CHAPTER 2

Exercises

E2.1 (a) R_2, R_3, and R_4 are in parallel. Furthermore R_1 is in series with the combination of the other resistors. Thus we have:

$$R_{eq} = R_1 + \frac{1}{1/R_2 + 1/R_3 + 1/R_4} = 3\ \Omega$$

(b) R_3 and R_4 are in parallel. Furthermore, R_2 is in series with the combination of R_3, and R_4. Finally R_1 is in parallel with the combination of the other resistors. Thus we have:

$$R_{eq} = \frac{1}{1/R_1 + 1/[R_2 + 1/(1/R_3 + 1/R_4)]} = 5\ \Omega$$

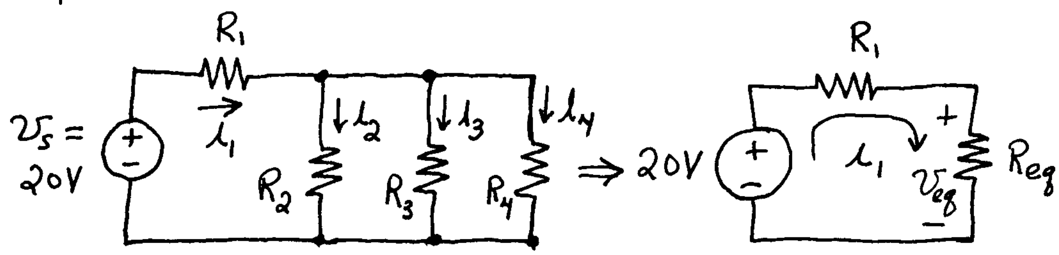
(c) R_1 and R_2 are in parallel. Furthermore, R_3, and R_4 are in parallel. Finally, the two parallel combinations are in series.

$$R_{eq} = \frac{1}{1/R_1 + 1/R_2} + \frac{1}{1/R_3 + 1/R_4} = 52.1\ \Omega$$

(d) R_1 and R_2 are in series. Furthermore, R_3 is in parallel with the series combination of R_1 and R_2.

$$R_{eq} = \frac{1}{1/R_3 + 1/(R_1 + R_2)} = 1.5\ \text{k}\Omega$$

E2.2 (a) First we combine R_2, R_3, and R_4 in parallel. Then R_1 is in series with the parallel combination.

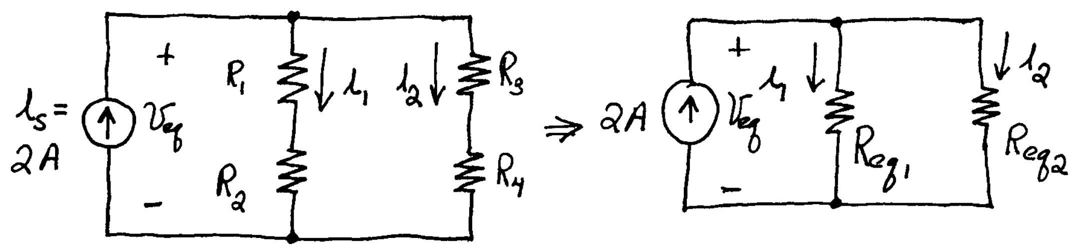


$$R_{eq} = \frac{1}{1/R_2 + 1/R_3 + 1/R_4} = 9.231\ \Omega \qquad i_1 = \frac{20\ \text{V}}{R_1 + R_{eq}} = \frac{20}{10 + 9.231} = 1.04\ A$$

$$v_{eq} = R_{eq} i_1 = 9.600\ \text{V} \qquad i_2 = v_{eq} / R_2 = 0.480\ A \qquad i_3 = v_{eq} / R_3 = 0.320\ A$$

$$i_4 = v_{eq} / R_4 = 0.240\ A$$

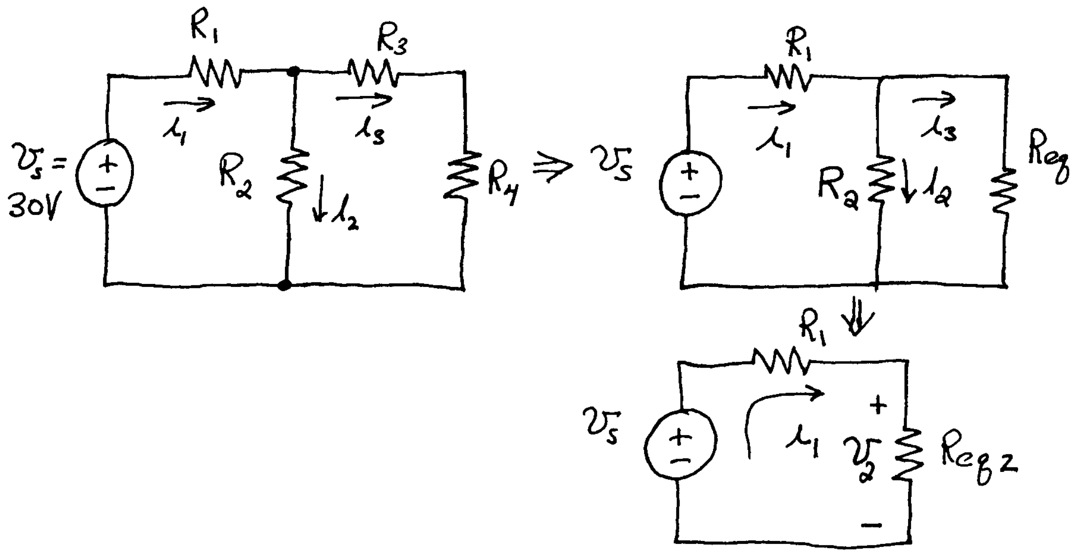
(b) R_1 and R_2 are in series. Furthermore, R_3, and R_4 are in series. Finally, the two series combinations are in parallel.



$$R_{eq1} = R_1 + R_2 = 20\,\Omega \qquad R_{eq2} = R_3 + R_4 = 20\,\Omega \quad R_{eq} = \frac{1}{1/R_{eq1} + 1/R_{eq2}} = 10\,\Omega$$

$$v_{eq} = 2 \times R_{eq} = 20\text{ V} \qquad i_1 = v_{eq} / R_{eq1} = 1\,A \qquad i_2 = v_{eq} / R_{eq2} = 1\,A$$

(c) R_3, and R_4 are in series. The combination of R_3 and R_4 is in parallel with R_2. Finally the combination of R_2, R_3, and R_4 is in series with R_1.



$$R_{eq1} = R_3 + R_4 = 40\,\Omega \quad R_{eq2} = \frac{1}{1/R_{eq1} + 1/R_2} = 20\,\Omega \quad i_1 = \frac{v_s}{R_1 + R_{eq2}} = 1\,A$$

$$v_2 = i_1 R_{eq2} = 20\text{ V} \quad i_2 = v_2 / R_2 = 0.5\,A \quad i_3 = v_2 / R_{eq1} = 0.5\,A$$

E2.3 (a) $v_1 = v_s \dfrac{R_1}{R_1 + R_2 + R_3 + R_4} = 10\text{ V}$. $v_2 = v_s \dfrac{R_2}{R_1 + R_2 + R_3 + R_4} = 20\text{ V}$.

Similarly, we find $v_3 = 30\text{ V}$ and $v_4 = 60\text{ V}$.

(b) First combine R_2 and R_3 in parallel: $R_{eq} = 1/(1/R_2 + 1/R_3) = 2.917\ \Omega$.

Then we have $v_1 = v_s \dfrac{R_1}{R_1 + R_{eq} + R_4} = 6.05\text{ V}$. Similarly, we find

$v_2 = v_s \dfrac{R_{eq}}{R_1 + R_{eq} + R_4} = 5.88\text{ V}$ and $v_4 = 8.07\text{ V}$.

E2.4 (a) First combine R_1 and R_2 in series: $R_{eq} = R_1 + R_2 = 30\ \Omega$. Then we have $i_1 = i_s \dfrac{R_3}{R_3 + R_{eq}} = \dfrac{15}{15+30} = 1\ A$ and $i_3 = i_s \dfrac{R_{eq}}{R_3 + R_{eq}} = \dfrac{30}{15+30} = 2\ A$.

(b) The current division principle applies to two resistances in parallel. Therefore, to determine i_1, first combine R_2 and R_3 in parallel: $R_{eq} = 1/(1/R_2 + 1/R_3) = 5\ \Omega$. Then we have $i_1 = i_s \dfrac{R_{eq}}{R_1 + R_{eq}} = \dfrac{5}{10+5} = 1\ A$.

Similarly, $i_2 = 1\ A$ and $i_3 = 1\ A$.

E2.5 Write KVL for the loop consisting of v_1, v_y, and v_2. The result is $-v_1 - v_y + v_2 = 0$ from which we obtain $v_y = v_2 - v_1$. Similarly we obtain $v_z = v_3 - v_1$.

E2.6 Node 1: $\dfrac{v_1 - v_3}{R_1} + \dfrac{v_1 - v_2}{R_2} = i_a$ Node 2: $\dfrac{v_2 - v_1}{R_2} + \dfrac{v_2}{R_3} + \dfrac{v_2 - v_3}{R_4} = 0$

Node 3: $\dfrac{v_3}{R_5} + \dfrac{v_3 - v_2}{R_4} + \dfrac{v_3 - v_1}{R_1} + i_b = 0$

E2.7 Following the step-by-step method in the book, we obtain

$$\begin{bmatrix} \dfrac{1}{R_1} + \dfrac{1}{R_2} & -\dfrac{1}{R_2} & 0 \\ -\dfrac{1}{R_2} & \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} & -\dfrac{1}{R_4} \\ 0 & -\dfrac{1}{R_4} & \dfrac{1}{R_4} + \dfrac{1}{R_5} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} -i_s \\ 0 \\ i_s \end{bmatrix}$$

E2.8 Instructions for various calculators vary. The MATLAB solution is given in the book following this exercise.

E2.9 (a) Writing the node equations we obtain:

$$\text{Node 1: } \frac{v_1 - v_3}{20} + \frac{v_1}{5} + \frac{v_1 - v_2}{10} = 0$$

$$\text{Node 2: } \frac{v_2 - v_1}{10} + 10 + \frac{v_2 - v_3}{5} = 0$$

$$\text{Node 3: } \frac{v_3 - v_1}{20} + \frac{v_3}{10} + \frac{v_3 - v_2}{5} = 0$$

(b) Simplifying the equations we obtain:

$$0.35v_1 - 0.10v_2 - 0.05v_3 = 0$$
$$-0.10v_1 + 0.30v_2 - 0.20v_3 = -10$$
$$-0.05v_1 - 0.20v_2 + 0.35v_3 = 0$$

(c) and (d) Solving using Matlab:

```
>>clear
>>G = [0.35 -0.1 -0.05; -0.10 0.30 -0.20; -0.05 -0.20 0.35];
>>I = [0; -10; 0];
>>V = G\I
V =
  -27.2727
  -72.7273
  -45.4545
>>Ix = (V(1) - V(3))/20
Ix =
    0.9091
```

E2.10 Using determinants we can solve for the unknown voltages as follows:

$$v_1 = \frac{\begin{vmatrix} 6 & -0.2 \\ 1 & 0.5 \end{vmatrix}}{\begin{vmatrix} 0.7 & -0.2 \\ -0.2 & 0.5 \end{vmatrix}} = \frac{3 + 0.2}{0.35 - 0.04} = 10.32 \text{ V}$$

$$v_2 = \frac{\begin{vmatrix} 0.7 & 6 \\ -0.2 & 1 \end{vmatrix}}{\begin{vmatrix} 0.7 & -0.2 \\ -0.2 & 0.5 \end{vmatrix}} = \frac{0.7 + 1.2}{0.35 - 0.04} = 6.129 \text{ V}$$

Many other methods exist for solving linear equations.

E2.11 First write KCL equations at nodes 1 and 2:

$$\text{Node 1:}\quad \frac{v_1 - 10}{2} + \frac{v_1}{5} + \frac{v_1 - v_2}{10} = 0$$

$$\text{Node 2:}\quad \frac{v_2 - 10}{10} + \frac{v_2}{5} + \frac{v_2 - v_1}{10} = 0$$

Then, simplify the equations to obtain:

$$8v_1 - v_2 = 50 \quad \text{and} \quad -v_1 + 4v_2 = 10$$

Solving manually or with a calculator, we find v_1 = 6.77 V and v_2 = 4.19 V. The MATLAB session using the symbolic approach is:

```
>> clear
[V1,V2] = solve('(V1-10)/2+(V1)/5 +(V1 - V2)/10 = 0' , ...
                 '(V2-10)/10 +V2/5 +(V2-V1)/10 = 0')
V1 =
210/31
V2 =
130/31
```

Next, we solve using the numerical approach.

```
>> clear
G = [8 -1; -1 4];
I = [50; 10];
V = G\I
V =
   6.7742
   4.1935
```

E2.12 The equation for the supernode enclosing the 15-V source is:

$$\frac{v_3 - v_2}{R_3} + \frac{v_3 - v_1}{R_1} = \frac{v_1}{R_2} + \frac{v_2}{R_4}$$

This equation can be readily shown to be equivalent to Equation 2.37 in the book. (Keep in mind that v_3 = -15 V.)

E2.13 Write KVL from the reference to node 1 then through the 10-V source to node 2 then back to the reference node:

$$-v_1 + 10 + v_2 = 0$$

Then write KCL equations. First for a supernode enclosing the 10-V source, we have:

$$\frac{v_1}{R_1} + \frac{v_1 - v_3}{R_2} + \frac{v_2 - v_3}{R_3} = 1$$

Node 3:

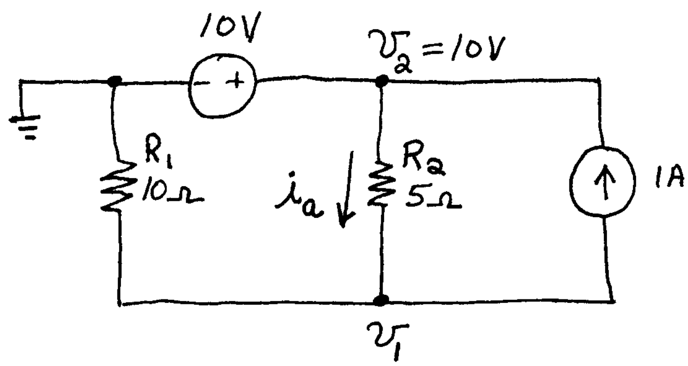
$$\frac{v_3}{R_4} + \frac{v_3 - v_1}{R_2} + \frac{v_3 - v_2}{R_3} = 0$$

Reference node:

$$\frac{v_1}{R_1} + \frac{v_3}{R_4} = 1$$

An independent set consists of the KVL equation and any two of the KCL equations.

E2.14 (a) Select the reference node at the left-hand end of the voltage source as shown at right.



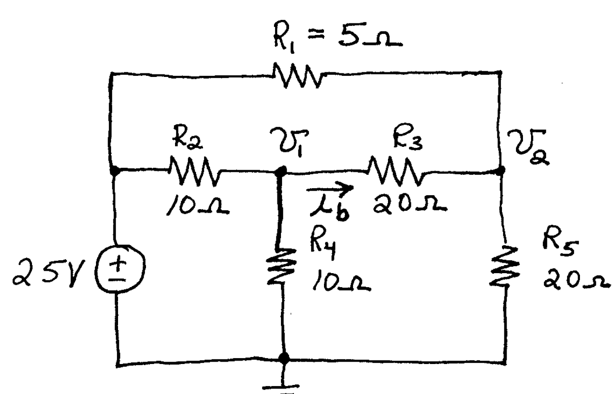
Then write a KCL equation at node 1.

$$\frac{v_1}{R_1} + \frac{v_1 - 10}{R_2} + 1 = 0$$

Substituting values for the resistances and solving, we find v_1 = 3.33 V.

Then we have $i_a = \frac{10 - v_1}{R_2} = 1.333$ A.

(b) Select the reference node and assign node voltages as shown.



Then write KCL equations at nodes 1 and 2.

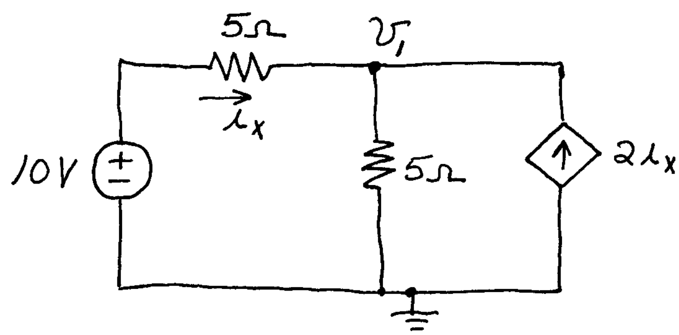
$$\frac{v_1 - 25}{R_2} + \frac{v_1}{R_4} + \frac{v_1 - v_2}{R_3} = 0$$

$$\frac{v_2 - 25}{R_1} + \frac{v_2 - v_1}{R_3} + \frac{v_2}{R_5} = 0$$

Substituting values for the resistances and solving, we find v_1 = 13.79 V and v_2 = 18.97 V. Then we have $i_b = \dfrac{v_1 - v_2}{R_3}$ = -0.259 A.

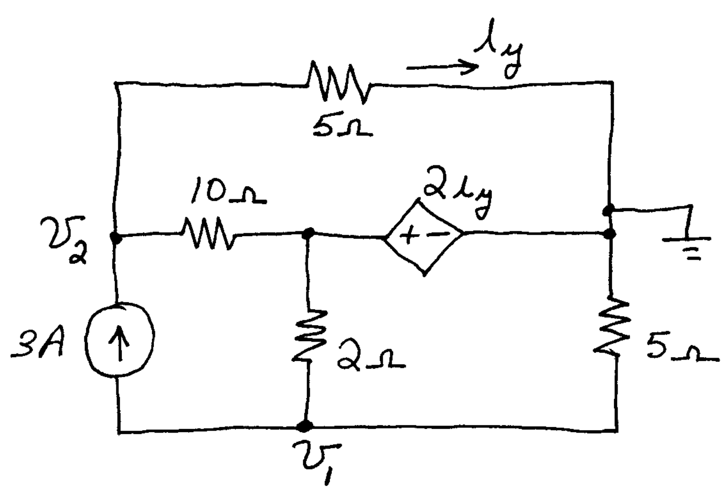
E2.15 (a) Select the reference node and node voltage as shown. Then write a KCL equation at node 1, resulting in

$$\frac{v_1}{5} + \frac{v_1 - 10}{5} - 2i_x = 0$$



Then use $i_x = (10 - v_1)/5$ to substitute and solve. We find v_1 = 7.5 V. Then we have $i_x = \dfrac{10 - v_1}{5} = 0.5$ A.

(b) Choose the reference node and node voltages shown:



Then write KCL equations at nodes 1 and 2:

$$\frac{v_1}{5} + \frac{v_1 - 2i_y}{2} + 3 = 0 \qquad \frac{v_2}{5} + \frac{v_2 - 2i_y}{10} = 3$$

Finally use $i_y = v_2 / 5$ to substitute and solve. This yields $v_2 = 11.54\text{ V}$ and $i_y = 2.31\text{ A}$.

E2.16

```
>> clear
>> [V1 V2 V3] = solve('V3/R4 + (V3 - V2)/R3 + (V3 - V1)/R1 = 0', ...
                      'V1/R2 + V3/R4 = Is', ...
                      'V1 = (1/2)*(V3 - V1) + V2' ,'V1','V2','V3');
>> pretty(V1), pretty(V2), pretty(V3)

           R2 Is (2 R3 R1 + 3 R4 R1 + 2 R4 R3)
       -----------------------------------------------
       2 R3 R1 + 3 R4 R1 + 3 R1 R2 + 2 R4 R3 + 2 R3 R2

           R2 Is (3 R3 R1 + 3 R4 R1 + 2 R4 R3)
       -----------------------------------------------
       2 R3 R1 + 3 R4 R1 + 3 R1 R2 + 2 R4 R3 + 2 R3 R2

            Is R2 R4 (3 R1 + 2 R3)
      -----------------------------------------------
      2 R3 R1 + 3 R4 R1 + 3 R1 R2 + 2 R4 R3 + 2 R3 R2
```

E2.17 Refer to Figure 2.33b in the book. (a) Two mesh currents flow through R_2: i_1 flows downward and i_4 flows upward. Thus the current flowing in R_2 referenced upward is $i_4 - i_1$. (b) Similarly, mesh current i_1 flows to the left through R_4 and mesh current i_2 flows to the right, so the total current referenced to the right is $i_2 - i_1$. (c) Mesh current i_3 flows downward through R_8 and mesh current i_4 flows upward, so the total current referenced downward is $i_3 - i_4$. (d) Finally, the total current referenced upward through R_8 is $i_4 - i_3$.

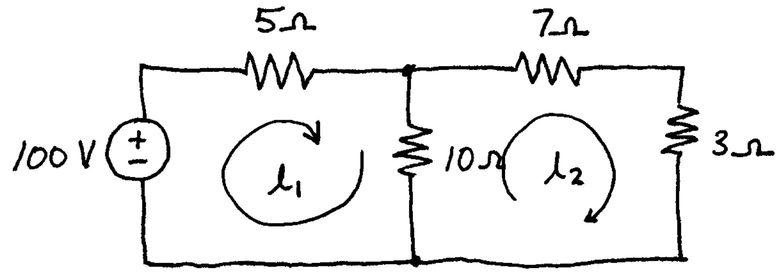
E2.18 Refer to Figure 2.33b in the book. Following each mesh current in turn, we have

$$R_1 i_1 + R_2(i_1 - i_4) + R_4(i_1 - i_2) - v_A = 0$$
$$R_5 i_2 + R_4(i_2 - i_1) + R_6(i_2 - i_3) = 0$$
$$R_7 i_3 + R_6(i_3 - i_2) + R_8(i_3 - i_4) = 0$$
$$R_3 i_4 + R_2(i_4 - i_1) + R_8(i_4 - i_3) = 0$$

In matrix form, these equations become

$$\begin{bmatrix} (R_1+R_2+R_4) & -R_4 & 0 & -R_2 \\ -R_4 & (R_4+R_5+R_6) & -R_6 & 0 \\ 0 & -R_6 & (R_6+R_7+R_8) & -R_8 \\ -R_2 & 0 & -R_8 & (R_2+R_3+R_8) \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{bmatrix} = \begin{bmatrix} v_A \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

E2.19 We choose the mesh currents as shown:

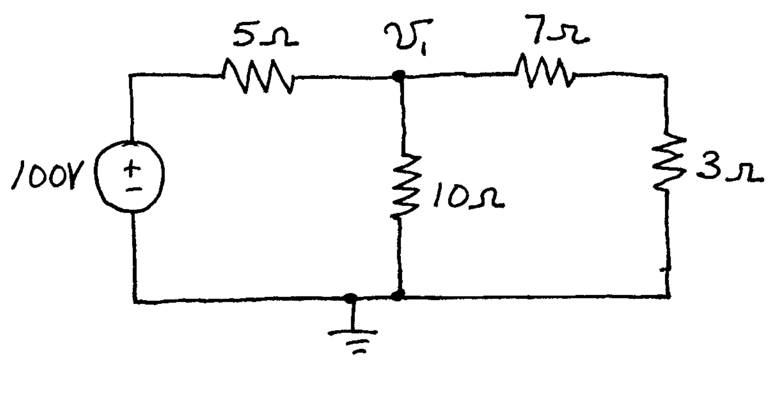


Then, the mesh equations are:

$$5i_1 + 10(i_1 - i_2) = 100 \quad \text{and} \quad 10(i_2 - i_1) + 7i_2 + 3i_2 = 0$$

Simplifying and solving these equations, we find that $i_1 = 10\text{ A}$ and $i_2 = 5\text{ A}$. The net current flowing downward through the 10-Ω resistance is $i_1 - i_2 = 5\text{ A}$.

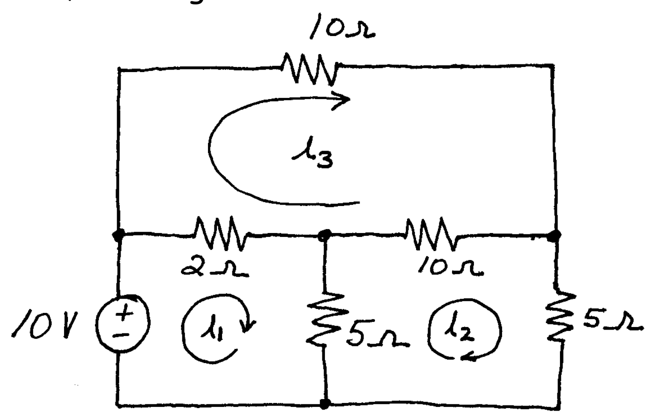
To solve by node voltages, we select the reference node and node voltage shown. (We do not need to assign a node voltage to the connection between the 7-Ω resistance and the 3-Ω resistance because we can treat the series combination as a single 10-Ω resistance.)



The node equation is $(v_1 - 10)/5 + v_1/10 + v_1/10 = 0$. Solving we find that v_1 = 50 V. Thus we again find that the current through the 10-Ω resistance is $i = v_1/10 = 5$ A.

Combining resistances in series and parallel, we find that the resistance "seen" by the voltage source is 10 Ω. Thus the current through the source and 5-Ω resistance is (100 V)/(10 Ω) = 10 A. This current splits equally between the 10-Ω resistance and the series combination of 7 Ω and 3 Ω.

E2.20 First, we assign the mesh currents as shown.



Then we write KVL equations following each mesh current:

$$2(i_1 - i_3) + 5(i_1 - i_2) = 10$$
$$5i_2 + 5(i_2 - i_1) + 10(i_2 - i_3) = 0$$
$$10i_3 + 10(i_3 - i_2) + 2(i_3 - i_1) = 0$$

Simplifying and solving, we find that i_1 = 2.194 A, i_2 = 0.839 A, and i_3 = 0.581 A. Thus the current in the 2-Ω resistance referenced to the right is i_1 - i_3 = 2.194 - 0.581 = 1.613 A.

E2.21 Following the step-by-step process, we obtain

$$\begin{bmatrix} (R_2 + R_3) & -R_3 & -R_2 \\ -R_3 & (R_3 + R_4) & 0 \\ -R_2 & 0 & (R_1 + R_2) \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} v_A \\ -v_B \\ v_B \end{bmatrix}$$

E2.22 Refer to Figure 2.39 in the book. In terms of the mesh currents, the current directed to the right in the 5-A current source is i_1, however by the definition of the current source, the current is 5 A directed to the left. Thus, we conclude that i_1 = -5 A. Then we write a KVL equation following i_2, which results in $10(i_2 - i_1) + 5i_2 = 100$.

E2.23 Refer to Figure 2.40 in the book. First, for the current source, we have

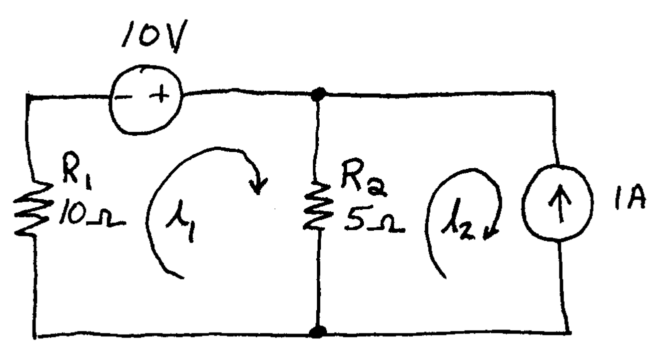
$$i_2 - i_1 = 1$$

Then, we write a KVL equation going around the perimeter of the entire circuit:

$$5i_1 + 10i_2 + 20 - 10 = 0$$

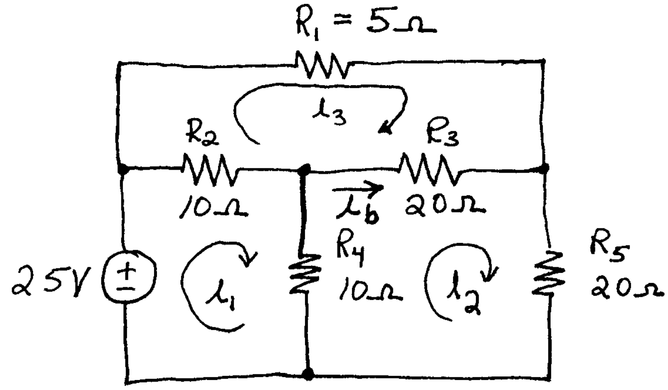
Simplifying and solving these equations we obtain i_1 = -4/3 A and i_2 = -1/3 A.

E2.24 (a) As usual, we select the mesh currents flowing clockwise around the meshes as shown. Then for the current source, we have i_2 = -1 A. This is because we defined the mesh



current i_2 as the current referenced downward through the current source. However, we know that the current through this source is 1 A flowing upward. Next we write a KVL equation around mesh 1: $10i_1 - 10 + 5(i_1 - i_2) = 0$. Solving, we find that i_1 = 1/3 A. Referring to Figure 2.30a in the book we see that the value of the current i_a referenced downward through the 5 Ω resistance is to be found. In terms of the mesh currents, we have $i_a = i_1 - i_2 = 4/3\ A$.

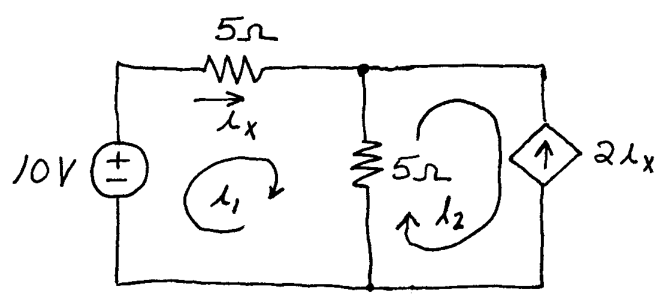
(b) As usual, we select the mesh currents flowing clockwise around the meshes as shown.
Then we write a KVL equation for each mesh.



$$-25 + 10(i_1 - i_3) + 10(i_1 - i_2) = 0$$
$$10(i_2 - i_1) + 20(i_2 - i_3) + 20i_2 = 0$$
$$10(i_3 - i_1) + 5i_3 + 20(i_3 - i_2) = 0$$

Simplifying and solving, we find i_1 = 2.3276 A, i_2 = 0.9483 A, and i_3 = 1.2069 A. Finally, we have $i_b = i_2 - i_3$ = -0.2586 A.

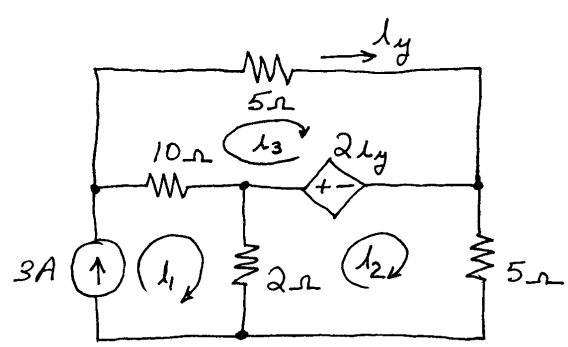
E2.25 (a) KVL mesh 1:
$-10 + 5i_1 + 5(i_1 - i_2) = 0$
For the current source:
$i_2 = -2i_x$
However, i_x and i_1 are the same current, so we also have $i_1 = i_x$.



Simplifying and solving, we find $i_x = i_1 = 0.5$ A.

(b) First for the current source, we have: $i_1 = 3$ A
Writing KVL around meshes 2 and 3, we have:

$$2(i_2 - i_1) + 2i_y + 5i_2 = 0$$
$$10(i_3 - i_1) + 5i_3 - 2i_y = 0$$

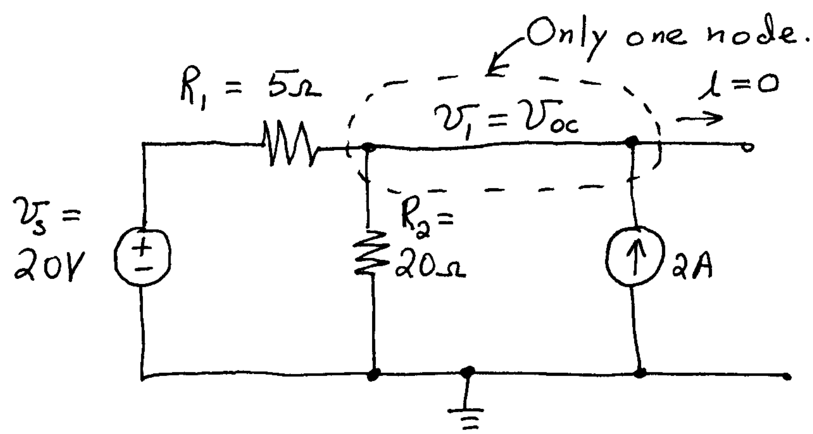


However i_3 and i_y are the same current: $i_y = i_3$. Simplifying and solving, we find that $i_3 = i_y = 2.31$ A.

E2.26 Under open-circuit conditions, 5 A circulates clockwise through the current source and the 10-Ω resistance. The voltage across the 10-Ω resistance is 50 V. No current flows through the 40-Ω resistance so the open circuit voltage is $V_t = 50$ V.

With the output shorted, the 5 A divides between the two resistances in parallel. The short-circuit current is the current through the 40-Ω resistance, which is $i_{sc} = 5\dfrac{10}{10+40} = 1$ A. Then, the Thévenin resistance is $R_t = v_{oc} / i_{sc} = 50\ \Omega$.

E2.27 Choose the reference node at the bottom of the circuit as shown:

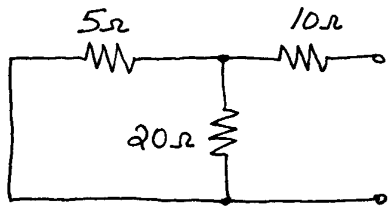


Notice that the node voltage is the open-circuit voltage. Then write a KCL equation:

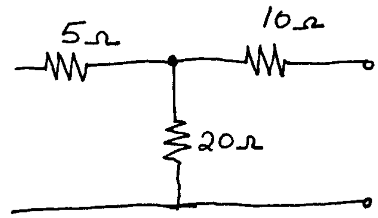
$$\frac{v_{oc} - 20}{5} + \frac{v_{oc}}{20} = 2$$

Solving we find that v_{oc} = 24 V which agrees with the value found in Example 2.17.

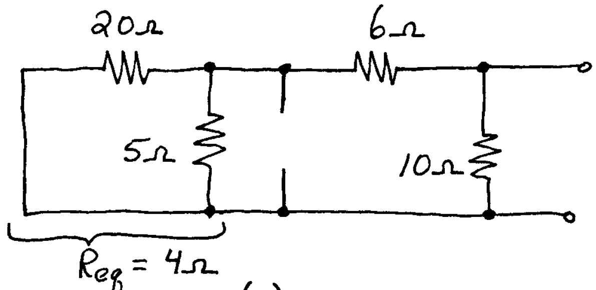
E2.28 To zero the sources, the voltage sources become short circuits and the current sources become open circuits. The resulting circuits are :



(a)



(b)



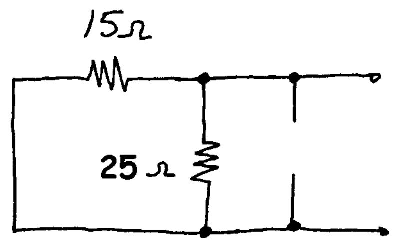
(c)

(a) $R_t = 10 + \dfrac{1}{1/5 + 1/20} = 14\ \Omega$ (b) $R_t = 10 + 20 = 30\ \Omega$

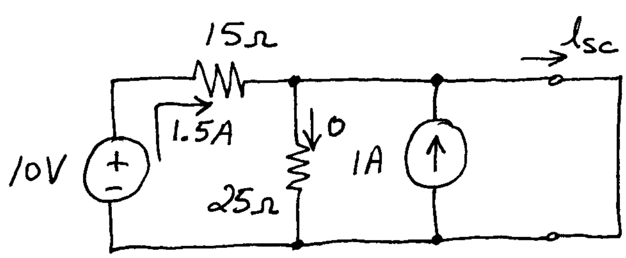
(c) $R_t = \dfrac{1}{\dfrac{1}{10} + \dfrac{1}{6 + \dfrac{1}{(1/5 + 1/20)}}} = 5\ \Omega$

E2.29 (a) Zero sources to determine Thévenin resistance. Thus

$R_t = \dfrac{1}{1/15 + 1/25} = 9.375\ \Omega.$

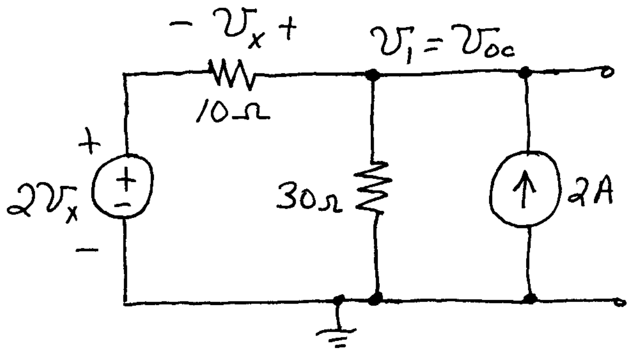


Then find short-circuit current:



$I_n = i_{sc} = 10/15 + 1 = 1.67\ A$

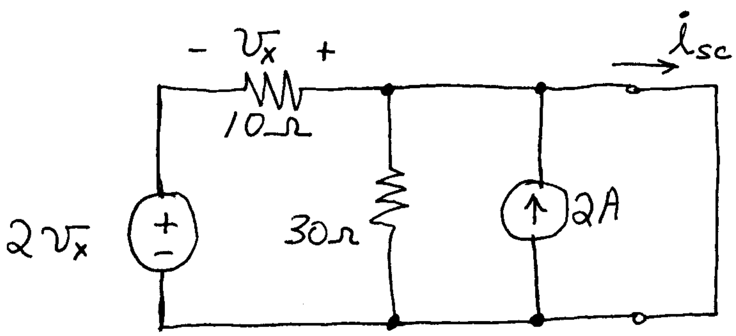
(b) We cannot find the Thévenin resistance by zeroing the sources, because we have a controlled source. Thus, we find the open-circuit voltage and the short-circuit current.



$$\frac{v_{oc} - 2v_x}{10} + \frac{v_{oc}}{30} = 2 \qquad\qquad v_{oc} = 3v_x$$

Solving, we find $V_t = v_{oc} = 30$ V.

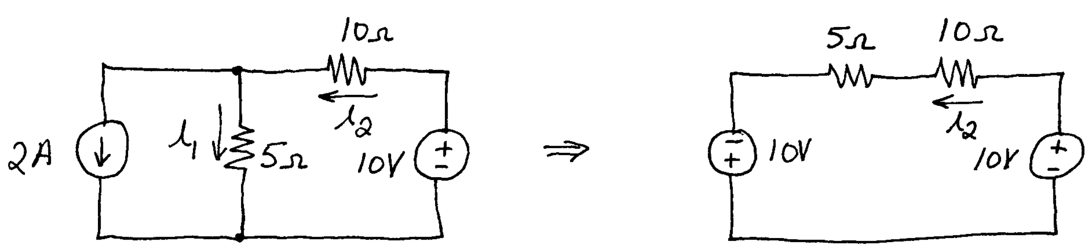
Now, we find the short-circuit current:



$$2v_x + v_x = 0 \qquad \Rightarrow \qquad v_x = 0$$

Therefore $i_{sc} = 2$ A. Then we have $R_t = v_{oc} / i_{sc} = 15\ \Omega$.

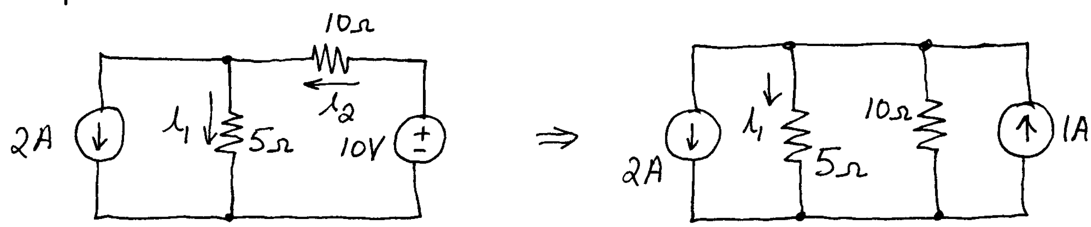
E2.30 First, we transform the 2-A source and the 5-Ω resistance into a voltage source and a series resistance:



Then we have $i_2 = \dfrac{10+10}{15} = 1.333$ A.

From the original circuit, we have $i_1 = i_2 - 2$, from which we find $i_1 = -0.667$ A.

The other approach is to start from the original circuit and transform the 10-Ω resistance and the 10-V voltage source into a current source and parallel resistance:



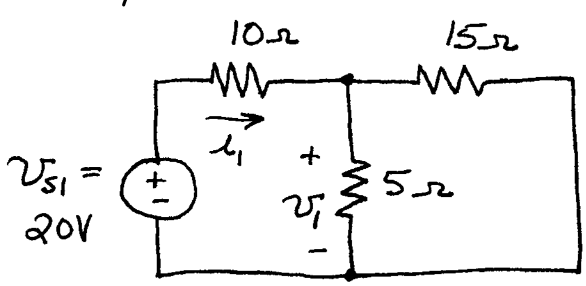
Then we combine the resistances in parallel. $R_{eq} = \dfrac{1}{1/5 + 1/10} = 3.333\,\Omega$.

The current flowing upward through this resistance is 1 A. Thus the voltage across R_{eq} referenced positive at the bottom is 3.333 V and $i_1 = -3.333/5 = -0.667$ A. Then from the original circuit we have $i_2 = 2 + i_1 = 1.333$ A, as before.

E2.31 Refer to Figure 2.62b. We have $i_1 = 15/15 = 1$ A.

Refer to Figure 2.62c. Using the current division principle, we have $i_2 = -2 \times \dfrac{5}{5+10} = -0.667$ A. (The minus sign is because of the reference direction of i_2.) Finally, by superposition we have $i_T = i_1 + i_2 = 0.333$ A.

E2.32 With only the first source active we have:

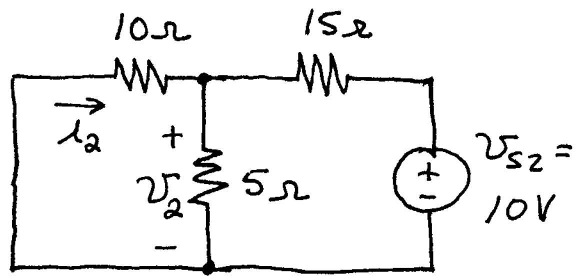


Then we combine resistances in series and parallel:

$$R_{eq} = 10 + \frac{1}{1/5 + 1/15} = 13.75\,\Omega$$

Thus, $i_1 = 20/13.75 = 1.455$ A, and $v_1 = 3.75 i_1 = 5.45$ V.

With only the second source active, we have:



Then we combine resistances in series and parallel:

$$R_{eq2} = 15 + \frac{1}{1/5 + 1/10} = 18.33\ \Omega$$

Thus, $i_s = 10/18.33 = 0.546$ A, and $v_2 = 3.33 i_s = 1.818$ V. Then, we have $i_2 = (-v_2)/10 = -0.1818$ A

Finally we have $v_T = v_1 + v_2 = 5.45 + 1.818 = 7.27$ V and $i_T = i_1 + i_2 = 1.455 - 0.1818 = 1.27$ A.

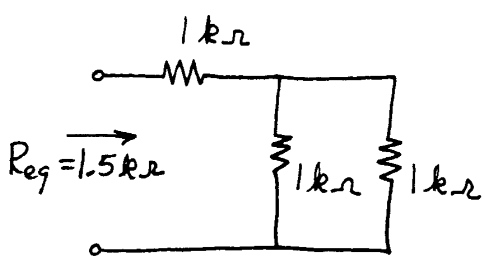
Answers for Selected Problems

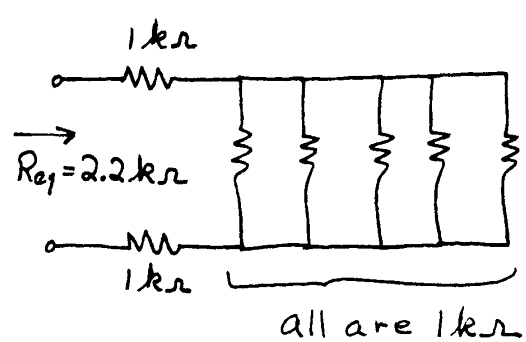
P2.1* (a) $R_{eq} = 20\ \Omega$ (b) $R_{eq} = 23\ \Omega$

P2.2* $R_x = 5\ \Omega$.

P2.3* $R_{ab} = 10\ \Omega$

P2.4*





P2.5* $R_{ab} = 9.6\ \Omega$

P2.23* $i_1 = 1\ A$ $i_2 = 0.5\ A$

P2.24* $v_1 = 3\ V$ $v_2 = 0.5\ V$

P2.25* $v = 140\ V;\ i = 1\ A$

P2.34* $i_1 = 1.5\ A$ $i_2 = 0.5\ A$
$P_{4A} = 30\ W$ delivering
$P_{2A} = 15\ W$ absorbing
$P_{5\Omega} = 11.25\ W$ absorbing
$P_{15\Omega} = 3.75\ W$ absorbing

P2.35* $i_1 = 2.5\ A$ $i_2 = 0.8333\ A$

P2.36* $v_1 = 5\ V$ $v_2 = 7\ V$ $v_3 = 13\ V$

P2.37* $i_1 = 1\ A$ $i_2 = 2\ A$

P2.38* $v = 3.333\ V$

P2.43* $R_g = 25\ m\Omega$

P2.48* $v_1 = 14.29\ V$ $v_2 = 11.43\ V$ $i_1 = 0.2857\ A$

P2.49* $v_1 = 6.667\ V$ $v_2 = -3.333\ V$ $i_s = -3.333\ A$

P2.56* $v_1 = 6\ V$ $v_2 = 4\ V$ $i_x = 0.4\ A$

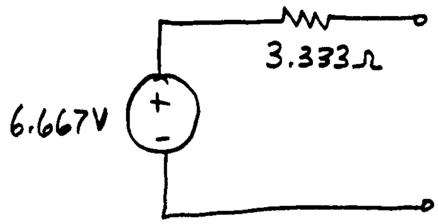
P2.57* $v_1 = 5.405\ V$ $v_2 = 7.297\ V$

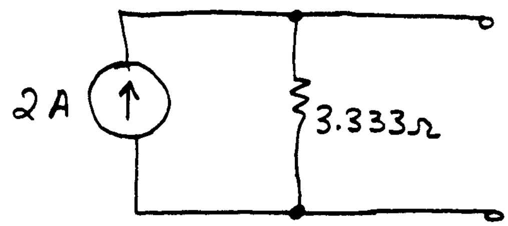
P2.65* $i_1 = 2.364\ A$ $i_2 = 1.818\ A$ $P = 4.471\ W$

P2.66* $v_2 = 0.500\ V$ $P = 6\ W$

P2.67* $i_1 = 0.2857 \ A$

P2.80*





P2.81* $R_t = 50\,\Omega$

P2.91* $R_t = 0$ $P_{\max} = 80\text{ W}$

P2.94* $i_v = 2\ A$ $i_c = 2\ A$ $i = i_v + i_c = 4\ A$

P2.95* $i_s = -3.333\ A$

P2.103* $R_3 = 5932\,\Omega$ $i_{\text{detector}} = 31.65\times 10^{-9}\ A$

Practice Test

T2.1 (a) 6, (b) 10, (c) 2, (d) 7, (e) 10 or 13 (perhaps 13 is the better answer), (f) 1 or 4 (perhaps 4 is the better answer), (g) 11, (h) 3, (i) 8, (j) 15, (k) 17, (l) 14.

T2.2 The equivalent resistance seen by the voltage source is:

$$R_{eq} = R_1 + \frac{1}{1/R_2 + 1/R_3 + 1/R_4} = 16\,\Omega$$

$$i_s = \frac{v_s}{R_{eq}} = 6\ A$$

Then, using the current division principle, we have

$$i_4 = \frac{G_4}{G_2 + G_3 + G_4} i_s = \frac{1/60}{1/48 + 1/16 + 1/60} 6 = 1\ A$$

T2.3 Writing KCL equations at each node gives

$$\frac{v_1}{4} + \frac{v_1 - v_2}{5} + \frac{v_1 - v_3}{2} = 0$$
$$\frac{v_2 - v_1}{5} + \frac{v_2}{10} = 2$$
$$\frac{v_3}{1} + \frac{v_3 - v_1}{2} = -2$$

In standard form, we have:

$$0.95v_1 - 0.20v_2 - 0.50v_3 = 0$$
$$-0.20v_1 + 0.30v_2 = 2$$
$$-0.50v_1 + 1.50v_3 = -2$$

In matrix form, we have

$$\mathbf{GV} = \mathbf{I}$$
$$\begin{bmatrix} 0.95 & -0.20 & -0.50 \\ -0.20 & 0.30 & 0 \\ -0.50 & 0 & 1.50 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 2 \\ -2 \end{bmatrix}$$

The MATLAB commands needed to obtain the column vector of the node voltages are

```
G = [0.95 -0.20 -0.50; -0.20 0.30 0; -0.50 0 1.50]
I = [0; 2; -2]
V = G\I      % As an alternative we could use V = inv(G)*I
```

Actually, because the circuit contains only resistances and independent current sources, we could have used the short-cut method to obtain the **G** and **I** matrices.

T2.4 We can write the following equations:

KVL mesh 1: $R_1 i_1 - V_s + R_3(i_1 - i_3) + R_2(i_1 - i_2) = 0$

KVL for the supermesh obtained by combining meshes 2 and 3:

$$R_4 i_2 + R_2(i_2 - i_1) + R_3(i_3 - i_1) + R_5 i_3 = 0$$

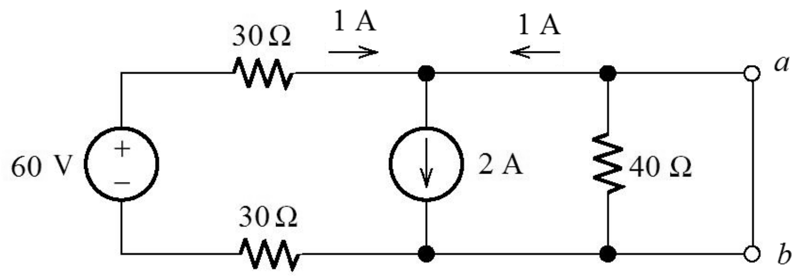
KVL around the periphery of the circuit:

$$R_1 i_1 - V_s + R_4 i_2 + R_5 i_3 = 0$$

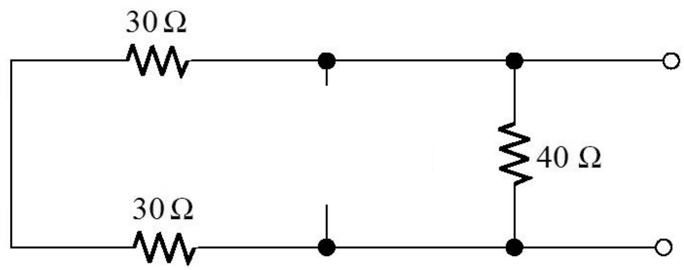
Current source: $i_2 - i_3 = I_s$

A set of equations for solving the network must include the current source equation plus two of the mesh equations. The three mesh equations are dependent and will not provide a solution by themselves.

T2.5 Under short-circuit conditions, the circuit becomes



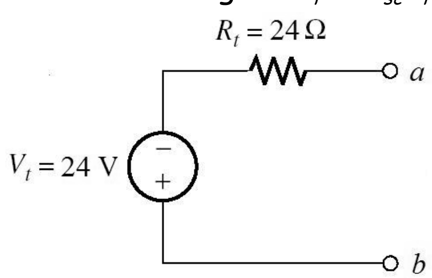
Thus, the short-circuit current is 1 A flowing out of *b* and into *a*. Zeroing the sources, we have

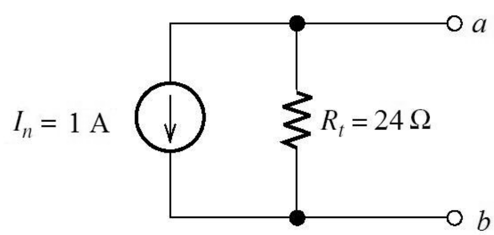


Thus, the Thévenin resistance is

$$R_t = \frac{1}{1/40 + 1/(30+30)} = 24\ \Omega$$

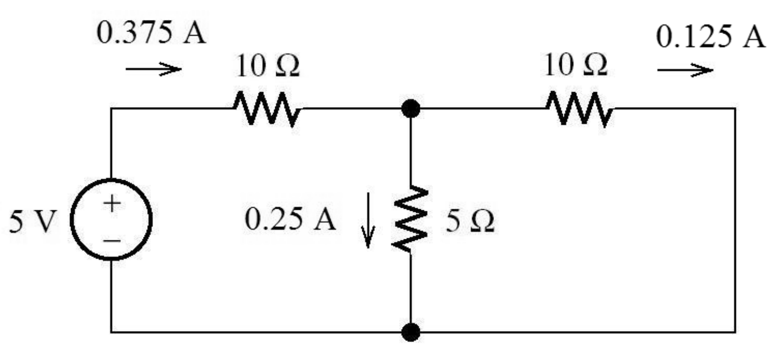
and the Thévenin voltage is $V_t = I_{sc}R_t = 24\text{ V}$. The equivalent circuits are:

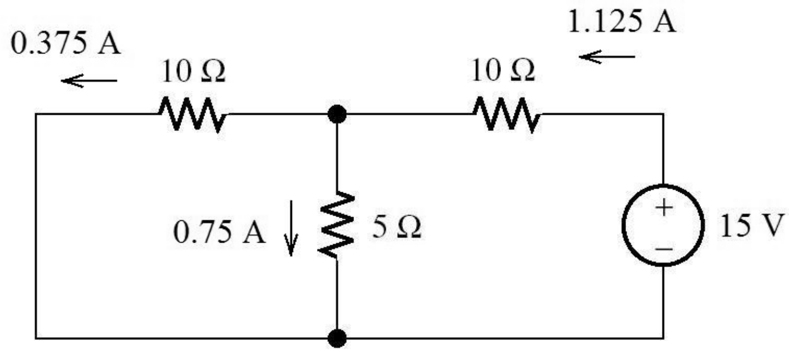




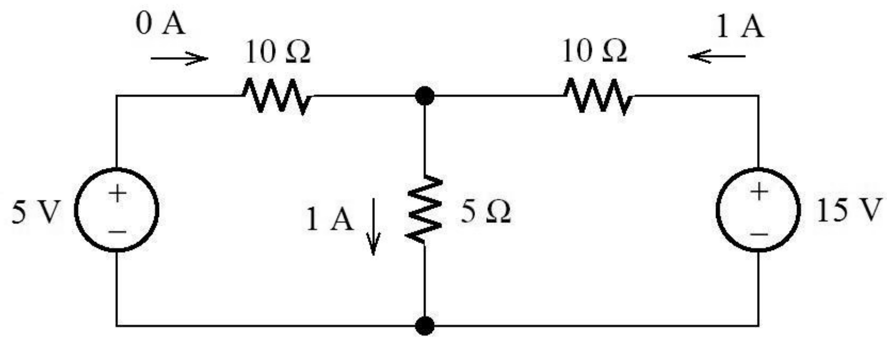
Because the short-circuit current flows out of terminal *b*, we have oriented the voltage polarity positive toward *b* and pointed the current source reference toward *b*.

T2.6 With one source active at a time, we have





Then, with both sources active, we have



We see that the 5-V source produces 25% of the total current through the 5-Ω resistance. However, the power produced by the 5-V source with both sources active is zero. Thus, the 5-V source produces 0% of the power delivered to the 5-Ω resistance. Strange, but true! Because power is a nonlinear function of current (i.e., $P = Ri^2$), the superposition principle does not apply to power.