = |\mathbf{Z}|^2 - R^2 = (3)^2 - (1.6)^2$$

$$X = 2.5377\ \text{k}\Omega$$

$$\theta = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left(\frac{2.5377}{1.6}\right) = 57.77°$$

$$\text{pf} = \cos\theta = \underline{\mathbf{0.5333}}$$

Chapter 11, Problem 88.

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 55º.

(a) Find the true power drawn by the circuit.
(b) Calculate the apparent power.

Chapter 11, Solution 88.

(a) $\mathbf{S} = (110)(2\angle 55°) = 220\angle 55°$

$$P = S\cos\theta = 220\cos(55°) = \underline{\mathbf{126.2\ W}}$$

(b) $S = |\mathbf{S}| = \underline{\mathbf{220\ VA}}$

Chapter 11, Problem 89.

An industrial heater has a nameplate that 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

Chapter 11, Solution 89.

(a) $\text{Apparent power} = S = \underline{\mathbf{12\ kVA}}$

$$P = S\cos\theta = (12)(0.78) = 9.36\text{ kW}$$
$$Q = S\sin\theta = 12\sin(\cos^{-1}(0.78)) = 7.51\text{ kVAR}$$

$$\mathbf{S} = P + jQ = \underline{\mathbf{9.36 + j7.51\ kVA}}$$

(b) $$\mathbf{S} = \frac{|\mathbf{V}|^2}{\mathbf{Z}^*} \longrightarrow \mathbf{Z}^* = \frac{|\mathbf{V}|^2}{\mathbf{S}} = \frac{(210)^2}{(9.36 + j7.51)\times 10^3} = 2.866 - j2.3$$

$$\mathbf{Z} = \underline{\mathbf{2.866 + j2.3\ \Omega}}$$

Chapter 11, Problem 90.

* 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?

* An asterisk indicates a challenging problem.

Chapter 11, Solution 90

Original load :

$$P_1 = 2000 \text{ kW}, \qquad \cos\theta_1 = 0.85 \longrightarrow \theta_1 = 31.79°$$

$$S_1 = \frac{P_1}{\cos\theta_1} = 2352.94 \text{ kVA}$$

$$Q_1 = S_1 \sin\theta_1 = 1239.5 \text{ kVAR}$$

Additional load :

$$P_2 = 300 \text{ kW}, \qquad \cos\theta_2 = 0.8 \longrightarrow \theta_2 = 36.87°$$

$$S_2 = \frac{P_2}{\cos\theta_2} = 375 \text{ kVA}$$

$$Q_2 = S_2 \sin\theta_2 = 225 \text{ kVAR}$$

Total load :

$$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 = (P_1 + P_2) + j(Q_1 + Q_2) = P + jQ$$

$$P = 2000 + 300 = 2300 \text{ kW}$$

$$Q = 1239.5 + 225 = 1464.5 \text{ kVAR}$$

The minimum operating pf for a 2300 kW load and not exceeding the kVA rating of the generator is

$$\cos\theta = \frac{P}{S_1} = \frac{2300}{2352.94} = 0.9775$$

or $\theta = 12.177°$

The maximum load kVAR for this condition is

$$Q_m = S_1 \sin\theta = 2352.94\sin(12.177°)$$

$$Q_m = 496.313 \text{ kVAR}$$

The capacitor must supply the difference between the total load kVAR (i.e. Q) and the permissible generator kVAR (i.e. Q_m). Thus,

$$Q_c = Q - Q_m = \underline{\mathbf{968.2 \text{ kVAR}}}$$

Chapter 11, Problem 91.

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.

Chapter 11, Solution 91

Original load :

$$P_1 = 2000 \text{ kW}, \qquad \cos\theta_1 = 0.85 \longrightarrow \theta_1 = 31.79°$$

$$S_1 = \frac{P_1}{\cos\theta_1} = 2352.94 \text{ kVA}$$

$$Q_1 = S_1 \sin\theta_1 = 1239.5 \text{ kVAR}$$

Additional load :

$$P_2 = 300 \text{ kW}, \qquad \cos\theta_2 = 0.8 \longrightarrow \theta_2 = 36.87°$$

$$S_2 = \frac{P_2}{\cos\theta_2} = 375 \text{ kVA}$$

$$Q_2 = S_2 \sin\theta_2 = 225 \text{ kVAR}$$

Total load :

$$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 = (P_1 + P_2) + j(Q_1 + Q_2) = P + jQ$$

$$P = 2000 + 300 = 2300 \text{ kW}$$

$$Q = 1239.5 + 225 = 1464.5 \text{ kVAR}$$

The minimum operating pf for a 2300 kW load and not exceeding the kVA rating of the generator is

$$\cos\theta = \frac{P}{S_1} = \frac{2300}{2352.94} = 0.9775$$

or $\qquad \theta = 12.177°$

The maximum load kVAR for this condition is

$$Q_m = S_1 \sin\theta = 2352.94 \sin(12.177°)$$

$$Q_m = 496.313 \text{ kVAR}$$

The capacitor must supply the difference between the total load kVAR (i.e. Q) and the permissible generator kVAR (i.e. Q_m). Thus,

$$Q_c = Q - Q_m = \underline{\mathbf{968.2 \text{ kVAR}}}$$

Chapter 11, Problem 92.

As shown in Fig. 11.97, 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.

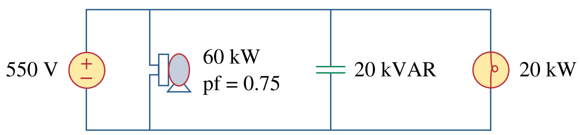


Figure 11.97
For Prob. 11.92.

Chapter 11, Solution 92

(a) Apparent power drawn by the motor is

$$S_m = \frac{P}{\cos\theta} = \frac{60}{0.75} = 80\ \text{kVA}$$

$$Q_m = \sqrt{S^2 - P^2} = \sqrt{(80)^2 - (60)^2} = 52.915\ \text{kVAR}$$

Total real power

$$P = P_m + P_c + P_L = 60 + 0 + 20 = 80\ \text{kW}$$

Total reactive power

$$Q = Q_m + Q_c + Q_L = 52.915 - 20 + 0 = \underline{\mathbf{32.91\ kVAR}}$$

Total apparent power

$$S = \sqrt{P^2 + Q^2} = \underline{\mathbf{86.51\ kVA}}$$

(b) $$pf = \frac{P}{S} = \frac{80}{86.51} = \underline{\mathbf{0.9248}}$$

(c) $$I = \frac{S}{V} = \frac{86510}{550} = \underline{\mathbf{157.3\ A}}$$

Chapter 11, Problem 93.

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 kVAR, 0.6 pf leading.

(a) Calculate the total real and reactive power.
(b) Find the overall power factor.

Chapter 11, Solution 93

(a) $P_1 = (5)(0.7457) = 3.7285 \text{ kW}$

$$S_1 = \frac{P_1}{pf} = \frac{3.7285}{0.8} = 4.661 \text{ kVA}$$

$$Q_1 = S_1 \sin(\cos^{-1}(0.8)) = 2.796 \text{ kVAR}$$

$$\mathbf{S}_1 = 3.7285 + j2.796 \text{ kVA}$$

$$P_2 = 1.2 \text{ kW}, \qquad Q_2 = 0 \text{ VAR}$$

$$\mathbf{S}_2 = 1.2 + j0 \text{ kVA}$$

$$P_3 = (10)(120) = 1.2 \text{ kW}, \qquad Q_3 = 0 \text{ VAR}$$

$$\mathbf{S}_3 = 1.2 + j0 \text{ kVA}$$

$$Q_4 = 1.6 \text{ kVAR}, \qquad \cos\theta_4 = 0.6 \longrightarrow \sin\theta_4 = 0.8$$

$$S_4 = \frac{Q_4}{\sin\theta_4} = 2 \text{ kVA}$$

$$P_4 = S_4 \cos\theta_4 = (2)(0.6) = 1.2 \text{ kW}$$

$$\mathbf{S}_4 = 1.2 - j1.6 \text{ kVA}$$

$$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2 + \mathbf{S}_3 + \mathbf{S}_4$$

$$\mathbf{S} = 7.3285 + j1.196 \text{ kVA}$$

Total real power = **<u>7.328 kW</u>**
Total reactive power = **<u>1.196 kVAR</u>**

(b) $$\theta = \tan^{-1}\left(\frac{1.196}{7.3285}\right) = 9.27°$$

$$pf = \cos\theta = \underline{\mathbf{0.987}}$$

Chapter 11, Problem 94.

e⊘d 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.

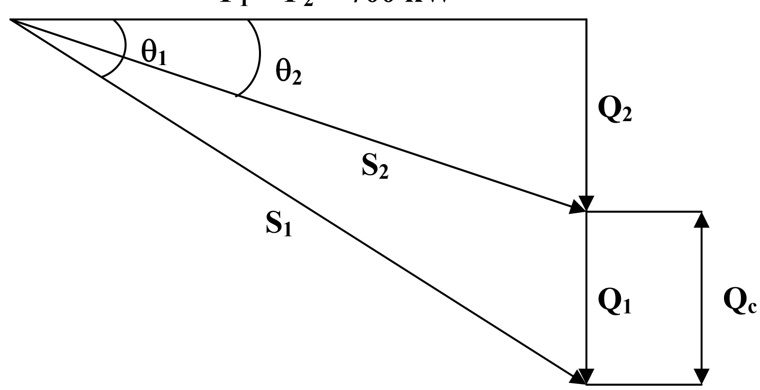
(a) Calculate the cost of capacitors needed.
(b) Find the savings in substation capacity released.
(c) Are capacitors economical for releasing the amount of substation capacity?

Chapter 11, Solution 94

$$\cos\theta_1 = 0.7 \longrightarrow \theta_1 = 45.57°$$
$$S_1 = 1\text{ MVA} = 1000\text{ kVA}$$
$$P_1 = S_1\cos\theta_1 = 700\text{ kW}$$
$$Q_1 = S_1\sin\theta_1 = 714.14\text{ kVAR}$$

For improved pf,

$$\cos\theta_2 = 0.95 \longrightarrow \theta_2 = 18.19°$$
$$P_2 = P_1 = 700\text{ kW}$$
$$S_2 = \frac{P_2}{\cos\theta_2} = \frac{700}{0.95} = 736.84\text{ kVA}$$
$$Q_2 = S_2\sin\theta_2 = 230.08\text{ kVAR}$$



(a) Reactive power across the capacitor

$$Q_c = Q_1 - Q_2 = 714.14 - 230.08 = 484.06\text{ kVAR}$$

Cost of installing capacitors $= \$30 \times 484.06 =$ **$14,521.80**

(b) Substation capacity released $= S_1 - S_2$

$$= 1000 - 736.84 = 263.16\text{ kVA}$$

Saving in cost of substation and distribution facilities

$= \$120 \times 263.16 =$ **$31,579.20**

(c) **Yes**, because (a) is greater than (b). Additional system capacity obtained by using capacitors costs only 46% as much as new substation and distribution facilities.

Chapter 11, Problem 95.

A coupling capacitor is used to block dc current from an amplifier as shown in Fig. 11.98(a). The amplifier and the capacitor act as the source, while the speaker is the load as in Fig. 11.98(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?

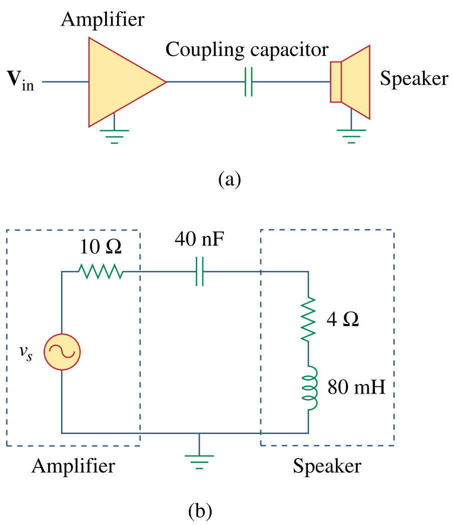


Figure 11.98
For Prob. 11.95.

Chapter 11, Solution 95

(a) Source impedance $\mathbf{Z}_s = R_s - jX_c$

Load impedance $\mathbf{Z}_L = R_L + jX_2$

For maximum load transfer

$$\mathbf{Z}_L = \mathbf{Z}_s^* \longrightarrow R_s = R_L, \quad X_c = X_L$$

$$X_c = X_L \longrightarrow \frac{1}{\omega C} = \omega L$$

$$\text{or} \qquad \omega = \frac{1}{\sqrt{LC}} = 2\pi f$$

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(80\times10^{-3})(40\times10^{-9})}} = \underline{\mathbf{2.814\ kHz}}$$

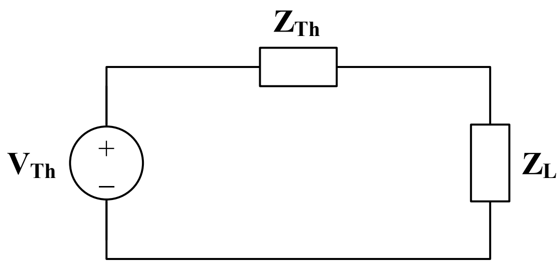
(b) $$P = \left(\frac{V_s}{(10+4)}\right)^2 4 = \left(\frac{4.6}{14}\right)^2 4 = \underline{\mathbf{431.8\ mW}} \quad (\text{since } V_s \text{ is in rms})$$

Chapter 11, Problem 96.

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.

Chapter 11, Solution 96



(a) $V_{Th} = 146\text{ V},\quad 300\text{ Hz}$

$Z_{Th} = 40 + j8\,\Omega$

$Z_L = Z_{Th}^* = \underline{\mathbf{40 - j8\,\Omega}}$

(b) $P = \dfrac{|V_{Th}|^2}{8R_{Th}} = \dfrac{(146)^2}{(8)(40)} = \underline{\mathbf{66.61\ W}}$

Chapter 11, Problem 97.

A power transmission system is modeled as shown in Fig. 11.99. If $\mathbf{V}_s = 240\angle 0^\circ$ rms, find the average power absorbed by the load.

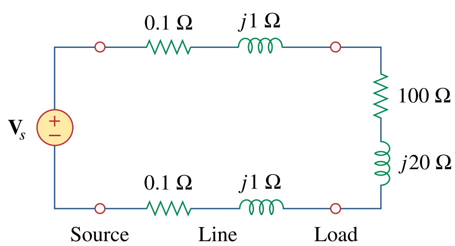


Figure 11.99
For Prob. 11.97.

Chapter 11, Solution 97

$$Z_T = (2)(0.1 + j) + (100 + j20) = 100.2 + j22\ \Omega$$

$$I = \frac{V_s}{Z_T} = \frac{240}{100.2 + j22}$$

$$P = |I|^2 R_L = 100|I|^2 = \frac{(100)(240)^2}{(100.2)^2 + (22)^2} = \underline{\mathbf{547.3\ W}}$$