Chapter 19, Problem 1.

Obtain the *z* parameters for the network in Fig. 19.65.

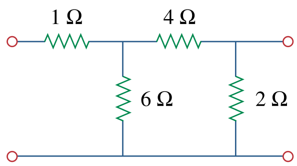

Figure 19.65

For Prob. 19.1 and 19.28.

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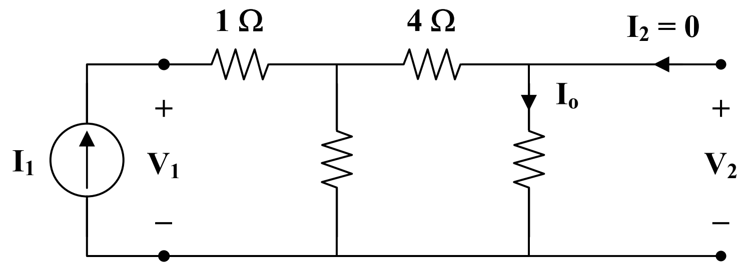
Chapter 19, Solution 1.

To get $\mathbf{z}_{11}$ and $\mathbf{z}_{21}$, consider the circuit in Fig. (a).



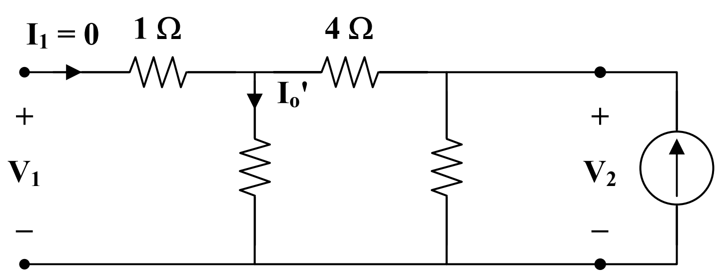
(a)

$$\mathbf{z}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = 1 + 6 \,||\, (4+2) = 4\,\Omega$$

$$\mathbf{I}_o = \frac{1}{2}\mathbf{I}_1, \qquad \mathbf{V}_2 = 2\mathbf{I}_o = \mathbf{I}_1$$

$$\mathbf{z}_{21} = \frac{\mathbf{V}_2}{\mathbf{I}_1} = 1\,\Omega$$

To get $\mathbf{z}_{22}$ and $\mathbf{z}_{12}$, consider the circuit in Fig. (b).



(b)

$$\mathbf{z}_{22} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = 2 \,||\, (4+6) = 1.667\,\Omega$$

$$\mathbf{I}_o' = \frac{2}{2+10}\mathbf{I}_2 = \frac{1}{6}\mathbf{I}_2, \qquad \mathbf{V}_1 = 6\mathbf{I}_o' = \mathbf{I}_2$$

$$\mathbf{z}_{12} = \frac{\mathbf{V}_1}{\mathbf{I}_2} = 1\,\Omega$$

Hence, $$[\mathbf{z}] = \begin{bmatrix} \mathbf{4} & \mathbf{1} \\ \mathbf{1} & \mathbf{1.667} \end{bmatrix}\Omega$$

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Chapter 19, Problem 2.

* Find the impedance parameter equivalent of the network in Fig. 19.66.

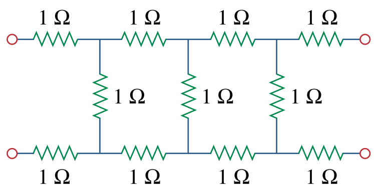
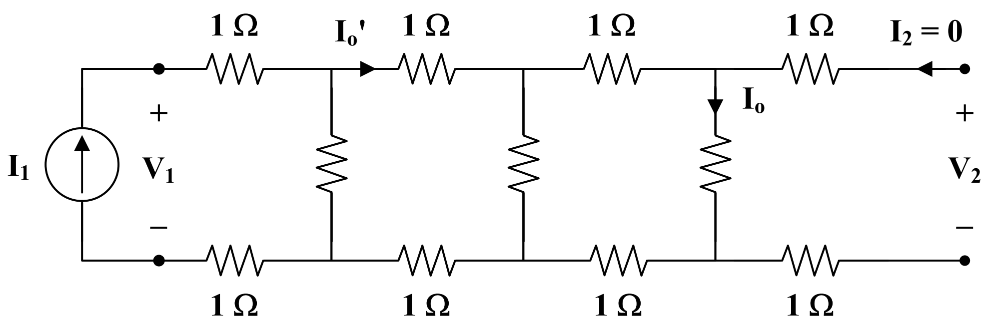


Figure 19.66
For Prob. 19.2.

* An asterisk indicates a challenging problem.

Chapter 19, Solution 2.

Consider the circuit in Fig. (a) to get $\mathbf{z}_{11}$ and $\mathbf{z}_{21}$.



(a)

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$$\mathbf{z}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = 2 + 1 \,||\, [\,2 + 1 \,||\, (2+1)\,]$$

$$\mathbf{z}_{11} = 2 + 1 \,||\left(2 + \frac{3}{4}\right) = 2 + \frac{(1)(11/4)}{1 + 11/4} = 2 + \frac{11}{15} = 2.733$$

$$\mathbf{I}_o = \frac{1}{1+3}\mathbf{I}_o' = \frac{1}{4}\mathbf{I}_o'$$

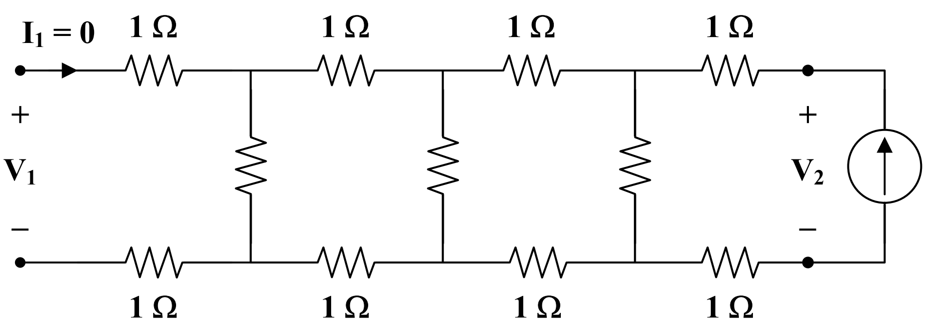
$$\mathbf{I}_o' = \frac{1}{1 + 11/4}\mathbf{I}_1 = \frac{4}{15}\mathbf{I}_1$$

$$\mathbf{I}_o = \frac{1}{4}\cdot\frac{4}{15}\mathbf{I}_1 = \frac{1}{15}\mathbf{I}_1$$

$$\mathbf{V}_2 = \mathbf{I}_o = \frac{1}{15}\mathbf{I}_1$$

$$\mathbf{z}_{21} = \frac{\mathbf{V}_2}{\mathbf{I}_1} = \frac{1}{15} = \mathbf{z}_{12} = 0.06667$$

To get $\mathbf{z}_{22}$, consider the circuit in Fig. (b).



(b)

$$\mathbf{z}_{22} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = 2 + 1 \,||\, (2 + 1 \,||\, 3) = \mathbf{z}_{11} = 2.733$$

Thus,

$$[\mathbf{z}] = \underline{\begin{bmatrix} \mathbf{2.733} & \mathbf{0.06667} \\ \mathbf{0.06667} & \mathbf{2.733} \end{bmatrix}\Omega}$$

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Chapter 19, Problem 3.

Find the z parameters of the circuit in Fig. 19.67.

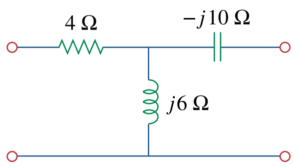

Figure 19.67
For Prob. 19.3.

Chapter 19, Solution 3.

$$z_{12} = j6 = z_{21}$$
$$z_{11} - z_{12} = 4 \longrightarrow z_{11} = z_{12} + 4 = 4 + j6\ \Omega$$
$$z_{22} - z_{12} = -j10 \longrightarrow z_{22} = z_{12} - j10 = -j4\ \Omega$$

$$[z] = \underline{\begin{bmatrix} 4+j6 & j6 \\ j6 & -j4 \end{bmatrix} \Omega} = \begin{bmatrix} 4+\mathrm{j}6 & \mathrm{j}6 \\ \mathrm{j}6 & -\mathrm{j}4 \end{bmatrix} \Omega$$

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Chapter 19, Problem 4.

Calculate the z parameters for the circuit in Fig. 19.68.

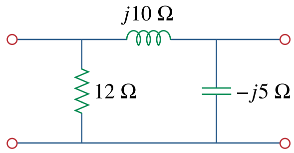
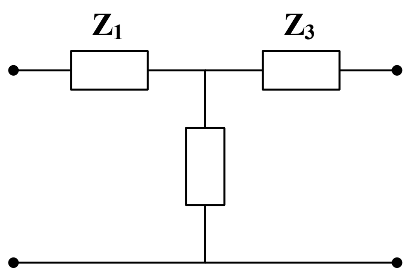


Figure 19.68

For Prob. 19.4.

Chapter 19, Solution 4.

Transform the Π network to a T network.



$$\mathbf{Z}_1 = \frac{(12)(j10)}{12 + j10 - j5} = \frac{j120}{12 + j5}$$

$$\mathbf{Z}_2 = \frac{-j60}{12 + j5}$$

$$\mathbf{Z}_3 = \frac{50}{12 + j5}$$

The z parameters are

$$\mathbf{z}_{12} = \mathbf{z}_{21} = \mathbf{Z}_2 = \frac{(-j60)(12 - j5)}{144 + 25} = -1.775 - j4.26$$

$$\mathbf{z}_{11} = \mathbf{Z}_1 + \mathbf{z}_{12} = \frac{(j120)(12 - j5)}{169} + \mathbf{z}_{12} = 1.775 + j4.26$$

$$\mathbf{z}_{22} = \mathbf{Z}_3 + \mathbf{z}_{21} = \frac{(50)(12 - j5)}{169} + \mathbf{z}_{21} = 1.7758 - j5.739$$

Thus,

$$[\mathbf{z}] = \begin{bmatrix} \mathbf{1.775 + j4.26} & \mathbf{-1.775 - j4.26} \\ \mathbf{-1.775 - j4.26} & \mathbf{1.775 - j5.739} \end{bmatrix} \Omega$$

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Chapter 19, Problem 5.

Obtain the *z* parameters for the network in Fig. 19.69 as functions of *s*.

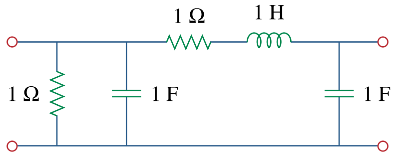
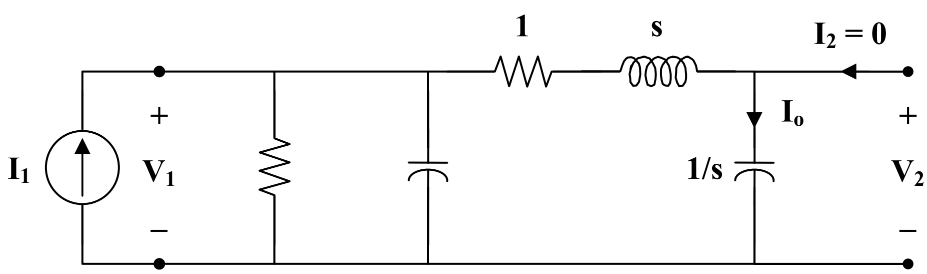


Figure 19.69

For Prob. 19.5.

Chapter 19, Solution 5.

Consider the circuit in Fig. (a).



(a)

$$\mathbf{z}_{11} = 1 \,||\, \frac{1}{s} \,||\, \left(1 + s + \frac{1}{s}\right) = \frac{\frac{1}{s}}{1+\frac{1}{s}} \,||\, \left(1 + s + \frac{1}{s}\right) = \frac{\left(\frac{1}{s+1}\right)\left(1+s+\frac{1}{s}\right)}{\left(\frac{1}{s+1}\right)+1+s+\frac{1}{s}}$$

$$\mathbf{z}_{11} = \frac{s^2+s+1}{s^3+2s^2+3s+1}$$

$$\mathbf{I}_o = \frac{1\,||\,\frac{1}{s}}{1\,||\,\frac{1}{s}+1+s+\frac{1}{s}}\mathbf{I}_1 = \frac{\frac{1}{s+1}}{\frac{1}{s+1}+1+s+\frac{1}{s}}\mathbf{I}_1 = \frac{\frac{s}{s+1}}{\frac{s}{s+1}+s^2+s+1}\mathbf{I}_1$$

$$\mathbf{I}_o = \frac{s}{s^3+2s^2+3s+1}\mathbf{I}_1$$

$$\mathbf{V}_2 = \frac{1}{s}\mathbf{I}_o = \frac{\mathbf{I}_1}{s^3+2s^2+3s+1}$$

$$\mathbf{z}_{21} = \frac{\mathbf{V}_2}{\mathbf{I}_1} = \frac{1}{s^3+2s^2+3s+1}$$

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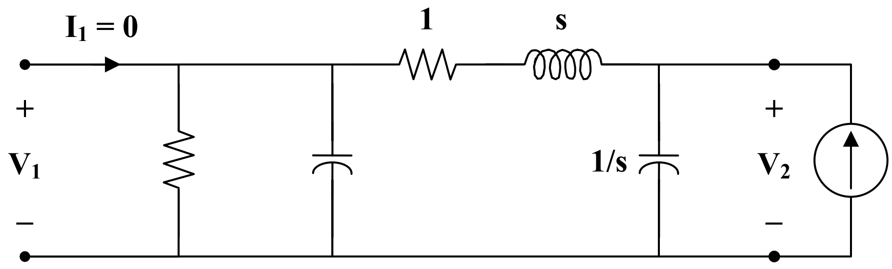
Consider the circuit in Fig. (b).



(b)

$$\mathbf{z}_{22} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = \frac{1}{s} \,||\, \left(1 + s + 1 \,||\, \frac{1}{s}\right) = \frac{1}{s} \,||\, \left(1 + s + \frac{1}{s+1}\right)$$

$$\mathbf{z}_{22} = \frac{\left(\frac{1}{s}\right)\left(1 + s + \frac{1}{s+1}\right)}{\frac{1}{s} + 1 + s + \frac{1}{s+1}} = \frac{1 + s + \frac{1}{s+1}}{1 + s + s^2 + \frac{s}{s+1}}$$

$$\mathbf{z}_{22} = \frac{s^2 + 2s + 2}{s^3 + 2s^2 + 3s + 1}$$

$$\mathbf{z}_{12} = \mathbf{z}_{21}$$

Hence,

$$[\mathbf{z}] = \begin{bmatrix} \dfrac{\mathbf{s^2 + s + 1}}{\mathbf{s^3 + 2s^2 + 3s + 1}} & \dfrac{\mathbf{1}}{\mathbf{s^3 + 2s^2 + 3s + 1}} \\ \dfrac{\mathbf{1}}{\mathbf{s^3 + 2s^2 + 3s + 1}} & \dfrac{\mathbf{s^2 + 2s + 2}}{\mathbf{s^3 + 2s^2 + 3s + 1}} \end{bmatrix}$$

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Chapter 19, Problem 6.

Compute the *z* parameters of the circuit in Fig. 19.70.

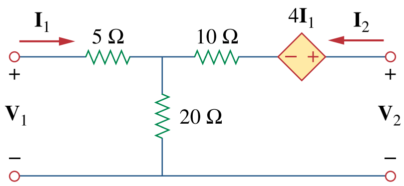
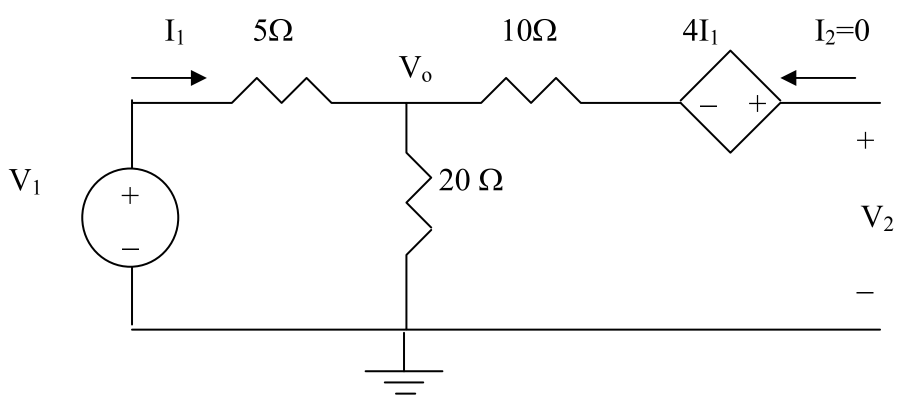


Figure 19.70

For Prob. 19.6 and 19.73.

Chapter 19, Solution 6.

To find z_{11} and z_{21}, consider the circuit below.



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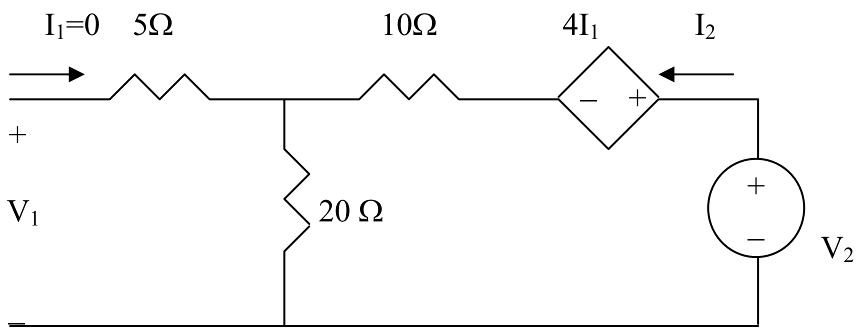
$$z_{11} = \frac{V_1}{I_1} = \frac{(20+5)I_1}{I_1} = 25\ \Omega$$

$$V_o = \frac{20}{25}V_1 = 20I_1$$

$$-V_o - 4I_2 + V_2 = 0 \quad \longrightarrow \quad V_2 = V_o + 4I_1 = 20I_1 + 4I_1 = 24I_1$$

$$z_{21} = \frac{V_2}{I_1} = 24\ \Omega$$

To find z_{12} and z_{22}, consider the circuit below.



$$V_2 = (10+20)I_2 = 30I_2$$

$$z_{22} = \frac{V_2}{I_1} = 30\ \Omega$$

$$V_1 = 20I_2$$

$$z_{12} = \frac{V_1}{I_2} = 20\ \Omega$$

Thus,

$$[z] = \begin{bmatrix} 25 & 20 \\ 24 & 30 \end{bmatrix} \Omega$$

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Chapter 19, Problem 7.

Calculate the impedance-parameter equivalent of the circuit in Fig. 19.71.

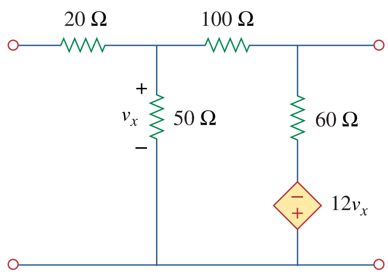
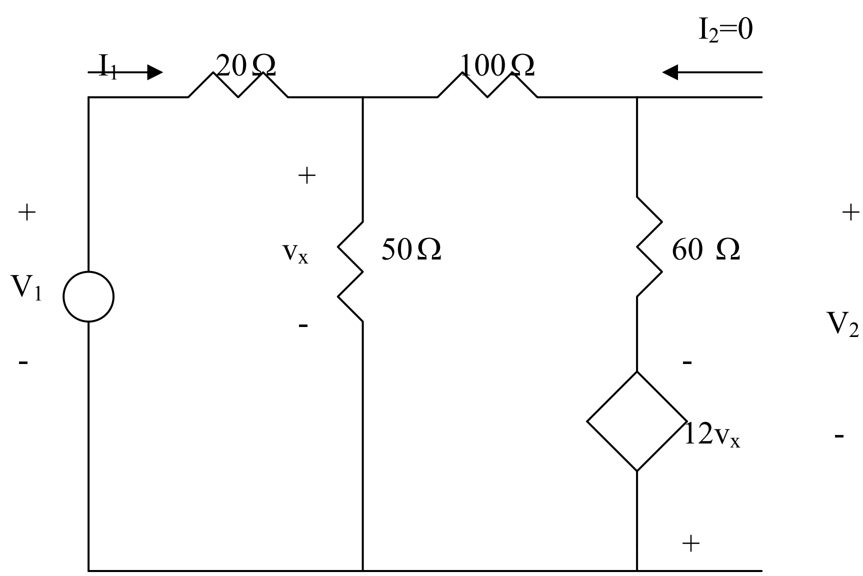


Figure 19.71

For Prob. 19.7 and 19.80.

Chapter 19, Solution 7.

To get z_{11} and z_{21}, we consider the circuit below.



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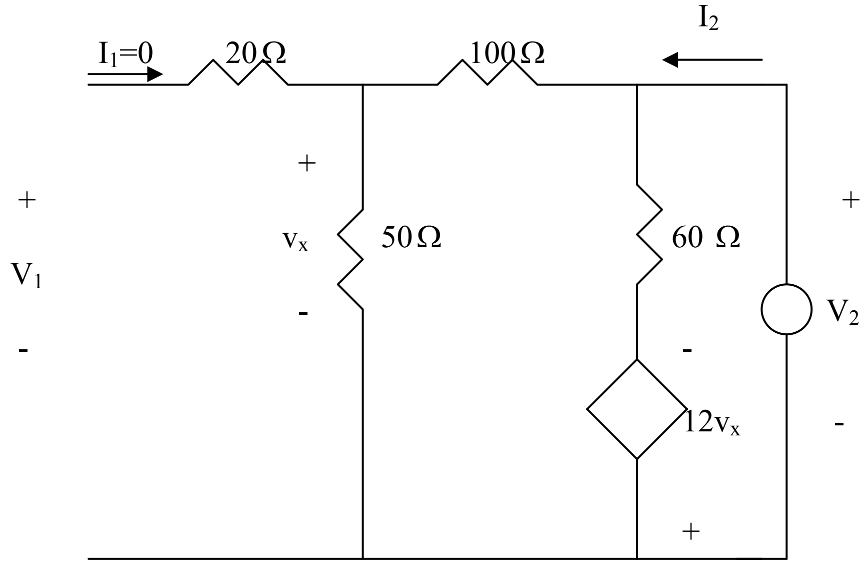
$$\frac{V_1 - V_x}{20} = \frac{V_x}{50} + \frac{V_x + 12V_x}{160} \longrightarrow V_x = \frac{40}{121}V_1$$

$$I_1 = \frac{V_1 - V_x}{20} = \frac{81}{121}(\frac{V_1}{20}) \longrightarrow z_{11} = \frac{V_1}{I_1} = 29.88$$

$$V_2 = 60(\frac{13V_x}{160}) - 12V_x = -\frac{57}{8}V_x = -\frac{57}{8}(\frac{40}{121})V_1 = -\frac{57}{8}(\frac{40}{121})\frac{20x121}{81}I_1$$

$$= -70.37I_1 \longrightarrow z_{21} = \frac{V_2}{I_1} = -70.37$$

To get z_{12} and z_{22}, we consider the circuit below.



$$V_x = \frac{50}{100+50}V_2 = \frac{1}{3}V_2, \quad I_2 = \frac{V_2}{150} + \frac{V_2 + 12V_x}{60} = 0.09V_2$$

$$z_{22} = \frac{V_2}{I_2} = 1/0.09 = 11.11$$

$$V_1 = V_x = \frac{1}{3}V_2 = \frac{11.11}{3}I_2 = 3.704I_2 \longrightarrow z_{12} = \frac{V_1}{I_2} = 3.704$$

Thus,

$$[z] = \begin{bmatrix} 29.88 & 3.704 \\ -70.37 & 11.11 \end{bmatrix}\Omega$$

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Chapter 19, Problem 8.

Find the z parameters of the two-port in Fig. 19.72.

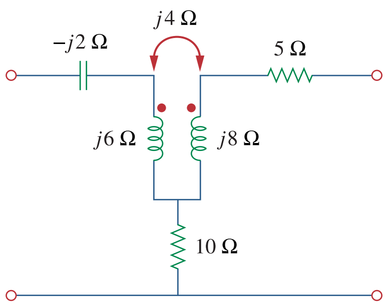
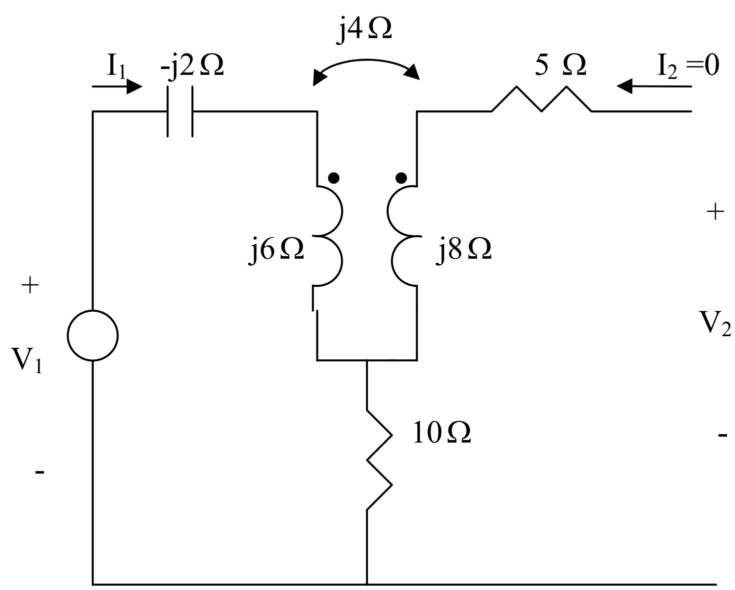


Figure 19.72

For Prob. 19.8.

Chapter 19, Solution 8.

To get z_{11} and z_{21}, consider the circuit below.



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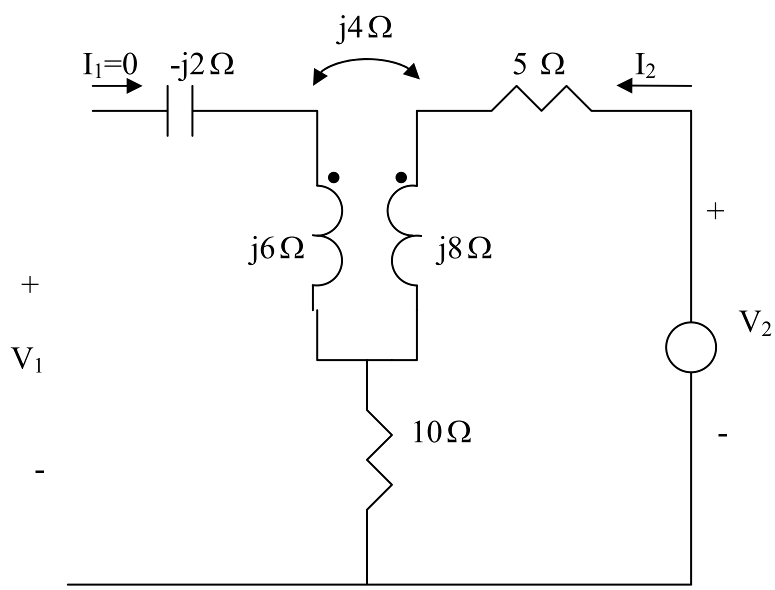
$$V_1 = (10 - j2 + j6)I_1 \longrightarrow z_{11} = \frac{V_1}{I_1} = 10 + j4$$

$$V_2 = -10I_1 - j4I_1 \longrightarrow z_{21} = \frac{V_2}{I_1} = -(10 + j4)$$

To get z_{22} and z_{12}, consider the circuit below.



$$V_2 = (5 + 10 + j8)I_2 \longrightarrow z_{22} = \frac{V_2}{I_2} = 15 + j8$$

$$V_1 = -(10 + j4)I_2 \longrightarrow z_{12} = \frac{V_1}{I_2} = -(10 + j4)$$

Thus,

$$[z] = \underline{\begin{bmatrix} (10 + j4) & -(10 + j4) \\ -(10 + j4) & (15 + j8) \end{bmatrix} \Omega}$$

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Chapter 19, Problem 9.

The y parameters of a network are:

$$[\mathbf{y}] = \begin{bmatrix} 0.5 & -0.2 \\ -0.2 & 0.4 \end{bmatrix}$$

Determine the z parameters for the network.

Chapter 19, Solution 9.

$$z_{11} = \frac{y_{22}}{\Delta y} = \frac{0.4}{0.16} = 2.5, \quad \Delta y = y_{11}y_{22} - y_{21}y_{12} = 05x0.4 - 0.2x0.2 = 0.16$$

$$z_{12} = \frac{-y_{12}}{\Delta y} = \frac{0.2}{0.16} = 1.25 = z_{21}$$

$$z_{22} = \frac{y_{11}}{\Delta y} = \frac{0.5}{0.16} = 3.125$$

Thus,

$$[z] = \underline{\begin{bmatrix} 2.5 & 1.25 \\ 1.25 & 3.125 \end{bmatrix}\Omega} \begin{bmatrix} 2.5 & 1.25 \\ 1.25 & 3.125 \end{bmatrix}\Omega$$

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Chapter 19, Problem 10.

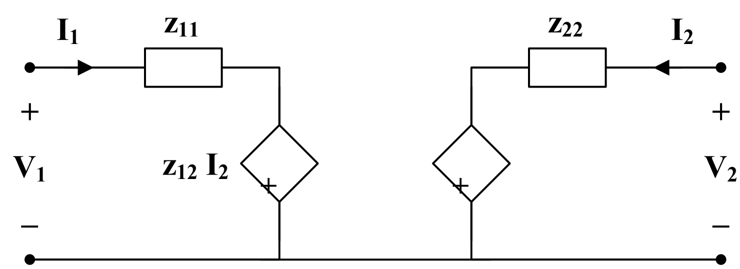
Construct a two-port that realizes each of the following *z* parameters.

(a) $[\mathbf{z}] = \begin{bmatrix} 25 & 20 \\ 5 & 10 \end{bmatrix} \Omega$

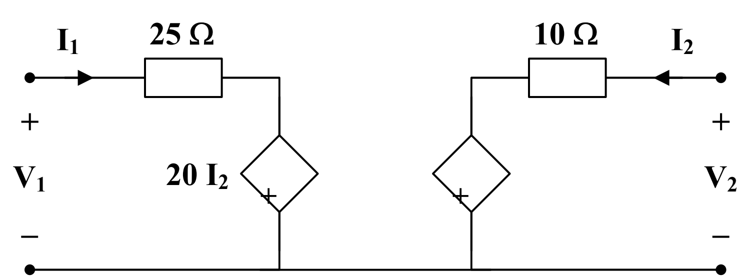
(b) $[\mathbf{z}] = \begin{bmatrix} 1+\frac{3}{s} & \frac{1}{s} \\ \frac{1}{s} & 2s+\frac{1}{s} \end{bmatrix} \Omega$

Chapter 19, Solution 10.

(a) This is a non-reciprocal circuit so that **the two-port looks like the one shown in Figs. (a) and (b)**.



(a)



(b)

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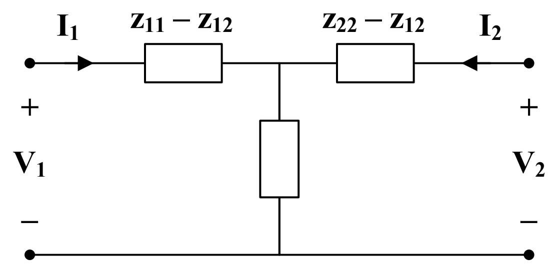
(b) This is a reciprocal network and **<u>the two-port look like the one shown in Figs. (c) and (d)</u>**.

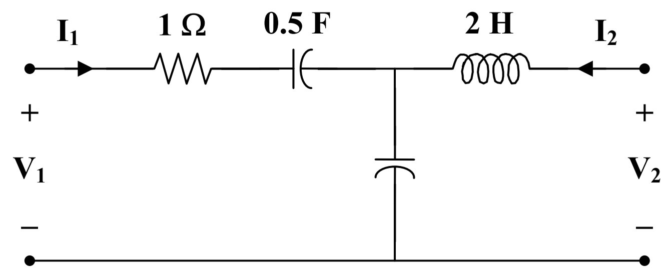


(c)

$$\mathbf{z}_{11} - \mathbf{z}_{12} = 1 + \frac{2}{s} = 1 + \frac{1}{0.5s}$$

$$\mathbf{z}_{22} - \mathbf{z}_{12} = 2s$$

$$\mathbf{z}_{12} = \frac{1}{s}$$



(d)

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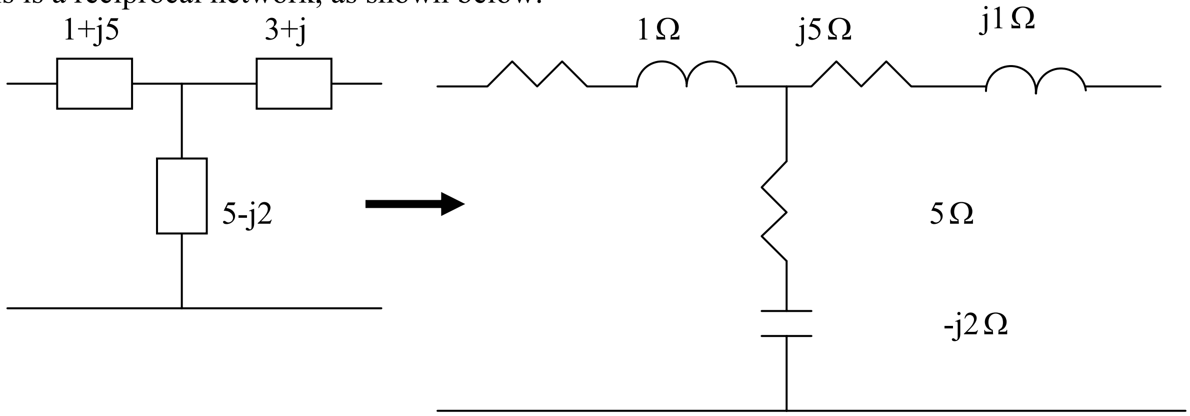
Chapter 19, Problem 11.

Determine a two-port network that is represented by the following *z* parameters:

$$[\mathbf{z}] = \begin{bmatrix} 6+j3 & 5-j2 \\ 5-j2 & 8-j \end{bmatrix} \Omega$$

Chapter 19, Solution 11.

This is a reciprocal network, as shown below.



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Chapter 19, Problem 12.

For the circuit shown in Fig. 19.73, let

$$[\mathbf{z}] = \begin{bmatrix} 10 & -6 \\ -4 & 12 \end{bmatrix}$$

Find I_1, I_2, V_1, and V_2.

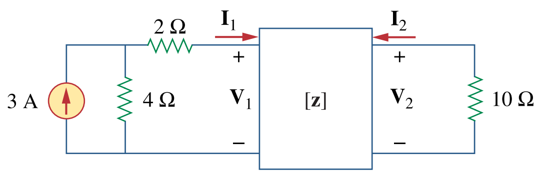

Figure 19.73

For Prob. 19.12.

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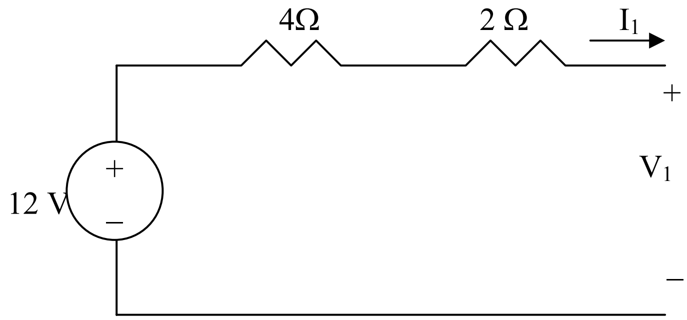
Chapter 19, Solution 12.

$$V_1 = 10I_1 - 6I_2 \qquad (1)$$
$$V_2 = -4I_2 + 12I_2 \qquad (2)$$
$$V_2 = -10I_2 \qquad (3)$$

If we convert the current source to a voltage source, that portion of the circuit becomes what is shown below.



$$-12 + 6I_1 + V_1 = 0 \longrightarrow V_1 = 12 - 6I_1 \qquad (4)$$

Substituting (3) and (4) into (1) and (2), we get

$$12 - 6I_1 = 10I_1 - 6I_2 \longrightarrow 12 = 16I_1 - 6I_2 \qquad (5)$$
$$-10I_2 = -4I_1 + 12I_2 \longrightarrow 0 = -4I_1 + 22I_2 \longrightarrow I_1 = 5.5I_2 \qquad (6)$$

From (5) and (6),

$$12 = 88I_2 - 6I_2 = 82I_2 \longrightarrow I_2 = \underline{0.1463\text{ A}}$$
$$I_1 = 5.5I_2 = \underline{0.8049\text{ A}}$$
$$V_2 = -10I_2 = \underline{-1.463\text{ V}}$$
$$V_1 = 12 - 6I_1 = \underline{7.1706\text{ V}}$$

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Chapter 19, Problem 13.

Determine the average power delivered to $Z_L = 5 + j4$ in the network of Fig. 19.74.
Note: The voltage is rms.

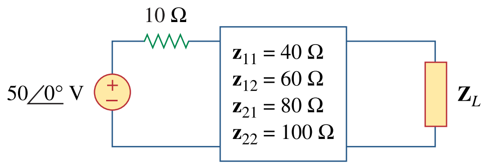
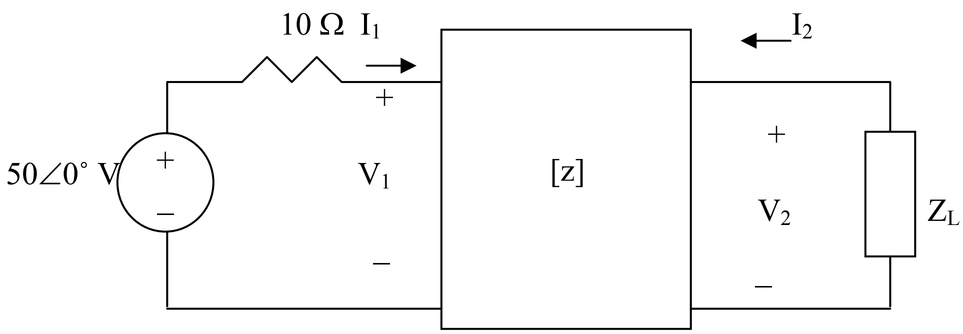


Figure 19.74

For Prob. 19.13.

Chapter 19, Solution 13.

Consider the circuit as shown below.



$$V_1 = 40I_1 + 60I_2 \qquad (1)$$
$$V_2 = 80I_1 + 100I_2 \qquad (2)$$
$$V_2 = -I_2 Z_L = -I_2(5 + j4) \qquad (3)$$
$$50 = V_1 + 10I_1 \longrightarrow V_1 = 50 - 10I_1 \qquad (4)$$

Substituting (4) in (1)

$$50 - 10I_1 = 40I_1 + 60I_2 \longrightarrow 5 = 5I_1 + 6I_2 \quad (5)$$

Substituting (3) into (2),

$$-I_2(5 + j4) = 80I_1 + 100I_2 \longrightarrow 0 = 80I_1 + (105 + j4)I_2 \qquad (6)$$

Solving (5) and (6) gives

$I_2 = -7.423 + j3.299$ A

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We can check the answer using MATLAB.

First we need to rewrite equations 1-4 as follows,

$$\begin{bmatrix} 1 & 0 & -40 & -60 \\ 0 & 1 & -80 & -100 \\ 0 & 1 & 0 & 5+j4 \\ 1 & 0 & 10 & 0 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ I_1 \\ I_2 \end{bmatrix} = A * X = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 50 \end{bmatrix} = U$$

```
>> A=[1,0,-40,-60;0,1,-80,-100;0,1,0,(5+4i);1,0,10,0]
A =
  1.0e+002 *
   0.0100          0           -0.4000         -0.6000
        0     0.0100           -0.8000         -1.0000
        0     0.0100                 0     0.0500 + 0.0400i
   0.0100          0            0.1000               0
>> U=[0;0;0;50]
U =
    0
    0
    0
   50
>> X=inv(A)*U
X =
 -49.0722 +39.5876i
  50.3093 +13.1959i
   9.9072 - 3.9588i
  -7.4227 + 3.2990i
```

$P = |I_2|^2 5 =$ **329.9 W**.

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Chapter 19, Problem 14.

For the two-port network shown in Fig. 19.75, show that at the output terminals,

$$\mathbf{Z}_{\text{Th}} = \mathbf{z}_{22} - \frac{\mathbf{z}_{12}\mathbf{z}_{21}}{\mathbf{z}_{11} + \mathbf{Z}_s}$$

and

$$\mathbf{V}_{\text{Th}} = \frac{\mathbf{z}_{21}}{\mathbf{z}_{11} + \mathbf{Z}_s}\mathbf{V}s$$

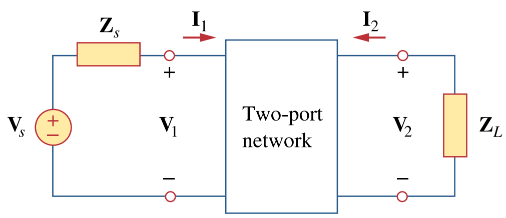
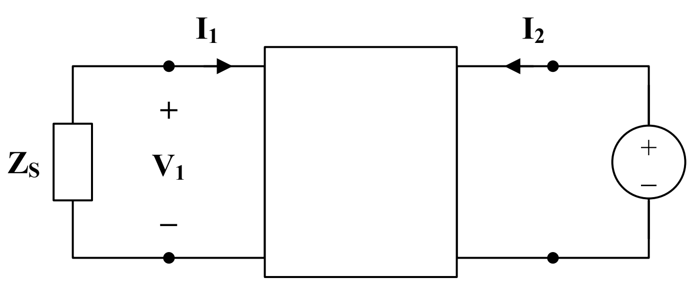


Figure 19.75

For Prob. 19.14 and 19.41.

Chapter 19, Solution 14.

To find $\mathbf{Z}_{\text{Th}}$, consider the circuit in Fig. (a).



(a)

$$\mathbf{V}_1 = \mathbf{z}_{11}\mathbf{I}_1 + \mathbf{z}_{12}\mathbf{I}_2 \qquad (1)$$

$$\mathbf{V}_2 = \mathbf{z}_{21}\mathbf{I}_1 + \mathbf{z}_{22}\mathbf{I}_2 \qquad (2)$$

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But

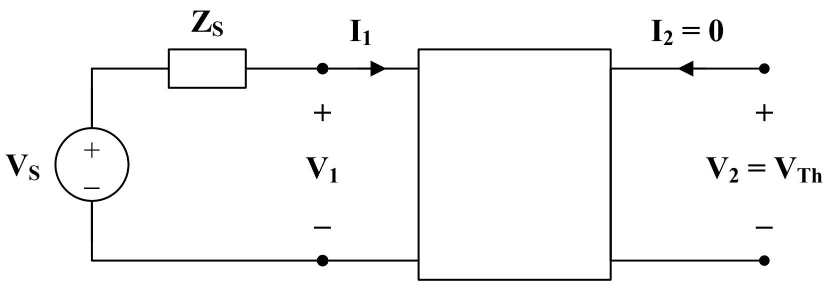
$$\mathbf{V}_2 = 1, \qquad \mathbf{V}_1 = -\mathbf{Z}_s \mathbf{I}_1$$

Hence, $\quad 0 = (\mathbf{z}_{11} + \mathbf{Z}_s)\mathbf{I}_1 + \mathbf{z}_{12}\mathbf{I}_2 \longrightarrow \mathbf{I}_1 = \dfrac{-\mathbf{z}_{12}}{\mathbf{z}_{11} + \mathbf{Z}_s}\mathbf{I}_2$

$$1 = \left(\frac{-\mathbf{z}_{21}\mathbf{z}_{12}}{\mathbf{z}_{11} + \mathbf{Z}_s} + \mathbf{z}_{22}\right)\mathbf{I}_2$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = \frac{1}{\mathbf{I}_2} = \underline{\mathbf{z}_{22} - \frac{\mathbf{z}_{21}\mathbf{z}_{12}}{\mathbf{z}_{11} + \mathbf{Z}_s}}$$

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



(b)

$$\mathbf{I}_2 = 0, \qquad \mathbf{V}_1 = \mathbf{V}_s - \mathbf{I}_1 \mathbf{Z}_s$$

Substituting these into (1) and (2),

$$\mathbf{V}_s - \mathbf{I}_1 \mathbf{Z}_s = \mathbf{z}_{11}\mathbf{I}_1 \longrightarrow \mathbf{I}_1 = \frac{\mathbf{V}_s}{\mathbf{z}_{11} + \mathbf{Z}_s}$$

$$\mathbf{V}_2 = \mathbf{z}_{21}\mathbf{I}_1 = \frac{\mathbf{z}_{21}\mathbf{V}_s}{\mathbf{z}_{11} + \mathbf{Z}_s}$$

$$\mathbf{V}_{Th} = \mathbf{V}_2 = \underline{\frac{\mathbf{z}_{21}\mathbf{V}_s}{\mathbf{z}_{11} + \mathbf{Z}_s}}$$

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Chapter 19, Problem 15.

For the two-port circuit in Fig. 19.76,

$$[\mathbf{z}] = \begin{bmatrix} 40 & 60 \\ 80 & 120 \end{bmatrix} \Omega$$

(a) Find $\mathbf{Z}_L$ for maximum power transfer to the load.
(b) Calculate the maximum power delivered to the load.

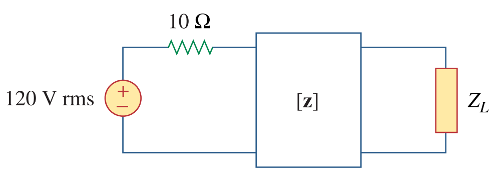

Figure 19.76

For Prob. 19.15.

Chapter 19, Solution 15.

(a) From Prob. 18.12,

$$Z_{Th} = z_{22} - \frac{z_{12}z_{21}}{z_{11} + Z_s} = 120 - \frac{80x60}{40 + 10} = 24$$

$$\underline{Z_L = Z_{Th} = 24\Omega}$$

(b) $$V_{Th} = \frac{z_{21}}{z_{11} + Z_s} V_s = \frac{80}{40 + 10}(120) = 192$$

$$P_{max} = \left(\frac{V_{Th}}{2R_{Th}}\right)^2 R_{Th} = 4^2 x24 = \underline{\mathbf{384W}}$$

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Chapter 19, Problem 16.

For the circuit in Fig. 19.77, at $\omega = 2$ rad/s, $\mathbf{z}_{11} = 10\Omega$, $\mathbf{z}_{12} = \mathbf{z}_{21} = j6\Omega$, $\mathbf{z}_{22} = 4\Omega$. Obtain the Thevenin equivalent circuit at terminals *a*-*b* and calculate v_o.

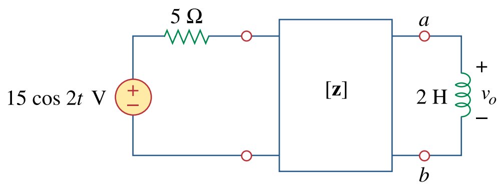

Figure 19.77

For Prob. 19.16.

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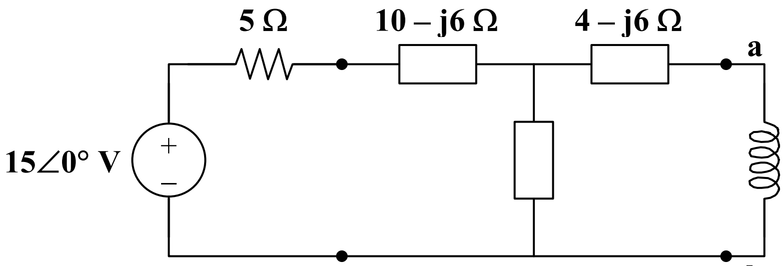
Chapter 19, Solution 16.

As a reciprocal two-port, the given circuit can be represented as shown in Fig. (a).



(a)

At terminals a-b,

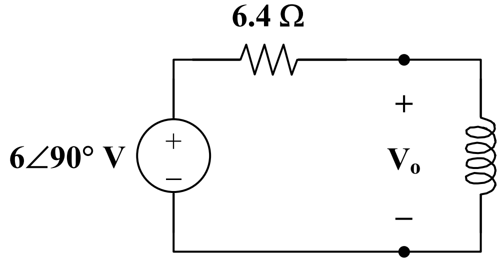
$$\mathbf{Z}_{Th} = (4 - j6) + j6 \,||\, (5 + 10 - j6)$$

$$\mathbf{Z}_{Th} = 4 - j6 + \frac{j6(15 - j6)}{15} = 4 - j6 + 2.4 + j6$$

$$\mathbf{Z}_{Th} = \underline{\mathbf{6.4\ \Omega}}$$

$$\mathbf{V}_{Th} = \frac{j6}{j6 + 5 + 10 - j6}(15\angle 0°) = j6 = \underline{\mathbf{6\angle 90°\ V}}$$

The Thevenin equivalent circuit is shown in Fig. (b).



(b)

From this,

$$\mathbf{V}_o = \frac{j4}{6.4 + j4}(j6) = 3.18\angle 148°$$

$$v_o(t) = \underline{\mathbf{3.18\cos(2t + 148°)\ V}}$$

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Chapter 19, Problem 17.

* Determine the *z* and *y* parameters for the circuit in Fig. 19.78.

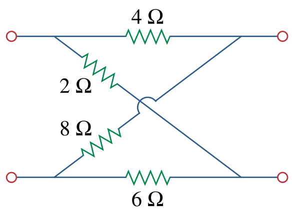


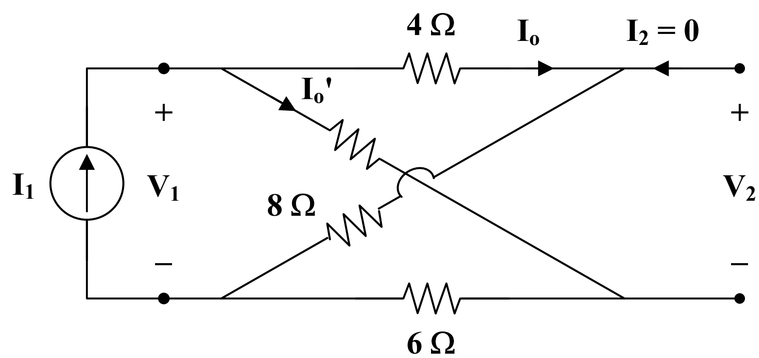
Figure 19.78

For Prob. 19.17.

* An asterisk indicates a challenging problem.

Chapter 19, Solution 17.

To obtain $\mathbf{z}_{11}$ and $\mathbf{z}_{21}$, consider the circuit in Fig. (a).



(a)

In this case, the 4-Ω and 8-Ω resistors are in series, since the same current, $\mathbf{I}_o$, passes through them. Similarly, the 2-Ω and 6-Ω resistors are in series, since the same current, $\mathbf{I}_o^{'}$, passes through them.

$$\mathbf{z}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = (4+8) \,||\, (2+6) = 12 \,||\, 8 = \frac{(12)(8)}{20} = 4.8\,\Omega$$

$$\mathbf{I}_o = \frac{8}{8+12}\mathbf{I}_1 = \frac{2}{5}\mathbf{I}_1 \qquad\qquad \mathbf{I}_o^{'} = \frac{3}{5}\mathbf{I}_1$$

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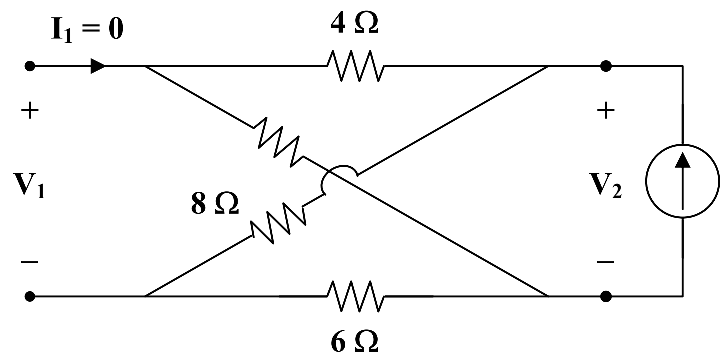
But $$-\mathbf{V}_2 - 4\mathbf{I}_o + 2\mathbf{I}_o^{'} = 0$$

$$\mathbf{V}_2 = -4\mathbf{I}_o + 2\mathbf{I}_o^{'} = \frac{-8}{5}\mathbf{I}_1 + \frac{6}{5}\mathbf{I}_1 = \frac{-2}{5}\mathbf{I}_1$$

$$\mathbf{z}_{21} = \frac{\mathbf{V}_2}{\mathbf{I}_1} = \frac{-2}{5} = -0.4\,\Omega$$

To get $\mathbf{z}_{22}$ and $\mathbf{z}_{12}$, consider the circuit in Fig. (b).



(b)

$$\mathbf{z}_{22} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = (4+2)\,||\,(8+6) = 6\,||\,14 = \frac{(6)(14)}{20} = 4.2\,\Omega$$

$$\mathbf{z}_{12} = \mathbf{z}_{21} = -0.4\,\Omega$$

Thus,

$$[\mathbf{z}] = \begin{bmatrix} \mathbf{4.8} & \mathbf{-0.4} \\ \mathbf{-0.4} & \mathbf{4.2} \end{bmatrix}\Omega$$

We may take advantage of Table 18.1 to get [**y**] from [**z**].

$$\Delta_z = (4.8)(4.2) - (0.4)^2 = 20$$

$$\mathbf{y}_{11} = \frac{\mathbf{z}_{22}}{\Delta_z} = \frac{4.2}{20} = 0.21 \qquad \mathbf{y}_{12} = \frac{-\mathbf{z}_{12}}{\Delta_z} = \frac{0.4}{20} = 0.02$$

$$\mathbf{y}_{21} = \frac{-\mathbf{z}_{21}}{\Delta_z} = \frac{0.4}{20} = 0.02 \qquad \mathbf{y}_{22} = \frac{\mathbf{z}_{11}}{\Delta_z} = \frac{4.8}{20} = 0.24$$

Thus,

$$[\mathbf{y}] = \begin{bmatrix} \mathbf{0.21} & \mathbf{0.02} \\ \mathbf{0.02} & \mathbf{0.24} \end{bmatrix}\mathbf{S}$$

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Chapter 19, Problem 18.

Calculate the *y* parameters for the two-port in Fig. 19.79.

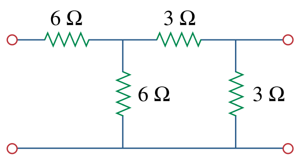
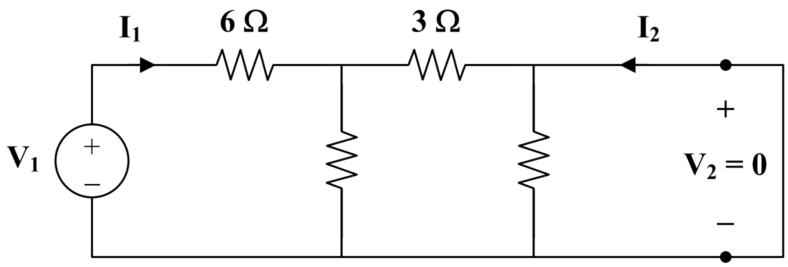


Figure 19.79

For Prob. 19.18 and 19.37.

Chapter 19, Solution 18.

To get $\mathbf{y}_{11}$ and $\mathbf{y}_{21}$, consider the circuit in Fig.(a).



(a)

$$\mathbf{V}_1 = (6 + 6 \,||\, 3)\mathbf{I}_1 = 8\mathbf{I}_1$$

$$\mathbf{y}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{1}{8}$$

$$\mathbf{I}_2 = \frac{-6}{6+3}\mathbf{I}_1 = \frac{-2}{3}\frac{\mathbf{V}_1}{8} = \frac{-\mathbf{V}_1}{12}$$

$$\mathbf{y}_{21} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = \frac{-1}{12}$$

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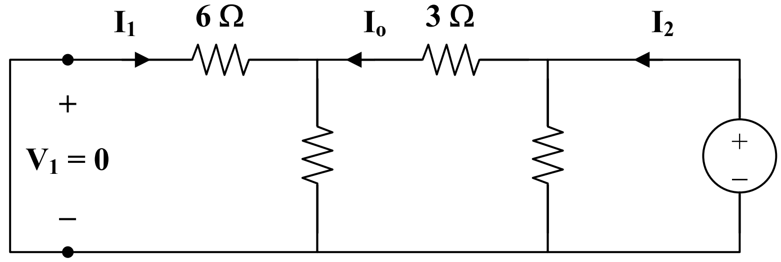
To get $\mathbf{y}_{22}$ and $\mathbf{y}_{12}$, consider the circuit in Fig.(b).



(b)

$$\mathbf{y}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{1}{3 \,\|\, (3 + 6 \,\|\, 6)} = \frac{1}{3 \,\|\, 6} = \frac{1}{2}$$

$$\mathbf{I}_1 = \frac{-\mathbf{I}_o}{2}, \qquad \mathbf{I}_o = \frac{3}{3+6}\mathbf{I}_2 = \frac{1}{3}\mathbf{I}_2$$

$$\mathbf{I}_1 = \frac{-\mathbf{I}_2}{6} = \left(\frac{-1}{6}\right)\left(\frac{1}{2}\mathbf{V}_2\right) = \frac{-\mathbf{V}_2}{12}$$

$$\mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{-1}{12} = \mathbf{y}_{21}$$

Thus,

$$[\mathbf{y}] = \begin{bmatrix} \frac{1}{8} & \frac{-1}{12} \\ \frac{-1}{12} & \frac{1}{2} \end{bmatrix} \mathbf{S}$$

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Chapter 19, Problem 19.

Find the *y* parameters of the two-port in Fig. 19.80 in terms of *s*.

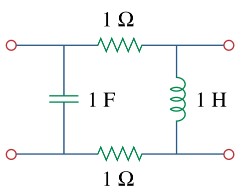
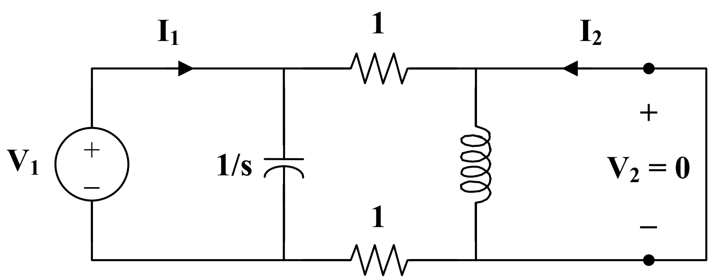


Figure 19.80
For Prob. 19.19.

Chapter 19, Solution 19.

Consider the circuit in Fig.(a) for calculating $\mathbf{y}_{11}$ and $\mathbf{y}_{21}$.



(a)

$$\mathbf{V}_1 = \left(\frac{1}{s} \parallel 2\right)\mathbf{I}_1 = \frac{2/s}{2+(1/s)}\mathbf{I}_1 = \frac{2}{2s+1}\mathbf{I}_1$$

$$\mathbf{y}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{2s+1}{2} = s + 0.5$$

$$\mathbf{I}_2 = \frac{(-1/s)}{(1/s)+2}\mathbf{I}_1 = \frac{-\mathbf{I}_1}{2s+1} = \frac{-\mathbf{V}_1}{2}$$

$$\mathbf{y}_{21} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = -0.5$$

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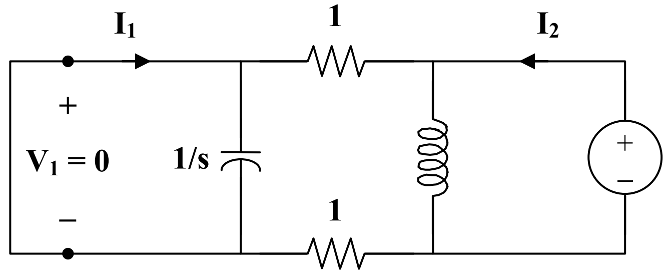
To get $\mathbf{y}_{22}$ and $\mathbf{y}_{12}$, refer to the circuit in Fig.(b).



(b)

$$\mathbf{V}_2 = (s \parallel 2)\mathbf{I}_2 = \frac{2s}{s+2}\mathbf{I}_2$$

$$\mathbf{y}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{s+2}{2s} = 0.5 + \frac{1}{s}$$

$$\mathbf{I}_1 = \frac{-s}{s+2}\mathbf{I}_2 = \frac{-s}{s+2} \cdot \frac{s+2}{2s}\mathbf{V}_2 = \frac{-\mathbf{V}_2}{2}$$

$$\mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = -0.5$$

Thus,

$$[\mathbf{y}] = \underline{\begin{bmatrix} \mathbf{s+0.5} & \mathbf{-0.5} \\ \mathbf{-0.5} & \mathbf{0.5+1/s} \end{bmatrix}\mathbf{S}}$$

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Chapter 19, Problem 20.

Find the y parameters for the circuit in Fig. 19.81.

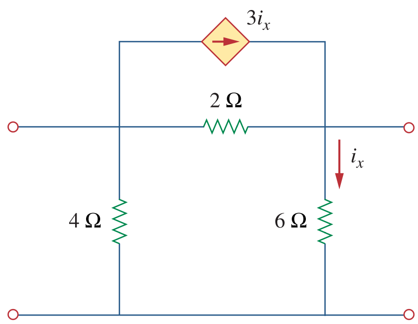
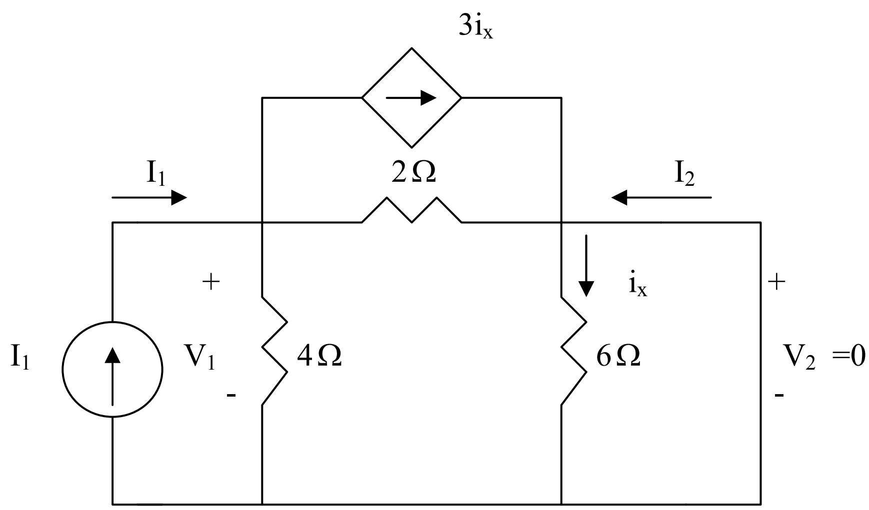


Figure 19.81

For Prob. 19.20.

Chapter 19, Solution 20.

To get y_{11} and y_{21}, consider the circuit below.



Since 6-ohm resistor is short-circuited, $i_x = 0$

$$V_1 = I_1(4//2) = \frac{8}{6} I_1 \quad \longrightarrow \quad y_{11} = \frac{I_1}{V_1} = 0.75$$

$$I_2 = -\frac{4}{4+2} I_1 = -\frac{2}{3}\left(\frac{6}{8} V_1\right) = -\frac{1}{2} V_1 \quad \longrightarrow \quad y_{21} = \frac{I_2}{V_1} = -0.5$$

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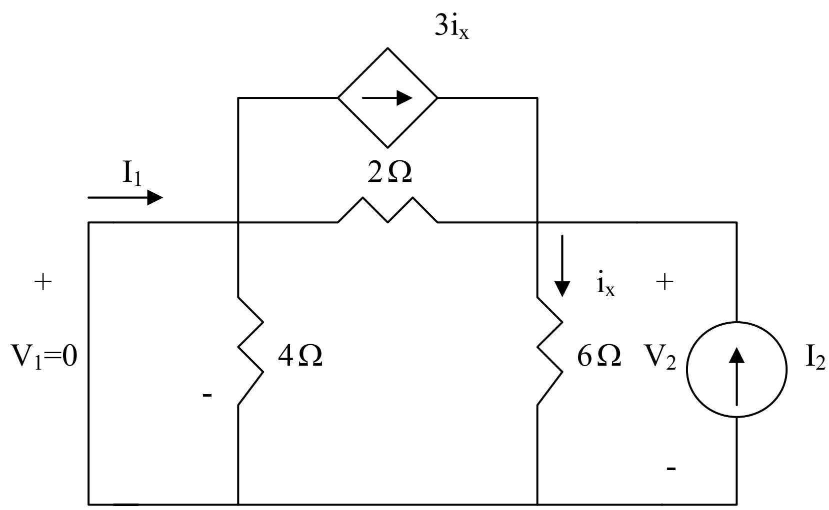
To get y_{22} and y_{12}, consider the circuit below.



$$i_x = \frac{V_2}{6}, \quad I_2 = i_x - 3i_x + \frac{V_2}{2} = \frac{V_2}{6} \quad \longrightarrow \quad y_{22} = \frac{I_2}{V_2} = \frac{1}{6} = 0.1667$$

$$I_1 = 3i_x - \frac{V_2}{2} = 0 \quad \longrightarrow \quad y_{12} = \frac{I_1}{V_2} = 0$$

Thus,

$$[y] = \underline{\begin{bmatrix} 0.75 & 0 \\ -0.5 & 0.1667 \end{bmatrix} S}$$

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Chapter 19, Problem 21.

Obtain the admittance parameter equivalent circuit of the two-port in Fig. 19.82.

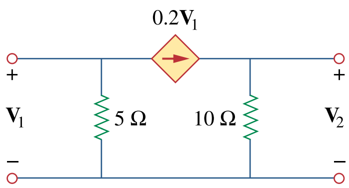
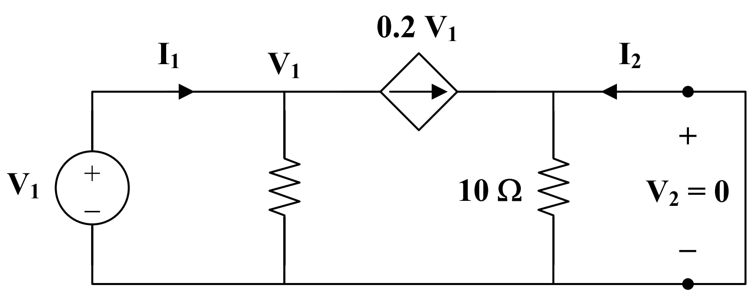


Figure 19.82
For Prob. 19.21.

Chapter 19, Solution 21.

To get $\mathbf{y}_{11}$ and $\mathbf{y}_{21}$, refer to Fig. (a).



(a)

At node 1,

$$\mathbf{I}_1 = \frac{\mathbf{V}_1}{5} + 0.2\mathbf{V}_1 = 0.4\mathbf{V}_1 \longrightarrow \mathbf{y}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = 0.4$$

$$\mathbf{I}_2 = -0.2\mathbf{V}_1 \longrightarrow \mathbf{y}_{21} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = -0.2$$

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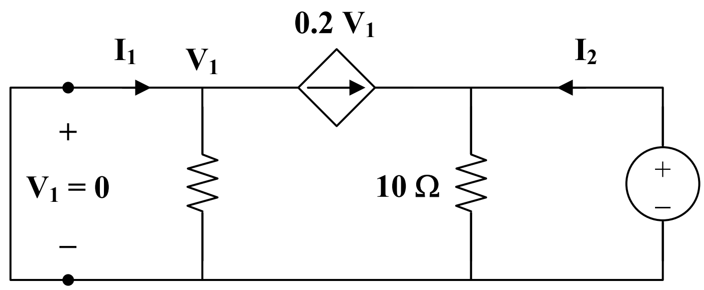
To get $\mathbf{y}_{22}$ and $\mathbf{y}_{12}$, refer to the circuit in Fig. (b).



(b)

Since $\mathbf{V}_1 = 0$, the dependent current source can be replaced with an open circuit.

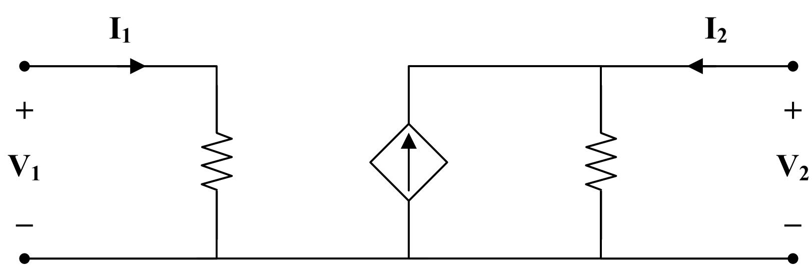
$$\mathbf{V}_2 = 10\mathbf{I}_2 \longrightarrow \mathbf{y}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{1}{10} = 0.1$$

$$\mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = 0$$

Thus,

$$[\mathbf{y}] = \begin{bmatrix} 0.4 & 0 \\ -0.2 & 0.1 \end{bmatrix} \text{S}$$

Consequently, **<u>the y parameter equivalent circuit is shown in Fig. (c)</u>**.



(c)

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Chapter 19, Problem 22.

Obtain the *y* parameters of the two-port network in Fig. 19.83.

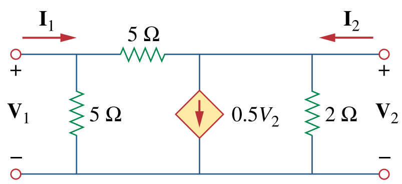

Figure 19.83

For Prob. 19.22.

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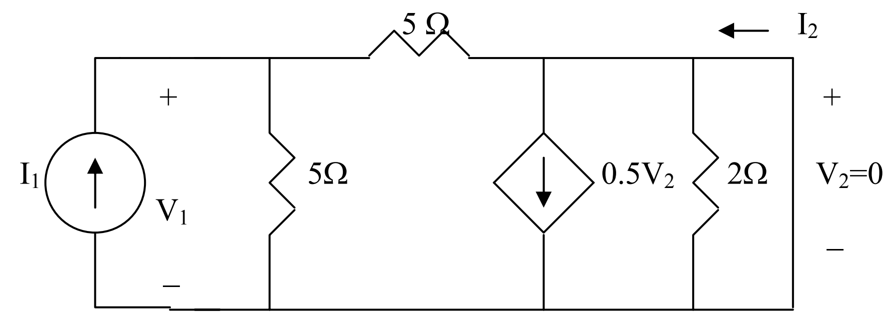
Chapter 19, Solution 22.

To obtain y_{11} and y_{21}, consider the circuit below.

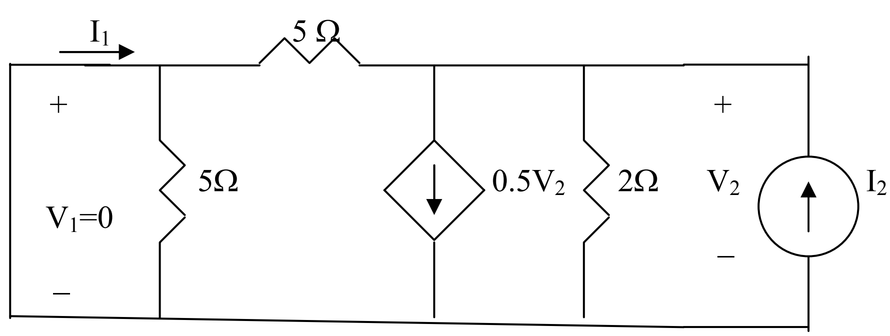


The 2-Ω resistor is short-circuited.

$$V_1 = 5\frac{I_1}{2} \longrightarrow y_{11} = \frac{I_1}{V_1} = \frac{2}{5} = 0.4$$

$$I_2 = \frac{1}{2}I_1 \longrightarrow y_{21} = \frac{I_2}{V_1} = \frac{\frac{1}{2}I_1}{2.5I_1} = 0.2$$

To obtain y_{12} and y_{22}, consider the circuit below.



At the top node, KCL gives

$$I_2 = 0.5V_2 + \frac{V_2}{2} + \frac{V_2}{5} = 1.2V_2 \longrightarrow y_{22} = \frac{I_2}{V_2} = 1.2$$

$$I_1 = -\frac{V_2}{5} = -0.2V_2 \longrightarrow y_{12} = \frac{I_1}{V_2} = -0.2$$

Hence,

$$[y] = \begin{bmatrix} 0.4 & -0.2 \\ 0.2 & 1.2 \end{bmatrix} \text{S}$$

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Chapter 19, Problem 23.

(a) Find the *y* parameters of the two-port in Fig. 19.84.
(b) Determine $\mathbf{V}_2(s)$ for $v_s = 2u(t)$V.

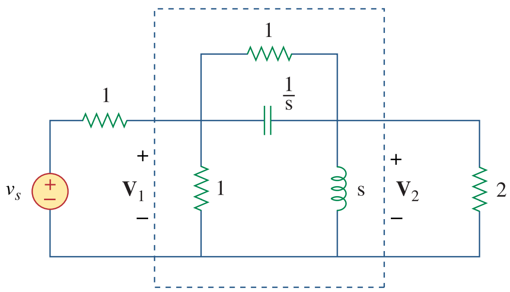

Figure 19.84
For Prob. 19.23.

Chapter 19, Solution 23.

(a)

$$-y_{12} = 1/\left(1 // \frac{1}{s}\right) = 1 + s \quad \longrightarrow \quad y_{12} = -(s+1)$$

$$y_{11} + y_{12} = 1 \quad \longrightarrow \quad y_{11} = 1 - y_{12} = 1 + s + 1 = s + 2$$

$$y_{22} + y_{12} = s \quad \longrightarrow \quad y_{22} = \frac{1}{s} - y_{12} = \frac{1}{s} + s + 1 = \frac{s^{2s} + s + 1}{s}$$

$$\underline{[y] = \begin{bmatrix} s+2 & -(s+1) \\ -(s+1) & \dfrac{s^2 + s + 1}{s} \end{bmatrix}}$$

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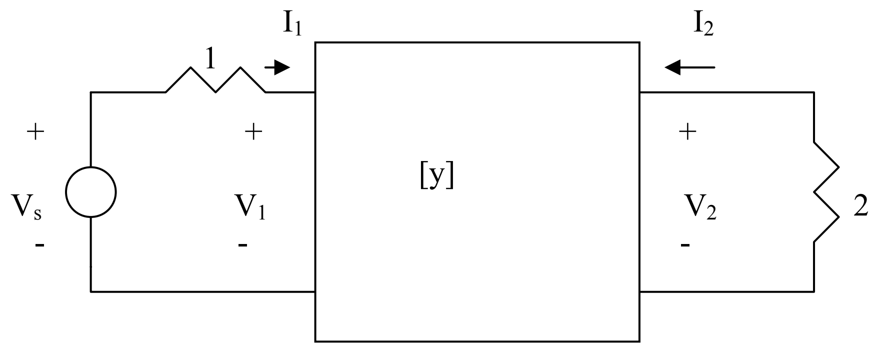
(b) Consider the network below.



$$V_s = I_1 + V_1 \text{ or } V_s - V_1 = I_1 \qquad (1)$$

$$V_2 = -2I_2 \qquad (2)$$

$$I_1 = y_{11}V_1 + y_{12}V_2 \qquad (3)$$

$$I_2 = y_{21}V_1 + y_{22}V_2 \qquad (4)$$

From (1) and (3)

$$V_s - V_1 = y_{11}V_1 + y_{12}V_2 \longrightarrow V_s = (1+y_{11})V_1 + y_{12}V_2 \qquad (5)$$

From (2) and (4),

$$-0.5V_2 = y_{21}V_1 + y_{22}V_2 \longrightarrow V_1 = -\frac{1}{y_{21}}(0.5+y_{22})V_2 \qquad (6)$$

Substituting (6) into (5),

$$V_s = -\frac{(1+y_{11})(0.5+y_{22})}{y_{21}}V_2 + y_{12}V_2$$

$$= \frac{2}{s} \longrightarrow V_2 = \frac{2/s}{\left[y_{12} - \frac{1}{y_{21}}(1+y_{11})(0.5+y_{22})\right]}$$

$$V_2 = \frac{2/s}{-(s+1) + \frac{1}{s+1}(1+s+2)\left(\frac{1}{2} + \frac{s^2+s+1}{s}\right)} = \frac{0.8(s+1)}{(s^2+1.8s+1.2)}$$

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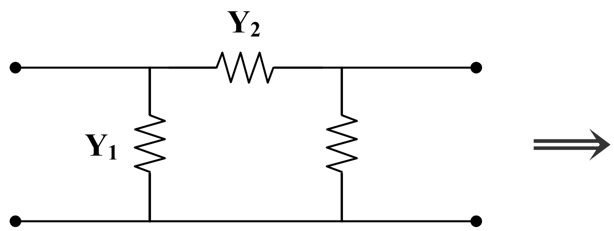
Chapter 19, Problem 24.

Find the resistive circuit that represents these *y* parameters:

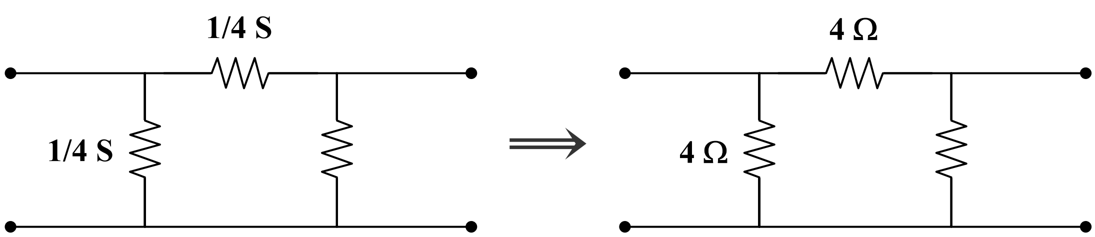
$$[\mathbf{y}] = \begin{bmatrix} \frac{1}{2} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{3}{8} \end{bmatrix}$$

Chapter 19, Solution 24.

Since this is a reciprocal network, **a Π network is appropriate, as shown below**.



(a)



(b) **(c)**

$$\mathbf{Y}_1 = \mathbf{y}_{11} + \mathbf{y}_{12} = \frac{1}{2} - \frac{1}{4} = \frac{1}{4}\,\text{S},$$ $\mathbf{Z}_1 = \mathbf{4\,\Omega}$

$$\mathbf{Y}_2 = -\mathbf{y}_{12} = \frac{1}{4}\,\text{S},$$ $\mathbf{Z}_2 = \mathbf{4\,\Omega}$

$$\mathbf{Y}_3 = \mathbf{y}_{22} + \mathbf{y}_{21} = \frac{3}{8} - \frac{1}{4} = \frac{1}{8}\,\text{S},$$ $\mathbf{Z}_3 = \mathbf{8\,\Omega}$

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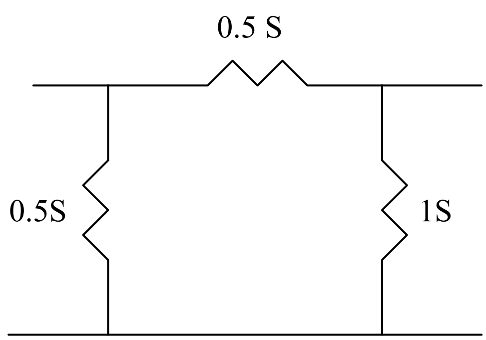
Chapter 19, Problem 25.

Draw the two-port network that has the following *y* parameters:

$$[\mathbf{y}] = \begin{bmatrix} 1 & -0.5 \\ -0.5 & 1.5 \end{bmatrix} \text{S}$$

Chapter 19, Solution 25.

This is a reciprocal network and is shown below.



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Chapter 19, Problem 26.

Calculate [**y**] for the two-port in Fig. 19.85.

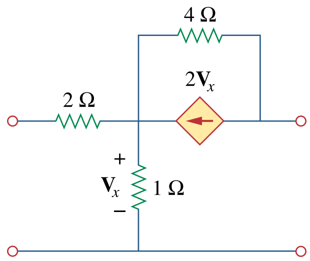
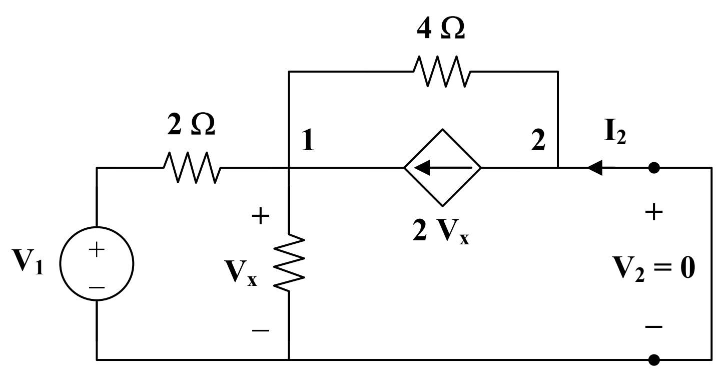


Figure 19.85

For Prob. 19.26.

Chapter 19, Solution 26.

To get $\mathbf{y}_{11}$ and $\mathbf{y}_{21}$, consider the circuit in Fig. (a).



(a)

At node 1,

$$\frac{\mathbf{V}_1 - \mathbf{V}_x}{2} + 2\mathbf{V}_x = \frac{\mathbf{V}_x}{1} + \frac{\mathbf{V}_x}{4} \longrightarrow 2\mathbf{V}_1 = \text{-}\mathbf{V}_x \qquad (1)$$

But $\mathbf{I}_1 = \dfrac{\mathbf{V}_1 - \mathbf{V}_x}{2} = \dfrac{\mathbf{V}_1 + 2\mathbf{V}_1}{2} = 1.5\mathbf{V}_1 \longrightarrow \mathbf{y}_{11} = \dfrac{\mathbf{I}_1}{\mathbf{V}_1} = 1.5$

Also, $\mathbf{I}_2 + \dfrac{\mathbf{V}_x}{4} = 2\mathbf{V}_x \longrightarrow \mathbf{I}_2 = 1.75\mathbf{V}_x = \text{-}3.5\mathbf{V}_1$

$$\mathbf{y}_{21} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = \text{-}3.5$$

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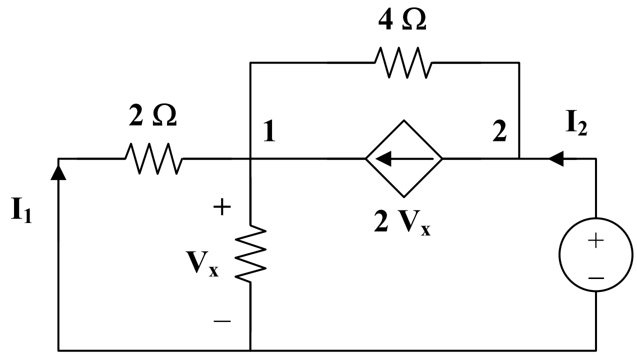
To get $\mathbf{y}_{22}$ and $\mathbf{y}_{12}$, consider the circuit in Fig.(b).



(b)

At node 2,

$$\mathbf{I}_2 = 2\mathbf{V}_x + \frac{\mathbf{V}_2 - \mathbf{V}_x}{4} \qquad (2)$$

At node 1,

$$2\mathbf{V}_x + \frac{\mathbf{V}_2 - \mathbf{V}_x}{4} = \frac{\mathbf{V}_x}{2} + \frac{\mathbf{V}_x}{1} = \frac{3}{2}\mathbf{V}_x \longrightarrow \mathbf{V}_2 = \text{-}\mathbf{V}_x \qquad (3)$$

Substituting (3) into (2) gives

$$\mathbf{I}_2 = 2\mathbf{V}_x - \frac{1}{2}\mathbf{V}_x = 1.5\mathbf{V}_x = \text{-}1.5\mathbf{V}_2$$

$$\mathbf{y}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \text{-}1.5$$

$$\mathbf{I}_1 = \frac{\text{-}\mathbf{V}_x}{2} = \frac{\mathbf{V}_2}{2} \longrightarrow \mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = 0.5$$

Thus,

$$[\mathbf{y}] = \underline{\begin{bmatrix} \mathbf{1.5} & \mathbf{0.5} \\ \mathbf{-3.5} & \mathbf{-1.5} \end{bmatrix}\mathbf{S}}$$

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Chapter 19, Problem 27.

Find the *y* parameters for the circuit in Fig. 19.86.

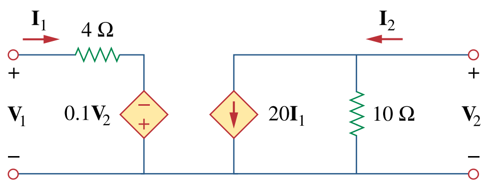
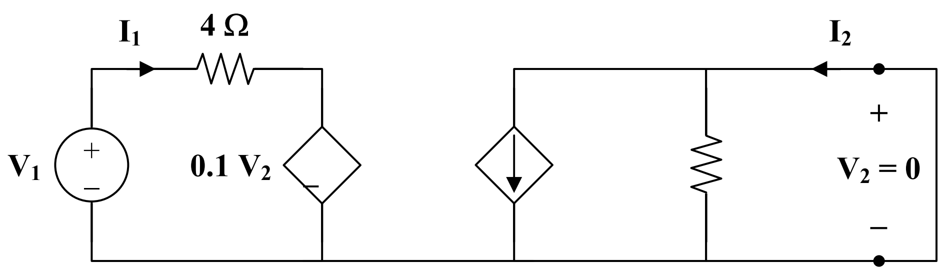


Figure 19.86

For Prob. 19.27.

Chapter 19, Solution 27.

Consider the circuit in Fig. (a).



(a)

$$V_1 = 4I_1 \longrightarrow y_{11} = \frac{I_1}{V_1} = \frac{I_1}{4I_1} = 0.25$$

$$I_2 = 20I_1 = 5V_1 \longrightarrow y_{21} = \frac{I_2}{V_1} = 5$$

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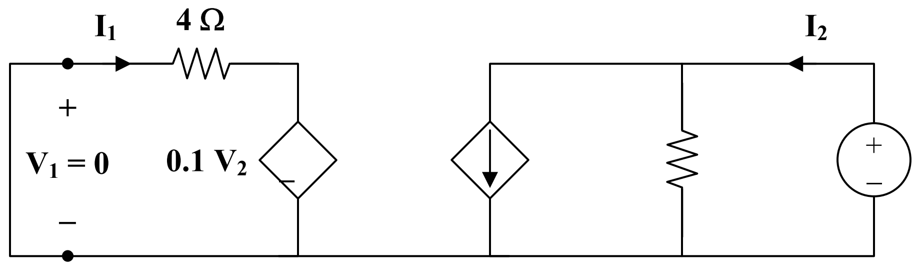
Consider the circuit in Fig. (b).



(b)

$$4\mathbf{I}_1 = 0.1\mathbf{V}_2 \longrightarrow \mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{0.1}{4} = 0.025$$

$$\mathbf{I}_2 = 20\mathbf{I}_1 + \frac{\mathbf{V}_2}{10} = 0.5\mathbf{V}_2 + 0.1\mathbf{V}_2 = 0.6\mathbf{V}_2 \longrightarrow \mathbf{y}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = 0.6$$

Thus,

$$[\mathbf{y}] = \underline{\begin{bmatrix} \mathbf{0.25} & \mathbf{0.025} \\ \mathbf{5} & \mathbf{0.6} \end{bmatrix} \mathbf{S}}$$

Alternatively, from the given circuit,

$$\mathbf{V}_1 = 4\mathbf{I}_1 - 0.1\mathbf{V}_2$$
$$\mathbf{I}_2 = 20\mathbf{I}_1 + 0.1\mathbf{V}_2$$

Comparing these with the equations for the h parameters show that

$$\mathbf{h}_{11} = 4, \qquad \mathbf{h}_{12} = \text{-}0.1, \qquad \mathbf{h}_{21} = 20, \qquad \mathbf{h}_{22} = 0.1$$

Using Table 18.1,

$$\mathbf{y}_{11} = \frac{1}{\mathbf{h}_{11}} = \frac{1}{4} = 0.25, \qquad \mathbf{y}_{12} = \frac{\text{-}\mathbf{h}_{12}}{\mathbf{h}_{11}} = \frac{0.1}{4} = 0.025$$

$$\mathbf{y}_{21} = \frac{\mathbf{h}_{21}}{\mathbf{h}_{11}} = \frac{20}{4} = 5, \qquad \mathbf{y}_{22} = \frac{\Delta_h}{\mathbf{h}_{11}} = \frac{0.4 + 2}{4} = 0.6$$

as above.

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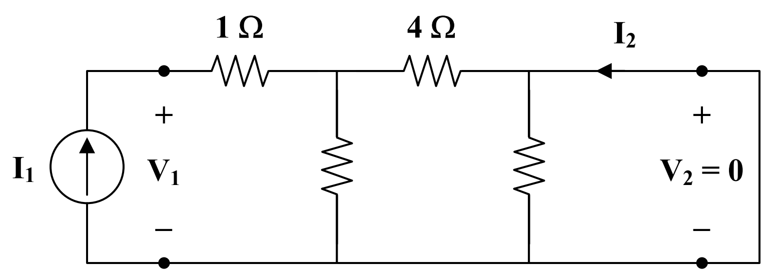
Chapter 19, Problem 28.

In the circuit of Fig. 19.65, the input port is connected to a 1-A dc current source. Calculate the power dissipated by the $2\text{-}\Omega$ resistor by using the *y* parameters. Confirm your result by direct circuit analysis.

Chapter 19, Solution 28.

We obtain $\mathbf{y}_{11}$ and $\mathbf{y}_{21}$ by considering the circuit in Fig.(a).



(a)

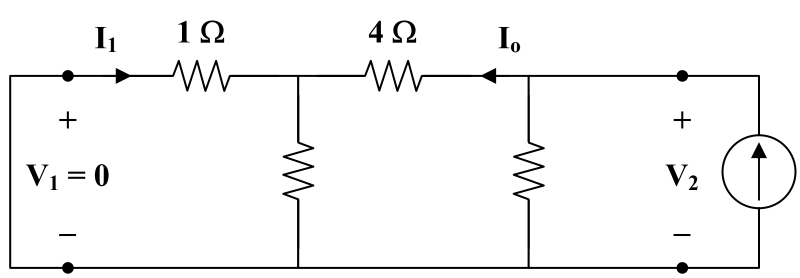
$$\mathbf{Z}_{in} = 1 + 6 \,||\, 4 = 3.4$$

$$\mathbf{y}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{1}{\mathbf{Z}_{in}} = 0.2941$$

$$\mathbf{I}_2 = \frac{-6}{10}\mathbf{I}_1 = \left(\frac{-6}{10}\right)\left(\frac{\mathbf{V}_1}{3.4}\right) = \frac{-6}{34}\mathbf{V}_1$$

$$\mathbf{y}_{21} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = \frac{-6}{34} = -0.1765$$

To get $\mathbf{y}_{22}$ and $\mathbf{y}_{12}$, consider the circuit in Fig. (b).



(b)

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$$\frac{1}{\mathbf{y}_{22}} = 2 \,||\, (4 + 6 \,||\, 1) = 2 \,||\, \left(4 + \frac{6}{7}\right) = \frac{(2)(34/7)}{2 + (34/7)} = \frac{34}{24} = \frac{V_2}{I_2}$$

$$\mathbf{y}_{22} = \frac{24}{34} = 0.7059$$

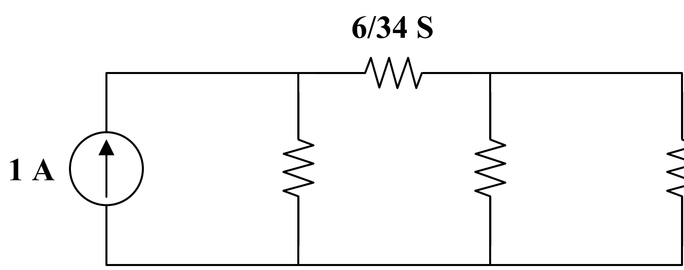
$$\mathbf{I}_1 = \frac{-6}{7}\mathbf{I}_o \qquad \mathbf{I}_o = \frac{2}{2 + (34/7)}\mathbf{I}_2 = \frac{14}{48}\mathbf{I}_2 = \frac{7}{34}\mathbf{V}_2$$

$$\mathbf{I}_1 = \frac{-6}{34}\mathbf{V}_2 \longrightarrow \mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{-6}{34} = -0.1765$$

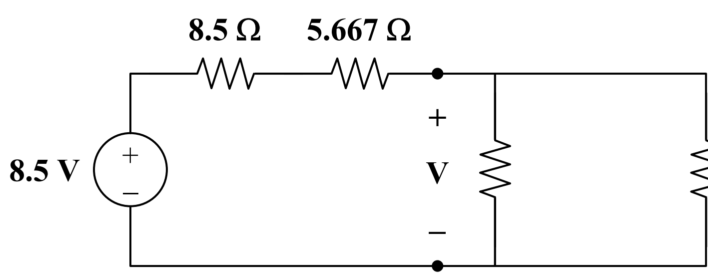
Thus,

$$[\mathbf{y}] = \begin{bmatrix} 0.2941 & -0.1765 \\ -0.1765 & 0.7059 \end{bmatrix} \mathrm{S}$$

The equivalent circuit is shown in Fig. (c). After transforming the current source to a voltage source, we have the circuit in Fig. (d).



(c)



(d)

$$V = \frac{(2 \,||\, 1.889)(8.5)}{2 \,||\, 1.889 + 8.5 + 5.667} = \frac{(0.9714)(8.5)}{0.9714 + 14.167} = 0.5454$$

$$P = \frac{V^2}{R} = \frac{(0.5454)^2}{2} = \underline{\mathbf{0.1487\ W}}$$

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Chapter 19, Problem 29.

In the bridge circuit of Fig. 19.87, $I_1 = 10$ A and $I_2 = -4$ A

(a) Find V_1 and V_2 using *y* parameters.
(b) -Confirm the results in part (a) by direct circuit analysis.

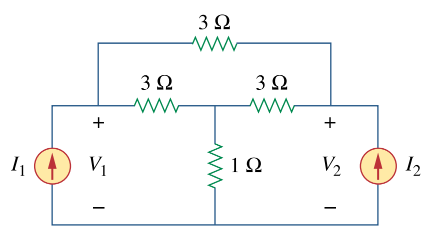
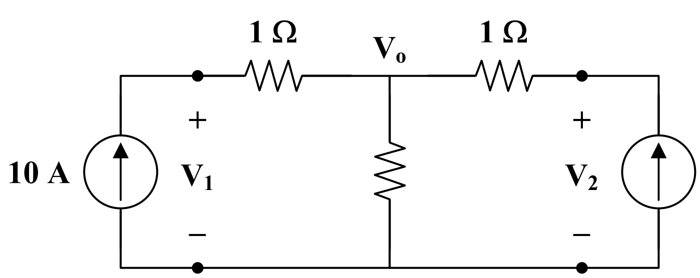


Figure 19.87
For Prob. 19.29.

Chapter 19, Solution 29.

(a) Transforming the Δ subnetwork to Y gives the circuit in Fig. (a).



(a)

It is easy to get the z parameters

$$\mathbf{z}_{12} = \mathbf{z}_{21} = 2, \quad \mathbf{z}_{11} = 1 + 2 = 3, \quad \mathbf{z}_{22} = 3$$

$$\Delta_z = \mathbf{z}_{11}\mathbf{z}_{22} - \mathbf{z}_{12}\mathbf{z}_{21} = 9 - 4 = 5$$

$$\mathbf{y}_{11} = \frac{\mathbf{z}_{22}}{\Delta_z} = \frac{3}{5} = \mathbf{y}_{22}, \qquad \mathbf{y}_{12} = \mathbf{y}_{21} = \frac{-\mathbf{z}_{12}}{\Delta_z} = \frac{-2}{5}$$

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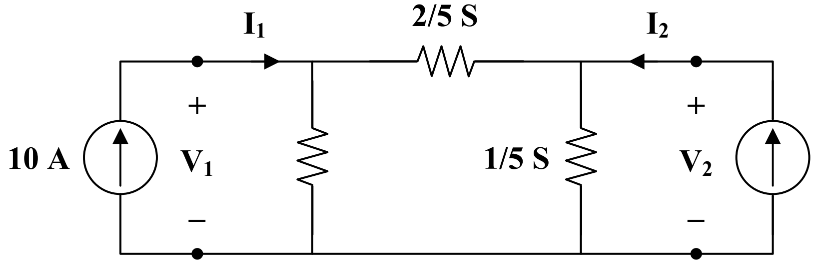
Thus, the equivalent circuit is as shown in Fig. (b).



(b)

$$\mathbf{I}_1 = 10 = \frac{3}{5}\mathbf{V}_1 - \frac{2}{5}\mathbf{V}_2 \longrightarrow 50 = 3\mathbf{V}_1 - 2\mathbf{V}_2 \qquad (1)$$

$$\mathbf{I}_2 = -4 = \frac{-2}{5}\mathbf{V}_1 + \frac{3}{5}\mathbf{V}_2 \longrightarrow -20 = -2\mathbf{V}_1 + 3\mathbf{V}_2$$

$$10 = \mathbf{V}_1 - 1.5\mathbf{V}_2 \longrightarrow \mathbf{V}_1 = 10 + 1.5\mathbf{V}_2 \qquad (2)$$

Substituting (2) into (1),

$$50 = 30 + 4.5\mathbf{V}_2 - 2\mathbf{V}_2 \longrightarrow \mathbf{V}_2 = \underline{\mathbf{8\ V}}$$

$$\mathbf{V}_1 = 10 + 1.5\mathbf{V}_2 = \underline{\mathbf{22\ V}}$$

(b) For direct circuit analysis, consider the circuit in Fig. (a).

For the main non-reference node,

$$10 - 4 = \frac{\mathbf{V}_o}{2} \longrightarrow \mathbf{V}_o = 12$$

$$10 = \frac{\mathbf{V}_1 - \mathbf{V}_o}{1} \longrightarrow \mathbf{V}_1 = 10 + \mathbf{V}_o = \underline{\mathbf{22\ V}}$$

$$-4 = \frac{\mathbf{V}_2 - \mathbf{V}_o}{1} \longrightarrow \mathbf{V}_2 = \mathbf{V}_o - 4 = \underline{\mathbf{8\ V}}$$

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Chapter 19, Problem 30.

Find the *h* parameters for the networks in Fig. 19.88.

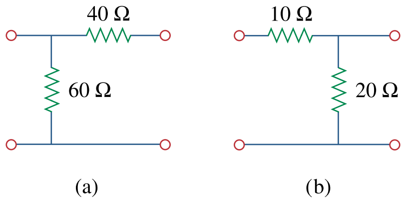

Figure 19.88

For Prob. 19.30.

Chapter 19, Solution 30.

(a) Convert to z parameters; then, convert to h parameters using Table 18.1.

$$\mathbf{z}_{11} = \mathbf{z}_{12} = \mathbf{z}_{21} = 60\,\Omega, \qquad \mathbf{z}_{22} = 100\,\Omega$$

$$\Delta_z = \mathbf{z}_{11}\mathbf{z}_{22} - \mathbf{z}_{12}\mathbf{z}_{21} = 6000 - 3600 = 2400$$

$$\mathbf{h}_{11} = \frac{\Delta_z}{\mathbf{z}_{22}} = \frac{2400}{100} = 24, \qquad \mathbf{h}_{12} = \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}} = \frac{60}{100} = 0.6$$

$$\mathbf{h}_{21} = \frac{-\mathbf{z}_{21}}{\mathbf{z}_{22}} = -0.6, \qquad \mathbf{h}_{22} = \frac{1}{\mathbf{z}_{22}} = 0.01$$

Thus,

$$[\mathbf{h}] = \underline{\begin{bmatrix} \mathbf{24\,\Omega} & \mathbf{0.6} \\ \mathbf{-0.6} & \mathbf{0.01\,S} \end{bmatrix}}$$

(b) Similarly,

$$\mathbf{z}_{11} = 30\,\Omega \qquad \mathbf{z}_{12} = \mathbf{z}_{21} = \mathbf{z}_{22} = 20\,\Omega$$

$$\Delta_z = 600 - 400 = 200$$

$$\mathbf{h}_{11} = \frac{200}{20} = 10 \qquad \mathbf{h}_{12} = \frac{20}{20} = 1$$

$$\mathbf{h}_{21} = -1 \qquad \mathbf{h}_{22} = \frac{1}{20} = 0.05$$

Thus,

$$[\mathbf{h}] = \underline{\begin{bmatrix} \mathbf{10\,\Omega} & \mathbf{1} \\ \mathbf{-1} & \mathbf{0.05\,S} \end{bmatrix}}$$

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Chapter 19, Problem 31.

Determine the hybrid parameters for the network in Fig. 19.89.

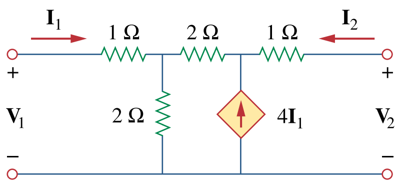
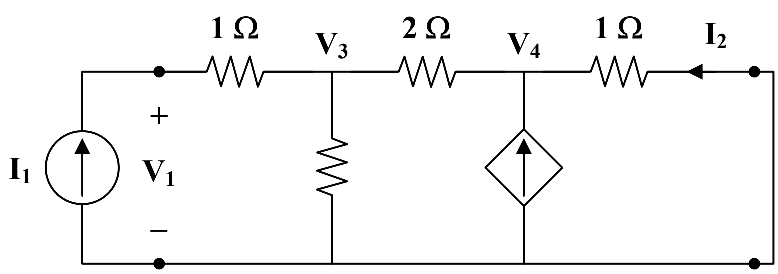


Figure 19.89

For Prob. 19.31.

Chapter 19, Solution 31.

We get $\mathbf{h}_{11}$ and $\mathbf{h}_{21}$ by considering the circuit in Fig. (a).



(a)

At node 1,

$$\mathbf{I}_1 = \frac{\mathbf{V}_3}{2} + \frac{\mathbf{V}_3 - \mathbf{V}_4}{2} \longrightarrow 2\mathbf{I}_1 = 2\mathbf{V}_3 - \mathbf{V}_4 \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_3 - \mathbf{V}_4}{2} + 4\mathbf{I}_1 = \frac{\mathbf{V}_4}{1}$$

$$8\mathbf{I}_1 = -\mathbf{V}_3 + 3\mathbf{V}_4 \longrightarrow 16\mathbf{I}_1 = -2\mathbf{V}_3 + 6\mathbf{V}_4 \qquad (2)$$

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Adding (1) and (2),

$$18\mathbf{I}_1 = 5\mathbf{V}_4 \longrightarrow \mathbf{V}_4 = 3.6\mathbf{I}_1$$

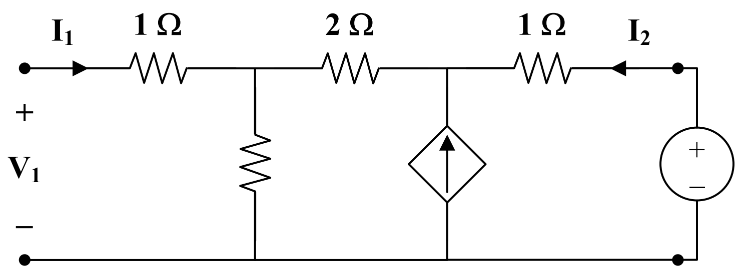
$$\mathbf{V}_3 = 3\mathbf{V}_4 - 8\mathbf{I}_1 = 2.8\mathbf{I}_1$$

$$\mathbf{V}_1 = \mathbf{V}_3 + \mathbf{I}_1 = 3.8\mathbf{I}_1$$

$$\mathbf{h}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = 3.8\,\Omega$$

$$\mathbf{I}_2 = \frac{-\mathbf{V}_4}{1} = -3.6\mathbf{I}_1 \longrightarrow \mathbf{h}_{21} = \frac{\mathbf{I}_2}{\mathbf{I}_1} = -3.6$$

To get $\mathbf{h}_{22}$ and $\mathbf{h}_{12}$, refer to the circuit in Fig. (b). The dependent current source can be replaced by an open circuit since $4\mathbf{I}_1 = 0$.



(b)

$$\mathbf{V}_1 = \frac{2}{2+2+1}\mathbf{V}_2 = \frac{2}{5}\mathbf{V}_2 \longrightarrow \mathbf{h}_{12} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = 0.4$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_2}{2+2+1} = \frac{\mathbf{V}_2}{5} \longrightarrow \mathbf{h}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{1}{5} = 0.2\text{ S}$$

Thus,

$$[\mathbf{h}] = \underline{\begin{bmatrix} \mathbf{38\,\Omega} & \mathbf{0.4} \\ \mathbf{-3.6} & \mathbf{0.2\ S} \end{bmatrix}}$$

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Chapter 19, Problem 32.

Find the *h* and *g* parameters of the two-port network in Fig. 19.90 as functions of *s*.

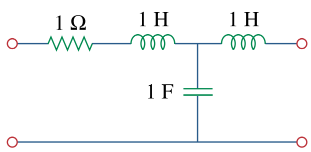

Figure 19.90
For Prob. 19.32.

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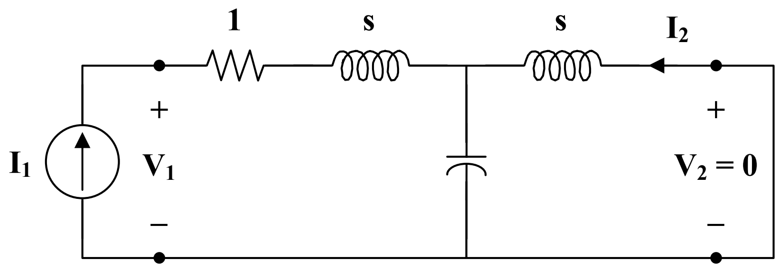
Chapter 19, Solution 32.

(a) We obtain $\mathbf{h}_{11}$ and $\mathbf{h}_{21}$ by referring to the circuit in Fig. (a).



(a)

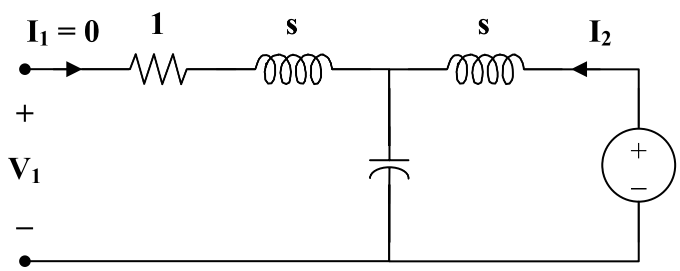
$$\mathbf{V}_1 = \left(1 + s + s \,||\, \frac{1}{s}\right)\mathbf{I}_1 = \left(1 + s + \frac{s}{s^2+1}\right)\mathbf{I}_1$$

$$\mathbf{h}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = s + 1 + \frac{s}{s^2+1}$$

By current division,

$$\mathbf{I}_2 = \frac{-1/s}{s+1/s}\mathbf{I}_1 = \frac{-\mathbf{I}_1}{s+1} \longrightarrow \mathbf{h}_{21} = \frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{-1}{s^2+1}$$

To get $\mathbf{h}_{22}$ and $\mathbf{h}_{12}$, refer to Fig. (b).



(b)

$$\mathbf{V}_1 = \frac{1/s}{s+1/s}\mathbf{V}_2 = \frac{\mathbf{V}_2}{s^2+1} \longrightarrow \mathbf{h}_{12} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = \frac{1}{s^2+1}$$

$$\mathbf{V}_2 = \left(s + \frac{1}{s}\right)\mathbf{I}_2 \longrightarrow \mathbf{h}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{1}{s+1/s} = \frac{s}{s^2+1}$$

Thus,

$$[\mathbf{h}] = \begin{bmatrix} \mathbf{s+1+\frac{s}{s^2+1}} & \mathbf{\frac{1}{s^2+1}} \\ \mathbf{\frac{-1}{s^2+1}} & \mathbf{\frac{s}{s^2+1}} \end{bmatrix}$$

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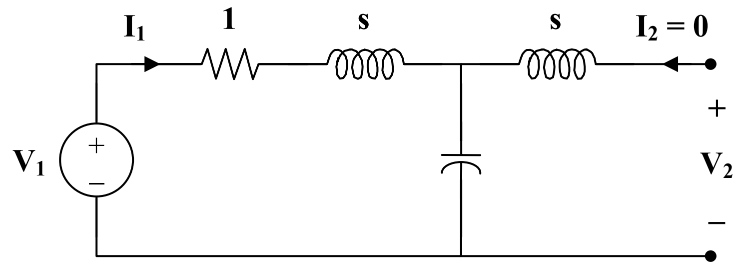
(b) To get $\mathbf{g}_{11}$ and $\mathbf{g}_{21}$, refer to Fig. (c).

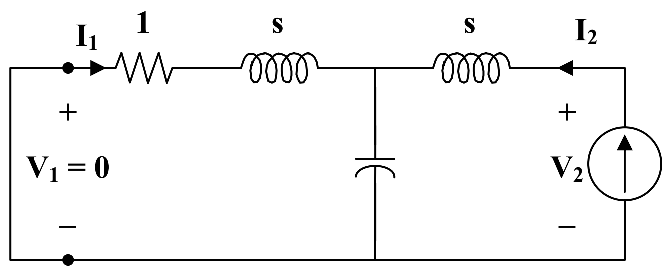


(c)

$$\mathbf{V}_1 = \left(1 + s + \frac{1}{s}\right)\mathbf{I}_1 \longrightarrow \mathbf{g}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{1}{1 + s + 1/s} = \frac{s}{s^2 + s + 1}$$

$$\mathbf{V}_2 = \frac{1/s}{1 + s + 1/s}\mathbf{V}_1 = \frac{\mathbf{V}_1}{s^2 + s + 1} \longrightarrow \mathbf{g}_{21} = \frac{\mathbf{V}_2}{\mathbf{V}_1} = \frac{1}{s^2 + s + 1}$$

To get $\mathbf{g}_{22}$ and $\mathbf{g}_{12}$, refer to Fig. (d).



(d)

$$\mathbf{V}_2 = \left(s + \frac{1}{s} \parallel (s+1)\right)\mathbf{I}_2 = \left(s + \frac{(s+1)/s}{1 + s + 1/s}\right)\mathbf{I}_2$$

$$\mathbf{g}_{22} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = s + \frac{s+1}{s^2 + s + 1}$$

$$\mathbf{I}_1 = \frac{-1/s}{1 + s + 1/s}\mathbf{I}_2 = \frac{-\mathbf{I}_2}{s^2 + s + 1} \longrightarrow \mathbf{g}_{12} = \frac{\mathbf{I}_1}{\mathbf{I}_2} = \frac{-1}{s^2 + s + 1}$$

Thus,

$$[\mathbf{g}] = \begin{bmatrix} \dfrac{\mathbf{s}}{\mathbf{s}^2 + \mathbf{s} + \mathbf{1}} & \dfrac{\mathbf{-1}}{\mathbf{s}^2 + \mathbf{s} + \mathbf{1}} \\ \dfrac{\mathbf{1}}{\mathbf{s}^2 + \mathbf{s} + \mathbf{1}} & \mathbf{s} + \dfrac{\mathbf{s} + \mathbf{1}}{\mathbf{s}^2 + \mathbf{s} + \mathbf{1}} \end{bmatrix}$$

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Chapter 19, Problem 33.

Obtain the *h* parameters for the two-port of Fig. 19.91.

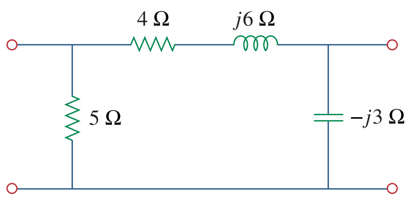

Figure 19.91

For Prob. 19.33.

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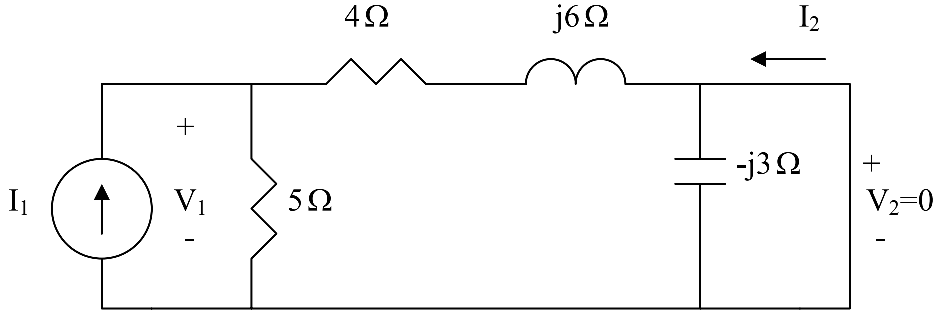
Chapter 19, Solution 33.

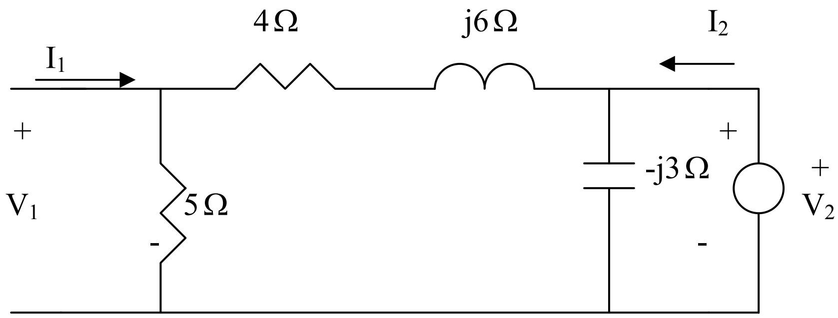
To get h_{11} and h_{21}, consider the circuit below.



$$V_1 = 5//(4+j6)I_1 = \frac{5(4+j6)I_1}{9+j6} \qquad h_{11} = \frac{V_1}{I_1} = 3.0769 + j1.2821$$

Also, $I_2 = -\frac{5}{9+j6}I_1 \longrightarrow h_{21} = \frac{I_2}{I_1} = -0.3846 + j0.2564$

To get h_{22} and h_{12}, consider the circuit below.



$$V_1 = \frac{5}{9+j6}V_2 \longrightarrow h_{12} = \frac{V_1}{V_2} = \frac{5}{9+j6} = 0.3846 - j0.2564$$

$$V_2 = -j3//(9+j6)I_2 \longrightarrow h_{22} = \frac{I_2}{V_2} = \frac{1}{-j3//(9+j6)} = \frac{9+j3}{-j3(9+j6)}$$
$$= 0.0769 + j0.2821$$

Thus,

$$[h] = \begin{bmatrix} 3.077 + j1.2821 & 0.3846 - j0.2564 \\ -0.3846 + j0.2564 & 0.0769 + j0.2821 \end{bmatrix}$$

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Chapter 19, Problem 34.

Obtain the *h* and *g* parameters of the two-port in Fig. 19.92.

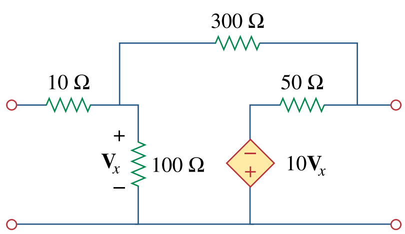
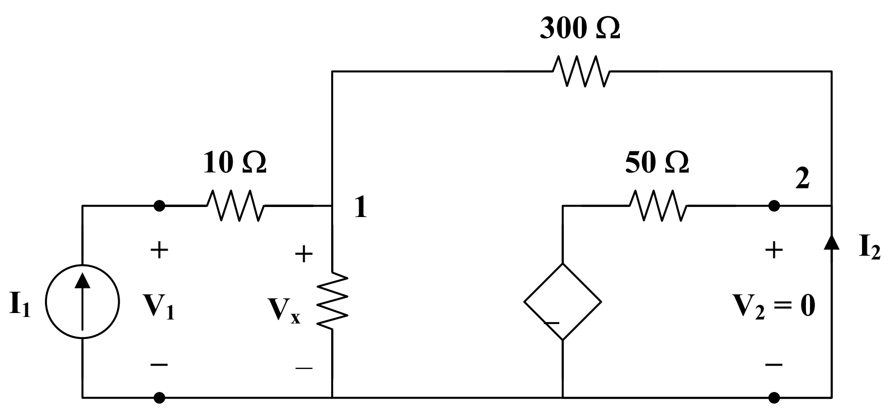


Figure 19.92

For Prob. 19.34.

Chapter 19, Solution 34.

Refer to Fig. (a) to get $\mathbf{h}_{11}$ and $\mathbf{h}_{21}$.



(a)

At node 1,

$$\mathbf{I}_1 = \frac{\mathbf{V}_x}{100} + \frac{\mathbf{V}_x - 0}{300} \longrightarrow 300\mathbf{I}_1 = 4\mathbf{V}_x \qquad (1)$$

$$\mathbf{V}_x = \frac{300}{4}\mathbf{I}_1 = 75\mathbf{I}_1$$

But $\qquad \mathbf{V}_1 = 10\mathbf{I}_1 + \mathbf{V}_x = 85\mathbf{I}_1 \longrightarrow \mathbf{h}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = 85\,\Omega$

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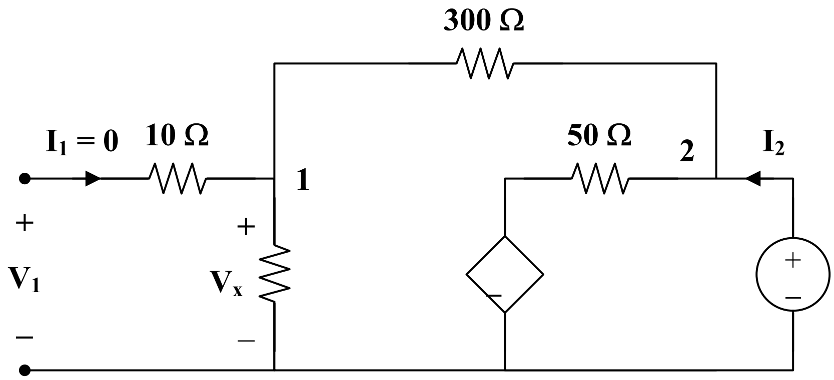
At node 2,

$$\mathbf{I}_2 = \frac{0+10\mathbf{V}_x}{50} - \frac{\mathbf{V}_x}{300} = \frac{\mathbf{V}_x}{5} - \frac{\mathbf{V}_x}{300} = \frac{75}{5}\mathbf{I}_1 - \frac{75}{300}\mathbf{I}_1 = 14.75\mathbf{I}_1$$

$$\mathbf{h}_{21} = \frac{\mathbf{I}_2}{\mathbf{I}_1} = 14.75$$

To get $\mathbf{h}_{22}$ and $\mathbf{h}_{12}$, refer to Fig. (b).



(b)

At node 2,

$$\mathbf{I}_2 = \frac{\mathbf{V}_2}{400} + \frac{\mathbf{V}_2 + 10\mathbf{V}_x}{50} \longrightarrow 400\mathbf{I}_2 = 9\mathbf{V}_2 + 80\mathbf{V}_x$$

But $$\mathbf{V}_x = \frac{100}{400}\mathbf{V}_2 = \frac{\mathbf{V}_2}{4}$$

Hence, $$400\mathbf{I}_2 = 9\mathbf{V}_2 + 20\mathbf{V}_2 = 29\mathbf{V}_2$$

$$\mathbf{h}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{29}{400} = 0.0725\text{ S}$$

$$\mathbf{V}_1 = \mathbf{V}_x = \frac{\mathbf{V}_2}{4} \longrightarrow \mathbf{h}_{12} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = \frac{1}{4} = 0.25$$

$$[\mathbf{h}] = \underline{\begin{bmatrix} \mathbf{85\,\Omega} & \mathbf{0.25} \\ \mathbf{14.75} & \mathbf{0.0725\ S} \end{bmatrix}}$$

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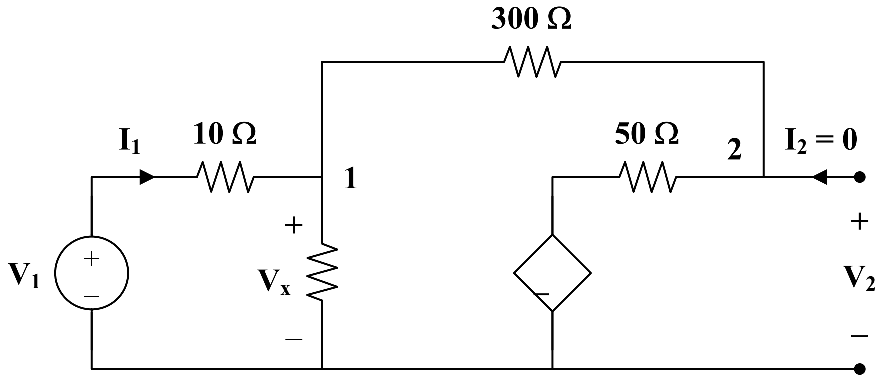
To get $\mathbf{g}_{11}$ and $\mathbf{g}_{21}$, refer to Fig. (c).



(c)

At node 1,

$$\mathbf{I}_1 = \frac{\mathbf{V}_x}{100} + \frac{\mathbf{V}_x + 10\mathbf{V}_x}{350} \longrightarrow 350\mathbf{I}_1 = 14.5\mathbf{V}_x \qquad (2)$$

But $\mathbf{I}_1 = \frac{\mathbf{V}_1 - \mathbf{V}_x}{10} \longrightarrow 10\mathbf{I}_1 = \mathbf{V}_1 - \mathbf{V}_x$

or $\mathbf{V}_x = \mathbf{V}_1 - 10\mathbf{I}_1 \qquad (3)$

Substituting (3) into (2) gives

$$350\mathbf{I}_1 = 14.5\mathbf{V}_1 - 145\mathbf{I}_1 \longrightarrow 495\mathbf{I}_1 = 14.5\mathbf{V}_1$$

$$\mathbf{g}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{14.5}{495} = 0.02929 \text{ S}$$

At node 2,

$$\mathbf{V}_2 = (50)\left(\frac{11}{350}\mathbf{V}_x\right) - 10\mathbf{V}_x = \text{-}8.4286\mathbf{V}_x$$

$$= \text{-}8.4286\mathbf{V}_1 + 84.286\mathbf{I}_1 = \text{-}8.4286\mathbf{V}_1 + (84.286)\left(\frac{14.5}{495}\right)\mathbf{V}_1$$

$$\mathbf{V}_2 = \text{-}5.96\mathbf{V}_1 \longrightarrow \mathbf{g}_{21} = \frac{\mathbf{V}_2}{\mathbf{V}_1} = \text{-}5.96$$

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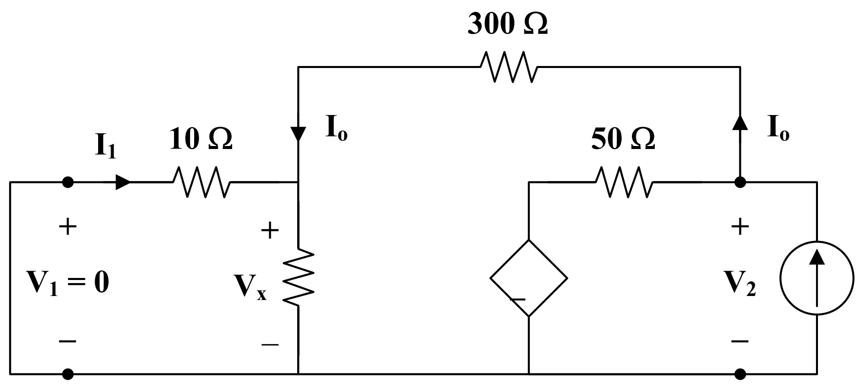
To get $\mathbf{g}_{22}$ and $\mathbf{g}_{12}$, refer to Fig. (d).



(d)

$$10 \,||\, 100 = 9.091$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_2 + 10\mathbf{V}_x}{50} + \frac{\mathbf{V}_2}{300 + 9.091}$$

$$309.091\mathbf{I}_2 = 7.1818\mathbf{V}_2 + 61.818\mathbf{V}_x \qquad (4)$$

But $$\mathbf{V}_x = \frac{9.091}{309.091}\mathbf{V}_2 = 0.02941\mathbf{V}_2 \qquad (5)$$

Substituting (5) into (4) gives

$$309.091\mathbf{I}_2 = 9\mathbf{V}_2$$

$$\mathbf{g}_{22} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = 34.34\,\Omega$$

$$\mathbf{I}_o = \frac{\mathbf{V}_2}{309.091} = \frac{34.34\mathbf{I}_2}{309.091}$$

$$\mathbf{I}_1 = \frac{-100}{110}\mathbf{I}_o = \frac{-34.34\mathbf{I}_2}{(1.1)(309.091)}$$

$$\mathbf{g}_{12} = \frac{\mathbf{I}_1}{\mathbf{I}_2} = -0.101$$

Thus,

$$[\mathbf{g}] = \begin{bmatrix} \mathbf{0.02929\,S} & \mathbf{-0.101} \\ \mathbf{-5.96} & \mathbf{34.34\,\Omega} \end{bmatrix}$$

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Chapter 19, Problem 35.

Determine the *h* parameters for the network in Fig. 19.93.

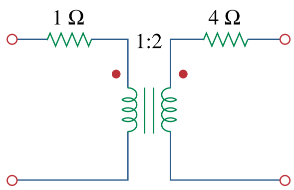

Figure 19.93
For Prob. 19.35.

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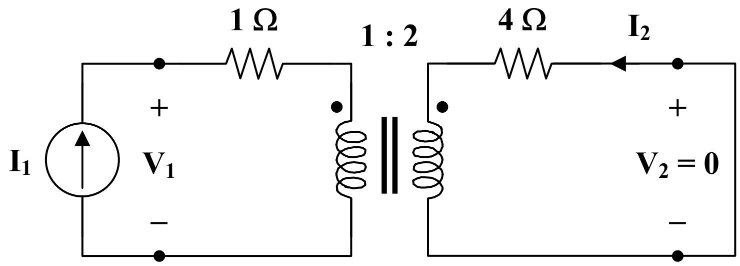
Chapter 19, Solution 35.

To get $\mathbf{h}_{11}$ and $\mathbf{h}_{21}$ consider the circuit in Fig. (a).



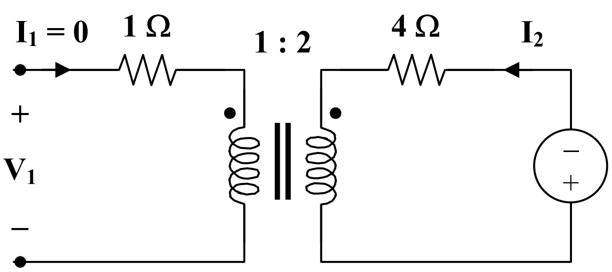
(a)

$$Z_R = \frac{4}{n^2} = \frac{4}{4} = 1$$

$$\mathbf{V}_1 = (1+1)\mathbf{I}_1 = 2\mathbf{I}_1 \longrightarrow \mathbf{h}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = 2\,\Omega$$

$$\frac{\mathbf{I}_1}{\mathbf{I}_2} = \frac{-N_2}{N_1} = -2 \longrightarrow \mathbf{h}_{21} = \frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{-1}{2} = -0.5$$

To get $\mathbf{h}_{22}$ and $\mathbf{h}_{12}$, refer to Fig. (b).



(b)

Since $\mathbf{I}_1 = 0$, $\mathbf{I}_2 = 0$.

Hence, $\mathbf{h}_{22} = 0$.

At the terminals of the transformer, we have $\mathbf{V}_1$ and $\mathbf{V}_2$ which are related as

$$\frac{\mathbf{V}_2}{\mathbf{V}_1} = \frac{N_2}{N_1} = n = 2 \longrightarrow \mathbf{h}_{12} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = \frac{1}{2} = 0.5$$

Thus,

$$[\mathbf{h}] = \begin{bmatrix} \mathbf{2\,\Omega} & \mathbf{0.5} \\ \mathbf{-0.5} & \mathbf{0} \end{bmatrix}$$

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Chapter 19, Problem 36.

For the two-port in Fig. 19.94,

$$[\mathbf{h}]\begin{bmatrix} 16\Omega & 3 \\ -2 & 0.01\text{S} \end{bmatrix}$$

Find:

(a) V_2 / V_1 (b) I_2 / I_1

(c) I_1 / V_1 (d) V_2 / I_1

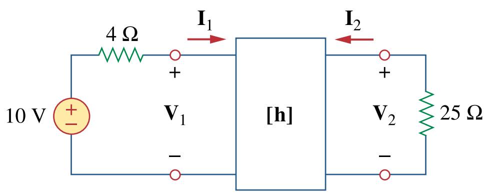

Figure 19.94

For Prob. 19.36.

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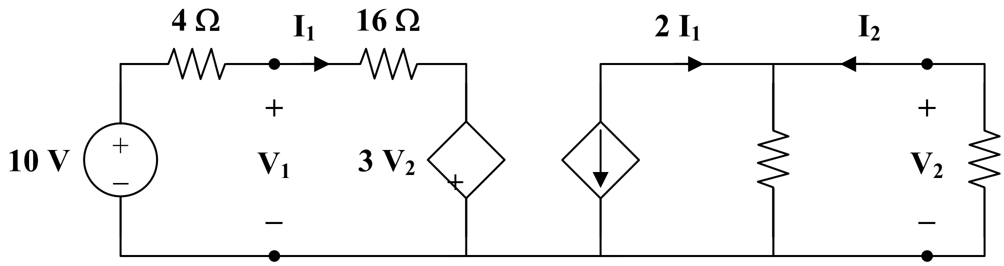
Chapter 19, Solution 36.

We replace the two-port by its equivalent circuit as shown below.



$$100 \parallel 25 = 20\,\Omega$$

$$\mathbf{V}_2 = (20)(2\mathbf{I}_1) = 40\mathbf{I}_1 \qquad (1)$$

$$-10 + 20\mathbf{I}_1 + 3\mathbf{V}_2 = 0$$
$$10 = 20\mathbf{I}_1 + (3)(40\mathbf{I}_1) = 140\mathbf{I}_1$$

$$\mathbf{I}_1 = \frac{1}{14}, \qquad \mathbf{V}_2 = \frac{40}{14}$$

$$\mathbf{V}_1 = 16\mathbf{I}_1 + 3\mathbf{V}_2 = \frac{136}{14}$$

$$\mathbf{I}_2 = \left(\frac{100}{125}\right)(2\mathbf{I}_1) = \frac{-8}{70}$$

(a) $\frac{\mathbf{V}_2}{\mathbf{V}_1} = \frac{40}{136} = \underline{\mathbf{0.2941}}$

(b) $\frac{\mathbf{I}_2}{\mathbf{I}_1} = \underline{\mathbf{-1.6}}$

(c) $\frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{1}{136} = \underline{\mathbf{7.353 \times 10^{-3}\ S}}$

(d) $\frac{\mathbf{V}_2}{\mathbf{I}_1} = \frac{40}{1} = \underline{\mathbf{40\,\Omega}}$

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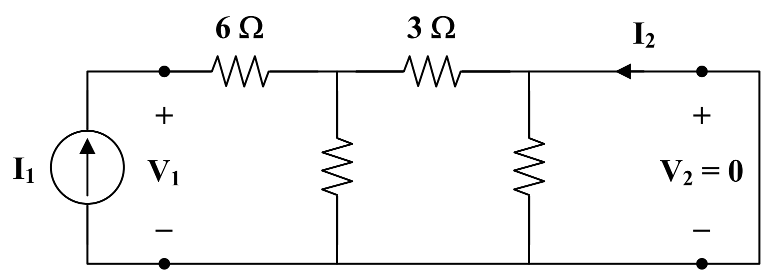
Chapter 19, Problem 37.

The input port of the circuit in Fig. 19.79 is connected to a 10-V dc voltage source while the output port is terminated by a $5\text{-}\Omega$ resistor. Find the voltage across the $5\text{-}\Omega$ resistor by using *h* parameters of the circuit. Confirm your result by using direct circuit analysis.

Chapter 19, Solution 37.

(a) We first obtain the h parameters. To get $\mathbf{h}_{11}$ and $\mathbf{h}_{21}$ refer to Fig. (a).



(a)

$3 \| 6 = 2$

$$\mathbf{V}_1 = (6+2)\mathbf{I}_1 = 8\mathbf{I}_1 \longrightarrow \mathbf{h}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = 8\,\Omega$$

$$\mathbf{I}_2 = \frac{-6}{3+6}\mathbf{I}_1 = \frac{-2}{3}\mathbf{I}_1 \longrightarrow \mathbf{h}_{21} = \frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{-2}{3}$$

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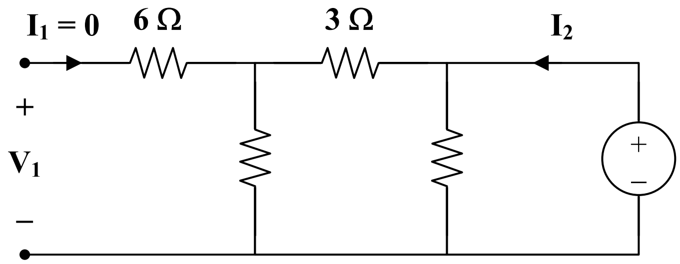
To get $\mathbf{h}_{22}$ and $\mathbf{h}_{12}$, refer to the circuit in Fig. (b).



(b)

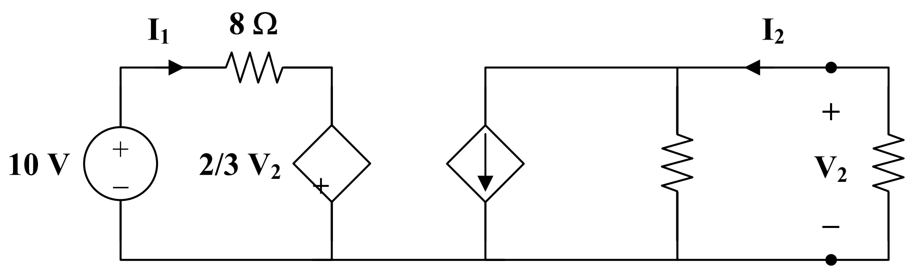
$$3 \,\|\, 9 = \frac{9}{4}$$

$$\mathbf{V}_2 = \frac{9}{4}\mathbf{I}_2 \longrightarrow \mathbf{h}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{4}{9}$$

$$\mathbf{V}_1 = \frac{6}{6+3}\mathbf{V}_2 = \frac{2}{3}\mathbf{V}_2 \longrightarrow \mathbf{h}_{12} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = \frac{2}{3}$$

$$[\mathbf{h}] = \begin{bmatrix} 8\,\Omega & \frac{2}{3} \\ \frac{-2}{3} & \frac{4}{9}\,\text{S} \end{bmatrix}$$

The equivalent circuit of the given circuit is shown in Fig. (c).



(c)

$$8\mathbf{I}_1 + \frac{2}{3}\mathbf{V}_2 = 10 \qquad (1)$$

$$\mathbf{V}_2 = \frac{2}{3}\mathbf{I}_1\left(5 \,\|\, \frac{9}{4}\right) = \frac{2}{3}\mathbf{I}_1\left(\frac{45}{29}\right) = \frac{30}{29}\mathbf{I}_1$$

$$\mathbf{I}_1 = \frac{29}{30}\mathbf{V}_2 \qquad (2)$$

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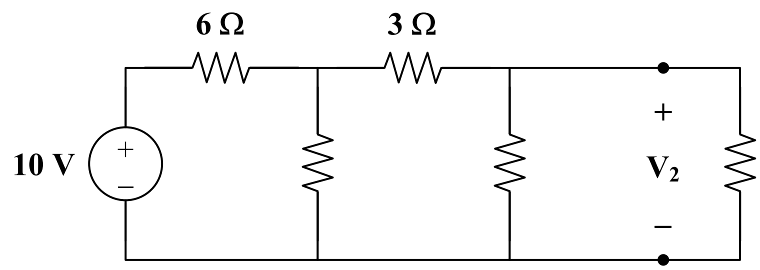
Substituting (2) into (1),

$$(8)\left(\frac{29}{30}\right)\mathbf{V}_2 + \frac{2}{3}\mathbf{V}_2 = 10$$

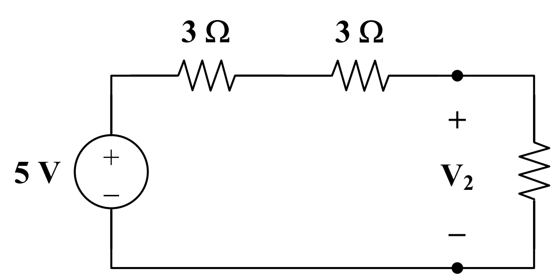
$$\mathbf{V}_2 = \frac{300}{252} = \underline{\mathbf{1.19\ V}}$$

(b) By direct analysis, refer to Fig.(d).



(d)

Transform the 10-V voltage source to a $\frac{10}{6}$-A current source. Since $6 \| 6 = 3\ \Omega$, we combine the two 6-Ω resistors in parallel and transform the current source back to $\frac{10}{6} \times 3 = 5\ \text{V}$ voltage source shown in Fig. (e).



(e)

$$3 \| 5 = \frac{(3)(5)}{8} = \frac{15}{8}$$

$$\mathbf{V}_2 = \frac{15/8}{6 + 15/8}(5) = \frac{75}{63} = \underline{\mathbf{1.1905\ V}}$$

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Chapter 19, Problem 38.

The h parameters of the two-port of Fig. 19.95 are:

$$[\mathbf{h}] = \begin{bmatrix} 600\Omega & 0.04 \\ 30 & 2\,\text{mS} \end{bmatrix}$$

Given the $Z_s = 2\,\text{k}\Omega$ and $Z_L = 400\Omega$, find Z_{in} and Z_{out}.

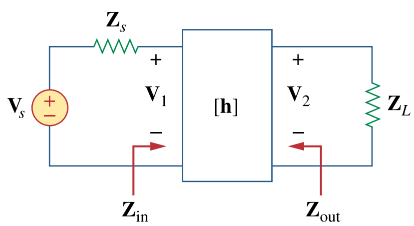

Figure 19.95
For Prob. 19.38.

Chapter 19, Solution 38.

From eq. (19.75),

$$Z_{in} = h_{ie} - \frac{h_{re}h_{fe}R_L}{1+h_{oe}R_L} = h_{11} - \frac{h_{12}h_{21}R_L}{1+h_{22}R_L} = 600 - \frac{0.04x30x400}{1+2x10^{-3}x400} = \underline{333.33\ \Omega}$$

From eq. (19.79),

$$Z_{out} = \frac{R_s + h_{ie}}{(R_s + h_{ie})h_{0e} - h_{re}h_{fe}} = \frac{R_s + h_{11}}{(R_s + h_{11})h_{22} - h_{21}h_{12}} = \frac{2,000+600}{2600x2x10^{-3} - 30x0.04} = \underline{650\ \Omega}$$

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Chapter 19, Problem 39.

Obtain the *g* parameters for the wye circuit of Fig. 19.96.

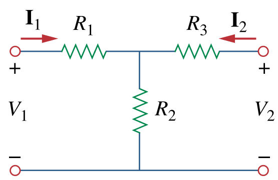

Figure 19.96

For Prob. 19.39.

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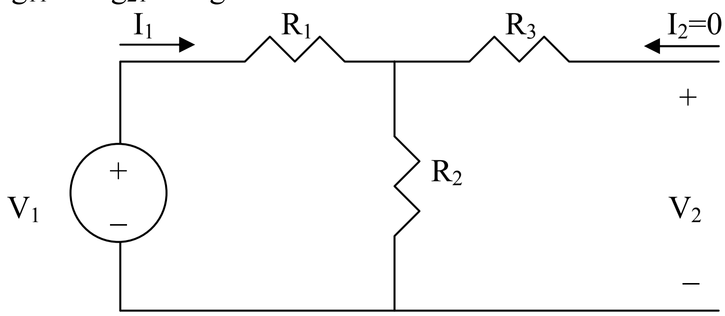
Chapter 19, Solution 39.

We obtain g_{11} and g_{21} using the circuit below.

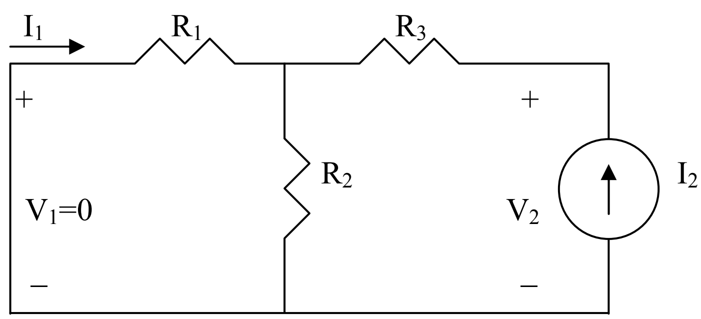


$$I_1 = \frac{V_1}{R_1 + R_2} \longrightarrow g_{11} = \frac{I_1}{V_1} = \underline{\frac{1}{R_1 + R_2}}$$

By voltage division,

$$V_2 = \frac{R_2}{R_1 + R_2} V_1 \longrightarrow g_{21} = \frac{V_2}{V_1} = \underline{\frac{R_2}{R_1 + R_2}}$$

We obtain g_{12} and g_{22} using the circuit below.



By current division,

$$I_1 = -\frac{R_2}{R_1 + R_2} I_2 \longrightarrow g_{12} = \frac{I_1}{I_2} = \underline{-\frac{R_2}{R_1 + R_2}}$$

Also,

$$V_2 = I_2(R_3 + R_1 // R_2) = I_2\left(R_3 + \frac{R_1R_2}{R_1 + R_2}\right) \quad g_{22} = \frac{V_2}{I_2} = \underline{R_3 + \frac{R_1R_2}{R_1 + R_2}}$$

$$g_{11} = \frac{1}{R_1 + R_2}, g_{12} = -\frac{R_2}{R_1 + R_2}$$

$$g_{21} = \frac{R_2}{R_1 + R_2}, g_{22} = R_3 + \frac{R_1R_2}{R_1 + R_2}$$

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Chapter 19, Problem 40.

Find the *g* parameters for the circuit in Fig. 19.97.

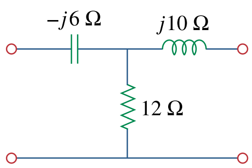

Figure 19.97
For Prob. 19.40.

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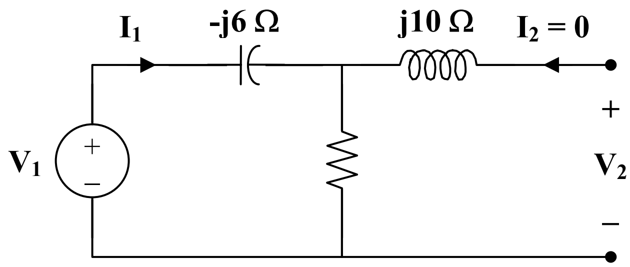
Chapter 19, Solution 40.

To get $\mathbf{g}_{11}$ and $\mathbf{g}_{21}$, consider the circuit in Fig. (a).

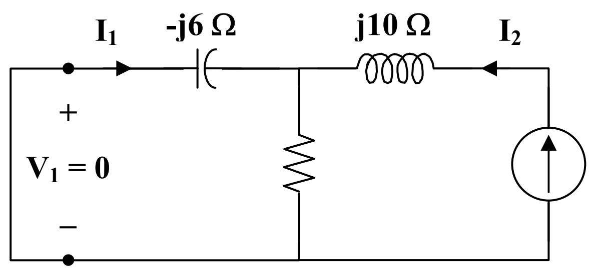


(a)

$$\mathbf{V}_1 = (12 - j6)\mathbf{I}_1 \quad \longrightarrow \quad \mathbf{g}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{1}{12 - j6} = 0.0667 + j0.0333 \text{ S}$$

$$\mathbf{g}_{21} = \frac{\mathbf{V}_2}{\mathbf{V}_1} = \frac{12\mathbf{I}_1}{(12 - j6)\mathbf{I}_1} = \frac{2}{2 - j} = 0.8 + j0.4$$

To get $\mathbf{g}_{12}$ and $\mathbf{g}_{22}$, consider the circuit in Fig. (b).



(b)

$$\mathbf{I}_1 = \frac{-12}{12 - j6}\mathbf{I}_2 \quad \longrightarrow \quad \mathbf{g}_{12} = \frac{\mathbf{I}_1}{\mathbf{I}_2} = \frac{-12}{12 - j6} = -\mathbf{g}_{21} = -0.8 - j0.4$$

$$\mathbf{V}_2 = (j10 + 12 \,||\, -j6)\mathbf{I}_2$$

$$\mathbf{g}_{22} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = j10 + \frac{(12)(-j6)}{12 - j6} = 2.4 + j5.2\,\Omega$$

$$[\mathbf{g}] = \begin{bmatrix} \mathbf{0.0667 + j0.0333\ S} & \mathbf{-0.8 - j0.4} \\ \mathbf{0.8 + j0.4} & \mathbf{2.4 + j5.2\,\Omega} \end{bmatrix}$$

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Chapter 19, Problem 41.

For the two-port in Fig. 19.75, show that

$$\frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{-\mathbf{g}_{21}}{\mathbf{g}_{11}\mathbf{Z}_L + \Delta_g}$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_s} = \frac{\mathbf{g}_{21}\mathbf{Z}_L}{(1+\mathbf{g}_{11}\mathbf{Z}_s)(\mathbf{g}_{22}+\mathbf{Z}_L) - \mathbf{g}_{21}\mathbf{g}_{12}\mathbf{Z}_s}$$

where Δ_g is the determinant of [**g**] matrix.

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Chapter 19, Solution 41.

For the g parameters

$$\mathbf{I}_1 = \mathbf{g}_{11}\,\mathbf{V}_1 + \mathbf{g}_{12}\,\mathbf{I}_2 \qquad (1)$$

$$\mathbf{V}_2 = \mathbf{g}_{21}\,\mathbf{V}_1 + \mathbf{g}_{22}\,\mathbf{I}_2 \qquad (2)$$

But $\mathbf{V}_1 = \mathbf{V}_s - \mathbf{I}_1\,\mathbf{Z}_s$ and

$$\mathbf{V}_2 = -\mathbf{I}_2\,\mathbf{Z}_L = \mathbf{g}_{21}\,\mathbf{V}_1 + \mathbf{g}_{22}\,\mathbf{I}_2$$

$$0 = \mathbf{g}_{21}\,\mathbf{V}_1 + (\mathbf{g}_{22} + \mathbf{Z}_L)\,\mathbf{I}_2$$

or

$$\mathbf{V}_1 = \frac{-(\mathbf{g}_{22} + \mathbf{Z}_L)}{\mathbf{g}_{21}}\,\mathbf{I}_2$$

Substituting this into (1),

$$\mathbf{I}_1 = \frac{(\mathbf{g}_{22}\,\mathbf{g}_{11} + \mathbf{Z}_L\,\mathbf{g}_{11} - \mathbf{g}_{21}\,\mathbf{g}_{12})}{-\mathbf{g}_{21}}\,\mathbf{I}_2$$

or

$$\underline{\frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{-\mathbf{g}_{21}}{\mathbf{g}_{11}\,\mathbf{Z}_L + \Delta_g}}$$

Also,

$$\mathbf{V}_2 = \mathbf{g}_{21}\,(\mathbf{V}_s - \mathbf{I}_1\,\mathbf{Z}_s) + \mathbf{g}_{22}\,\mathbf{I}_2$$

$$= \mathbf{g}_{21}\,\mathbf{V}_s - \mathbf{g}_{21}\,\mathbf{Z}_s\,\mathbf{I}_1 + \mathbf{g}_{22}\,\mathbf{I}_2$$

$$= \mathbf{g}_{21}\,\mathbf{V}_s + \mathbf{Z}_s\,(\mathbf{g}_{11}\,\mathbf{Z}_L + \Delta_g)\,\mathbf{I}_2 + \mathbf{g}_{22}\,\mathbf{I}_2$$

But

$$\mathbf{I}_2 = \frac{-\mathbf{V}_2}{\mathbf{Z}_L}$$

$$\mathbf{V}_2 = \mathbf{g}_{21}\,\mathbf{V}_s - [\mathbf{g}_{11}\,\mathbf{Z}_s\,\mathbf{Z}_L + \Delta_g\,\mathbf{Z}_s + \mathbf{g}_{22}]\left[\frac{\mathbf{V}_2}{\mathbf{Z}_L}\right]$$

$$\frac{\mathbf{V}_2\,[\mathbf{Z}_L + \mathbf{g}_{11}\,\mathbf{Z}_s\,\mathbf{Z}_L + \Delta_g\,\mathbf{Z}_s + \mathbf{g}_{22}]}{\mathbf{Z}_L} = \mathbf{g}_{21}\,\mathbf{V}_s$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_s} = \frac{\mathbf{g}_{21}\,\mathbf{Z}_L}{\mathbf{Z}_L + \mathbf{g}_{11}\,\mathbf{Z}_s\,\mathbf{Z}_L + \Delta_g\,\mathbf{Z}_s + \mathbf{g}_{22}}$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_s} = \frac{\mathbf{g}_{21}\,\mathbf{Z}_L}{\mathbf{Z}_L + \mathbf{g}_{11}\,\mathbf{Z}_s\,\mathbf{Z}_L + \mathbf{g}_{11}\,\mathbf{g}_{22}\,\mathbf{Z}_s - \mathbf{g}_{21}\,\mathbf{g}_{12}\,\mathbf{Z}_s + \mathbf{g}_{22}}$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_s} = \underline{\frac{\mathbf{g}_{21}\,\mathbf{Z}_L}{(1 + \mathbf{g}_{11}\,\mathbf{Z}_s)(\mathbf{g}_{22} + \mathbf{Z}_L) - \mathbf{g}_{12}\,\mathbf{g}_{21}\,\mathbf{Z}_s}}$$

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Chapter 19, Problem 42.

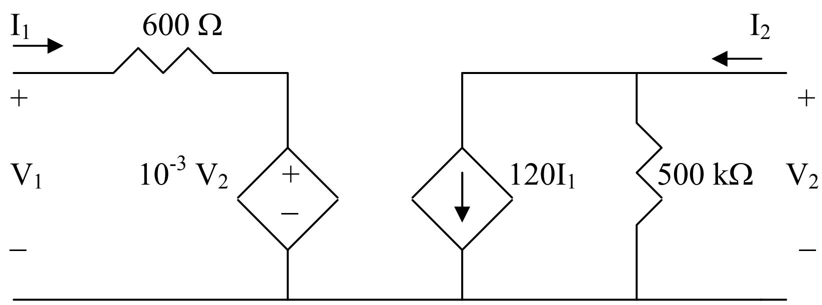
The *h* parameters of a two-port device are given by

$\mathbf{h}_{11} = 600\Omega$, $\mathbf{h}_{12} = 10^{-3}$, $\mathbf{h}_{21} = 120$, $\mathbf{h}_{22} = 2\times10^{-6}$ S

Draw a circuit model of the device including the value of each element.

Chapter 19, Solution 42.

With the help of Fig. 19.20, we obtain the circuit model below.



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Chapter 19, Problem 43.

Find the transmission parameters for the single-element two-port networks in Fig. 19.98.

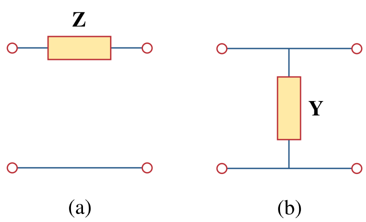

Figure 19.98

For Prob. 19.43.

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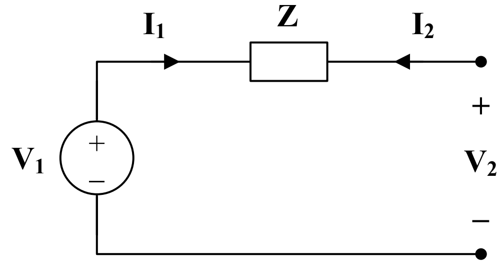
Chapter 19, Solution 43.

(a) To find $\mathbf{A}$ and $\mathbf{C}$, consider the network in Fig. (a).

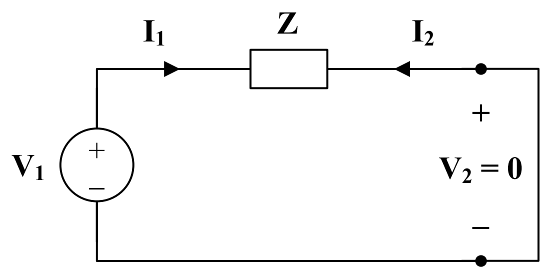


(a)

$$\mathbf{V}_1 = \mathbf{V}_2 \longrightarrow \mathbf{A} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = 1$$

$$\mathbf{I}_1 = 0 \longrightarrow \mathbf{C} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = 0$$

To get $\mathbf{B}$ and $\mathbf{D}$, consider the circuit in Fig. (b).



(b)

$$\mathbf{V}_1 = \mathbf{Z}\mathbf{I}_1, \qquad \mathbf{I}_2 = -\mathbf{I}_1$$

$$\mathbf{B} = \frac{-\mathbf{V}_1}{\mathbf{I}_2} = \frac{-\mathbf{Z}\mathbf{I}_1}{-\mathbf{I}_1} = \mathbf{Z}$$

$$\mathbf{D} = \frac{-\mathbf{I}_1}{\mathbf{I}_2} = 1$$

Hence,

$$[\mathbf{T}] = \begin{bmatrix} \mathbf{1} & \mathbf{Z} \\ \mathbf{0} & \mathbf{1} \end{bmatrix}$$

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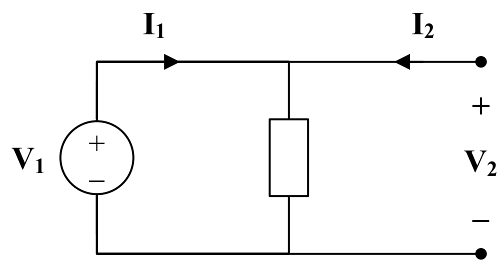
(b) To find $\mathbf{A}$ and $\mathbf{C}$, consider the circuit in Fig. (c).

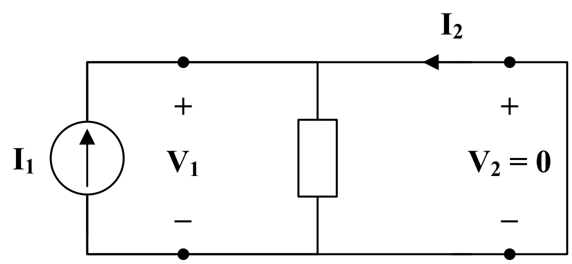


(c)

$$\mathbf{V}_1 = \mathbf{V}_2 \longrightarrow \mathbf{A} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = 1$$

$$\mathbf{V}_1 = \mathbf{Z}\mathbf{I}_1 = \mathbf{V}_2 \longrightarrow \mathbf{C} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{1}{\mathbf{Z}} = \mathbf{Y}$$

To get $\mathbf{B}$ and $\mathbf{D}$, refer to the circuit in Fig.(d).



(d)

$$\mathbf{V}_1 = \mathbf{V}_2 = 0 \qquad \mathbf{I}_2 = -\mathbf{I}_1$$

$$\mathbf{B} = \frac{-\mathbf{V}_1}{\mathbf{I}_2} = 0, \qquad \mathbf{D} = \frac{-\mathbf{I}_1}{\mathbf{I}_2} = 1$$

Thus,

$$[\mathbf{T}] = \underline{\begin{bmatrix} \mathbf{1} & \mathbf{0} \\ \mathbf{Y} & \mathbf{1} \end{bmatrix}}$$

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Chapter 19, Problem 44.

Determine the transmission parameters of the circuit in Fig. 19.99.

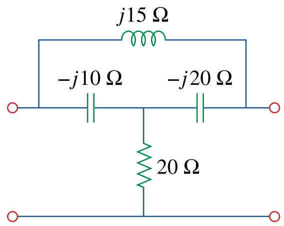
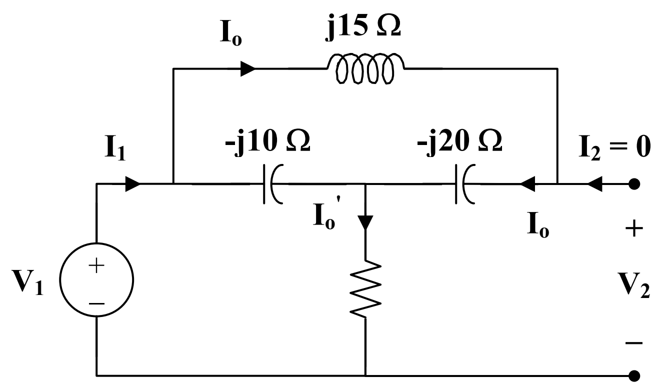


Figure 19.99

For Prob. 19.44.

Chapter 19, Solution 44.

To determine $\mathbf{A}$ and $\mathbf{C}$, consider the circuit in Fig.(a).



(a)

$$\mathbf{V}_1 = [\,20 + (\text{-j}10)\,||\,(\text{j}15 - \text{j}20)\,]\mathbf{I}_1$$

$$\mathbf{V}_1 = \left[20 + \frac{(\text{-j}10)(\text{-j}5)}{\text{-j}15}\right]\mathbf{I}_1 = \left[20 - \text{j}\frac{10}{3}\right]\mathbf{I}_1$$

$$\mathbf{I}_o^{'} = \mathbf{I}_1$$

$$\mathbf{I}_o = \left(\frac{\text{-j}10}{\text{-j}10 - \text{j}5}\right)\mathbf{I}_1 = \left(\frac{2}{3}\right)\mathbf{I}_1$$

$$\mathbf{V}_2 = (\text{-j}20)\mathbf{I}_o + 20\mathbf{I}_o' \;=\; -\text{j}\frac{40}{3}\text{I}_1 + 20\text{I}_1 \;=\; \left(20 - \text{j}\frac{40}{3}\right)\text{I}_1$$

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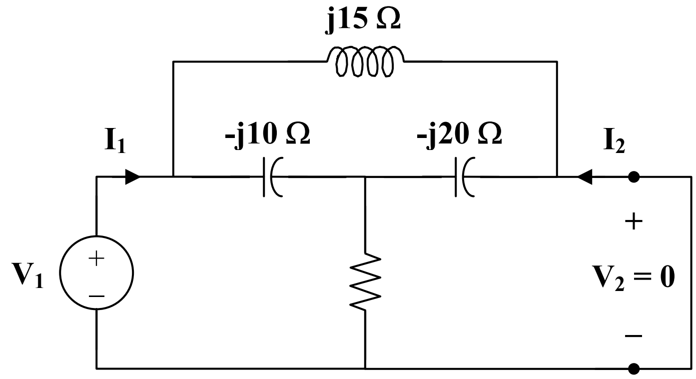
$$\mathbf{A} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = \frac{(20 - j10/3)\,\mathbf{I}_1}{\left(20 - j\frac{40}{3}\right)I_1} = 0.7692 + j0.3461$$

$$\mathbf{C} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{1}{20 - j\frac{40}{3}} = 0.03461 + j0.023$$

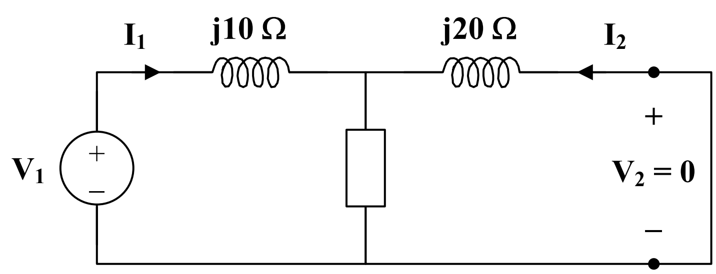
To find **B** and **D**, consider the circuit in Fig. (b).



(b)

We may transform the Δ subnetwork to a T as shown in Fig. (c).

$$\mathbf{Z}_1 = \frac{(j15)(-j10)}{j15 - j10 - j20} = j10$$
$$\mathbf{Z}_2 = \frac{(-j10)(-j20)}{-j15} = -j\frac{40}{3}$$
$$\mathbf{Z}_3 = \frac{(j15)(-j20)}{-j15} = j20$$



(c)

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$$-\mathbf{I}_2 = \frac{20 - j40/3}{20 - j40/3 + j20}\mathbf{I}_1 = \frac{3 - j2}{3 + j}\mathbf{I}_1$$

$$\mathbf{D} = \frac{-\mathbf{I}_1}{\mathbf{I}_2} = \frac{3 + j}{3 - j2} = 0.5385 + j0.6923$$

$$\mathbf{V}_1 = \left[j10 + \frac{(j20)(20 - j40/3)}{20 - j40/3 + j20} \right]\mathbf{I}_1$$

$$\mathbf{V}_1 = [\, j10 + 2\,(9 + j7)\,]\,\mathbf{I}_1 = j\mathbf{I}_1\,(24 - j18)$$

$$\mathbf{B} = \frac{-\mathbf{V}_1}{\mathbf{I}_2} = \frac{-\,j\mathbf{I}_1\,(24 - j18)}{\dfrac{-(3 - j2)}{3 + j}\mathbf{I}_1} = \frac{6}{13}(-15 + j55)$$

$$\mathbf{B} = -6.923 + j25.385\ \Omega$$

$$[\mathbf{T}] = \underline{\begin{bmatrix} \mathbf{0.7692 + j0.3461} & \mathbf{-6.923 + j25.385\ \Omega} \\ \mathbf{0.03461 + j0.023\ S} & \mathbf{0.5385 + j0.6923} \end{bmatrix}}$$

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Chapter 19, Problem 45.

Find the **ABCD** parameters for the circuit in Fig. 19.100.

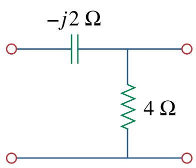

Figure 19.100
For Prob. 19.45.

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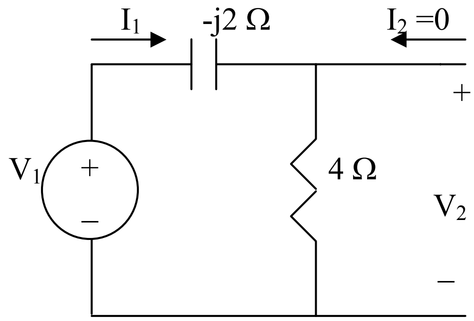
Chapter 19, Solution 45.

To determine A and C, consider the circuit below.

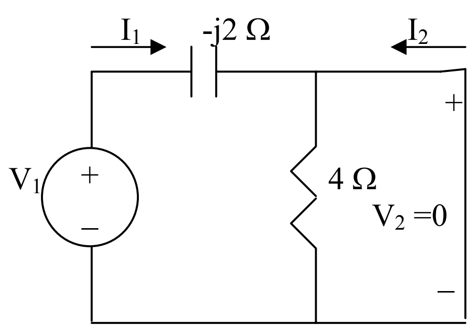


$$V_1 = (4 - j2)I_1, \qquad V_2 = 4I_1$$

$$A = \frac{V_1}{V_2} = \frac{4 - j2}{4} = 1 - j0.5$$

$$C = \frac{I_1}{V_2} = \frac{I_1}{4I_1} = 0.25$$

To determine B and D, consider the circuit below.



The 4-Ω resistor is short-circuited. Hence,

$$I_2 = -I_1, \qquad D = -\frac{I_1}{I_2} = 1$$

$$V_1 = -j2I_1 = j2I_2 \qquad B = -\frac{V_1}{I_2} = -\frac{j2I_2}{I_2} = -2j\Omega$$

Hence,

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 - j0.5 & -j2\Omega \\ 0.25S & 1 \end{bmatrix} = \begin{bmatrix} 1 - j0.5 & -j2\Omega \\ 0.25S & 1 \end{bmatrix}$$

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Chapter 19, Problem 46.

Find the transmission parameters for the circuit in Fig. 19.101.

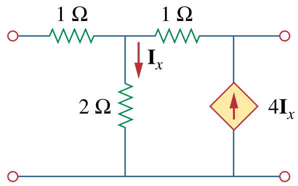
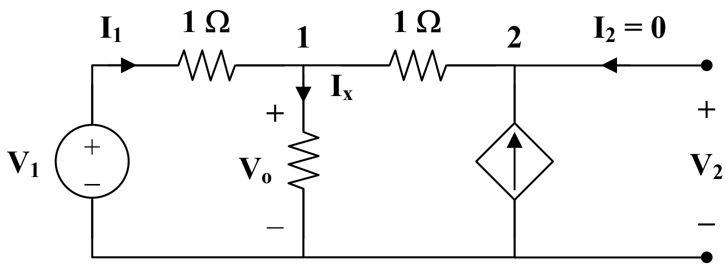


Figure 19.101

For Prob. 19.46.

Chapter 19, Solution 46.

To get $\mathbf{A}$ and $\mathbf{C}$, refer to the circuit in Fig.(a).



(a)

At node 1,

$$\mathbf{I}_1 = \frac{\mathbf{V}_o}{2} + \frac{\mathbf{V}_o - \mathbf{V}_2}{1} \longrightarrow 2\mathbf{I}_1 = 3\mathbf{V}_o - 2\mathbf{V}_2 \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_o - \mathbf{V}_2}{1} = 4\mathbf{I}_x = \frac{4\mathbf{V}_o}{2} = 2\mathbf{V}_o \longrightarrow \mathbf{V}_o = \text{-}\mathbf{V}_2 \qquad (2)$$

From (1) and (2),

$$2\mathbf{I}_1 = \text{-}5\mathbf{V}_2 \longrightarrow \mathbf{C} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{-5}{2} = \text{-}2.5\text{ S}$$

But $$\mathbf{I}_1 = \frac{\mathbf{V}_1 - \mathbf{V}_o}{1} = \mathbf{V}_1 + \mathbf{V}_2$$

$$\text{-}2.5\mathbf{V}_2 = \mathbf{V}_1 + \mathbf{V}_2 \longrightarrow \mathbf{V}_1 = \text{-}3.5\mathbf{V}_2$$

$$\mathbf{A} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = \text{-}3.5$$

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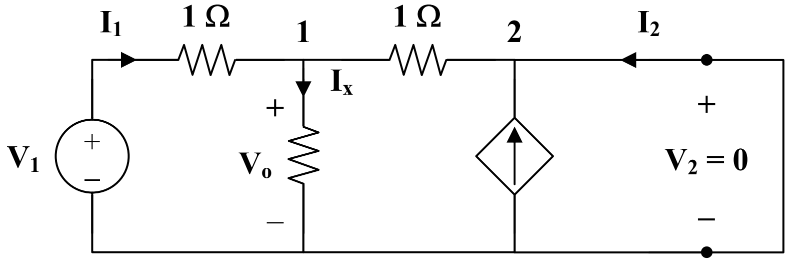
To get **B** and **D**, consider the circuit in Fig. (b).



(b)

At node 1,

$$\mathbf{I}_1 = \frac{\mathbf{V}_o}{2} + \frac{\mathbf{V}_o}{1} \longrightarrow 2\mathbf{I}_1 = 3\mathbf{V}_o \qquad (3)$$

At node 2,

$$\mathbf{I}_2 + \frac{\mathbf{V}_o}{1} + 4\mathbf{I}_x = 0$$

$$-\mathbf{I}_2 = \mathbf{V}_o + 2\mathbf{V}_o = 0 \longrightarrow \mathbf{I}_2 = \text{-}3\mathbf{V}_o \qquad (4)$$

Adding (3) and (4),

$$2\mathbf{I}_1 + \mathbf{I}_2 = 0 \longrightarrow \mathbf{I}_1 = \text{-}0.5\mathbf{I}_2 \qquad (5)$$

$$\mathbf{D} = \frac{\text{-}\mathbf{I}_1}{\mathbf{I}_2} = 0.5$$

But $$\mathbf{I}_1 = \frac{\mathbf{V}_1 - \mathbf{V}_o}{1} \longrightarrow \mathbf{V}_1 = \mathbf{I}_1 + \mathbf{V}_o \qquad (6)$$

Substituting (5) and (4) into (6),

$$\mathbf{V}_1 = \frac{\text{-}1}{2}\mathbf{I}_2 + \frac{\text{-}1}{3}\mathbf{I}_2 = \frac{\text{-}5}{6}\mathbf{I}_2$$

$$\mathbf{B} = \frac{\text{-}\mathbf{V}_1}{\mathbf{I}_2} = \frac{5}{6} = 0.8333\,\Omega$$

Thus,

$$[\mathbf{T}] = \begin{bmatrix} \mathbf{-3.5} & \mathbf{0.8333\,\Omega} \\ \mathbf{-2.5\,S} & \mathbf{-0.5} \end{bmatrix}$$

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Chapter 19, Problem 47.

Obtain the **ABCD** parameters for the network in Fig. 19.102.

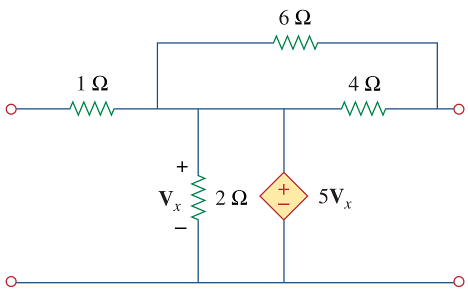
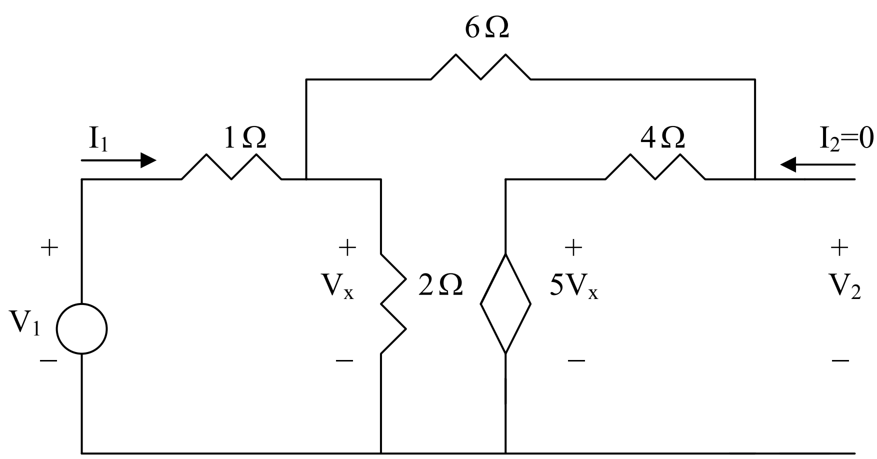


Figure 19.102

For Prob. 19.47.

Chapter 19, Solution 47.

To get A and C, consider the circuit below.



$$\frac{V_1 - V_x}{1} = \frac{V_x}{2} + \frac{V_x - 5V_x}{10} \longrightarrow V_1 = 1.1V_x$$

$$V_2 = 4(-0.4V_x) + 5V_x = 3.4V_x \longrightarrow A = \frac{V_1}{V_2} = 1.1/3.4 = 0.3235$$

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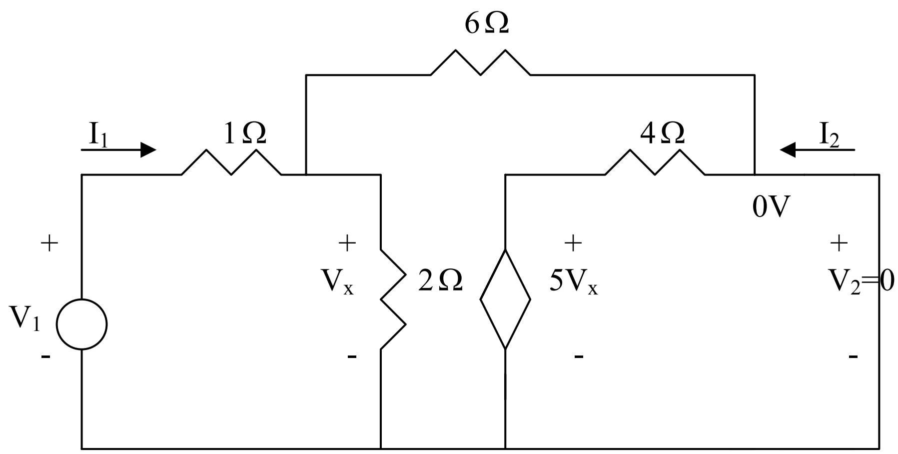
$$I_1 = \frac{V_1 - V_x}{1} = 1.1V_x - V_x = 0.1V_x \longrightarrow C = \frac{I_1}{V_2} = 0.1/3.4 = 0.02941$$

To get B and D, consider the circuit below.



$$\frac{V_1 - V_x}{1} = \frac{V_x}{6} + \frac{V_x}{2} \longrightarrow V_1 = \frac{10}{6}V_x \qquad (1)$$

$$I_2 = -\frac{5V_x}{4} - \frac{V_x}{6} = -\frac{17}{12}V_x \qquad (2)$$

$$V_1 = I_1 + V_x \qquad (3)$$

From (1) and (3)

$$I_1 = V_1 - V_x = \frac{4}{6}V_x \longrightarrow D = -\frac{I_1}{I_2} = \frac{4}{6}(\frac{12}{17}) = 0.4706$$

$$B = -\frac{V_1}{I_2} = \frac{10}{6}(\frac{12}{17}) = 1.176$$

$$[T] = \begin{bmatrix} 0.3235 & 1.176 \\ 0.02941 & 0.4706 \end{bmatrix}$$

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Chapter 19, Problem 48.

For a two-port, let **A** = 4, **B** = 30 Ω, **C** = 0.1 S, and **D** = 1.5. Calculate the input impedance, $\mathbf{Z}_{in} = \mathbf{V}_1 / \mathbf{I}_1$ when:

(a) the output terminals are short-circuited,
(b) the output port is open-circuited,
(c) the output port is terminated by a $10\text{-}\Omega$ load.

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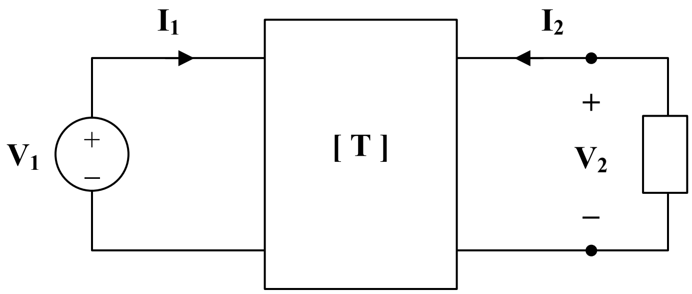
Chapter 19, Solution 48.

(a) Refer to the circuit below.



$$\mathbf{V}_1 = 4\mathbf{V}_2 - 30\mathbf{I}_2 \qquad (1)$$
$$\mathbf{I}_1 = 0.1\mathbf{V}_2 - \mathbf{I}_2 \qquad (2)$$

When the output terminals are shorted, $\mathbf{V}_2 = 0$.
So, (1) and (2) become

$\mathbf{V}_1 = \text{-}30\mathbf{I}_2$ and $\mathbf{I}_1 = \text{-}\mathbf{I}_2$

Hence,

$$\mathbf{Z}_{in} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = \underline{\mathbf{30\,\Omega}}$$

(b) When the output terminals are open-circuited, $\mathbf{I}_2 = 0$.
So, (1) and (2) become

$\mathbf{V}_1 = 4\mathbf{V}_2$

$\mathbf{I}_1 = 0.1\mathbf{V}_2$ or $\mathbf{V}_2 = 10\mathbf{I}_1$

$\mathbf{V}_1 = 40\mathbf{I}_1$

$$\mathbf{Z}_{in} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = \underline{\mathbf{40\,\Omega}}$$

(c) When the output port is terminated by a 10-Ω load, $V_2 = \text{-}10 I_2$.
So, (1) and (2) become

$\mathbf{V}_1 = \text{-}40\mathbf{I}_2 - 30\mathbf{I}_2 = \text{-}70\mathbf{I}_2$

$\mathbf{I}_1 = \text{-}\mathbf{I}_2 - \mathbf{I}_2 = \text{-}2\mathbf{I}_2$

$\mathbf{V}_1 = 35\mathbf{I}_1$

$$\mathbf{Z}_{in} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = \underline{\mathbf{35\,\Omega}}$$

Alternatively, we may use $\mathbf{Z}_{in} = \dfrac{\mathbf{A}\mathbf{Z}_L + \mathbf{B}}{\mathbf{C}\mathbf{Z}_L + \mathbf{D}}$

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Chapter 19, Problem 49.

Using impedances in the s domain, obtain the transmission parameters for the circuit in Fig. 19.103.

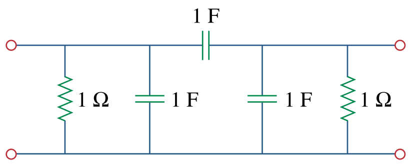
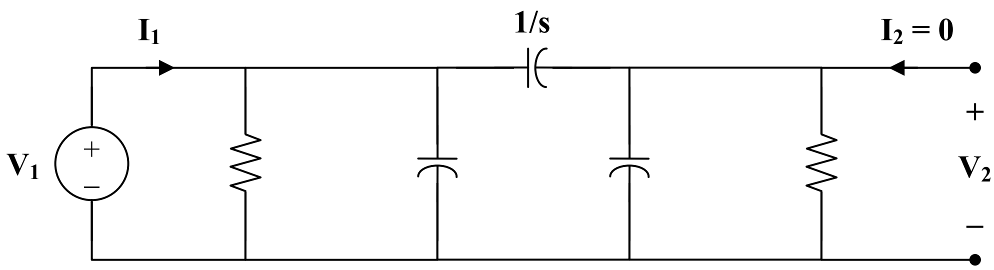


Figure 19.103

For Prob. 19.49.

Chapter 19, Solution 49.

To get $\mathbf{A}$ and $\mathbf{C}$, refer to the circuit in Fig.(a).



(a)

$$1 \| \frac{1}{s} = \frac{1/s}{1 + 1/s} = \frac{1}{s+1}$$

$$\mathbf{V}_2 = \frac{1 \| 1/s}{1/s + 1 \| 1/s} \mathbf{V}_1$$

$$\mathbf{A} = \frac{\mathbf{V}_1}{\mathbf{V}_2} = \frac{\dfrac{1}{s} + \dfrac{1}{s+1}}{\dfrac{1}{s+1}} = \frac{2s+1}{s}$$

$$\mathbf{V}_1 = \mathbf{I}_1 \left(\frac{1}{s+1}\right) \| \left(\frac{1}{s} + \frac{1}{s+1}\right) = \mathbf{I}_1 \left(\frac{1}{s+1}\right) \| \left(\frac{2s+1}{s(s+1)}\right)$$

$$\frac{\mathbf{V}_1}{\mathbf{I}_1} = \frac{\left(\dfrac{1}{s+1}\right) \cdot \left(\dfrac{2s+1}{s(s+1)}\right)}{\dfrac{1}{s+1} + \dfrac{2s+1}{s(s+1)}} = \frac{2s+1}{(s+1)(3s+1)}$$

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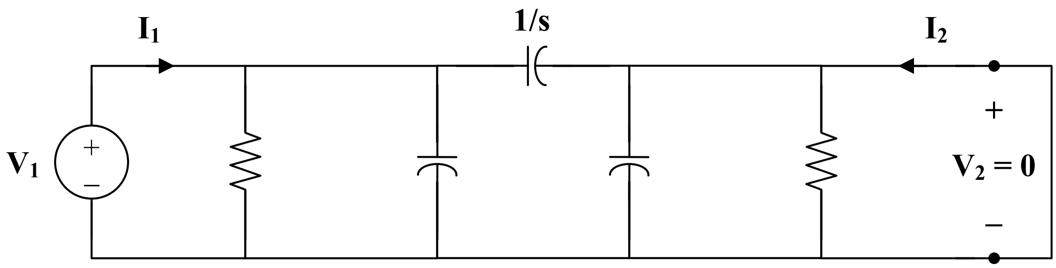
But $\quad \mathbf{V}_1 = \mathbf{V}_2 \cdot \dfrac{2s+1}{s}$

Hence, $\quad \dfrac{\mathbf{V}_2}{\mathbf{I}_1} \cdot \dfrac{2s+1}{s} = \dfrac{2s+1}{(s+1)(3s+1)}$

$$\mathbf{C} = \frac{\mathbf{V}_2}{\mathbf{I}_1} = \frac{(s+1)(3s+1)}{s}$$

To get $\mathbf{B}$ and $\mathbf{D}$, consider the circuit in Fig. (b).



(b)

$$\mathbf{V}_1 = \mathbf{I}_1\left(1 \,\|\, \frac{1}{s} \,\|\, \frac{1}{s}\right) = \mathbf{I}_1\left(1 \,\|\, \frac{1}{2s}\right) = \frac{\mathbf{I}_1}{2s+1}$$

$$\mathbf{I}_2 = \frac{\dfrac{-1}{s+1}\mathbf{I}_1}{\dfrac{1}{s+1} + \dfrac{1}{s}} = \frac{-s}{2s+1}\mathbf{I}_1$$

$$\mathbf{D} = \frac{-\mathbf{I}_1}{\mathbf{I}_2} = \frac{2s+1}{s} = 2 + \frac{1}{s}$$

$$\mathbf{V}_1 = \left(\frac{1}{2s+1}\right)\left(\frac{2s+1}{-s}\right)\mathbf{I}_2 = \frac{\mathbf{I}_2}{-s} \longrightarrow \mathbf{B} = \frac{-\mathbf{V}_1}{\mathbf{I}_2} = \frac{1}{s}$$

Thus,

$$[\mathbf{T}] = \underline{\begin{bmatrix} \dfrac{2s+1}{s} & \dfrac{1}{s} \\ \dfrac{(s+1)(3s+1)}{s} & 2+\dfrac{1}{s} \end{bmatrix}}$$

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Chapter 19, Problem 50.

Derive the *s*-domain expression for the *t* parameters of the circuit in Fig. 19.104.

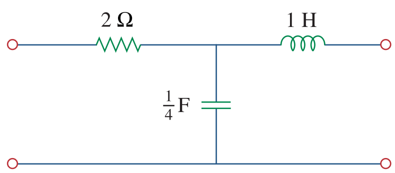

Figure 19.104

For Prob. 19.50.

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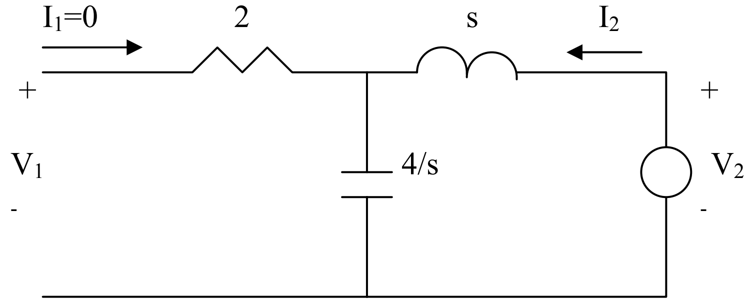
Chapter 19, Solution 50.

To get a and c, consider the circuit below.

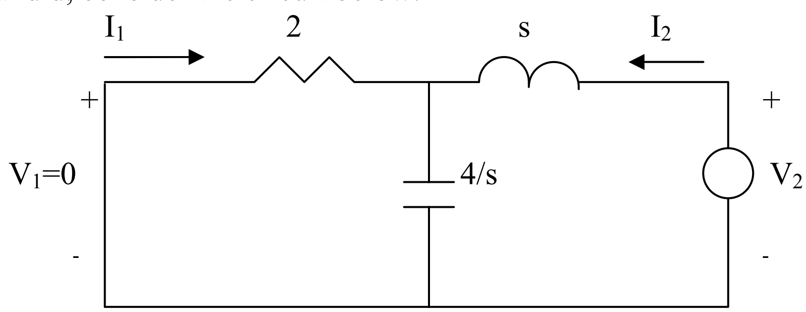


$$V_1 = \frac{4/s}{s+4/s}V_2 = \frac{4}{s^2+4}V_2 \longrightarrow a = V_2/V_1 = 1 + 0.25s^2$$

$V_2 = (s + 4/s)I_2$ or

$$I_2 = \frac{V_2}{s+4/s} = \frac{(1+0.25s^2)V_1}{s+4/s} \longrightarrow c = \frac{I_2}{V_1} = \frac{s+0.25s^3}{s^2+4}$$

To get b and d, consider the circuit below.



$$I_1 = \frac{-4/s}{2+4/s}I_2 = -\frac{2I_2}{s+2} \longrightarrow d = -\frac{I_2}{I_1} = 1 + 0.5s$$

$$V_2 = (s + 2//\frac{4}{s})I_2 = \frac{(s^2+2s+4)}{s+2}I_2$$

$$= -\frac{(s^2+2s+4)}{s+2}\frac{(s+2)}{2}I_1 \longrightarrow b = -\frac{V_2}{I_1} = 0.5s^2 + s + 2$$

$$[t] = \begin{bmatrix} 0.25s^2+1 & 0.5s^2+s+2 \\ \dfrac{0.25s^2+s}{s^2+4} & 0.5s+1 \end{bmatrix}$$

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Chapter 19, Problem 51.

Obtain the *t* parameters for the network in Fig. 19.105.

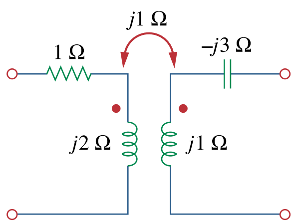
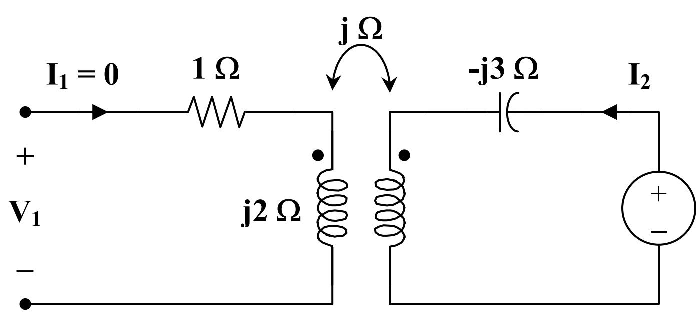


Figure 19.105
For Prob. 19.51.

Chapter 19, Solution 51.

To get **a** and **c**, consider the circuit in Fig. (a).



(a)

$$\mathbf{V}_2 = \mathbf{I}_2\,(\mathrm{j} - \mathrm{j}3) = \text{-j}2\,\mathbf{I}_2$$

$$\mathbf{V}_1 = \text{-j}\mathbf{I}_2$$

$$\mathbf{a} = \frac{\mathbf{V}_2}{\mathbf{V}_1} = \frac{-\,\mathrm{j}2\,\mathbf{I}_2}{-\,\mathrm{j}\,\mathbf{I}_2} = 2$$

$$\mathbf{c} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = \frac{1}{-\,\mathrm{j}} = \mathrm{j}$$

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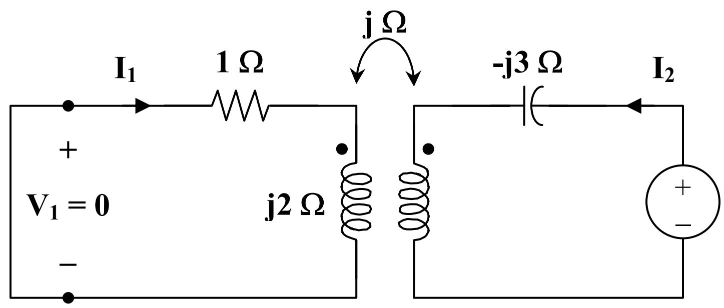
To get **b** and **d**, consider the circuit in Fig. (b).



(b)

For mesh 1,

$$0 = (1 + j2)\,\mathbf{I}_1 - j\,\mathbf{I}_2$$

or

$$\frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{1 + j2}{j} = 2 - j$$

$$\mathbf{d} = \frac{-\mathbf{I}_2}{\mathbf{I}_1} = -2 + j$$

For mesh 2,

$$\mathbf{V}_2 = \mathbf{I}_2\,(j - j3) - j\,\mathbf{I}_1$$

$$\mathbf{V}_2 = \mathbf{I}_1\,(2 - j)(-j2) - j\,\mathbf{I}_1 = (-2 - j5)\,\mathbf{I}_1$$

$$\mathbf{b} = \frac{-\mathbf{V}_2}{\mathbf{I}_1} = 2 + j5$$

Thus,

$$[\mathbf{t}] = \underline{\begin{bmatrix} \mathbf{2} & \mathbf{2 + j5} \\ \mathbf{j} & \mathbf{-2 + j} \end{bmatrix}}$$

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Chapter 19, Problem 52.

(a) For the *T* network in Fig. 19.106, show that the *h* parameters are:

$$\mathbf{h}_{11} = R_1 + \frac{R_2 R_3}{R_1 + R3}, \qquad \mathbf{h}_{12} = \frac{R_2}{R_2 + R_3}$$

$$\mathbf{h}_{21} = -\frac{R_2}{R_2 + R_3}, \qquad \mathbf{h}_{22} = \frac{1}{R_2 + R_3}$$

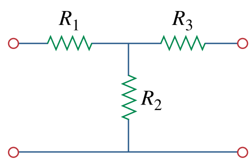

Figure 19.106

For Prob. 19.52.

(b) For the same network, show that the transmission parameters are:

$$\mathbf{A} = 1 + \frac{R_1}{R_2}, \qquad \mathbf{B} = R_3 + \frac{R_1}{R_2}(R_2 + R_3)$$

$$\mathbf{C} = \frac{1}{R_2}, \qquad \mathbf{D} = 1 + \frac{R_3}{R_2}$$

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Chapter 19, Solution 52.

It is easy to find the z parameters and then transform these to h parameters and T parameters.

$$[\mathbf{z}] = \begin{bmatrix} R_1 + R_2 & R_2 \\ R_2 & R_2 + R_3 \end{bmatrix}$$

$$\Delta_z = (R_1 + R_2)(R_2 + R_3) - R_2^2$$
$$= R_1R_2 + R_2R_3 + R_3R_1$$

(a) $$[\mathbf{h}] = \begin{bmatrix} \frac{\Delta_z}{\mathbf{z}_{22}} & \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}} \\ \frac{-\mathbf{z}_{21}}{\mathbf{z}_{22}} & \frac{1}{\mathbf{z}_{22}} \end{bmatrix} = \begin{bmatrix} \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2 + R_3} & \frac{R_2}{R_2 + R_3} \\ \frac{-R_2}{R_2 + R_3} & \frac{1}{R_2 + R_3} \end{bmatrix}$$

Thus,

$$\underline{\mathbf{h}_{11} = \mathbf{R}_1 + \frac{\mathbf{R}_2\mathbf{R}_3}{\mathbf{R}_2 + \mathbf{R}_3}}, \quad \underline{\mathbf{h}_{12} = \frac{\mathbf{R}_2}{\mathbf{R}_2 + \mathbf{R}_3} = -\mathbf{h}_{21}}, \quad \underline{\mathbf{h}_{22} = \frac{1}{\mathbf{R}_2 + \mathbf{R}_3}}$$

as required.

(b) $$[\mathbf{T}] = \begin{bmatrix} \frac{\mathbf{z}_{11}}{\mathbf{z}_{21}} & \frac{\Delta_z}{\mathbf{z}_{21}} \\ \frac{1}{\mathbf{z}_{21}} & \frac{\mathbf{z}_{22}}{\mathbf{z}_{21}} \end{bmatrix} = \begin{bmatrix} \frac{R_1 + R_2}{R_2} & \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} \\ \frac{1}{R_2} & \frac{R_2 + R_3}{R_2} \end{bmatrix}$$

Hence,

$$\underline{\mathbf{A} = 1 + \frac{\mathbf{R}_1}{\mathbf{R}_2}}, \quad \underline{\mathbf{B} = \mathbf{R}_3 + \frac{\mathbf{R}_1}{\mathbf{R}_2}(\mathbf{R}_2 + \mathbf{R}_3)}, \quad \underline{\mathbf{C} = \frac{1}{\mathbf{R}_2}}, \quad \underline{\mathbf{D} = 1 + \frac{\mathbf{R}_3}{\mathbf{R}_2}}$$

as required.

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Chapter 19, Problem 53.

Through derivation, express the z parameters in terms of the **ABCD** parameters.

Chapter 19, Solution 53.

For the z parameters,

$$\mathbf{V}_1 = \mathbf{z}_{11}\mathbf{I}_1 + \mathbf{z}_{12}\mathbf{I}_2 \qquad (1)$$

$$\mathbf{V}_2 = \mathbf{z}_{12}\mathbf{I}_1 + \mathbf{z}_{22}\mathbf{I}_2 \qquad (2)$$

For **ABCD** parameters,

$$\mathbf{V}_1 = \mathbf{A}\mathbf{V}_2 - \mathbf{B}\mathbf{I}_2 \qquad (3)$$

$$\mathbf{I}_1 = \mathbf{C}\mathbf{V}_2 - \mathbf{D}\mathbf{I}_2 \qquad (4)$$

From (4),

$$\mathbf{V}_2 = \frac{\mathbf{I}_1}{\mathbf{C}} + \frac{\mathbf{D}}{\mathbf{C}}\mathbf{I}_2 \qquad (5)$$

Comparing (2) and (5),

$$\mathbf{z}_{21} = \frac{1}{\mathbf{C}}, \qquad \mathbf{z}_{22} = \frac{\mathbf{D}}{\mathbf{C}}$$

Substituting (5) into (3),

$$\mathbf{V}_1 = \frac{\mathbf{A}}{\mathbf{C}}\mathbf{I}_1 + \left(\frac{\mathbf{AD}}{\mathbf{C}} - \mathbf{B}\right)\mathbf{I}_2$$

$$= \frac{\mathbf{A}}{\mathbf{C}}\mathbf{I}_1 + \frac{\mathbf{AD} - \mathbf{BC}}{\mathbf{C}}\mathbf{I}_2 \qquad (6)$$

Comparing (6) and (1),

$$\mathbf{z}_{11} = \frac{\mathbf{A}}{\mathbf{C}} \qquad \mathbf{z}_{12} = \frac{\mathbf{AD} - \mathbf{BC}}{\mathbf{C}} = \frac{\Delta_T}{\mathbf{C}}$$

Thus,

$$[Z] = \underline{\begin{bmatrix} \frac{\mathbf{A}}{\mathbf{C}} & \frac{\Delta_T}{\mathbf{C}} \\ \frac{\mathbf{1}}{\mathbf{C}} & \frac{\mathbf{D}}{\mathbf{C}} \end{bmatrix}}$$

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Chapter 19, Problem 54.

Show that the transmission parameters of a two-port may be obtained from the *y* parameters as:

$$A = -\frac{\mathbf{y}_{22}}{\mathbf{y}_{21}}, \qquad B = -\frac{1}{\mathbf{y}_{21}}$$

$$C = -\frac{\Delta_y}{\mathbf{y}_{21}}, \qquad D = -\frac{\mathbf{y}_{11}}{\mathbf{y}_{21}}$$

Chapter 19, Solution 54.

For the y parameters

$$\mathbf{I}_1 = \mathbf{y}_{11}\mathbf{V}_1 + \mathbf{y}_{12}\mathbf{V}_2 \qquad (1)$$

$$\mathbf{I}_2 = \mathbf{y}_{21}\mathbf{V}_1 + \mathbf{y}_{22}\mathbf{V}_2 \qquad (2)$$

From (2),

$$\mathbf{V}_1 = \frac{\mathbf{I}_2}{\mathbf{y}_{21}} - \frac{\mathbf{y}_{22}}{\mathbf{y}_{21}}\mathbf{V}_2$$

or

$$\mathbf{V}_1 = \frac{-\mathbf{y}_{22}}{\mathbf{y}_{12}}\mathbf{V}_2 + \frac{1}{\mathbf{y}_{21}}\mathbf{I}_2 \qquad (3)$$

Substituting (3) into (1) gives

$$\mathbf{I}_1 = \frac{-\mathbf{y}_{11}\mathbf{y}_{22}}{\mathbf{y}_{21}}\mathbf{V}_2 + \mathbf{y}_{12}\mathbf{V}_2 + \frac{\mathbf{y}_{11}}{\mathbf{y}_{21}}\mathbf{I}_2$$

or

$$\mathbf{I}_1 = \frac{-\Delta_y}{\mathbf{y}_{21}}\mathbf{V}_2 + \frac{\mathbf{y}_{11}}{\mathbf{y}_{21}}\mathbf{I}_2 \qquad (4)$$

Comparing (3) and (4) with the following equations

$$\mathbf{V}_1 = \mathbf{A}\mathbf{V}_2 - \mathbf{B}\mathbf{I}_2$$

$$\mathbf{I}_1 = \mathbf{C}\mathbf{V}_2 - \mathbf{D}\mathbf{I}_2$$

clearly shows that

$$\underline{\mathbf{A} = \frac{-\mathbf{y}_{22}}{\mathbf{y}_{21}}}, \quad \underline{\mathbf{B} = \frac{-\mathbf{1}}{\mathbf{y}_{21}}}, \quad \underline{\mathbf{C} = \frac{-\Delta_y}{\mathbf{y}_{21}}}, \quad \underline{\mathbf{D} = \frac{-\mathbf{y}_{11}}{\mathbf{y}_{21}}}$$

as required.

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Chapter 19, Problem 55.

Prove that the *g* parameters can be obtained from the *z* parameters as

$$\mathbf{g}_{11} = \frac{1}{\mathbf{z}_{11}}, \qquad \mathbf{g}_{12} = -\frac{\mathbf{z}_{12}}{\mathbf{z}_{11}}$$

$$\mathbf{g}_{21} = \frac{\mathbf{z}_{21}}{\mathbf{z}_{11}}, \qquad \mathbf{g}_{22} = \frac{\Delta_z}{\mathbf{z}_{11}}$$

Chapter 19, Solution 55.

For the z parameters

$$\mathbf{V}_1 = \mathbf{z}_{11}\,\mathbf{I}_1 + \mathbf{z}_{12}\,\mathbf{I}_2 \qquad (1)$$

$$\mathbf{V}_2 = \mathbf{z}_{21}\,\mathbf{I}_1 + \mathbf{z}_{22}\,\mathbf{I}_2 \qquad (2)$$

From (1),

$$\mathbf{I}_1 = \frac{1}{\mathbf{z}_{11}}\mathbf{V}_1 - \frac{\mathbf{z}_{12}}{\mathbf{z}_{11}}\mathbf{I}_2 \qquad (3)$$

Substituting (3) into (2) gives

$$\mathbf{V}_2 = \frac{\mathbf{z}_{21}}{\mathbf{z}_{11}}\mathbf{V}_1 + \left(\mathbf{z}_{22} - \frac{\mathbf{z}_{21}\,\mathbf{z}_{12}}{\mathbf{z}_{11}}\right)\mathbf{I}_2$$

or

$$\mathbf{V}_2 = \frac{\mathbf{z}_{21}}{\mathbf{z}_{11}}\mathbf{V}_1 + \frac{\Delta_z}{\mathbf{z}_{11}}\mathbf{I}_2 \qquad (4)$$

Comparing (3) and (4) with the following equations

$$\mathbf{I}_1 = \mathbf{g}_{11}\,\mathbf{V}_1 + \mathbf{g}_{12}\,\mathbf{I}_2$$

$$\mathbf{V}_2 = \mathbf{g}_{21}\,\mathbf{V}_1 + \mathbf{g}_{22}\,\mathbf{I}_2$$

indicates that

$$\underline{\mathbf{g}_{11} = \frac{1}{\mathbf{z}_{11}}}, \quad \underline{\mathbf{g}_{12} = \frac{-\mathbf{z}_{12}}{\mathbf{z}_{11}}}, \quad \underline{\mathbf{g}_{21} = \frac{\mathbf{z}_{21}}{\mathbf{z}_{11}}}, \quad \underline{\mathbf{g}_{22} = \frac{\Delta_z}{\mathbf{z}_{11}}}$$

as required.

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Chapter 19, Problem 56.

For the network of Fig. 19.107, obtain $\mathbf{V}_o/\mathbf{V}_s$.

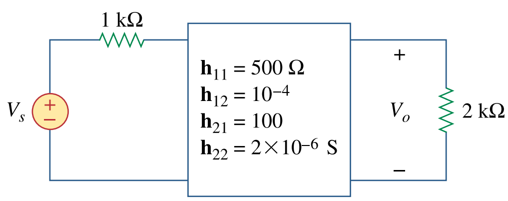
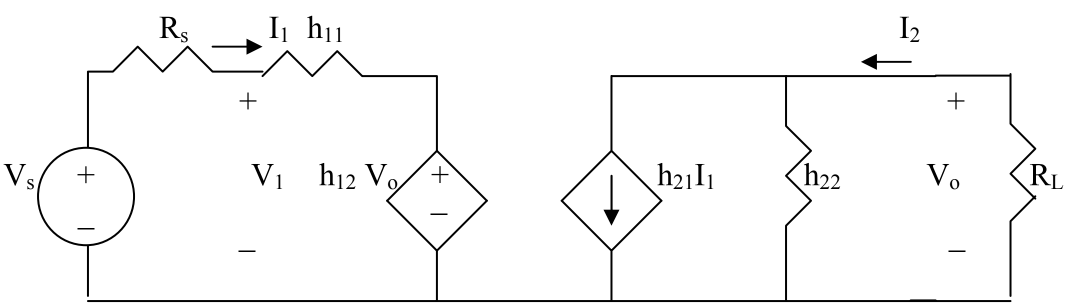


Figure 19.107
For Prob. 19.56.

Chapter 19, Solution 56.

Using Fig. 19.20, we obtain the equivalent circuit as shown below.



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We can solve this using MATLAB. First, we generate 4 equations from the given circuit. It may help to let $V_s = 10$ V.

$$-10 + R_sI_1 + V_1 = 0 \text{ or } V_1 + 1000I_1 = 10$$
$$-10 + R_sI_1 + h_{11}I_1 + h_{12}V_o = 0 \text{ or } 0.0001V_s + 1500 = 10$$
$$I_2 = -V_o/R_L \text{ or } V_o + 2000I_2 = 0$$
$$h_{21}I_1 + h_{22}V_o - I_2 = 0 \text{ or } 2\text{x}10^{-6}V_o + 100I_1 - I_2 = 0$$

```
>> A=[1,0,1000,0;0,0.0001,1500,0;0,1,0,2000;0,(2*10^-6),100,-1]
A =
  1.0e+003 *
    0.0010         0    1.0000         0
         0    0.0000    1.5000         0
         0    0.0010         0    2.0000
         0    0.0000    0.1000   -0.0010
>> U=[10;10;0;0]
U =
    10
    10
     0
     0
>> X=inv(A)*U
X =
  1.0e+003 *
    0.0032
   -1.3459
    0.0000
    0.0007
```

Gain = $V_o/V_s = -1{,}345.9/10 =$ **<u>–134.59</u>**.

There is a second approach we can take to check this problem. First, the resistive value of h_{22} is quite large, 500 kΩ versus R_L so can be ignored. Working on the right side of the circuit we obtain the following,

$I_2 = 100I_1$ which leads to $V_o = -I_2\text{x}2\text{k} = -2\text{x}10^5I_1$.

Now the left hand loop equation becomes,

$$-V_s + (1000 + 500 + 10^{-4}(-2\text{x}10^5))I_1 = 1480I_1.$$

Solving for V_o/V_s we get,

$V_o/V_s = -200{,}000/1480 =$ **<u>–134.14</u>**.

Our answer checks!

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Chapter 19, Problem 57.

Given the transmission parameters

$$[\mathbf{T}] = \begin{bmatrix} 3 & 20 \\ 1 & 7 \end{bmatrix}$$

obtain the other five two-port parameters.

Chapter 19, Solution 57.

$$\Delta_T = (3)(7) - (20)(1) = 1$$

$$[\mathbf{z}] = \begin{bmatrix} \dfrac{\mathbf{A}}{\mathbf{C}} & \dfrac{\Delta_T}{\mathbf{C}} \\ \dfrac{1}{\mathbf{C}} & \dfrac{\mathbf{D}}{\mathbf{C}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{3} & \mathbf{1} \\ \mathbf{1} & \mathbf{7} \end{bmatrix} \Omega}$$

$$[\mathbf{y}] = \begin{bmatrix} \dfrac{\mathbf{D}}{\mathbf{B}} & \dfrac{-\Delta_T}{\mathbf{B}} \\ \dfrac{-1}{\mathbf{B}} & \dfrac{\mathbf{A}}{\mathbf{B}} \end{bmatrix} = \underline{\begin{bmatrix} \dfrac{\mathbf{7}}{\mathbf{20}} & \dfrac{\mathbf{-1}}{\mathbf{20}} \\ \dfrac{\mathbf{-1}}{\mathbf{20}} & \dfrac{\mathbf{3}}{\mathbf{20}} \end{bmatrix} \mathbf{S}}$$

$$[\mathbf{h}] = \begin{bmatrix} \dfrac{\mathbf{B}}{\mathbf{D}} & \dfrac{\Delta_T}{\mathbf{D}} \\ \dfrac{-1}{\mathbf{D}} & \dfrac{\mathbf{C}}{\mathbf{D}} \end{bmatrix} = \underline{\begin{bmatrix} \dfrac{\mathbf{20}}{\mathbf{7}}\Omega & \dfrac{\mathbf{1}}{\mathbf{7}} \\ \dfrac{\mathbf{-1}}{\mathbf{7}} & \dfrac{\mathbf{1}}{\mathbf{7}}\mathbf{S} \end{bmatrix}}$$

$$[\mathbf{g}] = \begin{bmatrix} \dfrac{\mathbf{C}}{\mathbf{A}} & \dfrac{-\Delta_T}{\mathbf{A}} \\ \dfrac{1}{\mathbf{A}} & \dfrac{\mathbf{B}}{\mathbf{A}} \end{bmatrix} = \underline{\begin{bmatrix} \dfrac{\mathbf{1}}{\mathbf{3}}\mathbf{S} & \dfrac{\mathbf{-1}}{\mathbf{3}} \\ \dfrac{\mathbf{1}}{\mathbf{3}} & \dfrac{\mathbf{20}}{\mathbf{3}}\Omega \end{bmatrix}}$$

$$[\mathbf{t}] = \begin{bmatrix} \dfrac{\mathbf{D}}{\Delta_T} & \dfrac{\mathbf{B}}{\Delta_T} \\ \dfrac{\mathbf{C}}{\Delta_T} & \dfrac{\mathbf{A}}{\Delta_T} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{7} & \mathbf{20}\,\Omega \\ \mathbf{1\,S} & \mathbf{3} \end{bmatrix}}$$

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Chapter 19, Problem 58.

A two-port is described by

$\mathbf{V}_1 = \mathbf{I}_1 + 2\mathbf{V}_2, \qquad \mathbf{I}_2 = -2\mathbf{I}_1 + 0.4\mathbf{V}_2$

Find: (a) the *y* parameters, (b) the transmission parameters.

Chapter 19, Solution 58.

The given set of equations is for the h parameters.

$$[\mathbf{h}] = \begin{bmatrix} 1\,\Omega & 2 \\ -2 & 0.4\text{ S} \end{bmatrix} \qquad \Delta_h = (1)(0.4) - (2)(-2) = 4.4$$

(a)
$$[\mathbf{y}] = \begin{bmatrix} \dfrac{1}{\mathbf{h}_{11}} & \dfrac{-\mathbf{h}_{12}}{\mathbf{h}_{11}} \\ \dfrac{\mathbf{h}_{21}}{\mathbf{h}_{11}} & \dfrac{\Delta_h}{\mathbf{h}_{11}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{1} & \mathbf{-2} \\ \mathbf{-2} & \mathbf{4.4} \end{bmatrix}\mathbf{S}}$$

(b)
$$[\mathbf{T}] = \begin{bmatrix} \dfrac{-\Delta_h}{\mathbf{h}_{21}} & \dfrac{-\mathbf{h}_{11}}{\mathbf{h}_{21}} \\ \dfrac{-\mathbf{h}_{22}}{\mathbf{h}_{21}} & \dfrac{-1}{\mathbf{h}_{21}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{2.2} & \mathbf{0.5\,\Omega} \\ \mathbf{0.2\text{ S}} & \mathbf{0.5} \end{bmatrix}}$$

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Chapter 19, Problem 59.

Given that

$$[\mathbf{g}] = \begin{bmatrix} 0.06\text{S} & -0.4 \\ 0.2 & 2\Omega \end{bmatrix}$$

determine:

(a) [**z**] (b) [**y**] (c) [**h**] (d) [**T**]

Chapter 19, Solution 59.

$$\Delta_g = (0.06)(2) - (-0.4)(0.2) = 0.12 + 0.08 = 0.2$$

(a) $$[\mathbf{z}] = \begin{bmatrix} \dfrac{1}{\mathbf{g}_{11}} & \dfrac{-\mathbf{g}_{12}}{\mathbf{g}_{11}} \\ \dfrac{\mathbf{g}_{21}}{\mathbf{g}_{11}} & \dfrac{\Delta_g}{\mathbf{g}_{11}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{16.667} & \mathbf{6.667} \\ \mathbf{3.333} & \mathbf{3.333} \end{bmatrix} \Omega}$$

(b) $$[\mathbf{y}] = \begin{bmatrix} \dfrac{\Delta_g}{\mathbf{g}_{22}} & \dfrac{\mathbf{g}_{12}}{\mathbf{g}_{22}} \\ \dfrac{-\mathbf{g}_{21}}{\mathbf{g}_{22}} & \dfrac{1}{\mathbf{g}_{22}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{0.1} & \mathbf{-0.2} \\ \mathbf{-0.1} & \mathbf{0.5} \end{bmatrix} \mathbf{S}}$$

(c) $$[\mathbf{h}] = \begin{bmatrix} \dfrac{\mathbf{g}_{22}}{\Delta_g} & \dfrac{-\mathbf{g}_{12}}{\Delta_g} \\ \dfrac{-\mathbf{g}_{21}}{\Delta_g} & \dfrac{\mathbf{g}_{11}}{\Delta_g} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{10\,\Omega} & \mathbf{2} \\ \mathbf{-1} & \mathbf{0.3\,S} \end{bmatrix}}$$

(d) $$[\mathbf{T}] = \begin{bmatrix} \dfrac{1}{\mathbf{g}_{21}} & \dfrac{\mathbf{g}_{22}}{\mathbf{g}_{21}} \\ \dfrac{\mathbf{g}_{11}}{\mathbf{g}_{21}} & \dfrac{\Delta_g}{\mathbf{g}_{21}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{5} & \mathbf{10\,\Omega} \\ \mathbf{0.3\,S} & \mathbf{1} \end{bmatrix}}$$

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Chapter 19, Problem 60.

Design a **T** network necessary to realize the following z parameters at $\omega = 10^6$ rad/s

$$[\mathbf{z}] = \begin{bmatrix} 4+j3 & 2 \\ 2 & 5-j \end{bmatrix} \text{k}\Omega$$

Chapter 19, Solution 60.

Comparing this with Fig. 19.5,

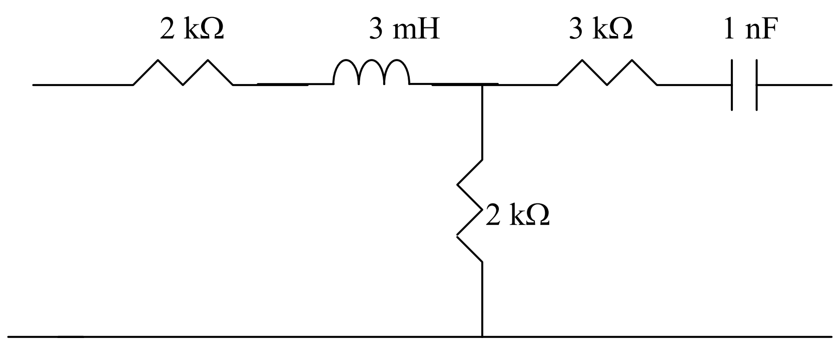
$$z_{11} - z_{12} = 4 + j3 - 2 = 2 + j3k\Omega$$

$z_{22} - z_{12} = 5 - j - 2 = 3 - j$ kΩ

$$X_L = 3x10^3 = \omega L \quad \longrightarrow \quad L = \frac{3x10^3}{10^6} = 3mH$$

$X_C = 1x10^3 = 1/(\omega C)$ or $C = 1/(10^3x10^6) = 1$ nF

Hence, the resulting T network is shown below.



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Chapter 19, Problem 61.

For the bridge circuit in Fig. 19.108, obtain:

(a) the *z* parameters
(b) the *h* parameters
(c) the transmission parameters

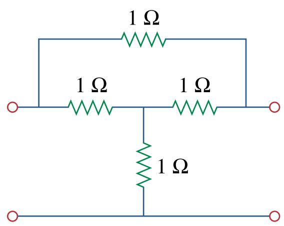
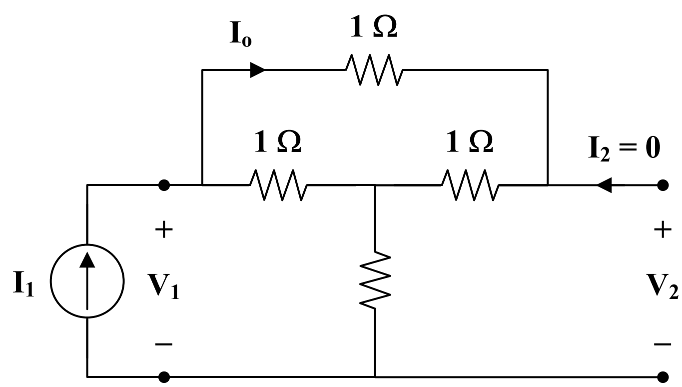


Figure 19.108

For Prob. 19.61.

Chapter 19, Solution 61.

(a) To obtain $\mathbf{z}_{11}$ and $\mathbf{z}_{21}$, consider the circuit in Fig. (a).



(a)

$$\mathbf{V}_1 = \mathbf{I}_1[1+1\,||\,(1+1)] = \mathbf{I}_1\left(1+\frac{2}{3}\right) = \frac{5}{3}\mathbf{I}_1$$

$$\mathbf{z}_{11} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = \frac{5}{3}$$

$$\mathbf{I}_o = \frac{1}{1+2}\mathbf{I}_1 = \frac{1}{3}\mathbf{I}_1$$

$$-\mathbf{V}_2 + \mathbf{I}_o + \mathbf{I}_1 = 0$$

$$\mathbf{V}_2 = \frac{1}{3}\mathbf{I}_1 + \mathbf{I}_1 = \frac{4}{3}\mathbf{I}_1$$

$$\mathbf{z}_{21} = \frac{\mathbf{V}_2}{\mathbf{I}_1} = \frac{4}{3}$$

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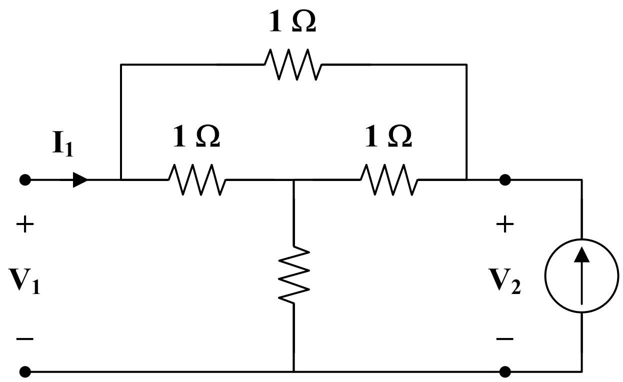
To obtain $\mathbf{z}_{22}$ and $\mathbf{z}_{12}$, consider the circuit in Fig. (b).



(b)

Due to symmetry, this is similar to the circuit in Fig. (a).

$$\mathbf{z}_{22} = \mathbf{z}_{11} = \frac{5}{3}, \qquad \mathbf{z}_{21} = \mathbf{z}_{12} = \frac{4}{3}$$

$$[\mathbf{z}] = \begin{bmatrix} \frac{5}{3} & \frac{4}{3} \\ \frac{4}{3} & \frac{5}{3} \end{bmatrix} \Omega$$

(b) $$[\mathbf{h}] = \begin{bmatrix} \frac{\Delta_z}{\mathbf{z}_{22}} & \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}} \\ \frac{-\mathbf{z}_{21}}{\mathbf{z}_{22}} & \frac{1}{\mathbf{z}_{22}} \end{bmatrix} = \begin{bmatrix} \frac{3}{5}\Omega & \frac{4}{5} \\ \frac{-4}{5} & \frac{3}{5}\text{S} \end{bmatrix}$$

(c) $$[\mathbf{T}] = \begin{bmatrix} \frac{\mathbf{z}_{11}}{\mathbf{z}_{21}} & \frac{\Delta_z}{\mathbf{z}_{21}} \\ \frac{1}{\mathbf{z}_{21}} & \frac{\mathbf{z}_{22}}{\mathbf{z}_{21}} \end{bmatrix} = \begin{bmatrix} \frac{5}{4} & \frac{3}{4}\Omega \\ \frac{3}{4}\text{S} & \frac{5}{4} \end{bmatrix}$$

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Chapter 19, Problem 62.

Find the z parameters of the op amp circuit in Fig. 19.109. Obtain the transmission parameters.

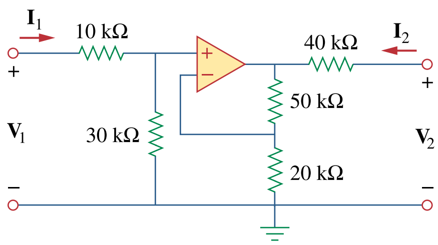

Figure 19.109

For Prob. 19.62.

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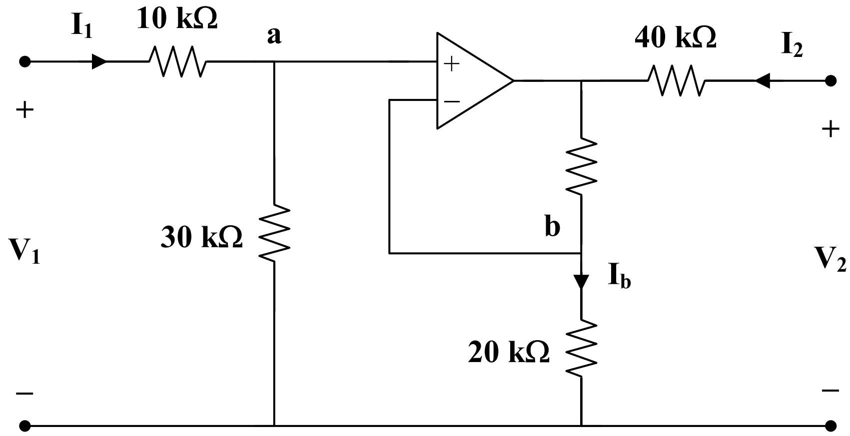
Chapter 19, Solution 62.

Consider the circuit shown below.



Since no current enters the input terminals of the op amp,

$$\mathbf{V}_1 = (10+30)\times 10^3\,\mathbf{I}_1 \qquad (1)$$

But $\quad \mathbf{V}_a = \mathbf{V}_b = \dfrac{30}{40}\mathbf{V}_1 = \dfrac{3}{4}\mathbf{V}_1$

$$\mathbf{I}_b = \frac{\mathbf{V}_b}{20\times 10^3} = \frac{3}{80\times 10^3}\mathbf{V}_1$$

which is the same current that flows through the 50-kΩ resistor.

Thus, $\quad \mathbf{V}_2 = 40\times 10^3\,\mathbf{I}_2 + (50+20)\times 10^3\,\mathbf{I}_b$

$$\mathbf{V}_2 = 40\times 10^3\,\mathbf{I}_2 + 70\times 10^3 \cdot \frac{3}{80\times 10^3}\mathbf{V}_1$$

$$\mathbf{V}_2 = \frac{21}{8}\mathbf{V}_1 + 40\times 10^3\,\mathbf{I}_2$$

$$\mathbf{V}_2 = 105\times 10^3\,\mathbf{I}_1 + 40\times 10^3\,\mathbf{I}_2 \qquad (2)$$

From (1) and (2),

$$[\mathbf{z}] = \underline{\begin{bmatrix} \mathbf{40} & \mathbf{0} \\ \mathbf{105} & \mathbf{40} \end{bmatrix}\mathbf{k\Omega}}$$

$$\Delta_z = \mathbf{z}_{11}\mathbf{z}_{22} - \mathbf{z}_{12}\mathbf{z}_{21} = 16\times 10^8$$

$$[\mathbf{T}] = \begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix} = \begin{bmatrix} \dfrac{\mathbf{z}_{11}}{\mathbf{z}_{21}} & \dfrac{\Delta_z}{\mathbf{z}_{21}} \\ \dfrac{1}{\mathbf{z}_{21}} & \dfrac{\mathbf{z}_{22}}{\mathbf{z}_{21}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{0.381} & \mathbf{15.24\ k\Omega} \\ \mathbf{9.52\ \mu S} & \mathbf{0.381} \end{bmatrix}}$$

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Chapter 19, Problem 63.

Determine the *z* parameters of the two-port in Fig. 19.110.

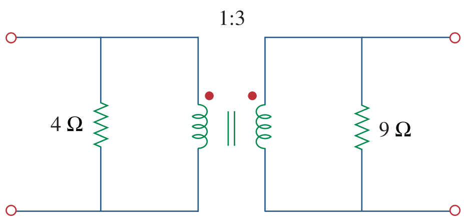

Figure 19.110
For Prob. 19.63.

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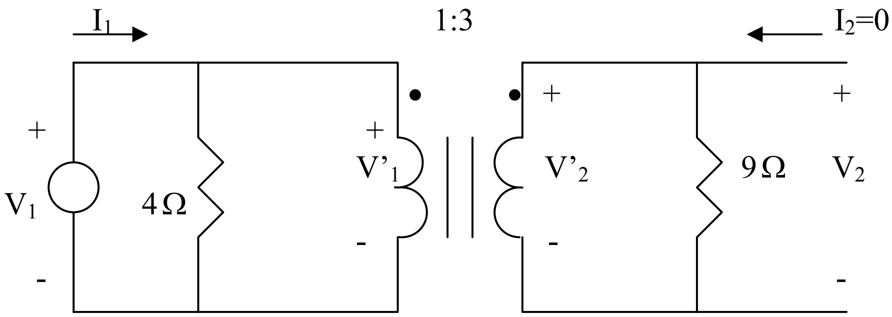
Chapter 19, Solution 63.

To get z_{11} and z_{21}, consider the circuit below.

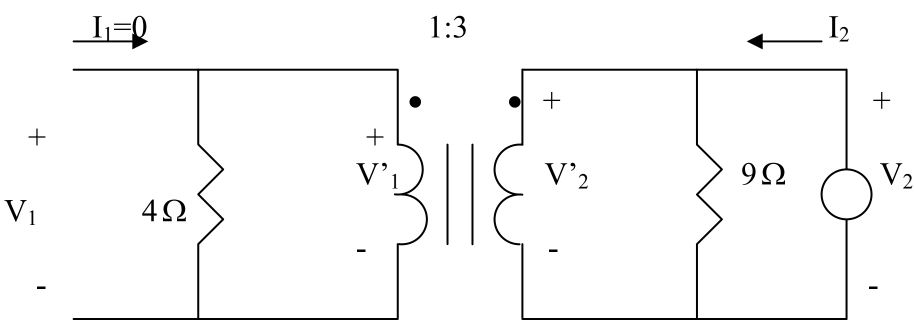


$$Z_R = \frac{9}{n^2} = 1, \qquad n = 3$$

$$V_1 = (4 // Z_R)I_1 = \frac{4}{5}I_1 \longrightarrow z_{11} = \frac{V_1}{I_1} = 0.8$$

$$V_2 = V_2' = nV_1' = nV_1 = 3(4/5)I_1 \longrightarrow z_{21} = \frac{V_2}{I_1} = 2.4$$

To get z_{21} and z_{22}, consider the circuit below.



$$Z_R' = n^2(4) = 36, \qquad n = 3$$

$$V_2 = (9 // Z_R')I_2 = \frac{9x36}{45}I_2 \longrightarrow z_{22} = \frac{V_2}{I_2} = 7.2$$

$$V_1 = \frac{V_2}{n} = \frac{V_2}{3} = 2.4I_2 \longrightarrow z_{21} = \frac{V_1}{I_2} = 2.4$$

Thus,

$$[z] = \begin{bmatrix} 0.8 & 2.4 \\ 2.4 & 7.2 \end{bmatrix} \Omega$$

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Chapter 19, Problem 64.

Determine the *y* parameters at $\omega = 1{,}000$ rad/s for the op amp circuit in Fig. 19.111. Find the corresponding *h* parameters.

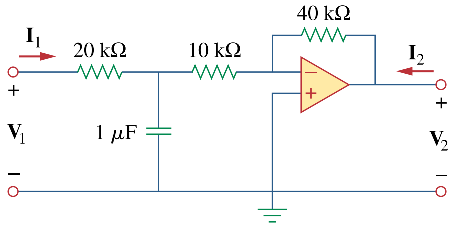


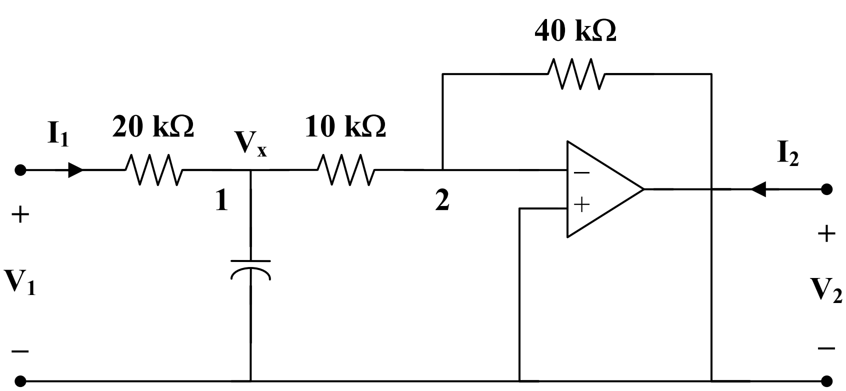
Figure 19.111

For Prob. 19.64.

Chapter 19, Solution 64.

$$1\,\mu F \longrightarrow \frac{1}{j\omega C} = \frac{-j}{(10^3)(10^{-6})} = -j\,k\Omega$$

Consider the op amp circuit below.



At node 1,

$$\frac{\mathbf{V}_1 - \mathbf{V}_x}{20} = \frac{\mathbf{V}_x}{-j} + \frac{\mathbf{V}_x - 0}{10}$$

$$\mathbf{V}_1 = (3 + j20)\,\mathbf{V}_x \qquad (1)$$

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At node 2,

$$\frac{\mathbf{V}_x - 0}{10} = \frac{0 - \mathbf{V}_2}{40} \quad \longrightarrow \quad \mathbf{V}_x = \frac{-1}{4}\mathbf{V}_2 \qquad (2)$$

But

$$\mathbf{I}_1 = \frac{\mathbf{V}_1 - \mathbf{V}_x}{20 \times 10^3} \qquad (3)$$

Substituting (2) into (3) gives

$$\mathbf{I}_1 = \frac{\mathbf{V}_1 + 0.25\,\mathbf{V}_2}{20 \times 10^3} = 50 \times 10^{-6}\,\mathbf{V}_1 + 12.5 \times 10^{-6}\,\mathbf{V}_2 \qquad (4)$$

Substituting (2) into (1) yields

$$\mathbf{V}_1 = \frac{-1}{4}(3 + j20)\,\mathbf{V}_2$$

or

$$0 = \mathbf{V}_1 + (0.75 + j5)\,\mathbf{V}_2 \qquad (5)$$

Comparing (4) and (5) with the following equations

$$\mathbf{I}_1 = \mathbf{y}_{11}\,\mathbf{V}_1 + \mathbf{y}_{12}\,\mathbf{V}_2$$
$$\mathbf{I}_2 = \mathbf{y}_{21}\,\mathbf{V}_1 + \mathbf{y}_{22}\,\mathbf{V}_2$$

indicates that $\mathbf{I}_2 = 0$ and that

$$[\mathbf{y}] = \begin{bmatrix} \mathbf{50 \times 10^{-6}} & \mathbf{12.5 \times 10^{-6}} \\ \mathbf{1} & \mathbf{0.75 + j5} \end{bmatrix} \mathbf{S}$$

$$\Delta_y = (77.5 + j25. - 12.5) \times 10^{-6} = (65 + j250) \times 10^{-6}$$

$$[\mathbf{h}] = \begin{bmatrix} \dfrac{1}{\mathbf{y}_{11}} & \dfrac{-\mathbf{y}_{12}}{\mathbf{y}_{11}} \\ \dfrac{\mathbf{y}_{21}}{\mathbf{y}_{11}} & \dfrac{\Delta_y}{\mathbf{y}_{11}} \end{bmatrix} = \begin{bmatrix} \mathbf{2 \times 10^4\ \Omega} & \mathbf{-0.25} \\ \mathbf{2 \times 10^4} & \mathbf{1.3 + j5\ S} \end{bmatrix}$$

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Chapter 19, Problem 65.

What is the *y* parameter presentation of the circuit in Fig. 19.112?

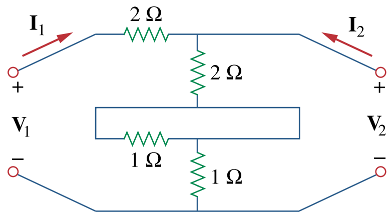

Figure 19.112
For Prob. 19.65.

Chapter 19, Solution 65.

The network consists of two two-ports in series. It is better to work with z parameters and then convert to y parameters.

For N_a, $$[\mathbf{z}_a] = \begin{bmatrix} 4 & 2 \\ 2 & 2 \end{bmatrix}$$

For N_b, $$[\mathbf{z}_b] = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}$$

$$[\mathbf{z}] = [\mathbf{z}_a] + [\mathbf{z}_b] = \begin{bmatrix} 6 & 3 \\ 3 & 3 \end{bmatrix}$$

$$\Delta_z = 18 - 9 = 9$$

$$[\mathbf{y}] = \begin{bmatrix} \frac{\mathbf{z}_{22}}{\Delta_z} & \frac{-\mathbf{z}_{12}}{\Delta_z} \\ \frac{-\mathbf{z}_{21}}{\Delta_z} & \frac{\mathbf{z}_{11}}{\Delta_z} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{\frac{1}{3}} & \mathbf{\frac{-1}{3}} \\ \mathbf{\frac{-1}{3}} & \mathbf{\frac{2}{3}} \end{bmatrix} \mathbf{S}}$$

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Chapter 19, Problem 66.

In the two-port of Fig. 19.113, let $\mathbf{y}_{12} = \mathbf{y}_{21} = 0$, $\mathbf{y}_{11} = 2$ mS, and $\mathbf{y}_{22} = 10$ mS. Find $\mathbf{V}_o/\mathbf{V}_s$.

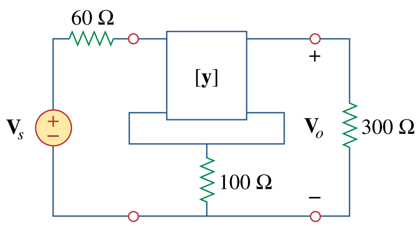

Figure 19.113

For Prob. 19.66.

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Chapter 19, Solution 66.

Since we have two two-ports in series, it is better to convert the given y parameters to z parameters.

$$\Delta_y = \mathbf{y}_{11}\mathbf{y}_{22} - \mathbf{y}_{12}\mathbf{y}_{21} = (2\times10^{-3})(10\times10^{-3}) - 0 = 20\times10^{-6}$$

$$[\mathbf{z}_a] = \begin{bmatrix} \dfrac{\mathbf{y}_{22}}{\Delta_y} & \dfrac{-\mathbf{y}_{12}}{\Delta_y} \\ \dfrac{-\mathbf{y}_{21}}{\Delta_y} & \dfrac{\mathbf{y}_{11}}{\Delta_y} \end{bmatrix} = \begin{bmatrix} 500\,\Omega & 0 \\ 0 & 100\,\Omega \end{bmatrix}$$

$$[\mathbf{z}] = \begin{bmatrix} 500 & 0 \\ 0 & 100 \end{bmatrix} + \begin{bmatrix} 100 & 100 \\ 100 & 100 \end{bmatrix} = \begin{bmatrix} 600 & 100 \\ 100 & 200 \end{bmatrix}$$

i.e.

$$\mathbf{V}_1 = \mathbf{z}_{11}\mathbf{I}_1 + \mathbf{z}_{12}\mathbf{I}_2$$
$$\mathbf{V}_2 = \mathbf{z}_{21}\mathbf{I}_1 + \mathbf{z}_{22}\mathbf{I}_2$$

or

$$\mathbf{V}_1 = 600\mathbf{I}_1 + 100\mathbf{I}_2 \qquad (1)$$
$$\mathbf{V}_2 = 100\mathbf{I}_1 + 200\mathbf{I}_2 \qquad (2)$$

But, at the input port,

$$\mathbf{V}_s = \mathbf{V}_1 + 60\mathbf{I}_1 \qquad (3)$$

and at the output port,

$$\mathbf{V}_2 = \mathbf{V}_o = -300\mathbf{I}_2 \qquad (4)$$

From (2) and (4),

$$100\mathbf{I}_1 + 200\mathbf{I}_2 = -300\mathbf{I}_2$$
$$\mathbf{I}_1 = -5\mathbf{I}_2 \qquad (5)$$

Substituting (1) and (5) into (3),

$$\mathbf{V}_s = 600\mathbf{I}_1 + 100\mathbf{I}_2 + 60\mathbf{I}_1$$
$$= (660)(-5)\mathbf{I}_2 + 100\mathbf{I}_2$$
$$= -3200\mathbf{I}_2 \qquad (6)$$

From (4) and (6),

$$\frac{\mathbf{V}_o}{\mathbf{V}_2} = \frac{-300\mathbf{I}_2}{-3200\mathbf{I}_2} = \underline{\mathbf{0.09375}}$$

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Chapter 19, Problem 67.

ML

If three copies of the circuit in Fig. 19.114 are connected in parallel, find the overall transmission parameters.

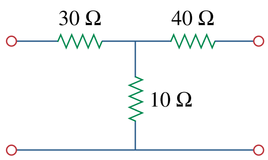
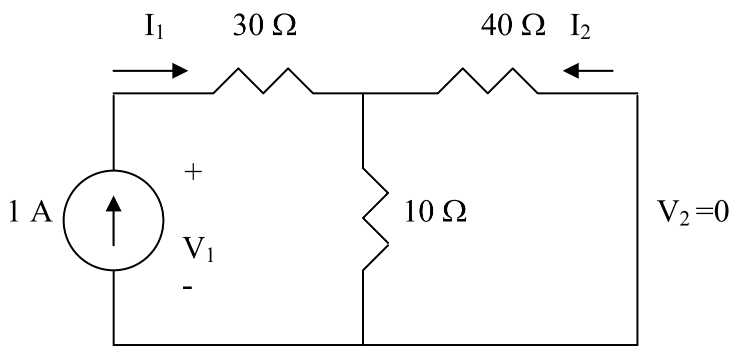


Figure 19.114

For Prob. 19.67.

Chapter 19, Solution 67.

We first the y parameters, to find y_{11} and y_{21} consider the circuit below.



$$V_1 = I_1(30 + 10 // 40) = 38I_1 \longrightarrow y_{11} = \frac{I_1}{V_1} = \frac{1}{38}$$

By current division,

$$I_2 = \frac{-10}{50} I_1 = -0.2I_1 \longrightarrow y_{21} = \frac{I_2}{V_1} = \frac{-0.2I_1}{38I_1} = \frac{-1}{190}$$

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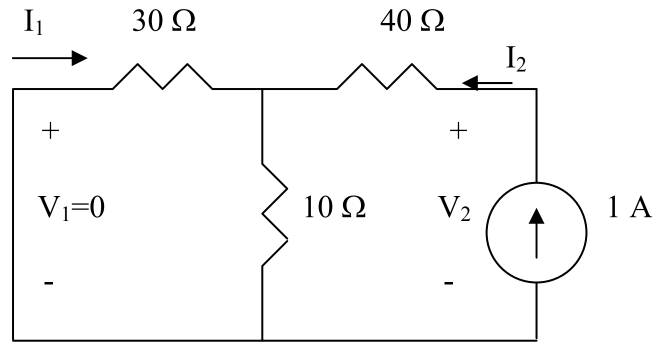
To find y_{22} and y_{12} consider the circuit below.



$$V_2 = (40 + 10 // 30)I_2 = 47.5I_2 \longrightarrow y_{22} = \frac{I_2}{V_2} = \frac{2}{93}$$ $y_{22} = 2/95$

By current division,

$$I_1 = -\frac{10}{30+10}I_2 = -\frac{I_2}{4} \longrightarrow y_{12} = \frac{I_1}{V_2} = \frac{-\frac{1}{4}I_2}{47.5I_2} = -\frac{1}{190}$$

$$[y] = \begin{bmatrix} 1/38 & -1/190 \\ -1/190 & 2/95 \end{bmatrix}$$

For three copies cascaded in parallel, we can use MATLAB.

```
>> Y=[1/38,-1/190;-1/190,2/95]
Y =
   0.0263   -0.0053
  -0.0053    0.0211
>> Y3=3*Y
Y3 =
   0.0789   -0.0158
  -0.0158    0.0632
>> DY=0.0789*0.0632-0.0158*0.158
DY =
   0.0025
>> T=[0.0632/0.0158,1/0.0158;DY/0.0158,0.0789/0.0158]
T =
   4.0000   63.2911
   0.1576    4.9937
```

$$T = \begin{bmatrix} 4 & 63.29 \\ 0.1576 & 4.994 \end{bmatrix}$$

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Chapter 19, Problem 68.

Obtain the *h* parameters for the network in Fig. 19.115.

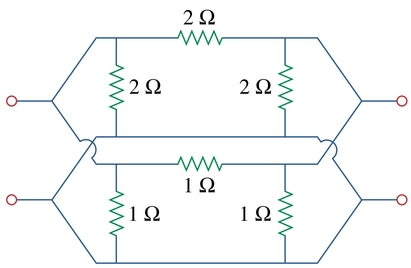

Figure 19.115

For Prob. 19.68.

Chapter 19, Solution 68.

For the upper network N_a, $[\mathbf{y}_a] = \begin{bmatrix} 4 & -2 \\ -2 & 4 \end{bmatrix}$

and for the lower network N_b, $[\mathbf{y}_b] = \begin{bmatrix} 2 & -1 \\ 1 & 2 \end{bmatrix}$

For the overall network,

$$[\mathbf{y}] = [\mathbf{y}_a] + [\mathbf{y}_b] = \begin{bmatrix} 6 & -3 \\ -3 & 6 \end{bmatrix}$$

$$\Delta_y = 36 - 9 = 27$$

$$[\mathbf{h}] = \begin{bmatrix} \dfrac{1}{\mathbf{y}_{11}} & \dfrac{-\mathbf{y}_{12}}{\mathbf{y}_{11}} \\ \dfrac{\mathbf{y}_{21}}{\mathbf{y}_{11}} & \dfrac{\Delta_y}{\mathbf{y}_{11}} \end{bmatrix} = \underline{\begin{bmatrix} \dfrac{1}{6}\Omega & \dfrac{1}{2} \\ \dfrac{1}{2} & \dfrac{9}{2}\mathrm{S} \end{bmatrix}}$$

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Chapter 19, Problem 69.

* The circuit in Fig. 19.116 may be regarded as two two-ports connected in parallel. Obtain the *y* parameters as functions of *s*.

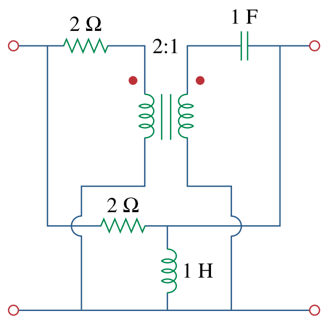

Figure 19.116

For Prob. 19.69.

* An asterisk indicates a challenging problem.

Chapter 19, Solution 69.

We first determine the y parameters for the upper network N_a.

To get $\mathbf{y}_{11}$ and $\mathbf{y}_{21}$, consider the circuit in Fig. (a).

$$n = \frac{1}{2}, \qquad \mathbf{Z}_R = \frac{1/s}{n^2} = \frac{4}{s}$$

$$\mathbf{V}_1 = (2 + \mathbf{Z}_R)\mathbf{I}_1 = \left(2 + \frac{4}{s}\right)\mathbf{I}_1 = \left(\frac{2s+4}{s}\right)\mathbf{I}_1$$

$$\mathbf{y}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{s}{2(s+2)}$$

$$\mathbf{I}_2 = \frac{-\mathbf{I}_1}{n} = -2\mathbf{I}_1 = \frac{-s\mathbf{V}_1}{s+2}$$

$$\mathbf{y}_{21} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = \frac{-s}{s+2}$$

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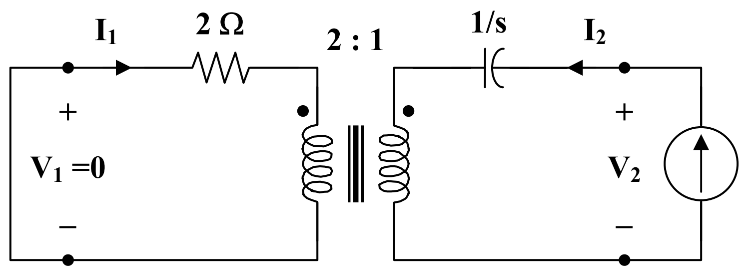
To get $\mathbf{y}_{22}$ and $\mathbf{y}_{12}$, consider the circuit in Fig. (b).



(b)

$$\mathbf{Z}_R' = (n^2)(2) = \left(\frac{1}{4}\right)(2) = \frac{1}{2}$$

$$\mathbf{V}_2 = \left(\frac{1}{s} + \mathbf{Z}_R'\right)\mathbf{I}_2 = \left(\frac{1}{s} + \frac{1}{2}\right)\mathbf{I}_2 = \left(\frac{s+2}{2s}\right)\mathbf{I}_2$$

$$\mathbf{y}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{2s}{s+2}$$

$$\mathbf{I}_1 = -n\,\mathbf{I}_2 = \left(\frac{-1}{2}\right)\left(\frac{2s}{s+2}\right)\mathbf{V}_2 = \left(\frac{-s}{s+2}\right)\mathbf{V}_2$$

$$\mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{-s}{s+2}$$

$$[\mathbf{y}_a] = \begin{bmatrix} \dfrac{s}{2(s+2)} & \dfrac{-s}{s+2} \\ \dfrac{-s}{s+2} & \dfrac{2s}{s+2} \end{bmatrix}$$

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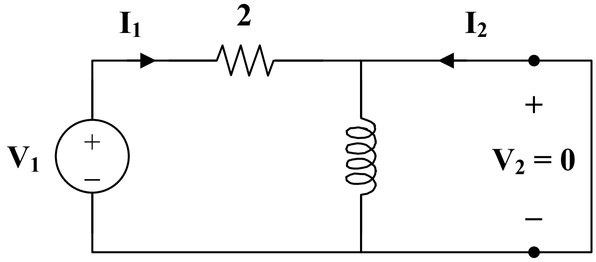
For the lower network N_b, we obtain $\mathbf{y}_{11}$ and $\mathbf{y}_{21}$ by referring to the network in Fig. (c).

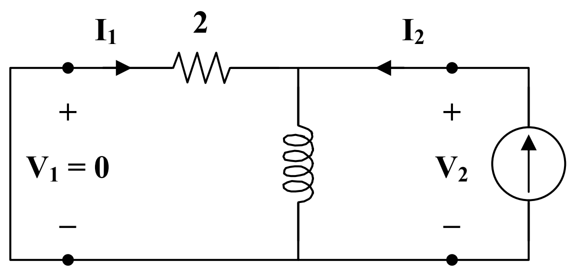


(c)

$$\mathbf{V}_1 = 2\mathbf{I}_1 \longrightarrow \mathbf{y}_{11} = \frac{\mathbf{I}_1}{\mathbf{V}_1} = \frac{1}{2}$$

$$\mathbf{I}_2 = -\mathbf{I}_1 = \frac{-\mathbf{V}_1}{2} \longrightarrow \mathbf{y}_{21} = \frac{\mathbf{I}_2}{\mathbf{V}_1} = \frac{-1}{2}$$

To get $\mathbf{y}_{22}$ and $\mathbf{y}_{12}$, refer to the circuit in Fig. (d).



(d)

$$\mathbf{V}_2 = (s \,\|\, 2)\mathbf{I}_2 = \frac{2s}{s+2}\mathbf{I}_2 \longrightarrow \mathbf{y}_{22} = \frac{\mathbf{I}_2}{\mathbf{V}_2} = \frac{s+2}{2s}$$

$$\mathbf{I}_1 = -\mathbf{I}_2 \cdot \frac{-s}{s+2} = \left(\frac{-s}{s+2}\right)\left(\frac{s+2}{2s}\right)\mathbf{V}_2 = \frac{-\mathbf{V}_2}{2}$$

$$\mathbf{y}_{12} = \frac{\mathbf{I}_1}{\mathbf{V}_2} = \frac{-1}{2}$$

$$[\mathbf{y}_b] = \begin{bmatrix} 1/2 & -1/2 \\ -1/2 & (s+2)/2s \end{bmatrix}$$

$$[\mathbf{y}] = [\mathbf{y}_a] + [\mathbf{y}_b] = \begin{bmatrix} \dfrac{\mathbf{s+1}}{\mathbf{s+2}} & \dfrac{\mathbf{-(3s+2)}}{\mathbf{2(s+2)}} \\ \dfrac{\mathbf{-(3s+2)}}{\mathbf{2(s+2)}} & \dfrac{\mathbf{5s^2+4s+4}}{\mathbf{2s(s+2)}} \end{bmatrix}$$

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Chapter 19, Problem 70.

* For the parallel-series connection of the two two-ports in Fig. 19.117, find the *g* parameters.

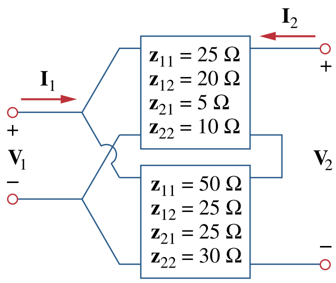

Figure 19.117

For Prob. 19.70.

* An asterisk indicates a challenging problem.

Chapter 19, Solution 70.

We may obtain the g parameters from the given z parameters.

$$[\mathbf{z}_a] = \begin{bmatrix} 25 & 20 \\ 5 & 10 \end{bmatrix}, \qquad \Delta_{z_a} = 250 - 100 = 150$$

$$[\mathbf{z}_b] = \begin{bmatrix} 50 & 25 \\ 25 & 30 \end{bmatrix}, \qquad \Delta_{z_b} = 1500 - 625 = 875$$

$$[\mathbf{g}] = \begin{bmatrix} \dfrac{1}{z_{11}} & \dfrac{-z_{12}}{z_{11}} \\ \dfrac{z_{21}}{z_{11}} & \dfrac{\Delta_z}{z_{11}} \end{bmatrix}$$

$$[\mathbf{g}_a] = \begin{bmatrix} 0.04 & -0.8 \\ 0.2 & 6 \end{bmatrix}, \qquad [\mathbf{g}_b] = \begin{bmatrix} 0.02 & -0.5 \\ 0.5 & 17.5 \end{bmatrix}$$

$$[\mathbf{g}] = [\mathbf{g}_a] + [\mathbf{g}_b] = \underline{\begin{bmatrix} \mathbf{0.06\ S} & \mathbf{-1.3} \\ \mathbf{0.7} & \mathbf{23.5\ \Omega} \end{bmatrix}}$$

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Chapter 19, Problem 71.

* Determine the z parameters for the network in Fig. 19.118.

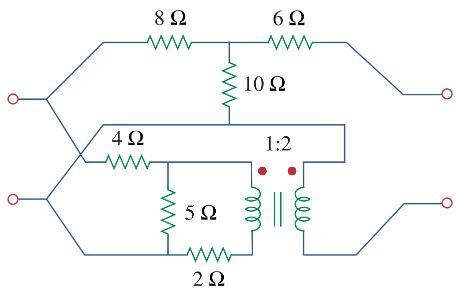

Figure 19.118

For Prob. 19.71.

* An asterisk indicates a challenging problem.

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Chapter 19, Solution 71.

This is a parallel-series connection of two two-ports. We need to add their g parameters together and obtain z parameters from there.

For the transformer,

$$V_1 = \frac{1}{2}V_2, \quad I_1 = -2I_2$$

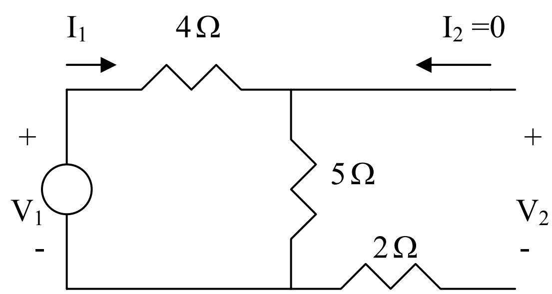
Comparing this with

$$V_1 = AV_2 - BI_2, \qquad I_1 = CV_2 - DI_2$$

shows that

$$[T_{b1}] = \begin{bmatrix} 0.5 & 0 \\ 0 & 2 \end{bmatrix}$$

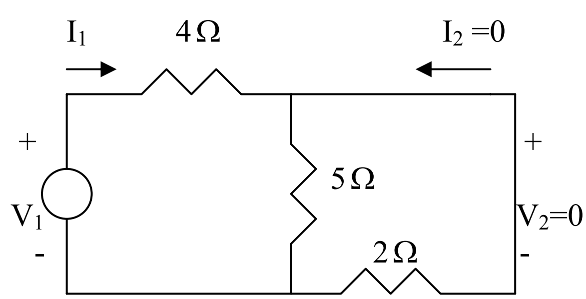
To get A and C for T_{b2}, consider the circuit below.



$$V_1 = 9I_1, \qquad V_2 = 5I_1$$

$$A = \frac{V_1}{V_2} = 9/5 = 1.8, \qquad C = \frac{I_1}{V_2} = 1/5 = 0.2$$

We obtain B and D by looking at the circuit below.



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$$I_2 = -\frac{5}{7}I_1 \quad \longrightarrow \quad D = -\frac{I_1}{I_2} = 7/5 = 1.4$$

$$V_1 = 4I_1 - 2I_2 = 4(-\frac{7}{5}I_2) - 2I_2 = -\frac{38}{5}I_2 \quad \longrightarrow \quad B = -\frac{V_1}{I_2} = 7.6$$

$$[T_{b2}] = \begin{bmatrix} 1.8 & 7.6 \\ 0.2 & 1.4 \end{bmatrix}$$

$$[T] = [T_{b1}][T_{b2}] = \begin{bmatrix} 0.9 & 3.8 \\ 0.4 & 2.8 \end{bmatrix}, \qquad \Delta_T = 1$$

$$[g_b] = \begin{bmatrix} C/A & -\Delta_T/A \\ 1/A & B/A \end{bmatrix} = \begin{bmatrix} 0.4444 & -1.1111 \\ 1.1111 & 4.2222 \end{bmatrix}$$

From Prob. 19.52,

$$[T_a] = \begin{bmatrix} 1.8 & 18.8 \\ 0.1 & 1.6 \end{bmatrix}$$

$$[g_a] = \begin{bmatrix} C/A & -\Delta_T/A \\ 1/A & B/A \end{bmatrix} = \begin{bmatrix} 0.05555 & -0.5555 \\ 0.5555 & 10.4444 \end{bmatrix}$$

$$[g] = [g_a] + [g_b] = \begin{bmatrix} 0.4999 & -1.6667 \\ 1.6667 & 14.667 \end{bmatrix}$$

Thus,

$$[z] = \begin{bmatrix} 1/g_{11} & -g_{21}/g_{11} \\ g_{21}/g_{11} & \Delta_g/g_{11} \end{bmatrix} = \underline{\begin{bmatrix} 2 & -3.334 \\ 3.334 & 20.22 \end{bmatrix}\Omega}$$

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Chapter 19, Problem 72.

* A series-parallel connection of two two-ports is shown in Fig. 19.119. Determine the z parameter representation of the network.

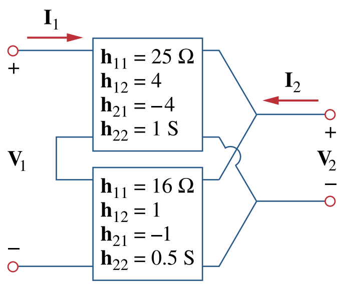

Figure 19.119

For Prob. 19.72.

* An asterisk indicates a challenging problem.

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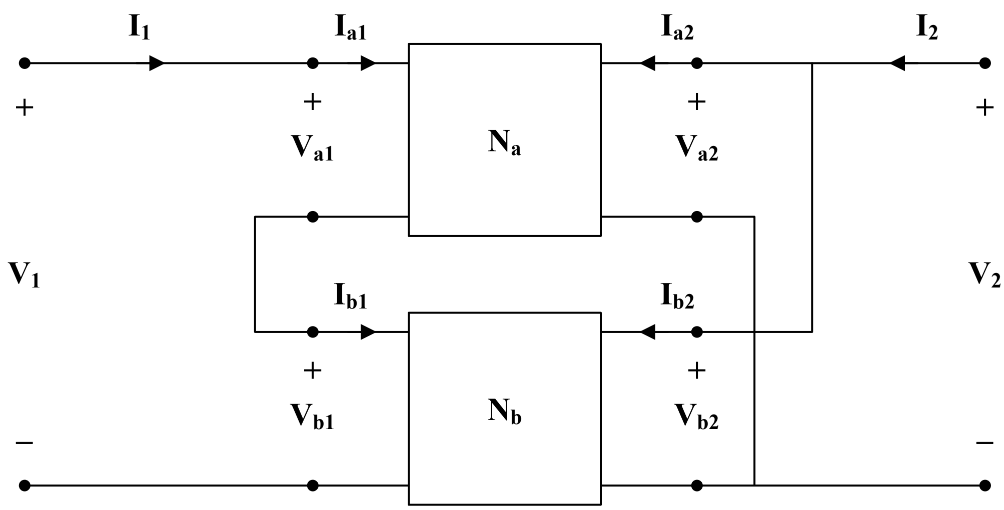
Chapter 19, Solution 72.

Consider the network shown below.



$$\mathbf{V}_{a1} = 25\mathbf{I}_{a1} + 4\mathbf{V}_{a2} \quad (1)$$
$$\mathbf{I}_{a2} = -4\mathbf{I}_{a1} + \mathbf{V}_{a2} \quad (2)$$
$$\mathbf{V}_{b1} = 16\mathbf{I}_{b1} + \mathbf{V}_{b2} \quad (3)$$
$$\mathbf{I}_{b2} = -\mathbf{I}_{b1} + 0.5\mathbf{V}_{b2} \quad (4)$$

$$\mathbf{V}_1 = \mathbf{V}_{a1} + \mathbf{V}_{b1}$$
$$\mathbf{V}_2 = \mathbf{V}_{a2} = \mathbf{V}_{b2}$$
$$\mathbf{I}_2 = \mathbf{I}_{a2} + \mathbf{I}_{b2}$$
$$\mathbf{I}_1 = \mathbf{I}_{a1}$$

Now, rewrite (1) to (4) in terms of $\mathbf{I}_1$ and $\mathbf{V}_2$

$$\mathbf{V}_{a1} = 25\mathbf{I}_1 + 4\mathbf{V}_2 \quad (5)$$
$$\mathbf{I}_{a2} = -4\mathbf{I}_1 + \mathbf{V}_2 \quad (6)$$
$$\mathbf{V}_{b1} = 16\mathbf{I}_{b1} + \mathbf{V}_2 \quad (7)$$
$$\mathbf{I}_{b2} = -\mathbf{I}_{b1} + 0.5\mathbf{V}_2 \quad (8)$$

Adding (5) and (7),

$$\mathbf{V}_1 = 25\mathbf{I}_1 + 16\mathbf{I}_{b1} + 5\mathbf{V}_2 \quad (9)$$

Adding (6) and (8),

$$\mathbf{I}_2 = -4\mathbf{I}_1 - \mathbf{I}_{b1} + 1.5\mathbf{V}_2 \quad (10)$$
$$\mathbf{I}_{b1} = \mathbf{I}_{a1} = \mathbf{I}_1 \quad (11)$$

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Because the two networks N_a and N_b are independent,

$$\mathbf{I}_2 = -5\mathbf{I}_1 + 1.5\mathbf{V}_2$$

or

$$\mathbf{V}_2 = 3.333\mathbf{I}_1 + 0.6667\mathbf{I}_2 \qquad (12)$$

Substituting (11) and (12) into (9),

$$\mathbf{V}_1 = 41\mathbf{I}_1 + \frac{25}{1.5}\mathbf{I}_1 + \frac{5}{1.5}\mathbf{I}_2$$

$$\mathbf{V}_1 = 57.67\mathbf{I}_1 + 3.333\mathbf{I}_2 \qquad (13)$$

Comparing (12) and (13) with the following equations

$$\mathbf{V}_1 = \mathbf{z}_{11}\mathbf{I}_1 + \mathbf{z}_{12}\mathbf{I}_2$$

$$\mathbf{V}_2 = \mathbf{z}_{21}\mathbf{I}_1 + \mathbf{z}_{22}\mathbf{I}_2$$

indicates that

$$[\mathbf{z}] = \underline{\begin{bmatrix} \mathbf{57.67} & \mathbf{3.333} \\ \mathbf{3.333} & \mathbf{0.6667} \end{bmatrix}\Omega}$$

Alternatively,

$$[\mathbf{h}_a] = \begin{bmatrix} 25 & 4 \\ -4 & 1 \end{bmatrix}, \qquad [\mathbf{h}_b] = \begin{bmatrix} 16 & 1 \\ -1 & 0.5 \end{bmatrix}$$

$$[\mathbf{h}] = [\mathbf{h}_a] + [\mathbf{h}_b] = \begin{bmatrix} 41 & 5 \\ -5 & 1.5 \end{bmatrix} \qquad \Delta_h = 61.5 + 25 = 86.5$$

$$[\mathbf{z}] = \begin{bmatrix} \dfrac{\Delta_h}{\mathbf{h}_{22}} & \dfrac{\mathbf{h}_{12}}{\mathbf{h}_{22}} \\ \dfrac{-\mathbf{h}_{21}}{\mathbf{h}_{22}} & \dfrac{1}{\mathbf{h}_{22}} \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{57.67} & \mathbf{3.333} \\ \mathbf{3.333} & \mathbf{0.6667} \end{bmatrix}\Omega}$$

as obtained previously.

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Chapter 19, Problem 73.

Three copies of the circuit shown in Fig. 19.70 are connected in cascade. Determine the *z* parameters.

Chapter 19, Solution 73.

From Problem 19.6,

$$[z] = \begin{bmatrix} 25 & 20 \\ 24 & 30 \end{bmatrix}, \qquad \Delta z = 25x30 - 20x24 = 270$$

$$A = \frac{z_{11}}{z_{21}} = \frac{25}{24}, \qquad B = \frac{\Delta z}{z_{21}} = \frac{270}{24}$$

$$C = \frac{1}{z_{21}} = \frac{1}{24}, \; D = \frac{z_{22}}{z_{21}} = \frac{30}{24}$$

The overall ABCD parameters can be found using MATLAB.

```
>> T=[25/24,270/24;1/24,30/24]
T =
   1.0417   11.2500
   0.0417    1.2500
>> T3=T*T*T
T3 =
   2.6928   49.7070
   0.1841    3.6133
>> Z=[2.693/0.1841,(2.693*3.613-0.1841*49.71)/0.1841;1/0.1841,3.613/0.1841]
Z =
  14.6279    3.1407
   5.4318   19.6252
```

$$Z = \begin{bmatrix} 14.628 & 3.141 \\ 5.432 & 19.625 \end{bmatrix}$$

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Chapter 19, Problem 74.

* Determine the **ABCD** parameters of the circuit in Fig. 19.120 as functions of *s*. (*Hint:* Partition the circuit into subcircuits and cascade them using the results of Prob. 19.43.)

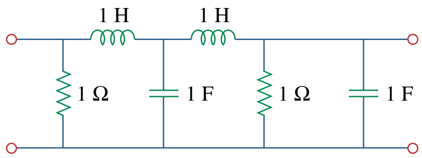


Figure 19.120

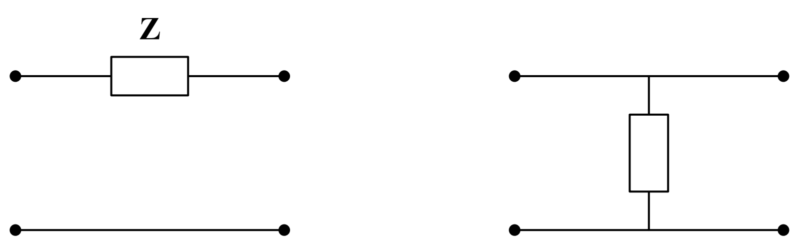
For Prob. 19.74.

* An asterisk indicates a challenging problem.

Chapter 19, Solution 74.

From Prob. 18.35, the transmission parameters for the circuit in Figs. (a) and (b) are

$$[\mathbf{T}_a] = \begin{bmatrix} 1 & \mathbf{Z} \\ 0 & 1 \end{bmatrix}, \qquad [\mathbf{T}_b] = \begin{bmatrix} 1 & 0 \\ 1/\mathbf{Z} & 1 \end{bmatrix}$$



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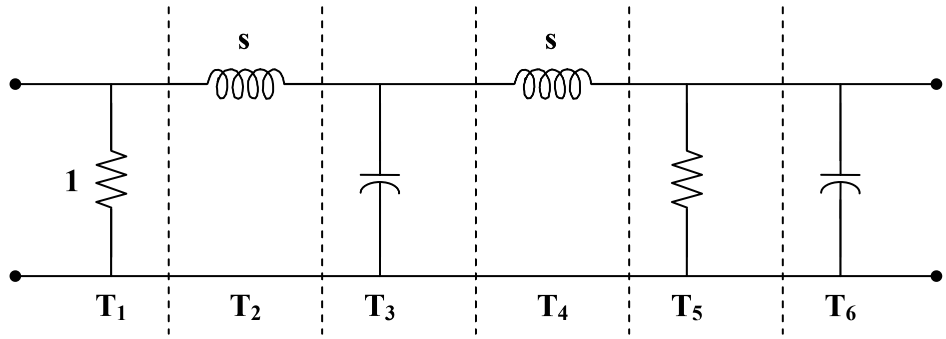
We partition the given circuit into six subcircuits similar to those in Figs. (a) and (b) as shown in Fig. (c) and obtain [**T**] for each.



$$[\mathbf{T}_1] = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}, \qquad [\mathbf{T}_2] = \begin{bmatrix} 1 & s \\ 0 & 1 \end{bmatrix}, \qquad [\mathbf{T}_3] = \begin{bmatrix} 1 & 0 \\ s & 1 \end{bmatrix}$$

$$[\mathbf{T}_4] = [\mathbf{T}_2], \qquad [\mathbf{T}_5] = [\mathbf{T}_1], \qquad [\mathbf{T}_6] = [\mathbf{T}_3]$$

$$[\mathbf{T}] = [\mathbf{T}_1][\mathbf{T}_2][\mathbf{T}_3][\mathbf{T}_4][\mathbf{T}_5][\mathbf{T}_6] = [\mathbf{T}_1][\mathbf{T}_2][\mathbf{T}_3][\mathbf{T}_4]\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ s & 1 \end{bmatrix}$$

$$= [\mathbf{T}_1][\mathbf{T}_2][\mathbf{T}_3][\mathbf{T}_4]\begin{bmatrix} 1 & 0 \\ s+1 & 1 \end{bmatrix} = [\mathbf{T}_1][\mathbf{T}_2][\mathbf{T}_3]\begin{bmatrix} 1 & s \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ s+1 & 1 \end{bmatrix}$$

$$= [\mathbf{T}_1][\mathbf{T}_2]\begin{bmatrix} 1 & 0 \\ s & 1 \end{bmatrix}\begin{bmatrix} s^2+s+1 & s \\ s+1 & 1 \end{bmatrix}$$

$$= [\mathbf{T}_1]\begin{bmatrix} 1 & s \\ 0 & 1 \end{bmatrix}\begin{bmatrix} s^2+s+1 & s \\ s^3+s^2+2s+1 & s^2+1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} s^4+s^3+3s^2+2s+1 & s^3+2s \\ s^3+s^2+2s+1 & s^2+1 \end{bmatrix}$$

$$[\mathbf{T}] = \begin{bmatrix} \mathbf{s^4+s^3+3s^2+2s+1} & \mathbf{s^3+2s} \\ \mathbf{s^4+2s^3+4s^2+4s+2} & \mathbf{s^3+s^2+2s+1} \end{bmatrix}$$

Note that $\mathbf{AB}-\mathbf{CD}=1$ as expected.

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Chapter 19, Problem 75.

* For the individual two-ports shown in Fig. 19.121 where,

$$[\mathbf{z}_a] = \begin{bmatrix} 8 & 6 \\ 4 & 5 \end{bmatrix} \Omega \qquad [\mathbf{y}_b] = \begin{bmatrix} 8 & -4 \\ 2 & 10 \end{bmatrix} \text{S}$$

(a) Determine the y parameters of the overall two-port.
(b) Find the voltage ratio $\mathbf{V}_o / \mathbf{V}_i$ when $\mathbf{Z}_L = 2\ \Omega$.

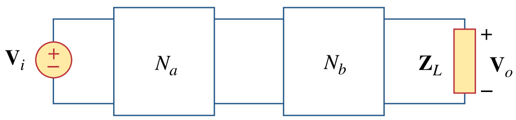

Figure 19.110

For Prob. 19.63.

* An asterisk indicates a challenging problem.

Chapter 19, Solution 75.

(a) We convert $[z_a]$ and $[z_b]$ to T-parameters. For N_a, $\Delta_z = 40 - 24 = 16$.

$$[T_a] = \begin{bmatrix} z_{11}/z_{21} & \Delta_z/z_{21} \\ 1/z_{21} & z_{22}/z_{21} \end{bmatrix} = \begin{bmatrix} 2 & 4 \\ 0.25 & 1.25 \end{bmatrix}$$

For N_b, $\Delta_y = 80 + 8 = 88$.

$$[T_b] = \begin{bmatrix} -y_{22}/y_{21} & -1/y_{21} \\ -\Delta_y/y_{21} & -y_{11}/y_{21} \end{bmatrix} = \begin{bmatrix} -5 & -0.5 \\ -44 & -4 \end{bmatrix}$$

$$[T] = [T_a][T_b] = \begin{bmatrix} -186 & -17 \\ -56.25 & -5.125 \end{bmatrix}$$

We convert this to y-parameters. $\Delta_T = AD - BC = -3$.

$$[y] = \begin{bmatrix} D/B & -\Delta_T/B \\ -1/B & A/B \end{bmatrix} = \underline{\begin{bmatrix} 0.3015 & -0.1765 \\ 0.0588 & 10.94 \end{bmatrix}}$$

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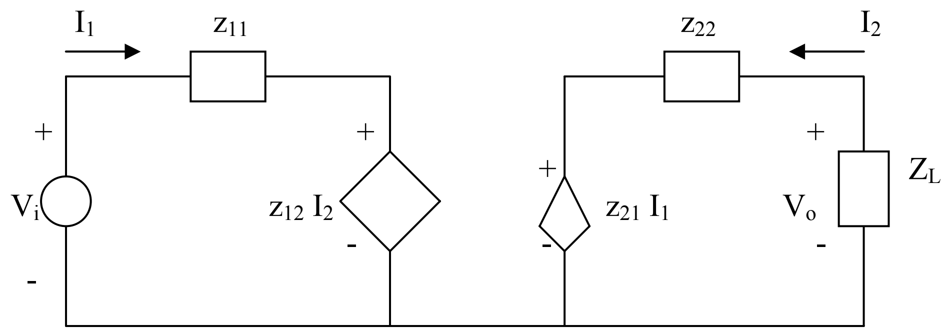
(b) The equivalent z-parameters are

$$[z] = \begin{bmatrix} A/C & \Delta_T/C \\ 1/C & D/C \end{bmatrix} = \begin{bmatrix} 3.3067 & 0.0533 \\ -0.0178 & 0.0911 \end{bmatrix}$$

Consider the equivalent circuit below.



$$V_i = z_{11}I_1 + z_{12}I_2 \qquad (1)$$

$$V_o = z_{21}I_1 + z_{22}I_2 \qquad (2)$$

But $V_o = -I_2 Z_L \longrightarrow I_2 = -V_o / Z_L$ (3)

From (2) and (3) ,

$$V_o = z_{21}I_1 - z_{22}\frac{V_o}{Z_L} \longrightarrow I_1 = V_o\left(\frac{1}{z_{21}} + \frac{z_{22}}{Z_L z_{21}}\right) \qquad (4)$$

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

$$\frac{V_i}{V_o} = \left(\frac{z_{11}}{z_{21}} + \frac{z_{11}z_{22}}{z_{21}Z_L}\right) - \frac{z_{12}}{Z_L} = -194.3 \longrightarrow \underline{\frac{V_{o.}}{V_i} = -0.0051}$$

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Chapter 19, Problem 76.

Use *PSpice* to obtain the z parameters of the network in Fig. 19.122.

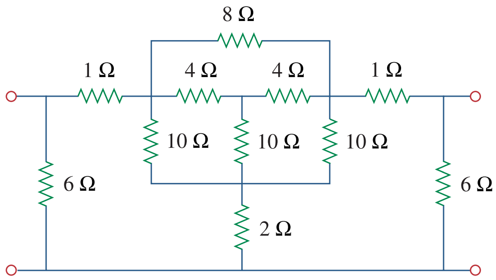

Figure 19.122
For Prob. 19.76.

Chapter 19, Solution 76.

To get z_{11} and z_{21}, we open circuit the output port and let $I_1 = 1A$ so that

$$z_{11} = \frac{V_1}{I_1} = V_1, \qquad z_{21} = \frac{V_2}{I_1} = V_2$$

The schematic is shown below. After it is saved and run, we obtain

$$z_{11} = V_1 = 3.849, \qquad z_{21} = V_2 = 1.122$$

Similarly, to get z_{22} and z_{12}, we open circuit the input port and let $I_2 = 1A$ so that

$$z_{12} = \frac{V_1}{I_2} = V_1, \qquad z_{22} = \frac{V_2}{I_2} = V_2$$

The schematic is shown below. After it is saved and run, we obtain

$$z_{12} = V_1 = 1.122, \qquad z_{22} = V_2 = 3.849$$

Thus,

$$\underline{[z] = \begin{bmatrix} 3.949 & 1.122 \\ 1.122 & 3.849 \end{bmatrix} \Omega}$$

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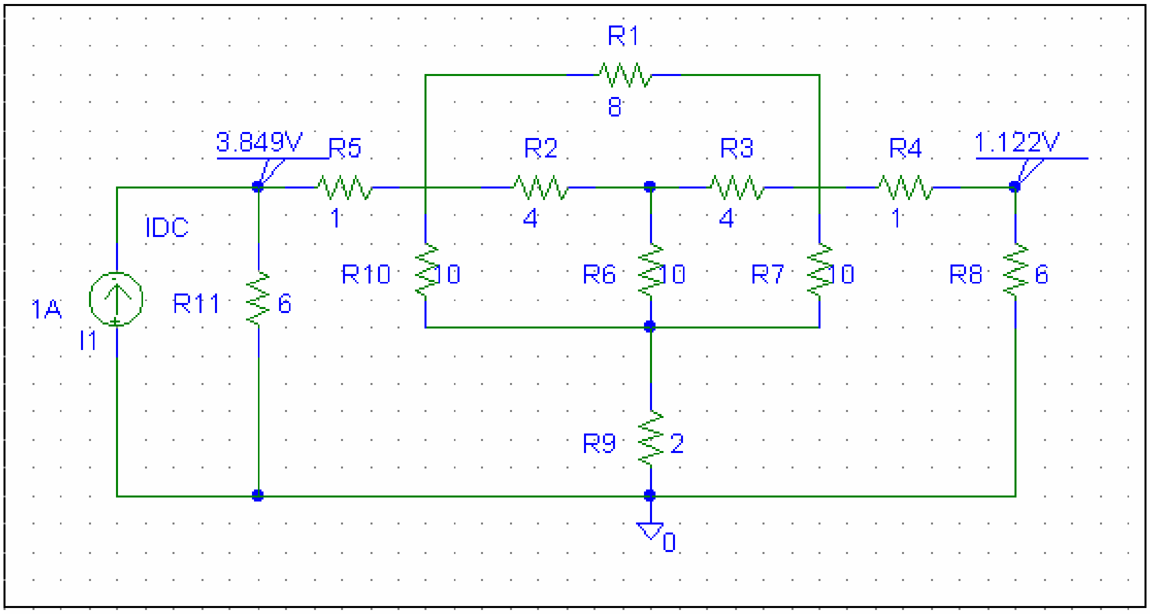

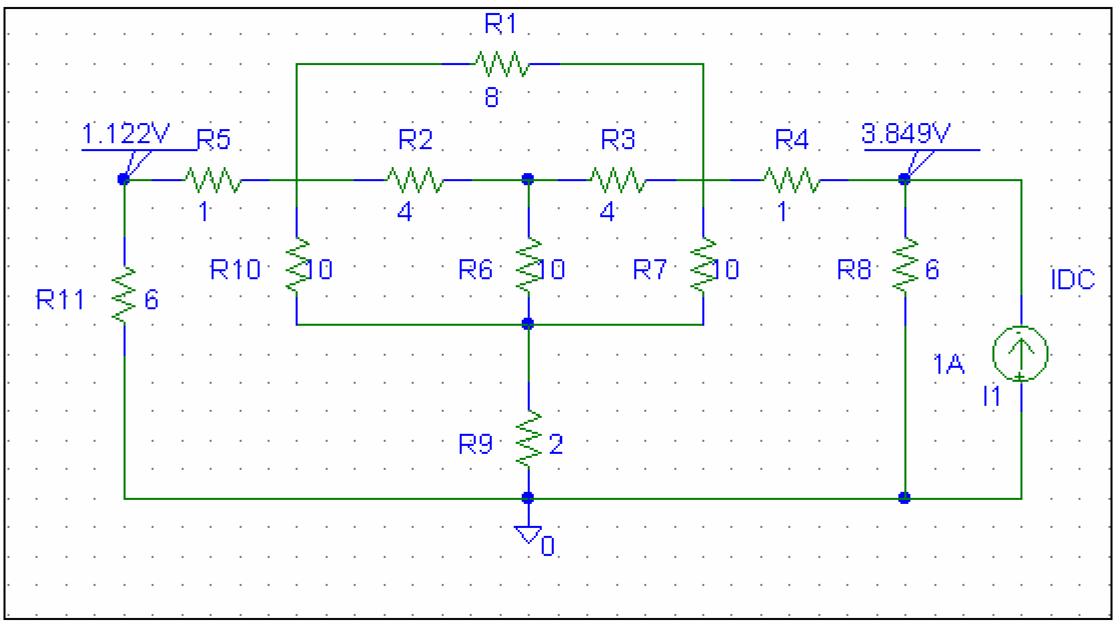

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Chapter 19, Problem 77.

Using *PSpice*, find the *h* parameters of the network in Fig. 19.123. Take $\omega = 1$ rad/s

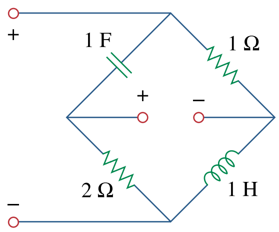

Figure 19.123

For Prob. 19.77.

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Chapter 19, Solution 77.

We follow Example 19.15 except that this is an AC circuit.

(a) We set $V_2 = 0$ and $I_1 = 1$ A. The schematic is shown below. In the AC Sweep Box, set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592. After simulation, the output file includes

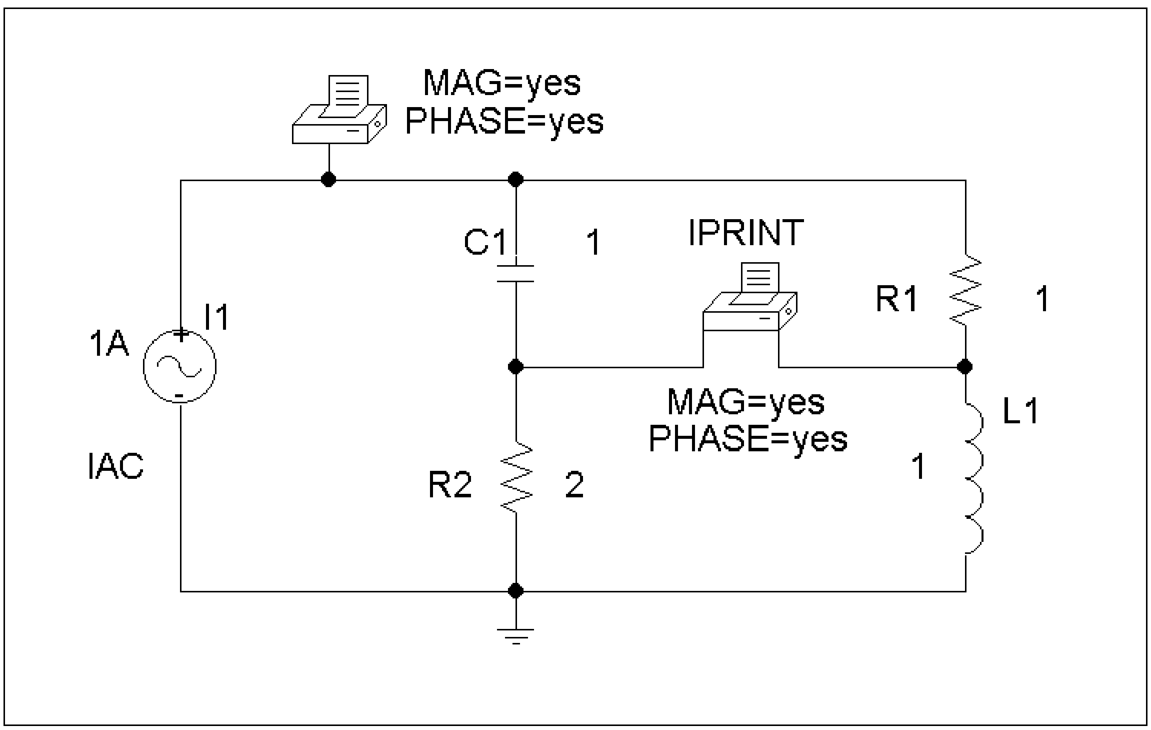
FREQ	IM(V_PRINT2)	IP(V_PRINT2)
1.592 E–01	3.163 E–.01	–1.616 E+02

FREQ	VM($N_0001)	VP($N_0001)
1.592 E–01	9.488 E–01	–1.616 E+02

From this we obtain

$$h_{11} = V_1/1 = 0.9488\angle{-161.6^\circ}$$

$$h_{21} = I_2/1 = 0.3163\angle{-161.6^\circ}.$$



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(b) In this case, we set $I_1 = 0$ and $V_2 = 1$V. The schematic is shown below. In the AC Sweep box, we set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592. After simulation, we obtain an output file which includes

FREQ	VM($N_0001)	VP($N_0001)
1.592 E–01	3.163 E–.01	1.842 E+01

FREQ	IM(V_PRINT2)	IP(V_PRINT2)
1.592 E–01	9.488 E–01	–1.616 E+02

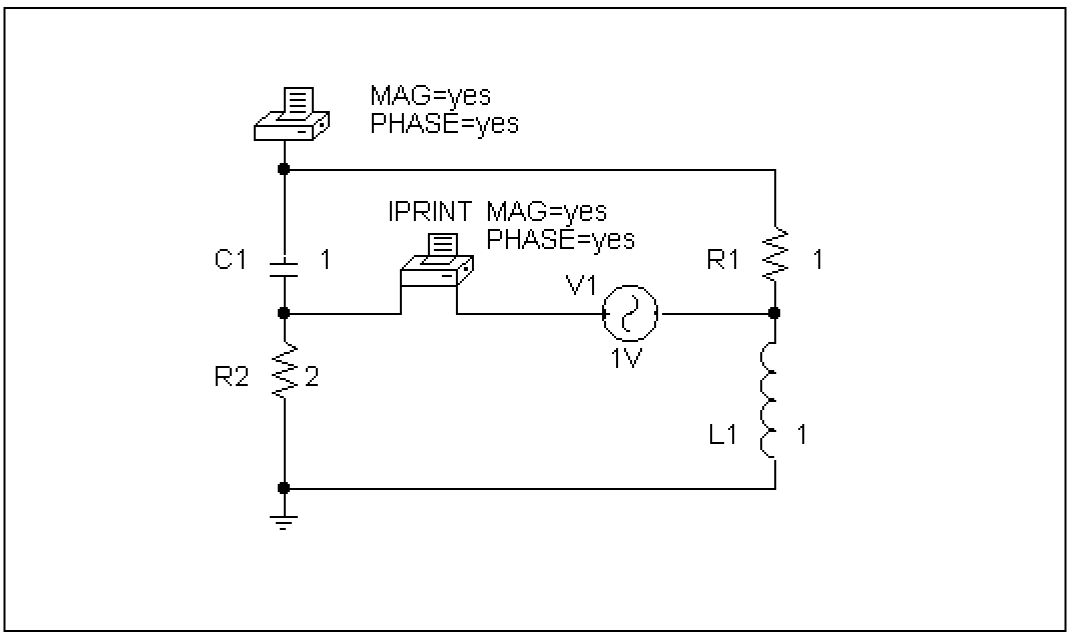
From this,

$$h_{12} = V_1/1 = 0.3163\angle 18.42^\circ$$

$$h_{21} = I_2/1 = 0.9488\angle -161.6^\circ.$$

Thus,

$$[h] = \underline{\begin{bmatrix} \mathbf{0.9488\angle -161.6^\circ} & \mathbf{0.3163\angle 18.42^\circ} \\ \mathbf{0.3163\angle -161.6^\circ} & \mathbf{0.9488\angle -161.6^\circ} \end{bmatrix}}$$



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Chapter 19, Problem 78.

Obtain the *h* parameters at $\omega = 4$ rad/s for the circuit in Fig. 19.124 using *PSpice*.

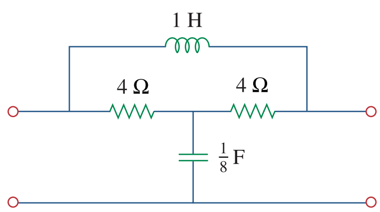

Figure 19.124

For Prob. 19.78.

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Chapter 19, Solution 78

For h_{11} and h_{21}, short-circuit the output port and let $I_1 = 1A$. $f = \omega / 2\pi = 0.6366$. The schematic is shown below. When it is saved and run, the output file contains the following:

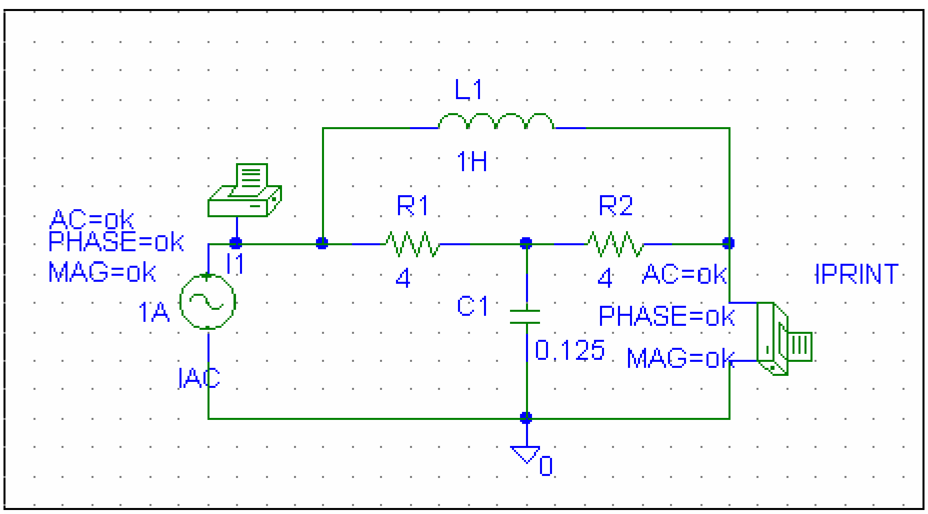
```
FREQ        IM(V_PRINT1)IP(V_PRINT1)

  6.366E-01   1.202E+00   1.463E+02

 FREQ        VM($N_0003) VP($N_0003)

  6.366E-01   3.771E+00  -1.350E+02
```

From the output file, we obtain

$$I_2 = 1.202\angle 146.3^o, \qquad V_1 = 3.771\angle -135^o$$

so that

$$h_{11} = \frac{V_1}{1} = 3.771\angle -135^o, \qquad h_{21} = \frac{I_2}{1} = 1.202\angle 146.3^o$$



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For h_{12} and h_{22}, open-circuit the input port and let $V_2 = 1V$. The schematic is shown below. When it is saved and run, the output file includes:

```
FREQ       VM($N_0003) VP($N_0003)


 6.366E-01   1.202E+00  -3.369E+01

FREQ       IM(V_PRINT1)IP(V_PRINT1)


 6.366E-01   3.727E-01  -1.534E+02
```

From the output file, we obtain

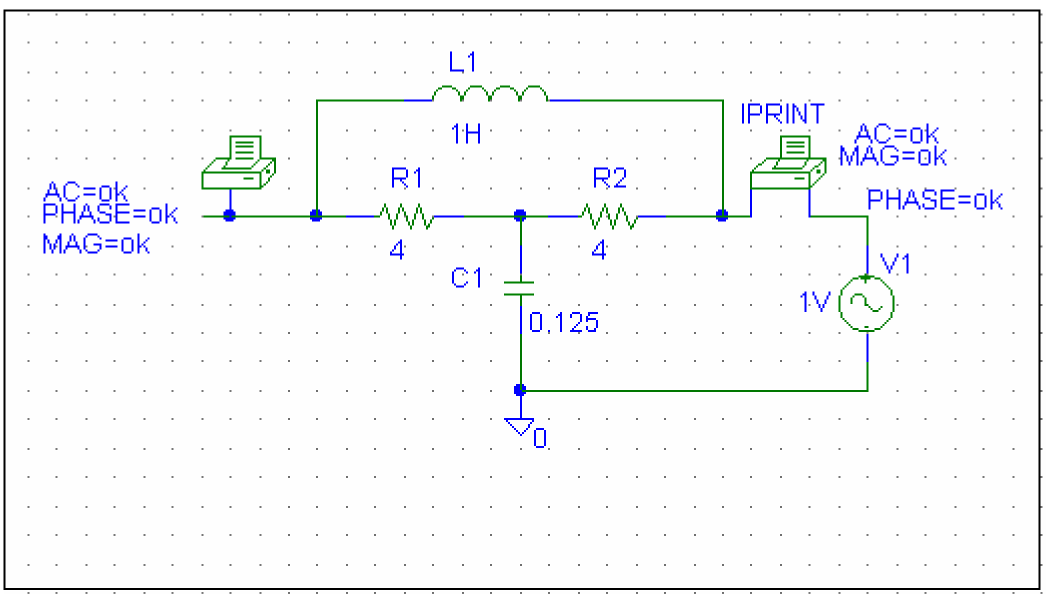
$$I_2 = 0.3727\angle -153.4^o, \qquad V_1 = 1.202\angle -33.69^o$$

so that

$$h_{12} = \frac{V_1}{1} = 1.202\angle -33.69^o, \qquad h_{22} = \frac{I_2}{1} = 0.3727\angle -153.4^o$$

Thus,

$$[h] = \begin{bmatrix} 3.771\angle -135^o & 1.202\angle -33.69^o \\ 1.202\angle 146.3 & 0.3727\angle -153.4^o \end{bmatrix}$$



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Chapter 19, Problem 79.

Use *PSpice* to determine the *z* parameters of the circuit in Fig. 19.125. Take $\omega = 2$ rad/s.

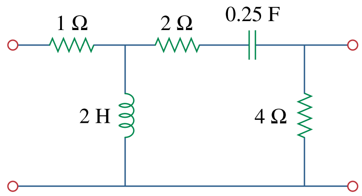

Figure 19.125
For Prob. 19.79.

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Chapter 19, Solution 79

We follow Example 19.16.

(a) We set $I_1 = 1$ A and open-circuit the output-port so that $I_2 = 0$. The schematic is shown below with two VPRINT1s to measure V_1 and V_2. In the AC Sweep box, we enter Total Pts = 1, Start Freq = 0.3183, and End Freq = 0.3183. After simulation, the output file includes

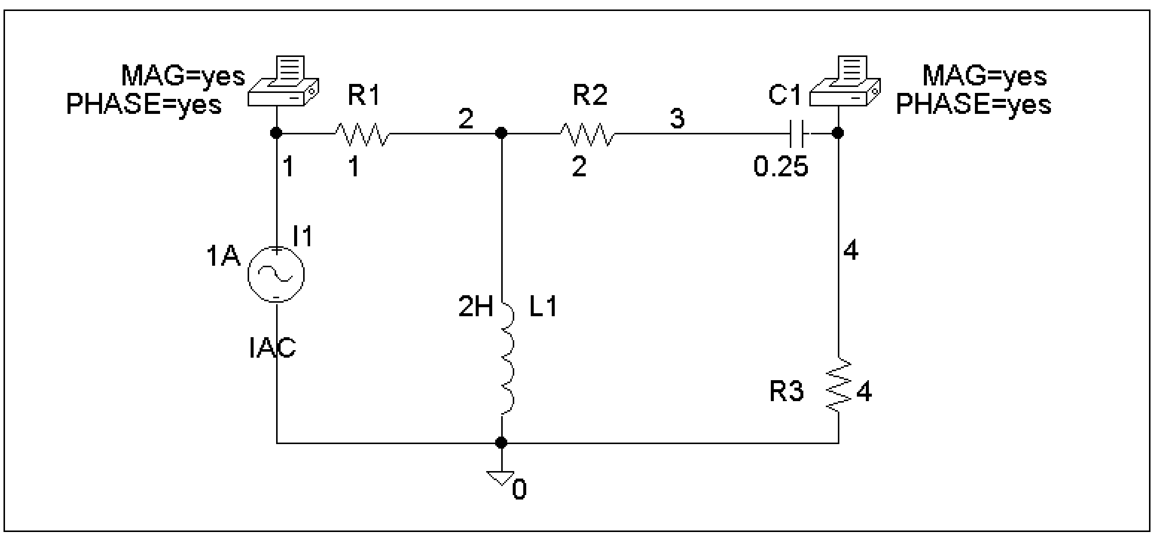
FREQ	VM(1)	VP(1)
3.183 E–01	4.669 E+00	–1.367 E+02

FREQ	VM(4)	VP(4)
3.183 E–01	2.530 E+00	–1.084 E+02

From this,

$$z_{11} = V_1/I_1 = 4.669\angle -136.7°/1 = 4.669\angle -136.7°$$

$$z_{21} = V_2/I_1 = 2.53\angle -108.4°/1 = 2.53\angle -108.4°.$$



(b) In this case, we let $I_2 = 1$ A and open-circuit the input port. The schematic is shown below. In the AC Sweep box, we type Total Pts = 1, Start Freq = 0.3183, and End Freq = 0.3183. After simulation, the output file includes

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FREQ	VM(1)	VP(1)
3.183 E–01	2.530 E+00	–1.084 E+02

FREQ	VM(2)	VP(2)
3.183 E–01	1.789 E+00	–1.534 E+02

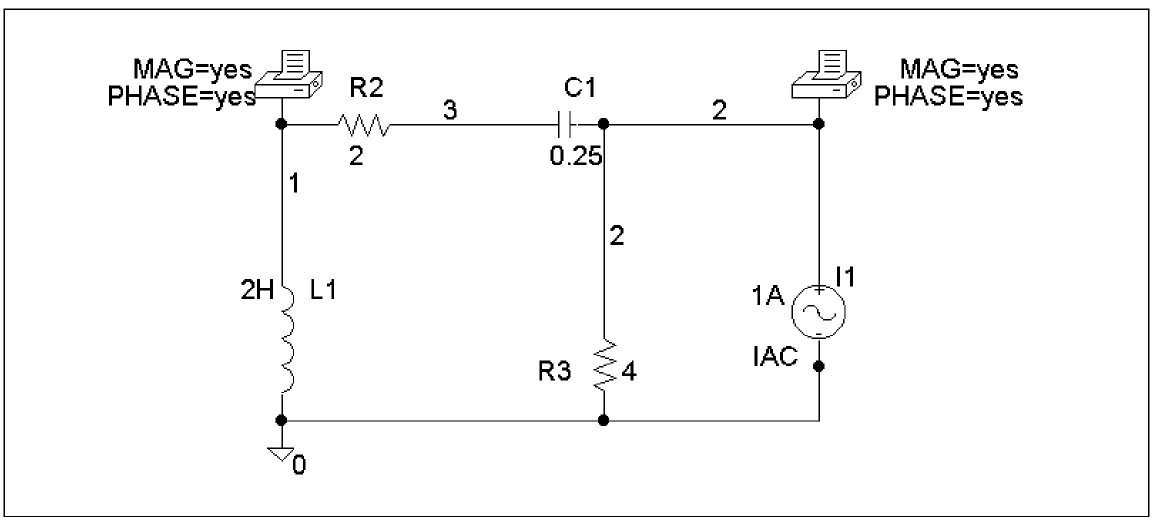
From this,

$$z_{12} = V_1/I_2 = 2.53\angle{-108.4°}/1 = 2.53\angle{-108..4°}$$

$$z_{22} = V_2/I_2 = 1.789\angle{-153.4°}/1 = 1.789\angle{-153.4°}.$$

Thus,

$$[z] = \underline{\begin{bmatrix} \mathbf{4.669\angle-136.7°} & \mathbf{2.53\angle-108.4°} \\ \mathbf{2.53\angle-108.4°} & \mathbf{1.789\angle-153.4°} \end{bmatrix}} \mathbf{\underline{\Omega}}$$



Chapter 19, Problem 80.

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Use *PSpice* to find the *z* parameters of the circuit in Fig. 19.71.

Chapter 19, Solution 80

To get z_{11} and z_{21}, we open circuit the output port and let $I_1 = 1A$ so that

$$z_{11} = \frac{V_1}{I_1} = V_1, \quad z_{21} = \frac{V_2}{I_1} = V_2$$

The schematic is shown below. After it is saved and run, we obtain

$$z_{11} = V_1 = 29.88, \quad z_{21} = V_2 = -70.37$$

Similarly, to get z_{22} and z_{12}, we open circuit the input port and let $I_2 = 1A$ so that

$$z_{12} = \frac{V_1}{I_2} = V_1, \quad z_{22} = \frac{V_2}{I_2} = V_2$$

The schematic is shown below. After it is saved and run, we obtain

$$z_{12} = V_1 = 3.704, \quad z_{22} = V_2 = 11.11$$

Thus,

$$[z] = \begin{bmatrix} 29.88 & 3.704 \\ -70.37 & 11.11 \end{bmatrix} \Omega$$

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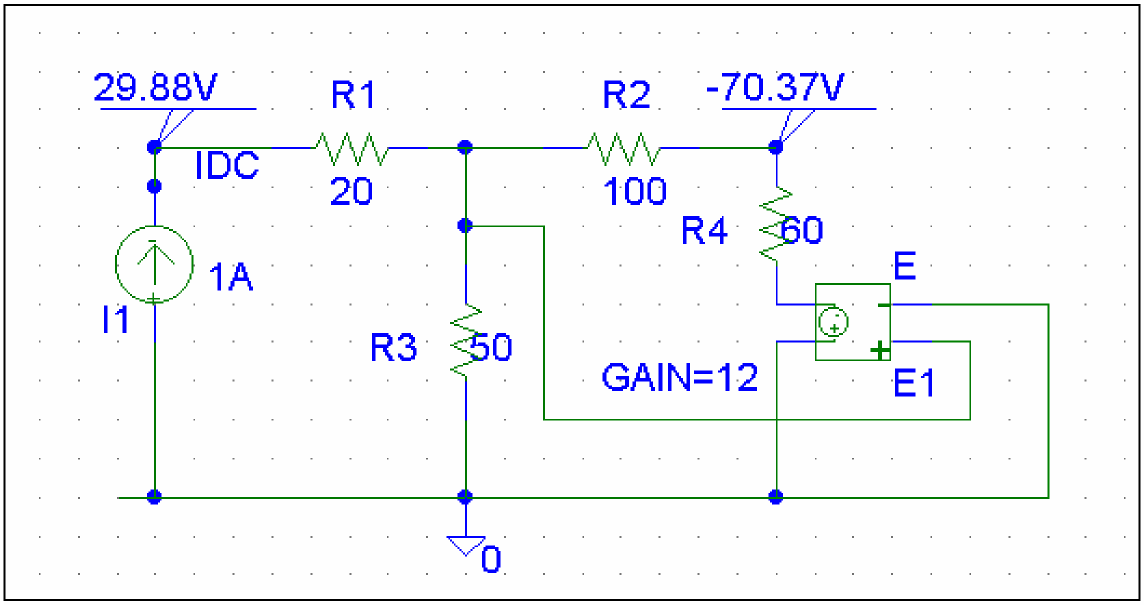

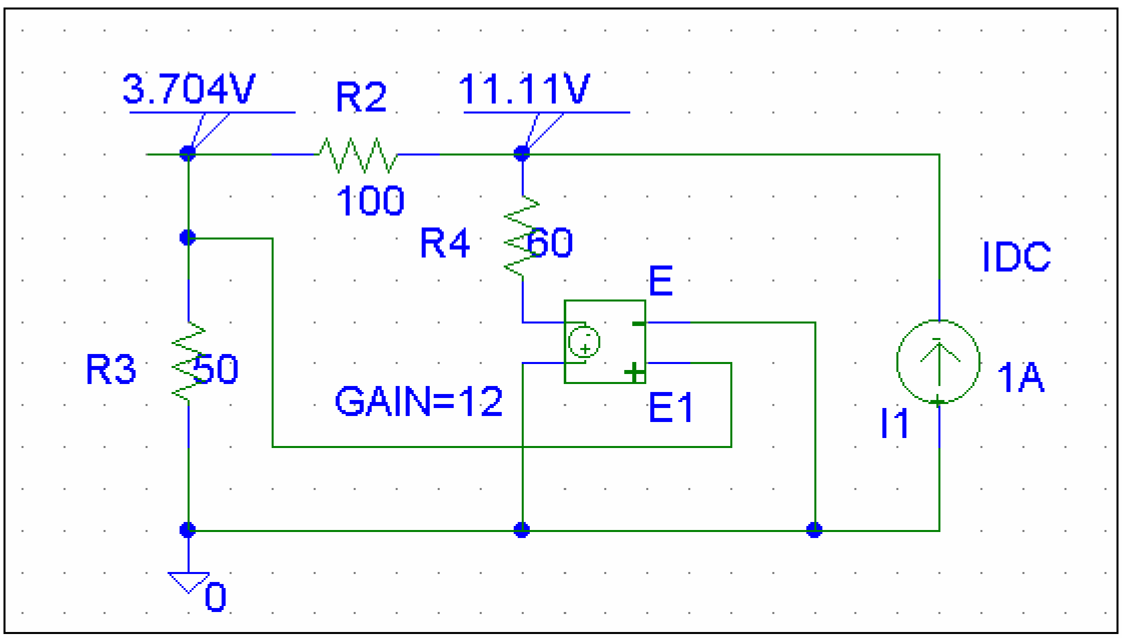

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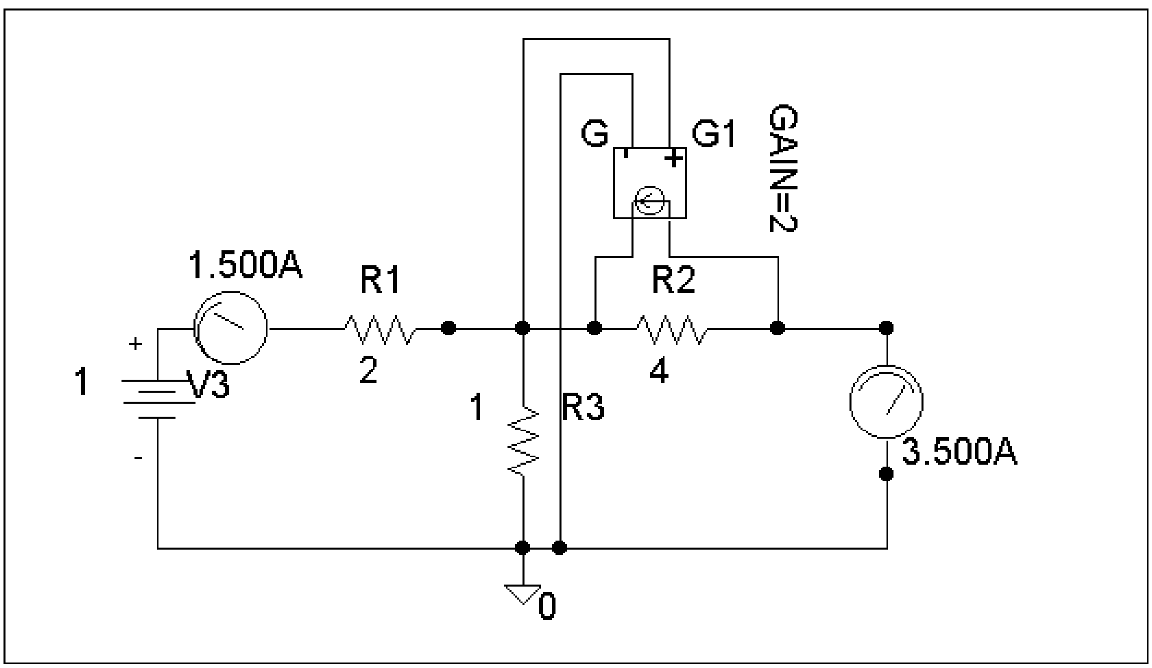
Chapter 19, Problem 81.

Repeat Prob. 19.26 using *PSpice*.

Chapter 19, Solution 81

(a) We set $V_1 = 1$ and short circuit the output port. The schematic is shown below. After simulation we obtain

$$y_{11} = I_1 = 1.5, \; y_{21} = I_2 = 3.5$$



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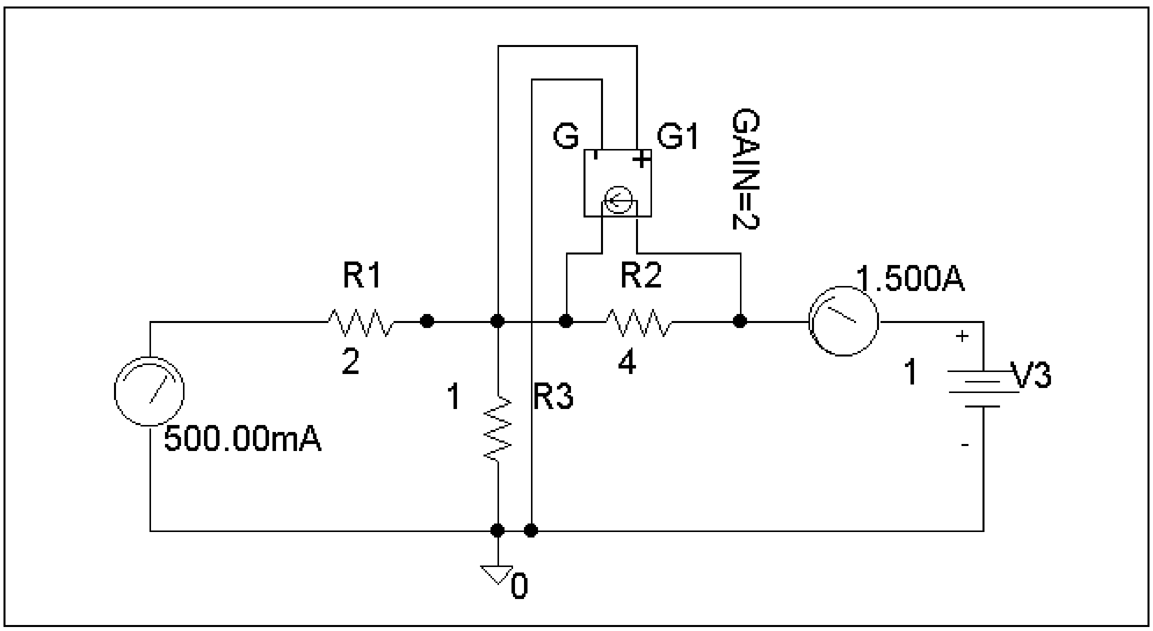
(b) We set $V_2 = 1$ and short-circuit the input port. The schematic is shown below. Upon simulating the circuit, we obtain

$$y_{12} = I_1 = -0.5, \; y_{22} = I_2 = 1.5$$

$$[Y] = \underline{\begin{bmatrix} \mathbf{1.5} & \mathbf{-0.5} \\ \mathbf{3.5} & \mathbf{1.5} \end{bmatrix} \mathbf{S}}$$



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Chapter 19, Problem 82.

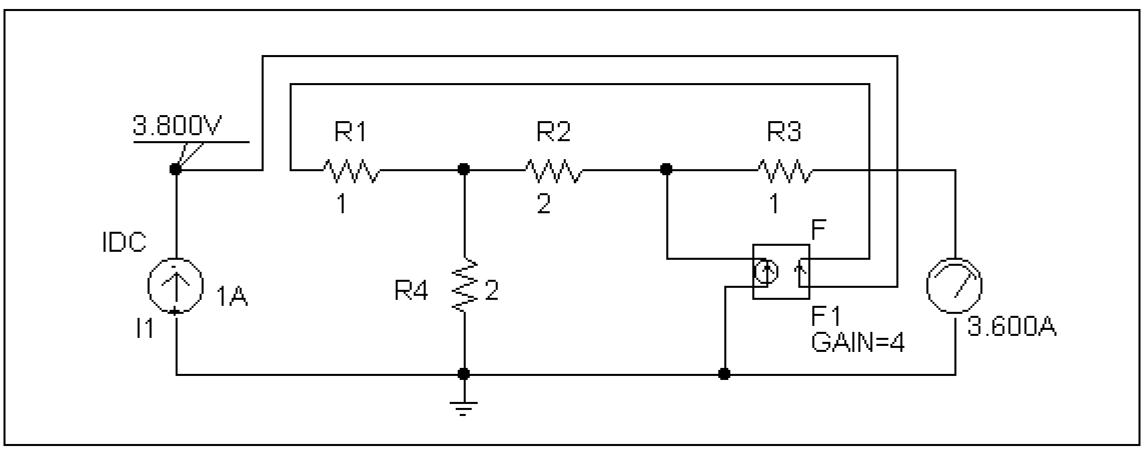
Use *PSpice* to rework Prob. 19.31.

Chapter 19, Solution 82

We follow Example 19.15.

(a) Set $V_2 = 0$ and $I_1 = 1A$. The schematic is shown below. After simulation, we obtain

$$h_{11} = V_1/1 = 3.8, \quad h_{21} = I_2/1 = 3.6$$



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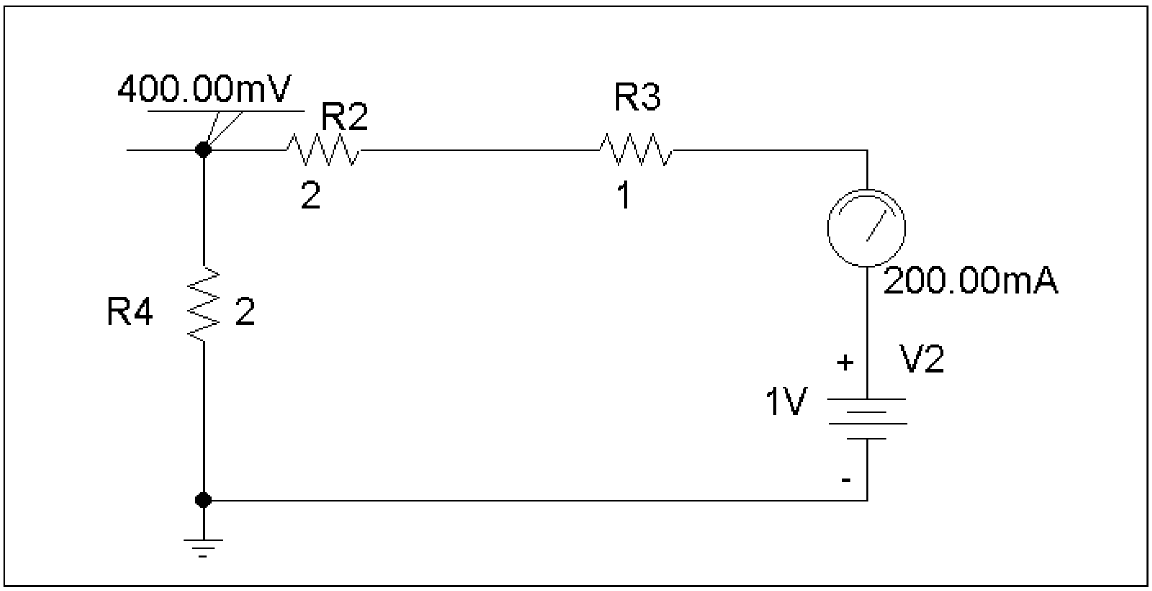
(b) Set $V_1 = 1$ V and $I_1 = 0$. The schematic is shown below. After simulation, we obtain

$$h_{12} = V_1/1 = 0.4, \quad h_{22} = I_2/1 = 0.25$$

Hence, $$[h] = \underline{\begin{bmatrix} \mathbf{3.8} & \mathbf{0.4} \\ \mathbf{3.6} & \mathbf{0.25} \end{bmatrix}}$$



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Chapter 19, Problem 83.

Rework Prob. 19.47 using *PSpice*.

Chapter 19, Solution 83

To get A and C, we open-circuit the output and let $I_1 = 1A$. The schematic is shown below. When the circuit is saved and simulated, we obtain $V_1 = 11$ and $V_2 = 34$.

$$A = \frac{V_1}{V_2} = 0.3235, \qquad C = \frac{I_1}{V_2} = \frac{1}{34} = 0.02941$$

Similarly, to get B and D, we open-circuit the output and let $I_1 = 1A$. The schematic is shown below. When the circuit is saved and simulated, we obtain $V_1 = 2.5$ and $I_2 = -2.125$.

$$B = -\frac{V_1}{I_2} = \frac{2.5}{2.125} = 1.1765, \qquad D = -\frac{I_1}{I_2} = \frac{1}{2.125} = 0.4706$$

Thus,

$$[T] = \begin{bmatrix} 0.3235 & 1.1765 \\ 0.02941 & 0.4706 \end{bmatrix}$$

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Chapter 19, Problem 84.

Using *PSpice*, find the transmission parameters for the network in Fig. 19.126.

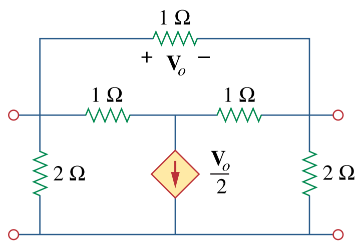


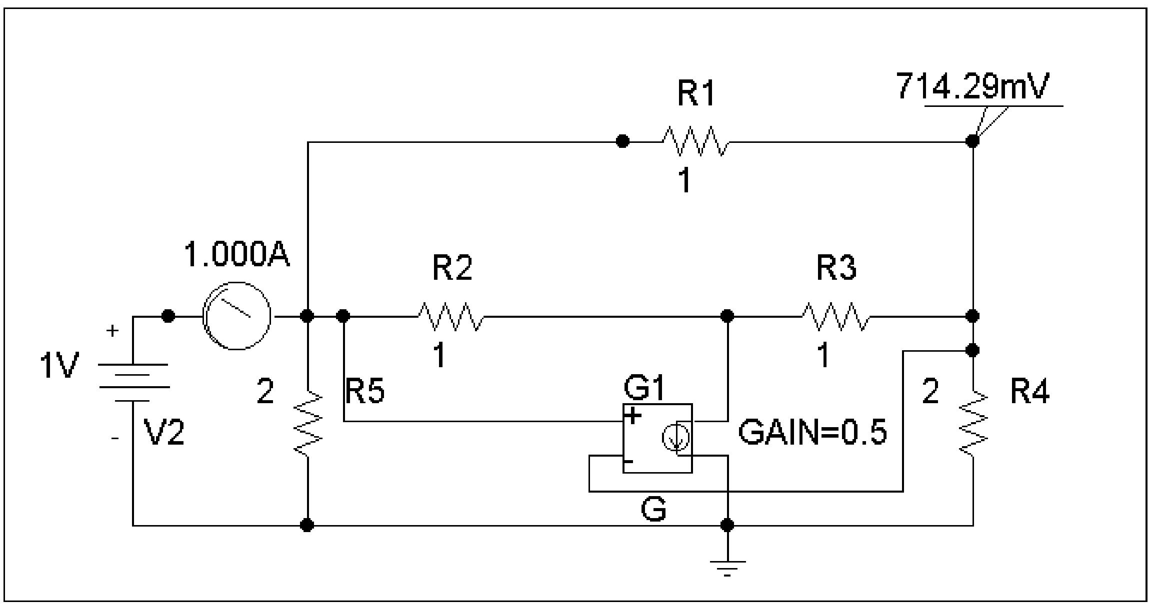
Figure 19.126
For Prob. 19.84.

Chapter 19, Solution 84

(a) Since $A = \left.\frac{V_1}{V_2}\right|_{I_2=0}$ and $C = \left.\frac{I_1}{V_2}\right|_{I_2=0}$, we open-circuit the output port and let V_1 = 1 V. The schematic is as shown below. After simulation, we obtain

$$A = 1/V_2 = 1/0.7143 = 1.4$$

$$C = I_2/V_2 = 1.0/0.7143 = 1.4$$



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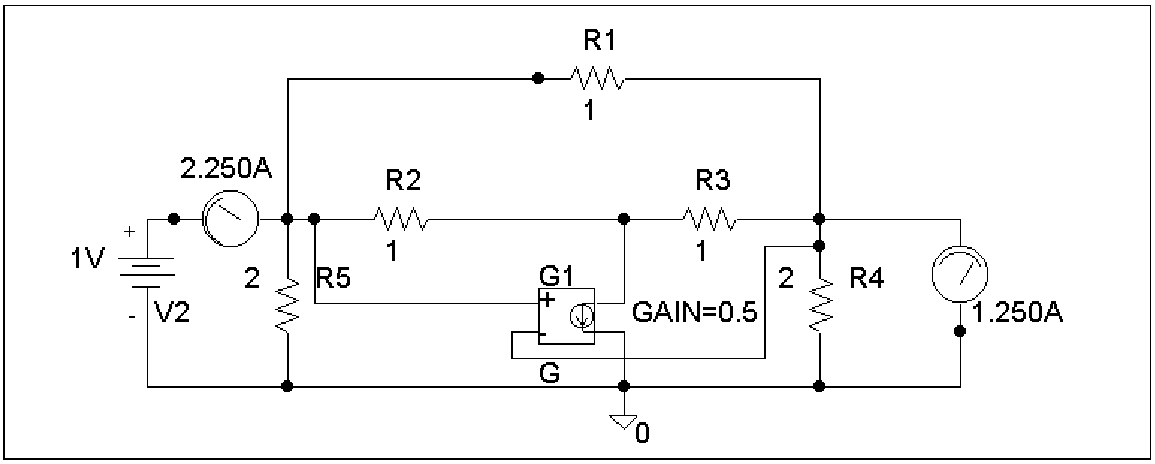
(b) To get B and D, we short-circuit the output port and let $V_1 = 1$. The schematic is shown below. After simulating the circuit, we obtain

$$B = -V_1/I_2 = -1/1.25 = -0.8$$

$$D = -I_1/I_2 = -2.25/1.25 = -1.8$$

Thus
$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{1.4} & \mathbf{-0.8} \\ \mathbf{1.4} & \mathbf{-1.8} \end{bmatrix}}$$



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Chapter 19, Problem 85.

At $\omega = 1$ rad/s find the transmission parameters of the network in Fig. 19.127 using *PSpice*.

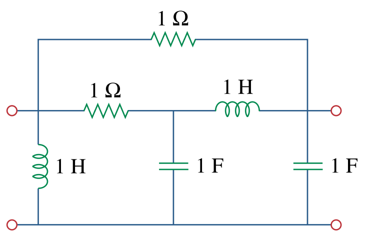

Figure 19.127

For Prob. 19.85.

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Chapter 19, Solution 85

(a) Since $A = \left.\frac{V_1}{V_2}\right|_{I_2=0}$ and $C = \left.\frac{I_1}{V_2}\right|_{I_2=0}$, we let V_1 = 1 V and open-circuit the output port. The schematic is shown below. In the AC Sweep box, we set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592. After simulation, we obtain an output file which includes

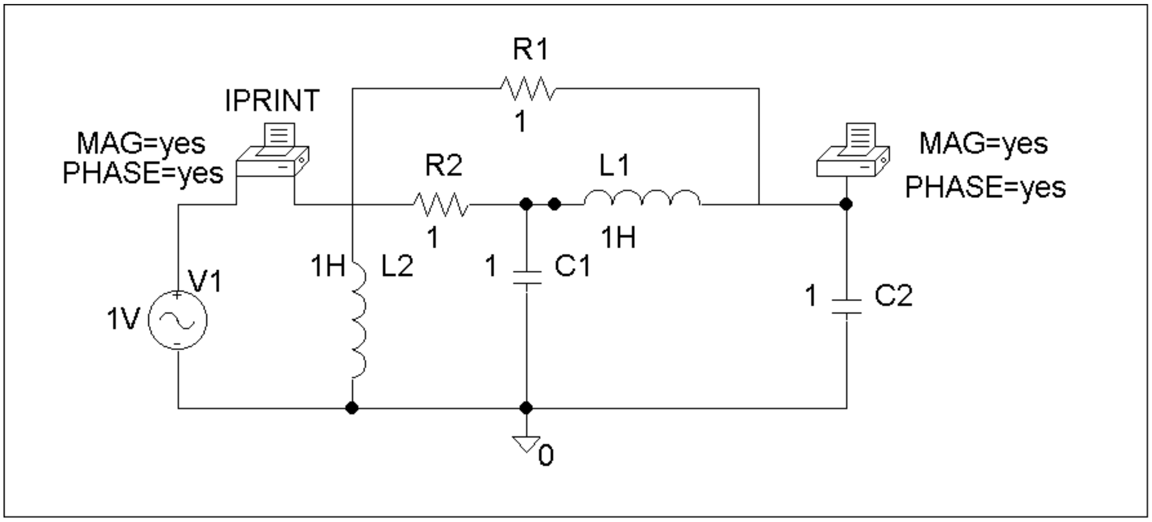
FREQ	IM(V_PRINT1)	IP(V_PRINT1)
1.592 E–01	6.325 E–01	1.843 E+01

FREQ	VM($N_0002)	VP($N_0002)
1.592 E–01	6.325 E–01	–7.159 E+01

From this, we obtain

$$A = \frac{1}{V_2} = \frac{1}{0.6325\angle -71.59^\circ} = 1.581\angle 71.59^\circ$$

$$C = \frac{I_1}{V_2} = \frac{0.6325\angle 18.43^\circ}{0.6325\angle -71.59^\circ} = 1\angle 90^\circ = j$$



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(b) Similarly, since $B = \left.\frac{V_1}{I_2}\right|_{V_2=0}$ and $D = -\left.\frac{I_1}{I_2}\right|_{V_2=0}$, we let $V_1 = 1$ V and short-circuit the output port. The schematic is shown below. Again, we set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592 in the AC Sweep box. After simulation, we get an output file which includes the following results:

FREQ	IM(V_PRINT1)	IP(V_PRINT1)
1.592 E–01	5.661 E–04	8.997 E+01

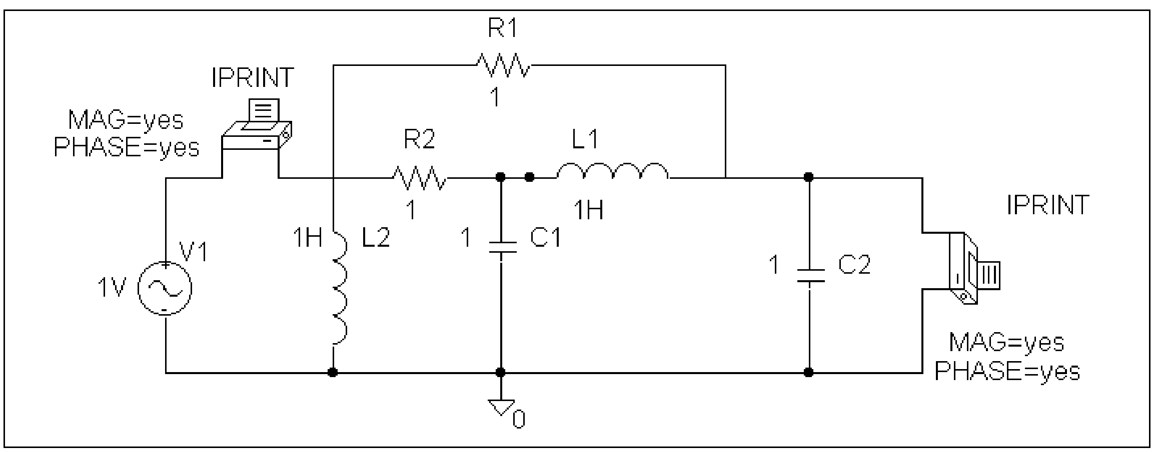
FREQ	IM(V_PRINT3)	IP(V_PRINT3)
1.592 E–01	9.997 E–01	–9.003 E+01

From this,

$$B = -\frac{1}{I_2} = -\frac{1}{0.9997\angle -90^\circ} = -1\angle 90^\circ = -j$$

$$D = -\frac{I_1}{I_2} = -\frac{5.661\text{x}10^{-4}\angle 89.97^\circ}{0.9997\angle -90^\circ} = 5.561\text{x}10^{-4}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \underline{\begin{bmatrix} \mathbf{1.581\angle 71.59^\circ} & \mathbf{-j} \\ \mathbf{j} & \mathbf{5.661x10^{-4}} \end{bmatrix}}$$



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Chapter 19, Problem 86.

Obtain the *g* parameters for the network in Fig. 19.128 using *PSpice*.

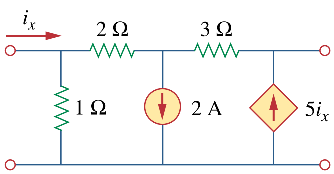


Figure 19.128

For Prob. 19.86.

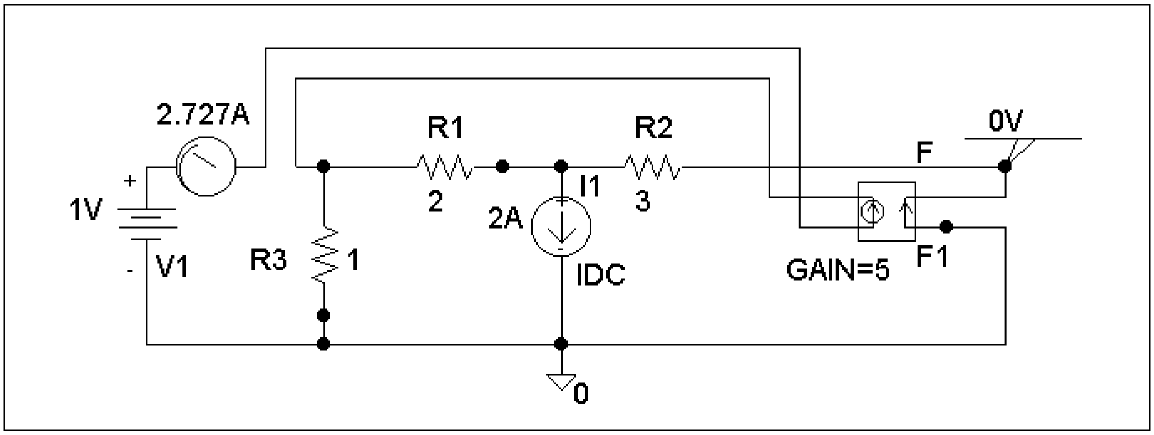
Chapter 19, Solution 86

(a) By definition, $g_{11} = \left.\frac{I_1}{V_1}\right|_{I_2=0}$, $g_{21} = \left.\frac{V_1}{V_2}\right|_{I_2=0}$.

We let $V_1 = 1$ V and open-circuit the output port. The schematic is shown below. After simulation, we obtain

$$g_{11} = I_1 = 2.7$$

$$g_{21} = V_2 = 0.0$$



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(b) Similarly,

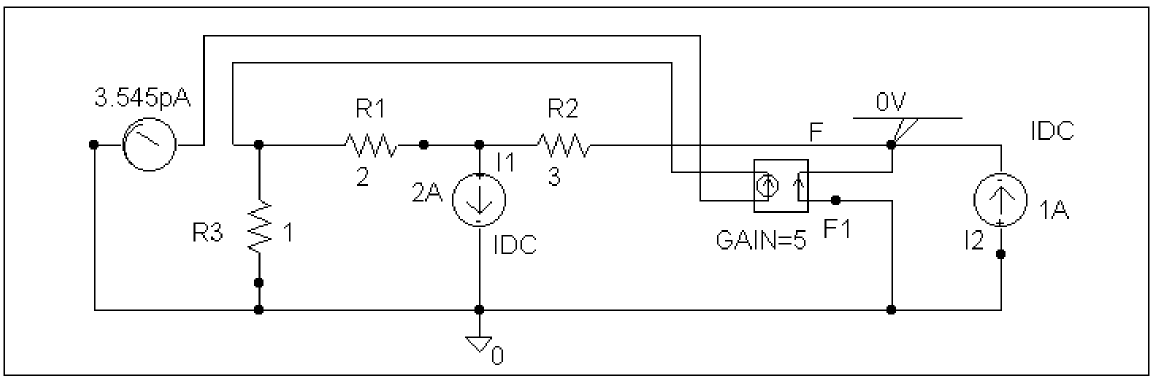
$$g_{12} = \left.\frac{I_1}{I_2}\right|_{V_1=0}, \quad g_{22} = \left.\frac{V_2}{I_2}\right|_{V_1=0}$$

We let $I_2 = 1$ A and short-circuit the input port. The schematic is shown below. After simulation,

$$g_{12} = I_1 = 0$$

$$g_{22} = V_2 = 0$$

Thus $$[g] = \underline{\begin{bmatrix} \mathbf{2.727S} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}}$$



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Chapter 19, Problem 87.

For the circuit shown in Fig. 19.129, use *PSpice* to obtain the *t* parameters. Assume ω = 1 rad/s.

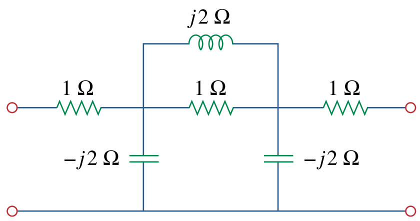


Figure 19.129

For Prob. 19.87.

Chapter 19, Solution 87

(a) Since $a = \left.\frac{V_2}{V_1}\right|_{I_1=0}$ and $c = \left.\frac{I_2}{V_1}\right|_{I_1=0}$,

we open-circuit the input port and let V_2 = 1 V. The schematic is shown below. In the AC Sweep box, set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592. After simulation, we obtain an output file which includes

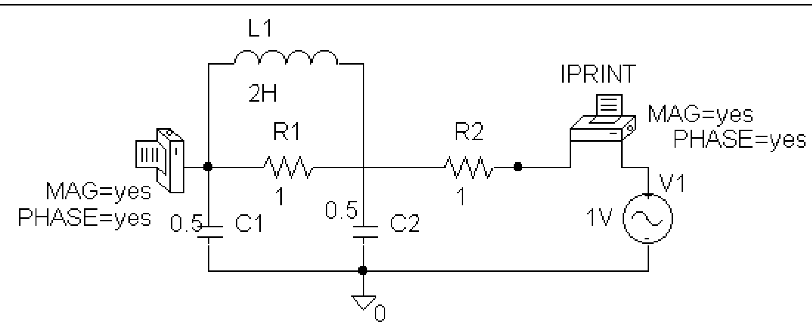
FREQ	IM(V_PRINT2)	IP(V_PRINT2)
1.592 E–01	5.000 E–01	1.800 E+02

FREQ	VM($N_0001)	VP($N_0001)
1.592 E–01	5.664 E–04	8.997 E+01

From this,

$$a = \frac{1}{5.664x10^{-4}\angle 89.97°} = 1765\angle -89.97°$$

$$c = \frac{0.5\angle 180°}{5.664x10^{-4}\angle 89.97°} = -882.28\angle -89.97°$$



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(b) Similarly,

$$b = -\frac{V_2}{I_1}\bigg|_{V_1=0} \quad \text{and} \quad d = -\frac{I_2}{I_1}\bigg|_{V_1=0}$$

We short-circuit the input port and let $V_2 = 1$ V. The schematic is shown below. After simulation, we obtain an output file which includes

FREQ	IM(V_PRINT2)	IP(V_PRINT2)
1.592 E–01	5.000 E–01	1.800 E+02

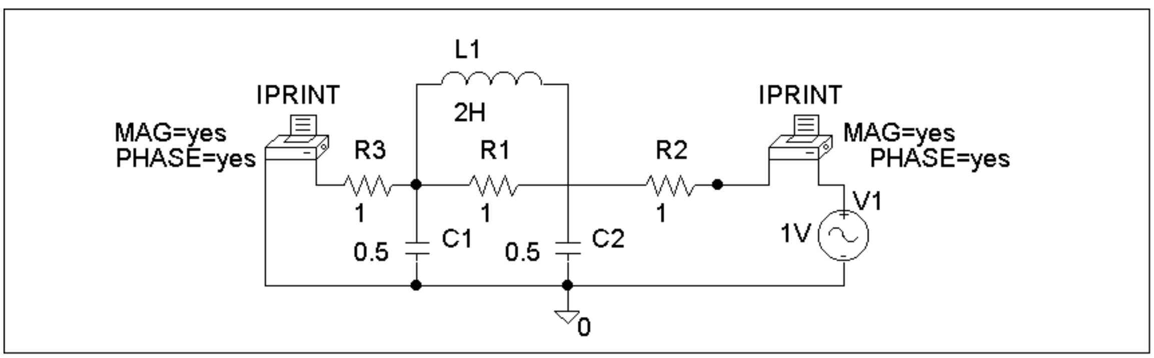
FREQ	IM(V_PRINT3)	IP(V_PRINT3)
1.592 E–01	5.664 E–04	–9.010 E+01

From this, we get

$$b = -\frac{1}{5.664\text{x}10^{-4}\angle -90.1^\circ} = -j1765$$

$$d = -\frac{0.5\angle 180^\circ}{5.664\text{x}10^{-4}\angle -90.1^\circ} = j888.28$$

Thus $$[t] = \underline{\begin{bmatrix} \mathbf{-j1765} & \mathbf{-j1765} \\ \mathbf{j888.2} & \mathbf{j888.2} \end{bmatrix}}$$



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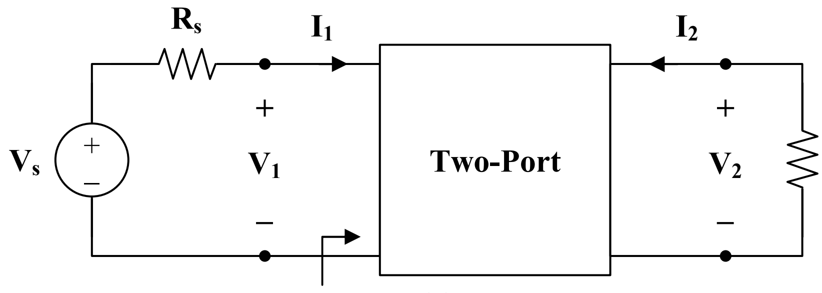
Chapter 19, Problem 88.

Using the *y* parameters, derive formulas for Z_{in}, Z_{out}, A_i, and A_v for the common-emitter transistor circuit.

Chapter 19, Solution 88

To get Z_{in}, consider the network in Fig. (a).



(a)

$$\mathbf{I}_1 = \mathbf{y}_{11}\mathbf{V}_1 + \mathbf{y}_{12}\mathbf{V}_2 \qquad (1)$$

$$\mathbf{I}_2 = \mathbf{y}_{21}\mathbf{V}_1 + \mathbf{y}_{22}\mathbf{V}_2 \qquad (2)$$

But

$$\mathbf{I}_2 = \frac{-\mathbf{V}_2}{R_L} = \mathbf{y}_{21}\mathbf{V}_1 + \mathbf{y}_{22}\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{-\mathbf{y}_{21}\mathbf{V}_1}{\mathbf{y}_{22} + 1/R_L} \qquad (3)$$

Substituting (3) into (1) yields

$$\mathbf{I}_1 = \mathbf{y}_{11}\mathbf{V}_1 + \mathbf{y}_{12}\cdot\left(\frac{-\mathbf{y}_{21}\mathbf{V}_1}{\mathbf{y}_{22} + 1/R_L}\right), \qquad \mathbf{Y}_L = \frac{1}{R_L}$$

$$\mathbf{I}_1 = \left(\frac{\Delta_y + \mathbf{y}_{11}\mathbf{Y}_L}{\mathbf{y}_{22} + \mathbf{Y}_L}\right)\mathbf{V}_1, \qquad \Delta_y = \mathbf{y}_{11}\mathbf{y}_{22} - \mathbf{y}_{12}\mathbf{y}_{21}$$

or

$$Z_{in} = \frac{\mathbf{V}_1}{\mathbf{I}_1} = \underline{\frac{\mathbf{y}_{22} + \mathbf{Y}_L}{\Delta_y + \mathbf{y}_{11}\mathbf{Y}_L}}$$

$$A_i = \frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{\mathbf{y}_{21}\mathbf{V}_1 + \mathbf{y}_{22}\mathbf{V}_2}{\mathbf{I}_1} = \mathbf{y}_{21}Z_{in} + \left(\frac{\mathbf{y}_{22}}{\mathbf{I}_1}\right)\left(\frac{-\mathbf{y}_{21}\mathbf{V}_1}{\mathbf{y}_{22} + \mathbf{Y}_L}\right)$$

$$= \mathbf{y}_{21}Z_{in} - \frac{\mathbf{y}_{22}\mathbf{y}_{21}Z_{in}}{\mathbf{y}_{22} + \mathbf{Y}_L} = \left(\frac{\mathbf{y}_{22} + \mathbf{Y}_L}{\Delta_y + \mathbf{y}_{11}\mathbf{Y}_L}\right)\left(\mathbf{y}_{21} - \frac{\mathbf{y}_{22}\mathbf{y}_{21}}{\mathbf{y}_{22} + \mathbf{Y}_L}\right)$$

$$A_i = \underline{\frac{\mathbf{y}_{21}\mathbf{Y}_L}{\Delta_y + \mathbf{y}_{11}\mathbf{Y}_L}}$$

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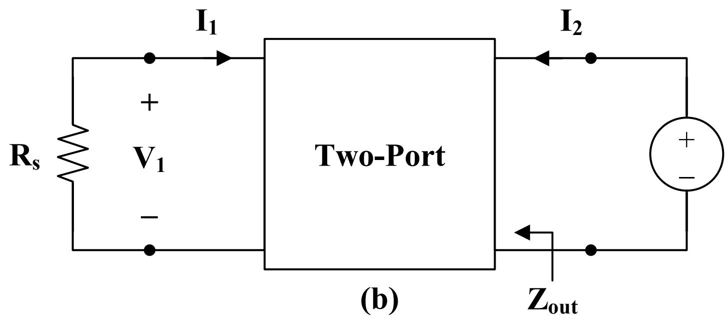
From (3),

$$A_v = \frac{\mathbf{V}_2}{\mathbf{V}_1} = \underline{\frac{-\mathbf{y}_{21}}{\mathbf{y}_{22} + \mathbf{Y}_L}}$$

To get Z_{out}, consider the circuit in Fig. (b).



(b)

$$Z_{out} = \frac{\mathbf{V}_2}{\mathbf{I}_2} = \frac{\mathbf{V}_2}{\mathbf{y}_{21}\,\mathbf{V}_1 + \mathbf{y}_{22}\,\mathbf{V}_2} \qquad (4)$$

But $\qquad \mathbf{V}_1 = -R_s\,\mathbf{I}_1$

Substituting this into (1) yields

$$\mathbf{I}_1 = -\mathbf{y}_{11}\,R_s\,\mathbf{I}_1 + \mathbf{y}_{12}\,\mathbf{V}_2$$

$$(1 + \mathbf{y}_{11}\,R_s)\,\mathbf{I}_1 = \mathbf{y}_{12}\,\mathbf{V}_2$$

$$\mathbf{I}_1 = \frac{\mathbf{y}_{12}\,\mathbf{V}_2}{1 + \mathbf{y}_{11}\,R_s} = \frac{-\mathbf{V}_1}{R_s}$$

or

$$\frac{\mathbf{V}_1}{\mathbf{V}_2} = \frac{-\mathbf{y}_{12}\,R_s}{1 + \mathbf{y}_{11}\,R_s}$$

Substituting this into (4) gives

$$Z_{out} = \frac{1}{\mathbf{y}_{22} - \dfrac{\mathbf{y}_{12}\,\mathbf{y}_{21}\,R_s}{1 + \mathbf{y}_{11}\,R_s}}$$

$$= \frac{1 + \mathbf{y}_{11}\,R_s}{\mathbf{y}_{22} + \mathbf{y}_{11}\,\mathbf{y}_{22}\,R_s - \mathbf{y}_{21}\,\mathbf{y}_{22}\,R_s}$$

$$Z_{out} = \underline{\frac{\mathbf{y}_{11} + \mathbf{Y}_s}{\Delta_y + \mathbf{y}_{22}\,\mathbf{Y}_s}}$$

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Chapter 19, Problem 89.

A transistor has the following parameters in a common-emitter circuit:

$h_{ie} = 2{,}640\,\Omega$, $h_{re} = 2.6 \times 10^{-4}$

$h_{fe} = 72$, $h_{oe} = 16\,\mu$S, $R_L = 100\ \text{k}\Omega$

What is the voltage amplification of the transistor? How many decibels gain is this?

Chapter 19, Solution 89

$$A_v = \frac{-h_{fe} R_L}{h_{ie} + (h_{ie} h_{oe} - h_{re} h_{fe}) R_L}$$

$$A_v = \frac{-72 \cdot 10^5}{2640 + (2640 \times 16 \times 10^{-6} - 2.6 \times 10^{-4} \times 72) \cdot 10^5}$$

$$A_v = \frac{-72 \cdot 10^5}{2640 + 1824} = \underline{\mathbf{-1613}}$$

$$\text{dc gain} = 20 \log \left| A_v \right| = 20 \log(1613) = \underline{\mathbf{64.15}}$$

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Chapter 19, Problem 90.

A transistor with

$h_{fe} = 120,$ $h_{ie} = 2\text{k}\Omega$

$h_{re} = 10^{-4},$ $h_{oe} = 20\,\mu\text{S}$

is used for a CE amplifier to provide an input resistance of $1.5\ \text{k}\Omega$.

(a) Determine the necessary load resistance R_L.

(b) Calculate A_v, A_i, and Z_{out} if the amplifier is driven by a 4-mV source having an internal resistance of $600\,\Omega$.

(c) Find the voltage across the load.

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Chapter 19, Solution 90

(a) $$Z_{in} = h_{ie} - \frac{h_{re}\,h_{fe}\,R_L}{1 + h_{oe}\,R_L}$$

$$1500 = 2000 - \frac{10^{-4} \times 120\,R_L}{1 + 20 \times 10^{-6}\,R_L}$$

$$500 = \frac{12 \times 10^{-3}}{1 + 2 \times 10^{-5}\,R_L}$$

$$500 + 10^{-2}\,R_L = 12 \times 10^{-3}\,R_L$$

$$500 \times 10^{2} = 0.2\,R_L$$

$$R_L = \underline{\mathbf{250\ k\Omega}}$$

(b) $$A_v = \frac{-h_{fe} R_L}{h_{ie} + (h_{ie}\,h_{oe} - h_{re}\,h_{fe})\,R_L}$$

$$A_v = \frac{-120 \times 250 \times 10^{3}}{2000 + (2000 \times 20 \times 10^{-6} - 120 \times 10^{-4}) \times 250 \times 10^{3}}$$

$$A_v = \frac{-30 \times 10^{6}}{2 \times 10^{3} + 7 \times 10^{3}} = \underline{-3333}$$

$$A_i = \frac{h_{fe}}{1 + h_{oe}\,R_L} = \frac{120}{1 + 20 \times 10^{-6} \times 250 \times 10^{3}} = \underline{\mathbf{20}}$$

$$Z_{out} = \frac{R_s + h_{ie}}{(R_s + h_{ie})\,h_{oe} - h_{re}\,h_{fe}} = \frac{600 + 2000}{(600 + 2000) \times 20 \times 10^{-6} - 10^{-4} \times 120}$$

$$Z_{out} = \frac{2600}{40}\ \text{k}\Omega = \underline{\mathbf{65\ k\Omega}}$$

(c) $$A_v = \frac{\mathbf{V}_c}{\mathbf{V}_b} = \frac{\mathbf{V}_c}{\mathbf{V}_s} \longrightarrow \mathbf{V}_c = A_v \mathbf{V}_s = -3333 \times 4 \times 10^{-3} = \underline{\mathbf{-13.33\ V}}$$

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Chapter 19, Problem 91.

For the transistor network of Fig. 19.130,

$h_{fe} = 80,$ $h_{ie} = 1.2\text{k}\Omega$

$h_{re} = 1.5 \times 10^{-4},$ $h_{oe} = 20\,\mu\text{S}$

Determine the following:

(a) voltage gain $A_v = V_o/V_s$,

(b) current gain $A_i = I_0/I_i$,

(c) input impedance Z_{in},

(d) output impedance Z_{out}.

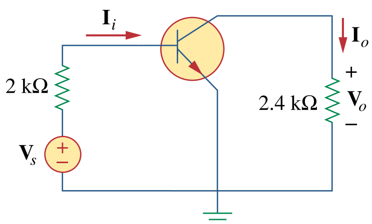

Figure 19.130

For Prob. 19.91.

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Chapter 19, Solution 91

$$R_s = 1.2\ \text{k}\Omega, \qquad R_L = 4\ \text{k}\Omega$$

(a) $$A_v = \frac{-h_{fe} R_L}{h_{ie} + (h_{ie} h_{oe} - h_{re} h_{fe}) R_L}$$

$$A_v = \frac{-80 \times 4 \times 10^3}{1200 + (1200 \times 20 \times 10^{-6} - 1.5 \times 10^{-4} \times 80) \times 4 \times 10^3}$$

$A_V = \dfrac{-32000}{1248} = \underline{\mathbf{-25.64}}$ for the transistor. However, the problem asks for V_o/V_s.

Thus,

$V_b = Vo/ATransV = –V_o/25.64$
$I_b = V_s/(2000 + 1200) = V_s/3200$ (Note, we used Z_{in} from (c) below.)
$V_b = 1200xI_b = (1200/3200)V_s = 0.375V_s = –V_o/25.64$

A_V for the circuit = V_o/V_s = **–9.615**

(b) $$A_i = \frac{h_{fe}}{1 + h_{oe} R_L} = \frac{80}{1 + 20 \times 10^{-6} \times 4 \times 10^3} = \underline{74.07}$$

(c) $$Z_{in} = h_{ie} - h_{re} A_i$$

$$Z_{in} = 1200 - 1.5 \times 10^{-4} \times 74.074 \cong \underline{\mathbf{1.2\ k\Omega}}$$

(d) $$Z_{out} = \frac{R_s + h_{ie}}{(R_s + h_{ie}) h_{oe} - h_{re} h_{fe}}$$

$$Z_{out} = \frac{1200 + 1200}{2400 \times 20 \times 10^{-6} - 1.5 \times 10^{-4} \times 80} = \frac{2400}{0.0468} = \underline{51.28\ \text{k}\Omega}$$

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Chapter 19, Problem 92.

* Determine A_v, A_i, Z_{in}, and Z_{out} for the amplifier shown in Fig. 19.131. Assume that

$h_{ie} = 4\ \text{k}\Omega$, $h_{re} = 10^{-4}$

$h_{fe} = 100$, $h_{oe} = 30\ \mu\text{S}$

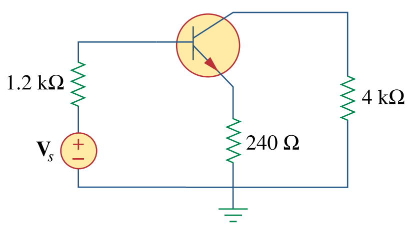


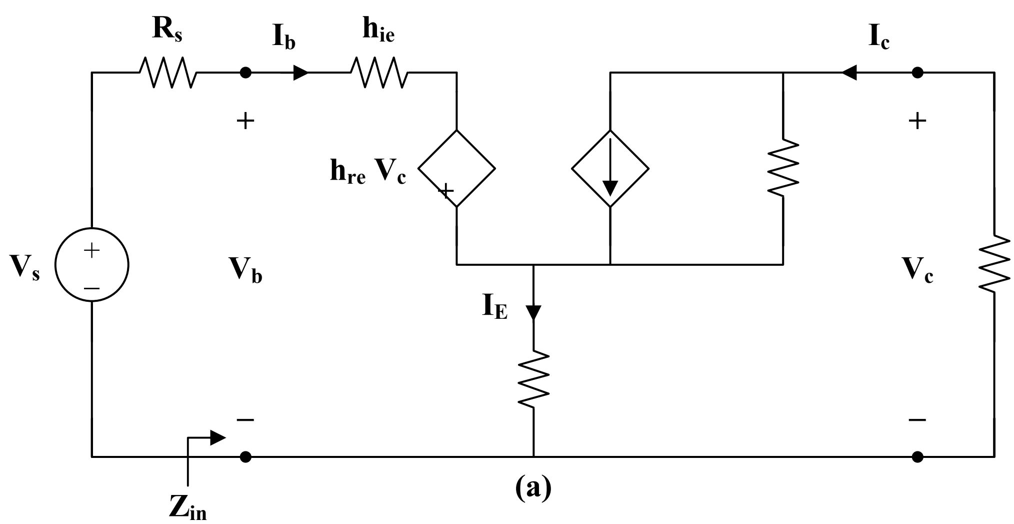
Figure 19.131

For Prob. 19.92.

* An asterisk indicates a challenging problem.

Chapter 19, Solution 92

Due to the resistor $R_E = 240\ \Omega$, we cannot use the formulas in section 18.9.1. We will need to derive our own. Consider the circuit in Fig. (a).



(a)

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$$\mathbf{I}_E = \mathbf{I}_b + \mathbf{I}_c \tag{1}$$

$$\mathbf{V}_b = h_{ie}\mathbf{I}_b + h_{re}\mathbf{V}_c + (\mathbf{I}_b + \mathbf{I}_c)R_E \tag{2}$$

$$\mathbf{I}_c = h_{fe}\mathbf{I}_b + \frac{\mathbf{V}_c}{R_E + 1/h_{oe}} \tag{3}$$

But $$\mathbf{V}_c = -\mathbf{I}_c R_L \tag{4}$$

Substituting (4) into (3),

$$\mathbf{I}_c = h_{fe}\mathbf{I}_b - \frac{R_L}{R_E + 1/h_{oe}}\mathbf{I}_c$$

or $$A_i = \frac{\mathbf{I}_c}{\mathbf{I}_b} = \frac{h_{fe}(1 + R_E h_{oe})}{1 + h_{oe}(R_L} \tag{5}$$

$$A_i = \frac{100(1 + 240x30x10^{-6})}{1 + 30\times 10^{-6}(4{,}000 + 240)}$$

$$A_i = \underline{\mathbf{79.18}}$$

From (3) and (5),

$$\mathbf{I}_c = \frac{h_{fe}(1 + R_E)h_{oe}}{1 + h_{oe}(R_L + R_E)}\mathbf{I}_b = h_{fe}\mathbf{I}_b + \frac{\mathbf{V}_c}{R_E + 1/h_{oe}} \tag{6}$$

Substituting (4) and (6) into (2),

$$\mathbf{V}_b = (h_{ie} + R_E)\mathbf{I}_b + h_{re}\mathbf{V}_c + \mathbf{I}_c R_E$$

$$\mathbf{V}_b = \frac{\mathbf{V}_c(h_{ie} + R_E)}{\left(R_E + \frac{1}{h_{oe}}\right)\left[\frac{h_{fe}(1 + R_E h_{oe})}{1 + h_{oe}(R_L + R_E)} - h_{fe}\right]} + h_{re}\mathbf{V}_c - \frac{\mathbf{V}_c}{R_L}R_E$$

$$\frac{1}{A_v} = \frac{\mathbf{V}_b}{\mathbf{V}_c} = \frac{(h_{ie} + R_E)}{\left(R_E + \frac{1}{h_{oe}}\right)\left[\frac{h_{fe}(1 + R_E h_{oe})}{1 + h_{oe}(R_L + R_E)} - h_{fe}\right]} + h_{re} - \frac{R_E}{R_L} \tag{7}$$

$$\frac{1}{A_v} = \frac{(4000 + 240)}{\left(240 + \frac{1}{30x10^{-6}}\right)\left[\frac{100(1 + 240x30x10^{-6})}{1 + 30\times 10^{-6}\times 4240} - 100\right]} + 10^{-4} - \frac{240}{4000}$$

$$\frac{1}{A_v} = -6.06x10^{-3} + 10^{-4} - 0.06 = -0.066$$

$$A_v = \underline{\mathbf{-15.15}}$$

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From (5),

$$\mathbf{I}_c = \frac{h_{fe}}{1 + h_{oe} R_L} \mathbf{I}_b$$

We substitute this with (4) into (2) to get

$$\mathbf{V}_b = (h_{ie} + R_E)\mathbf{I}_b + (R_E - h_{re} R_L)\mathbf{I}_c$$

$$\mathbf{V}_b = (h_{ie} + R_E)\mathbf{I}_b + (R_E - h_{re} R_L)\left(\frac{h_{fe}(1 + R_E h_{oe})}{1 + h_{oe}(R_L + R_E)}\mathbf{I}_b\right)$$

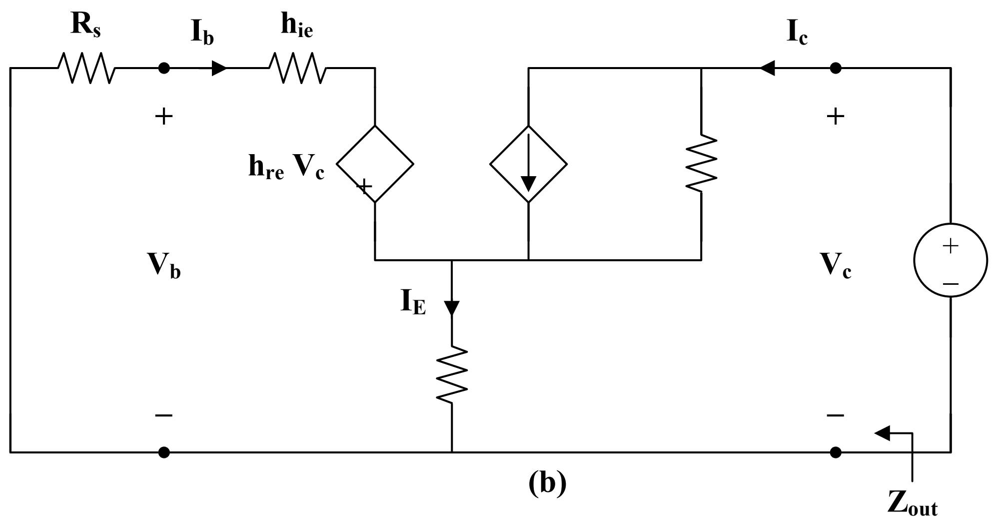
$$Z_{in} = \frac{\mathbf{V}_b}{\mathbf{I}_b} = h_{ie} + R_E + \frac{h_{fe}(R_E - h_{re} R_L)(1 + R_E h_{oe})}{1 + h_{oe}(R_L + R_E)}$$

(8)

$$Z_{in} = 4000 + 240 + \frac{(100)(240 \times 10^{-4} \times 4 \times 10^3)(1 + 240x30x10^{-6})}{1 + 30 \times 10^{-6} \times 4240}$$

Z_{in} = **12.818 kΩ**

To obtain Z_{out}, which is the same as the Thevenin impedance at the output, we introduce a 1-V source as shown in Fig. (b).



(b)

From the input loop,

$$\mathbf{I}_b(R_s + h_{ie}) + h_{re}\mathbf{V}_c + R_E(\mathbf{I}_b + \mathbf{I}_c) = 0$$

But $\quad \mathbf{V}_c = 1$

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So,

$$\mathbf{I}_b (R_s + h_{ie} + R_E) + h_{re} + R_E \mathbf{I}_c = 0 \qquad (9)$$

From the output loop,

$$\mathbf{I}_c = \frac{\mathbf{V}_c}{R_E + \frac{1}{h_{oe}}} + h_{fe}\mathbf{I}_b = \frac{h_{oe}}{R_E h_{oe} + 1} + h_{fe}\mathbf{I}_b$$

or

$$\mathbf{I}_b = \frac{\mathbf{I}_c}{h_{fe}} - \frac{h_{oe}/h_{fe}}{1 + R_E h_{oe}} \qquad (10)$$

Substituting (10) into (9) gives

$$(R_s + R_E + h_{ie})\left(\frac{\mathbf{I}_c}{h_{fe}}\right) + h_{re} + R_E \mathbf{I}_c - \frac{(R_s + R_E + h_{ie})\left(h_{oe}/h_{fe}\right)}{1 + R_E h_{oe}} = 0$$

$$\frac{R_s + R_E + h_{ie}}{h_{fe}}\mathbf{I}_c + R_E \mathbf{I}_c = \frac{R_s + R_E + h_{ie}}{1 + R_E h_{oe}}\left(\frac{h_{oe}}{h_{fe}}\right) - h_{re}$$

$$\mathbf{I}_c = \frac{(h_{oe}/h_{fe})\left[\frac{R_s + R_E + h_{ie}}{1 + R_E h_{oe}}\right] - h_{re}}{R_E + (R_s + R_E + h_{ie})/h_{fe}}$$

$$Z_{out} = \frac{1}{\mathbf{I}_c} = \frac{R_E h_{fe} + R_s + R_E + h_{ie}}{\left[\frac{R_s + R_E + h_{ie}}{1 + R_E h_{oe}}\right] h_{oe} - h_{re} h_{fe}}$$

$$Z_{out} = \frac{240 \times 100 + (1200 + 240 + 4000)}{\left[\frac{1200 + 240 + 4000}{1 + 240\text{x}30\text{x}10^{-6}}\right] \times 30 \times 10^{-6} - 10^{-4} \times 100}$$

$$Z_{out} = \frac{24000 + 5440}{0.152} = \underline{\mathbf{193.7\ k\Omega}}$$

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***Chapter 19, Problem 93.**

Calculate A_v, A_i, Z_{in}, and Z_{out}, for the transistor network in Fig. 19.132. Assume that

$h_{ie} = 2\ \text{k}\Omega$, $\quad h_{re} = 2.5 \times 10^{-4}$

$h_{fe} = 150$, $\quad h_{oe} = 10\,\mu\text{S}$

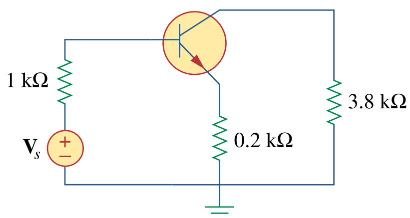

Figure 19.110
For Prob. 19.63.
*An asterisk indicates a challenging problem.

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Chapter 19, Solution 93

We apply the same formulas derived in the previous problem.

$$\frac{1}{A_v} = \frac{(h_{ie} + R_E)}{\left(R_E + \frac{1}{h_{oe}}\right)\left[\frac{h_{fe}(1 + R_E h_{oe})}{1 + h_{oe}(R_L + R_E)} - h_{fe}\right]} + h_{re} - \frac{R_E}{R_L}$$

$$\frac{1}{A_v} = \frac{(2000 + 200)}{(200 + 10^5)\left[\frac{150(1 + 0.002)}{1 + 0.04} - 150\right]} + 2.5\times10^{-4} - \frac{200}{3800}$$

$$\frac{1}{A_v} = -0.004 + 2.5\times10^{-4} - 0.05263 = -0.05638$$

$$A_v = \underline{\mathbf{-17.74}}$$

$$A_i = \frac{h_{fe}(1 + R_E h_{oe})}{1 + h_{oe}(R_L + R_E)} = \frac{150(1 + 200\text{x}10^{-5})}{1 + 10^{-5}\times(200 + 3800)} = \underline{\mathbf{144.5}}$$

$$Z_{in} = h_{ie} + R_E + \frac{h_{fe}(R_E - h_{re} R_L)(1 + R_E h_{oe})}{1 + h_{oe}(R_L + R_E)}$$

$$Z_{in} = 2000 + 200 + \frac{(150)(200 - 2.5\times10^{-4}\times3.8\times10^3)(1.002)}{1.04}$$

$$Z_{in} = 2200 + 28966$$

$$Z_{in} = \underline{\mathbf{31.17\ k\Omega}}$$

$$Z_{out} = \frac{R_E h_{fe} + R_s + R_E + h_{ie}}{\left[\frac{R_s + R_E + h_{ie}}{1 + R_E h_{oe}}\right]h_{oe} - h_{re} h_{fe}}$$

$$Z_{out} = \frac{200\times150 + 1000 + 200 + 2000}{\left[\frac{3200\times10^{-5}}{1.002}\right] - 2.5\times10^{-4}\times150} = \frac{33200}{-0.0055}$$

$$Z_{out} = \underline{\mathbf{-6.148\ M\Omega}}$$

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Chapter 19, Problem 94.

A transistor in its common-emitter mode is specified by

$$[\mathbf{h}] = \begin{bmatrix} 200\Omega & 0 \\ 100 & 10^{-6}\,\text{S} \end{bmatrix}$$

Two such identical transistors are connected in cascade to form a two-stage amplifier used at audio frequencies. If the amplifier is terminated by a 4-kΩ resistor, calculate the overall A_v and Z_{in}.

Chapter 19, Solution 94

We first obtain the **ABCD** parameters.

Given $$[\mathbf{h}] = \begin{bmatrix} 200 & 0 \\ 100 & 10^{-6} \end{bmatrix}, \qquad \Delta_h = \mathbf{h}_{11}\mathbf{h}_{22} - \mathbf{h}_{12}\mathbf{h}_{21} = 2\times 10^{-4}$$

$$[\mathbf{T}] = \begin{bmatrix} \dfrac{\Delta_h}{\mathbf{h}_{21}} & \dfrac{-\mathbf{h}_{11}}{\mathbf{h}_{21}} \\ \dfrac{-\mathbf{h}_{22}}{\mathbf{h}_{21}} & \dfrac{-1}{\mathbf{h}_{21}} \end{bmatrix} = \begin{bmatrix} -2\times 10^{-6} & -2 \\ -10^{-8} & -10^{-2} \end{bmatrix}$$

The overall **ABCD** parameters for the amplifier are

$$[\mathbf{T}] = \begin{bmatrix} -2\times 10^{-6} & -2 \\ -10^{-8} & -10^{-2} \end{bmatrix}\begin{bmatrix} -2\times 10^{-6} & -2 \\ -10^{-8} & -10^{-2} \end{bmatrix} \cong \begin{bmatrix} 2\times 10^{-8} & 2\times 10^{-2} \\ 10^{-10} & 10^{-4} \end{bmatrix}$$

$$\Delta_T = 2\times 10^{-12} - 2\times 10^{-12} = 0$$

$$[\mathbf{h}] = \begin{bmatrix} \dfrac{\mathbf{B}}{\mathbf{D}} & \dfrac{\Delta_T}{\mathbf{D}} \\ \dfrac{-1}{\mathbf{D}} & \dfrac{\mathbf{C}}{\mathbf{D}} \end{bmatrix} = \begin{bmatrix} 200 & 0 \\ -10^{4} & 10^{-6} \end{bmatrix}$$

Thus, $$h_{ie} = 200, \quad h_{re} = 0, \quad h_{fe} = -10^{4}, \quad h_{oe} = 10^{-6}$$

$$A_v = \frac{(10^4)(4\times 10^3)}{200 + (2\times 10^{-4} - 0)\times 4\times 10^3} = \underline{\mathbf{2\times 10^5}}$$

$$Z_{in} = h_{ie} - \frac{h_{re}\,h_{fe}\,R_L}{1 + h_{oe}\,R_L} = 200 - 0 = \underline{\mathbf{200\,\Omega}}$$

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Chapter 19, Problem 95.

Realize an *LC* ladder network such that

$$y_{22} = \frac{s^3 + 5s}{s^4 + 10s^2 + 8}$$

Chapter 19, Solution 95

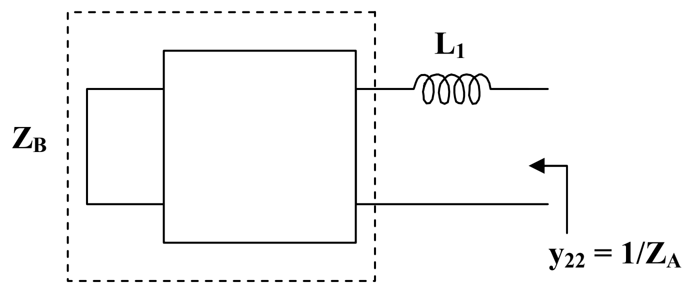
Let $\mathbf{Z}_A = \dfrac{1}{\mathbf{y}_{22}} = \dfrac{s^4 + 10s^2 + 8}{s^3 + 5s}$

Using long division,

$$\mathbf{Z}_A = s + \frac{5s^2 + 8}{s^3 + 5s} = sL_1 + \mathbf{Z}_B$$

i.e. $L_1 = 1\,H$ and $\mathbf{Z}_B = \dfrac{5s^2 + 8}{s^3 + 5s}$

as shown in Fig (a).



(a)

$$\mathbf{Y}_B = \frac{1}{\mathbf{Z}_B} = \frac{s^3 + 5s}{5s^2 + 8}$$

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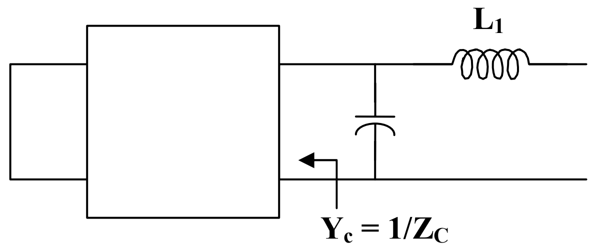
Using long division,

$$\mathbf{Y}_B = 0.2s + \frac{3.4s}{5s^2 + 8} = sC_2 + \mathbf{Y}_C$$

where $C_2 = 0.2$ F and $\mathbf{Y}_C = \frac{3.4s}{5s^2 + 8}$

as shown in Fig. (b).



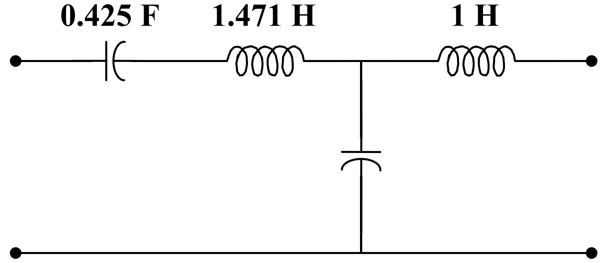
(b)

$$\mathbf{Z}_C = \frac{1}{\mathbf{Y}_C} = \frac{5s^2 + 8}{3.4s} = \frac{5s}{3.4} + \frac{8}{3.4s} = s\,L_3 + \frac{1}{s\,C_4}$$

i.e. an inductor in series with a capacitor

$$L_3 = \frac{5}{3.4} = 1.471 \text{ H} \quad \text{and} \quad C_4 = \frac{3.4}{8} = 0.425 \text{ F}$$

Thus, **the LC network is shown in Fig. (c)**.



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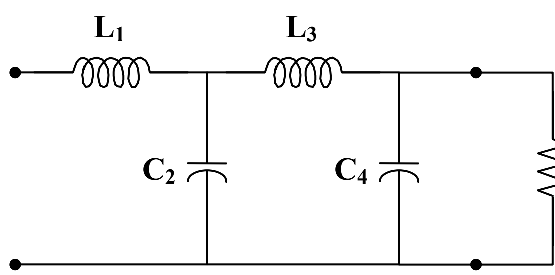
Chapter 19, Problem 96.

Design an *LC* ladder network to realize a lowpass filter with transfer function

$$H(s) = \frac{1}{s^4 + 2.613s^2 + 3.414s^2 + 2.613s + 1}$$

Chapter 19, Solution 96

This is a fourth order network which can be realized with the network shown in Fig. (a).



(a)

$$\Delta(s) = (s^4 + 3.414s^2 + 1) + (2.613s^3 + 2.613s)$$

$$H(s) = \frac{\dfrac{1}{2.613s^3 + 2.613s}}{1 + \dfrac{s^4 + 3.414s^2 + 1}{2.613s^3 + 2.613s}}$$

which indicates that

$$\mathbf{y}_{21} = \frac{-1}{2.613s^3 + 2.613s}$$

$$\mathbf{y}_{22} = \frac{s^4 + 3.414s + 1}{2.613s^3 + 2.613s}$$

We seek to realize $\mathbf{y}_{22}$.

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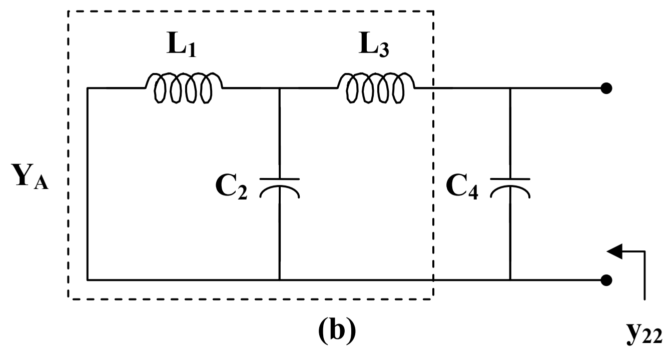
By long division,

$$\mathbf{y}_{22} = 0.383s + \frac{2.414s^2 + 1}{2.613s^3 + 2.613s} = sC_4 + \mathbf{Y}_A$$

i.e. $C_4 = 0.383$ F and $\mathbf{Y}_A = \dfrac{2.414s^2 + 1}{2.613s^3 + 2.613s}$

as shown in Fig. (b).



(b)

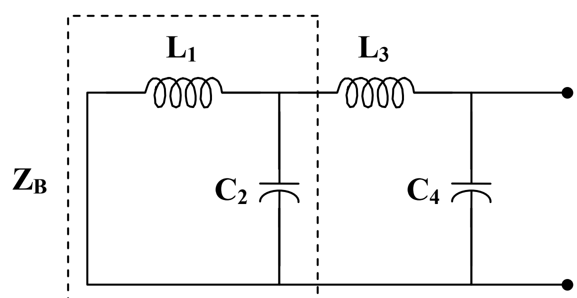
$$\mathbf{Z}_A = \frac{1}{\mathbf{Y}_A} = \frac{2.613s^3 + 2.613s}{2.414s^2 + 1}$$

By long division,

$$\mathbf{Z}_A = 1.082s + \frac{1.531s}{2.414s^2 + 1} = sL_3 + \mathbf{Z}_B$$

i.e. $L_3 = 1.082$ H and $\mathbf{Z}_B = \dfrac{1.531s}{2.414s^2 + 1}$

as shown in Fig.(c).



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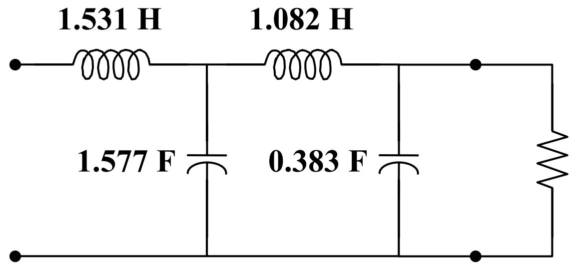
$$\mathbf{Y}_B = \frac{1}{\mathbf{Z}_B} = 1.577s + \frac{1}{1.531s} = sC_2 + \frac{1}{sL_1}$$

i.e. $C_2 = 1.577\ \text{F}$ and $L_1 = 1.531\ \text{H}$

Thus, **<u>the network is shown in Fig. (d)</u>**.



(d)

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Chapter 19, Problem 97.

Synthesize the transfer function

$$H(s) = \frac{V_o}{V_s} = \frac{s^3}{s^3 + 6s + 12s + 24}$$

using the *LC* ladder network in Fig. 19.133.

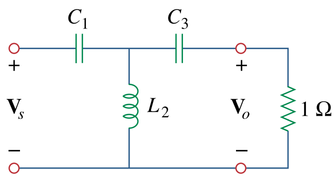


Figure 19.133
For Prob. 19.97.

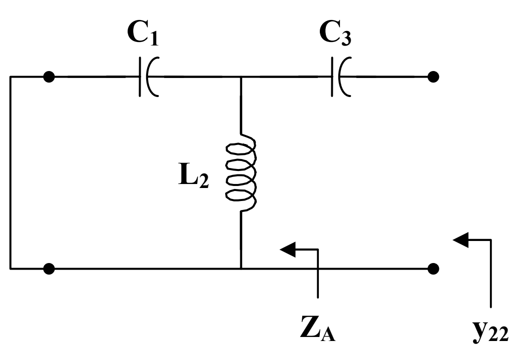
Chapter 19, Solution 97

$$H(s) = \frac{s^3}{(s^3 + 12s) + (6s^2 + 24)} = \frac{\dfrac{s^3}{s^3 + 12s}}{1 + \dfrac{6s^2 + 24}{s^3 + 12s}}$$

Hence,

$$\mathbf{y}_{22} = \frac{6s^2 + 24}{s^3 + 12s} = \frac{1}{sC_3} + \mathbf{Z}_A \qquad (1)$$

where $\mathbf{Z}_A$ is shown in the figure below.



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We now obtain C_3 and $\mathbf{Z}_A$ using partial fraction expansion.

Let
$$\frac{6s^2+24}{s(s^2+12)} = \frac{A}{s} + \frac{Bs+C}{s^2+12}$$
$$6s^2+24 = A(s^2+12) + Bs^2 + Cs$$

Equating coefficients :

s^0 : $24 = 12A \longrightarrow A = 2$

s^1: $0 = C$

s^2 : $6 = A + B \longrightarrow B = 4$

Thus,
$$\frac{6s^2+24}{s(s^2+12)} = \frac{2}{s} + \frac{4s}{s^2+12} \tag{2}$$

Comparing (1) and (2),
$$C_3 = \frac{1}{A} = \frac{1}{2}\,F$$

$$\frac{1}{\mathbf{Z}_A} = \frac{s^2+12}{4s} = \frac{1}{4}s + \frac{3}{s} \tag{3}$$

But
$$\frac{1}{\mathbf{Z}_A} = sC_1 + \frac{1}{sL_2} \tag{4}$$

Comparing (3) and (4),
$$C_1 = \frac{1}{4}\,F \qquad \text{and} \qquad L_2 = \frac{1}{3}\,H$$

Therefore,
$$C_1 = \underline{\mathbf{0.25\ F}}, \qquad L_2 = \underline{\mathbf{0.3333\ H}}, \qquad C_3 = \underline{\mathbf{0.5\ F}}$$

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Chapter 19, Problem 98.

A two-stage amplifier in Fig. 19.134 contains two identical stages with

$$[\mathbf{h}] = \begin{bmatrix} 2\,k\Omega & 0.004 \\ 200 & 500\,\mu\text{S} \end{bmatrix}$$

If $\mathbf{Z}_L = 20\,\text{k}\Omega$, find the required value of $\mathbf{V}_s$ to produce $\mathbf{V}_o = 16$ V.

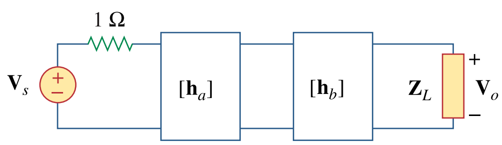

Figure 19.134
For Prob. 19.98.

Chapter 19, Solution 98

$$\Delta_h = 1 - 0.8 = 0.2$$

$$[T_a] = [T_b] = \begin{bmatrix} -\Delta_h / h_{21} & -h_{11}/h_{21} \\ -h_{22}/h_{21} & -1/h_{21} \end{bmatrix} = \begin{bmatrix} -0.001 & -10 \\ -2.5\text{x}10^{-6} & -0.005 \end{bmatrix}$$

$$[T] = [T_a][T_b] = \begin{bmatrix} 2.6\text{x}10^{-5} & 0.06 \\ 1.5\text{x}10^{-8} & 5\text{x}10^{-5} \end{bmatrix}$$

We now convert this to z-parameters

$$[z] = \begin{bmatrix} A/C & \Delta_T/C \\ 1/C & D/C \end{bmatrix} = \begin{bmatrix} 1.733\text{x}10^{3} & 0.0267 \\ 6.667\text{x}10^{7} & 3.33\text{x}10^{3} \end{bmatrix}$$

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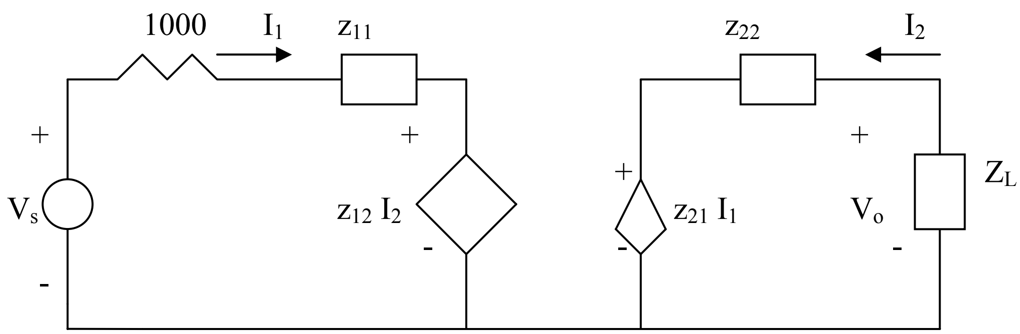

$$V_s = (1000 + z_{11})I_1 + z_{12}I_2 \qquad (1)$$

$$V_o = z_{22}I_2 + z_{21}I_1 \qquad (2)$$

But $V_o = -I_2 Z_L \longrightarrow I_2 = -V_o / Z_L$ (3)

Substituting (3) into (2) gives

$$I_1 = V_o\left(\frac{1}{z_{21}} + \frac{z_{22}}{z_{21}Z_L}\right) \qquad (4)$$

We substitute (3) and (4) into (1)

$$V_s = (1000 + z_{11})\left(\frac{1}{z_{11}} + \frac{z_{22}}{z_{21}Z_L}\right)V_o - \frac{z_{12}}{Z_L}V_o$$

$$= 7.653\text{x}10^{-4} - 2.136\text{x}10^{-5} = \underline{744\mu\text{V}}$$

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Chapter 19, Problem 99.

Assume that the two circuits in Fig. 19.135 are equivalent. The parameters of the two circuits must be equal. Using this factor and the z parameters, derive Eqs. (9.67) and (9.68).

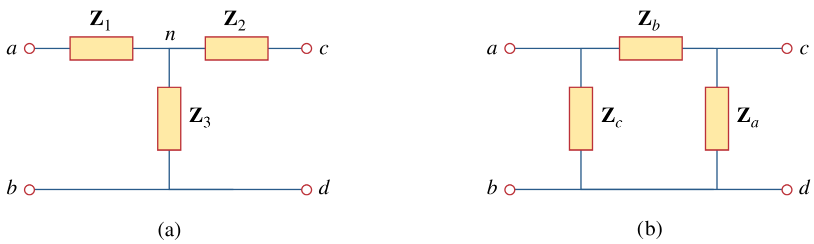

Figure 19.135
For Prob. 19.99.

Chapter 19, Solution 99

$$\mathbf{Z}_{ab} = \mathbf{Z}_1 + \mathbf{Z}_3 = \mathbf{Z}_c \parallel (\mathbf{Z}_b + \mathbf{Z}_a)$$

$$\mathbf{Z}_1 + \mathbf{Z}_3 = \frac{\mathbf{Z}_c(\mathbf{Z}_a + \mathbf{Z}_b)}{\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c} \qquad (1)$$

$$\mathbf{Z}_{cd} = \mathbf{Z}_2 + \mathbf{Z}_3 = \mathbf{Z}_a \parallel (\mathbf{Z}_b + \mathbf{Z}_c)$$

$$\mathbf{Z}_2 + \mathbf{Z}_3 = \frac{\mathbf{Z}_a(\mathbf{Z}_b + \mathbf{Z}_c)}{\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c} \qquad (2)$$

$$\mathbf{Z}_{ac} = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{Z}_b \parallel (\mathbf{Z}_a + \mathbf{Z}_c)$$

$$\mathbf{Z}_1 + \mathbf{Z}_2 = \frac{\mathbf{Z}_b(\mathbf{Z}_a + \mathbf{Z}_c)}{\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c} \qquad (3)$$

Subtracting (2) from (1),

$$\mathbf{Z}_1 - \mathbf{Z}_2 = \frac{\mathbf{Z}_b(\mathbf{Z}_c - \mathbf{Z}_a)}{\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c} \qquad (4)$$

Adding (3) and (4),

$$\underline{\mathbf{Z}_1 = \frac{\mathbf{Z}_b \mathbf{Z}_c}{\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c}} \qquad (5)$$

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Subtracting (5) from (3),

$$\mathbf{Z}_2 = \frac{\mathbf{Z_a Z_b}}{\mathbf{Z_a + Z_b + Z_c}} \tag{6}$$

Subtracting (5) from (1),

$$\mathbf{Z}_3 = \frac{\mathbf{Z_c Z_a}}{\mathbf{Z_a + Z_b + Z_c}} \tag{7}$$

Using (5) to (7)

$$\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_2\mathbf{Z}_3 + \mathbf{Z}_3\mathbf{Z}_1 = \frac{\mathbf{Z}_a\mathbf{Z}_b\mathbf{Z}_c(\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c)}{(\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c)^2}$$

$$\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_2\mathbf{Z}_3 + \mathbf{Z}_3\mathbf{Z}_1 = \frac{\mathbf{Z}_a\mathbf{Z}_b\mathbf{Z}_c}{\mathbf{Z}_a + \mathbf{Z}_b + \mathbf{Z}_c} \tag{8}$$

Dividing (8) by each of (5), (6), and (7),

$$\mathbf{Z}_a = \frac{\mathbf{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}}{\mathbf{Z_1}}$$

$$\mathbf{Z}_b = \frac{\mathbf{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}}{\mathbf{Z_3}}$$

$$\mathbf{Z}_c = \frac{\mathbf{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}}{\mathbf{Z_2}}$$

as required. Note that the formulas above are not exactly the same as those in Chapter 9 because the locations of $\mathbf{Z}_b$ and $\mathbf{Z}_c$ are interchanged in Fig. 18.122.

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