**Section 11.9: Circuit Analysis**
**Tutorial 1 Practice, Case 1, page 532**

1. **Step 1.** Find the total resistance of the circuit. Start by finding the equivalent resistance for the parallel part of the circuit.

\[
\frac{1}{R_{\text{parallel}}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{30.0 \, \Omega} + \frac{1}{30.0 \, \Omega}
\]

\[
R_{\text{parallel}} = 15.0 \, \Omega
\]

Now find the total resistance. \( R_{\text{parallel}} \) is in series with \( R_1 \), so

\[
R_{\text{total}} = R_1 + R_{\text{parallel}} = 25.0 \, \Omega + 15.0 \, \Omega
\]

\[
R_{\text{total}} = 40.0 \, \Omega
\]

2. **Step 2.** Find \( I_{\text{source}} \) using Ohm’s law written as

\[
I = \frac{V}{R}.
\]

\[
I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}} = \frac{40.0 \, \Omega}{40.0 \, \Omega} = 1.00 \, \text{A}
\]

3. **Step 3.** Apply KCL to find \( I_1 \). Note that the source is in series with \( I_1 \) and the parallel part \( I_{\text{parallel}} \).

\[
I_{\text{series}} = I_1 = I_2 = I_3 = \cdots
\]

\[
I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = 1.00 \, \text{A}
\]

4. **Step 4.** Find \( V_1 \) using Ohm’s law written as \( V = IR \).

\[
V_1 = I_1 R_1 = (1.00 \, \text{A})(25.0 \, \Omega)
\]

\[
V_1 = 25.0 \, \text{V}
\]

5. **Step 5.** Apply KVL to find \( V_{\text{parallel}} \).

\[
V_{\text{series}} = V_1 + V_2 + V_3 + \cdots
\]

\[
V_{\text{source}} = V_1 + V_{\text{parallel}}
\]

\[
V_{\text{parallel}} = V_{\text{source}} - V_1
\]

\[
V_{\text{parallel}} = 40.0 \, \text{V} - 25.0 \, \text{V}
\]

\[
V_{\text{parallel}} = 15.0 \, \text{V}
\]

6. **Step 6.** Apply KVL to find \( V_2 \) and \( V_3 \).

\[
V_{\text{parallel}} = V_1 = V_2 = V_3 = \cdots
\]

\[
V_{\text{parallel}} = V_2 = 15.0 \, \text{V}
\]

7. **Step 7.** Find \( I_2 \) and \( I_3 \) using Ohm’s law written as

\[
I = \frac{V}{R}.
\]

\[
I_2 = \frac{V_2}{R_2} = \frac{15.0 \, \text{V}}{30.0 \, \Omega} = 0.500 \, \text{A}
\]

\[
I_3 = \frac{V_3}{R_3} = \frac{15.0 \, \text{V}}{30.0 \, \Omega} = 0.500 \, \text{A}
\]

8. **Step 8.** Record your final answers using the correct number of significant digits. Look back at the circuit and see if the values you have calculated coincide with Kirchoff’s laws.

\[
R_{\text{total}} = 40.0 \, \Omega; \quad I_{\text{source}} = 1.00 \, \text{A}; \quad I_1 = 1.00 \, \text{A};
\]

\[
I_2 = 0.500 \, \text{A}; \quad I_3 = 0.500 \, \text{A}; \quad V_1 = 25.0 \, \text{V};
\]

\[
V_2 = 15.0 \, \text{V}; \quad V_3 = 15.0 \, \text{V}
\]

The electric potential energies associated with the electrons are marked on the diagram. We chose a reference point of 0 V. The boxes represent the voltage across each point in the circuit. In each complete path, the sum of the voltage gains (40.0 V) equals the sum of the voltage drops (25.0 V + 15.0 V). Therefore, the problem is solved correctly.
The values on the diagram represent the current at various points in the circuit. The only junction is where the current splits into $R_2$ and $R_3$. The current going into the junction is 1.00 A. The current coming out is also 1.00 A. The current in each path of the parallel part of the circuit must add up to 0.500 A. A check of the values (0.500 A + 0.500 A = 1.00 A) shows that the current in the parallel part of the circuit adds up to 1.00 A.

**Tutorial 1 Practice, Case 2, page 534**

1. **Step 1.** Apply KVL to any complete pathway. In this case, one complete pathway involves the source, resistor 1, and resistor 4.

   \[
   V_{\text{source}} = V_1 + V_4 \\
   V_1 = V_{\text{source}} - V_4 \\
   V_1 = 42.0 \text{ V} - 17.5 \text{ V} \\
   V_1 = 24.5 \text{ V} 
   \]

2. **Step 2.** Apply KVL to any complete pathway. In this case, another complete pathway involves the source, resistor 1, resistor 2, and resistor 3.

   \[
   V_{\text{source}} = V_1 + V_2 + V_3 \\
   V_3 = V_{\text{source}} - V_1 - V_2 \\
   = 42.0 \text{ V} - 24.5 \text{ V} - 8.75 \text{ V} \\
   V_3 = 8.75 \text{ V} 
   \]

3. **Step 3.** Find $I_2$ using Ohm’s law written as $I = \frac{V}{R}$.

   \[
   I_2 = \frac{V_2}{R_2} \\
   = \frac{8.75 \text{ V}}{35.0 \text{ } \Omega} \\
   I_2 = 0.250 \text{ A} 
   \]

4. **Step 4.** Apply KCL to find the missing current values. Note that $I_{2,3}$ represents the current going through the path that contains $I_2$ and $I_3$.

   - Find $I_{\text{source}}$:
     \[
     I_{\text{source}} = I_1 \\
     = 1.75 \text{ A} 
     \]

   - Find $I_3$:
     \[
     I_{\text{source}} = I_3 \\
     = I_2 \\
     = 0.250 \text{ A} \\
     I_3 = 0.250 \text{ A} 
     \]

   - Find $I_4$:
     \[
     I_{\text{source}} = I_{2,3} + I_4 \\
     I_4 = I_{\text{source}} - I_{2,3} \\
     I_4 = 1.75 \text{ A} - 0.250 \text{ A} \\
     I_4 = 1.50 \text{ A} 
     \]

5. **Step 5.** Find all other missing values using Ohm’s law.

   \[
   R_1 = \frac{V_1}{I_1} \\
   = \frac{24.5 \text{ V}}{1.75 \text{ A}} \\
   R_1 = 14.0 \text{ } \Omega 
   \]

   \[
   R_3 = \frac{V_3}{I_3} \\
   = \frac{8.75 \text{ V}}{0.250 \text{ A}} \\
   R_3 = 35.0 \text{ } \Omega 
   \]

   \[
   R_4 = \frac{V_4}{I_4} \\
   = \frac{17.5 \text{ V}}{1.50 \text{ A}} \\
   R_4 = 11.7 \text{ } \Omega 
   \]

   \[
   R_{\text{total}} = \frac{V_{\text{source}}}{I_{\text{source}}} \\
   = \frac{42.0 \text{ V}}{1.75 \text{ A}} \\
   R_{\text{total}} = 24.0 \text{ } \Omega 
   \]
Step 6. Record your final answers with the correct number of significant digits. Now that you have finished the problem, you can look back at the circuit and see if the values you have calculated coincide with Kirchhoff’s laws.

\[ I_{\text{source}} = 1.75 \text{ A}; \ I_2 = 0.250 \text{ A}; \ I_3 = 0.250 \text{ A}; \ I_4 = 1.50 \text{ A}; \ V_1 = 24.5 \text{ V}; \ V_3 = 8.75 \text{ V}; \ R_1 = 14.0 \Omega; \ R_3 = 35.0 \Omega; \ R_4 = 11.7 \Omega; \ R_{\text{total}} = 24.0 \Omega \]

A check of the values (1.50 A + 0.250 = 1.75 A) shows that they do. Note that the current in the two resistors connected in series (R_2 and R_3) stays constant.

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1. (a)

Step 1. Find the total resistance of the circuit. Start by finding the equivalent resistance for the parallel part of the circuit.

\[ \frac{1}{R_{\text{parallel}}} = \frac{1}{R_2} + \frac{1}{R_3} \]

\[ \frac{1}{R_{\text{parallel}}} = \frac{1}{12.0 \Omega} + \frac{1}{12.0 \Omega} \]

\[ R_{\text{parallel}} = 6.00 \Omega \]

Now find the total resistance. \( R_{\text{total}} \) is in series with \( R_1 \), so

\[ R_{\text{total}} = R_1 + R_{\text{parallel}} = 12.0 \Omega + 6.00 \Omega \]

\[ R_{\text{total}} = 18.0 \Omega \]

Step 2. Find \( I_{\text{source}} \) using Ohm’s law written as

\[ I = \frac{V}{R} \]

\[ I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}} = \frac{6.0 \text{ V}}{18.0 \Omega} = 0.33 \text{ A} \]

Step 3. Apply KCL to find \( I_1 \). Note that the source is in series with \( I_1 \) and the parallel part \( I_{\text{parallel}} \).

\[ I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = 0.33 \text{ A} \]

Step 4. Find \( V_1 \) using Ohm’s law written as \( V = IR \).

\[ V_1 = I_1 R_1 = (0.33 \text{ A})(12.0 \Omega) \]

\[ V_1 = 4.0 \text{ V} \]

Step 5. Apply KVL to find \( V_{\text{parallel}} \).

\[ V_{\text{source}} = V_1 + V_{\text{parallel}} \]

\[ V = V_{\text{source}} - V_1 = 6.0 \text{ V} - 4.0 \text{ V} \]

\[ V_{\text{parallel}} = 2.0 \text{ V} \]

The electric potential energies associated with the electrons are marked on the diagram. We chose a reference point of 0 V. The red boxes represent the electric potential difference (or voltage) across the electric circuit parts. In one complete path, the sum of the voltage gains (42.0 V) equals the sum of the voltage drops (17.5 V + 15.75 V + 8.75 V). In the other complete path, the sum of the voltage gains (42.0 V) equals the sum of the voltage drops (24.5 V + 17.5 V). Therefore, you have solved the problem correctly.

The values on the diagram represent the current at various points in the circuit. The only junction is at the parallel part where the current splits into \( R_{2,3} \) (\( R_2 \) and \( R_3 \) together) and \( R_4 \). The current going into the junction is 1.75 A. The current coming out is also 1.75 A. The currents in both paths of the parallel part of the circuit must add up to 1.75 A.
**Step 6.** Apply KVL to find \( V_2 \) and \( V_3 \).
\[
\frac{V}{V_{\text{parallel}}} = V_2 = V_3 = 2.0 \, \text{V}
\]

**Step 7.** Find \( I_2 \) and \( I_3 \) using Ohm’s law written as
\[
I = \frac{V}{R}
\]
\[
I_2 = \frac{V}{R_2} = \frac{2.0 \, \text{V}}{12.0 \, \Omega} = 0.17 \, \text{A}
\]
\[
I_3 = \frac{V}{R_3} = \frac{2.0 \, \text{V}}{12.0 \, \Omega} = 0.17 \, \text{A}
\]

**Step 8.** Final answers:
\[
R_{\text{source}} = 18.0 \, \Omega; \quad I_{\text{source}} = 0.33 \, \text{A}; \quad I_1 = 0.33 \, \text{A};
\]
\[
I_2 = 0.17 \, \text{A}; \quad I_3 = 0.17 \, \text{A}; \quad V_1 = 4.0 \, \text{V}; \quad V_2 = 2.0 \, \text{V};
\]
\[
V_3 = 2.0 \, \text{V}
\]

(b)

**Step 1.** Find the total resistance of the circuit. Start by finding the equivalent resistance for the resistors in series in the parallel part of the circuit.

Find \( R_{\text{series}1} \), the equivalent of \( R_2 \) and \( R_3 \):
\[
R_{\text{series}1} = R_2 + R_3 = 12.0 \, \Omega + 12.0 \, \Omega
\]
\[
R_{\text{series}1} = 24.0 \, \Omega
\]

Find \( R_{\text{series}2} \), the equivalent of \( R_4 \) and \( R_5 \):
\[
R_{\text{series}2} = R_4 + R_5 = 12.0 \, \Omega + 12.0 \, \Omega
\]
\[
R_{\text{series}2} = 24.0 \, \Omega
\]

Now find the equivalent resistance for the parallel part of the circuit.
\[
\frac{1}{R_{\text{parallel}}} = \frac{1}{R_{\text{series}1}} + \frac{1}{R_{\text{series}2}}
\]
\[
\frac{1}{R_{\text{parallel}}} = \frac{1}{24.0 \, \Omega} + \frac{1}{24.0 \, \Omega}
\]
\[
R_{\text{parallel}} = 12.0 \, \Omega
\]

Now find the total resistance. \( R_{\text{parallel}} \) is in series with \( R_1 \) and \( R_6 \), so
\[
R_{\text{total}} = R_1 + R_{\text{parallel}} + R_6 = 12.0 \, \Omega + 12.0 \, \Omega + 12.0 \, \Omega
\]
\[
R_{\text{total}} = 36.0 \, \Omega
\]

**Step 2.** Find \( I_{\text{source}} \) using Ohm’s law written as
\[
I = \frac{V}{R}
\]
\[
I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}} = \frac{6.0 \, \text{V}}{36.0 \, \Omega}
\]
\[
I_{\text{source}} = 0.17 \, \text{A}
\]

**Step 3.** Apply KCL to find \( I_1 \). Note that the source is in series with \( I_1 \), the parallel part \( I_{\text{parallel}} \), and \( I_6 \).
\[
I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = I_6 = 0.17 \, \text{A}
\]

**Step 4.** Find \( V_1 \) and \( V_6 \) using Ohm’s law written as \( V = IR \).
\[
V_1 = I_1 R_1 = (0.17 \, \text{A})(12.0 \, \Omega)
\]
\[
V_1 = 2.0 \, \text{V}
\]
\[
V_6 = I_6 R_6 = (0.17 \, \text{A})(12.0 \, \Omega)
\]
\[
V_6 = 2.0 \, \text{V}
\]

**Step 5.** Apply KVL to find \( V_{\text{parallel}} \):
\[
V_{\text{source}} = V_1 + V_{\text{parallel}} + V_6
\]
\[
V_{\text{parallel}} = V_{\text{source}} - V_1 - V_6 = 6.0 \, \text{V} - 2.0 \, \text{V} - 2.0 \, \text{V}
\]
\[
V_{\text{parallel}} = 2.0 \, \text{V}
\]

**Step 6.** Apply KVL to find \( V_{2,3} \) and \( V_{4,5} \).
\[
V_{\text{parallel}} = V_{2,3} = V_{4,5} = 2.0 \, \text{V}
\]

**Step 7.** Find \( I_{2,3} \) and \( I_{4,5} \) using Ohm’s law written as \( I = \frac{V}{R} \). Note that \( I_{2,3} \) represents the current going through the path that contains \( I_2 \) and \( I_3 \), and \( I_{4,5} \) represents the current going through the path that contains \( I_4 \) and \( I_5 \).
\[
I_{2,3} = \frac{V_{2,3}}{R_{\text{series}1}} = \frac{2.0 \, \text{V}}{24.0 \, \Omega}
\]
\[
I_{2,3} = 0.083 \, \text{A}
\]
The same amount of current goes through both $I_2$ and $I_3$, so:
$I_{2,3} = I_2 = I_3 = 0.083$ A

$I_{4,5} = \frac{V_{4,5}}{R_{\text{series2}}}$
\[= \frac{2.0 \text{ V}}{24.0 \Omega}\]
$I_{4,5} = 0.083$ A

The same amount of current goes through both $I_4$ and $I_5$, so:
$I_{4,5} = I_4 = I_5 = 0.083$ A

**Step 8.** Find all other missing values using Ohm’s law.

$V_2 = I_2 R_2$
\[= (0.083 \text{ A})(12.0 \Omega)\]
$V_2 = 1.0$ V

$V_3 = I_3 R_3$
\[= (0.083 \text{ A})(12.0 \Omega)\]
$V_3 = 1.0$ V

$V_4 = I_4 R_4$
\[= (0.083 \text{ A})(12.0 \Omega)\]
$V_4 = 1.0$ V

$V_5 = I_5 R_5$
\[= (0.083 \text{ A})(12.0 \Omega)\]
$V_5 = 1.0$ V

**Step 9.** Final answers:

$R_{\text{source}} = 36.0 \Omega$; $I_{\text{source}} = 0.17$ A; $I_1 = 0.17$ A;
$I_2 = 0.083$ A; $I_3 = 0.083$ A; $I_4 = 0.083$ A;
$I_5 = 0.083$ A; $I_6 = 0.17$ A; $V_1 = 2.0$ V; $V_2 = 1.0$ V;
$V_3 = 1.0$ V; $V_4 = 1.0$ V; $V_5 = 1.0$ V; $V_6 = 2.0$ V

(c)

**Step 1.** Find the total resistance of the circuit. Start by finding the equivalent resistance for the resistors in series in the parallel part of the circuit. Find $R_{\text{series1}}$, the equivalent of $R_2$ and $R_3$:

$R_{\text{series1}} = R_2 + R_3$
\[= 12.0 \Omega + 12.0 \Omega\]
$R_{\text{series1}} = 24.0 \Omega$

Now find the equivalent resistance for the parallel part of the circuit.

\[
\frac{1}{R_{\text{parallel}}} = \frac{1}{R_{\text{series1}}} + \frac{1}{R_4}
\]
\[
= \frac{1}{24.0 \Omega} + \frac{1}{12.0 \Omega}
\]
$R_{\text{parallel}} = 8.00 \Omega$

Now find the total resistance. $R_{\text{parallel}}$ is in series with $R_1$, so

$R_{\text{total}} = R_1 + R_{\text{parallel}}$
\[= 12.0 \Omega + 8.0 \Omega\]
$R_{\text{total}} = 20.0 \Omega$

**Step 2.** Find $I_{\text{source}}$ using Ohm’s law written as $I = \frac{V}{R}$.

$I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}}$
\[= \frac{6.0 \text{ V}}{20.0 \Omega}\]
$I_{\text{source}} = 0.30$ A

**Step 3.** Apply KCL to find $I_1$. Note that the source is in series with $I_1$ and the parallel part $I_{\text{parallel}}$.

$I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = 0.30$ A

**Step 4.** Find $V_1$ using Ohm’s law written as $V = IR$.

$V_1 = I_1 R_1$
\[= (0.3 \text{ A})(12.0 \Omega)\]
$V_1 = 3.6$ V

**Step 5.** Apply KVL to find $V_{\text{parallel}}$.

$V_{\text{source}} = V_1 + V_{\text{parallel}}$

$V_{\text{parallel}} = V_{\text{source}} - V_1$
\[= 6.0 \text{ V} - 3.6 \text{ V}\]
$V_{\text{parallel}} = 2.4$ V

**Step 6.** Apply KVL to find $V_{2,3}$ and $V_4$.

$V_{\text{parallel}} = V_{2,3} = V_4 = 2.4$ V
Step 7. Find $I_{2,3}$ and $I_4$ using Ohm’s law written as $I = \frac{V}{R}$. Note that $I_{2,3}$ represents the current going through the path that contains $I_2$ and $I_3$. 

\[ I_{2,3} = \frac{V_{2,3}}{R_{\text{series}1}} = \frac{2.4 \text{ V}}{24.0 \Omega} \]

\[ I_{2,3} = 0.10 \text{ A} \]

The same amount of current goes through both $I_2$ and $I_3$, so:

\[ I_{2,3} = I_2 = I_3 = 0.10 \text{ A} \]

\[ I_4 = \frac{V_4}{R_4} = \frac{2.4 \text{ V}}{12.0 \Omega} \]

\[ I_{4,5} = 0.20 \text{ A} \]

Step 8. Find all other missing values using Ohm’s law.

\[ V_2 = I_2 R_2 = (0.10 \text{ A})(12.0 \Omega) \]

\[ V_2 = 1.2 \text{ V} \]

\[ V_3 = I_3 R_3 = (0.10 \text{ A})(12.0 \Omega) \]

\[ V_3 = 1.2 \text{ V} \]

\[ V_4 = I_4 R_4 = (0.20 \text{ A})(12.0 \Omega) \]

\[ V_4 = 2.4 \text{ V} \]

Step 9. Final answers:

\[ R_{\text{source}} = 20.0 \Omega; \quad R_{\text{source}} = 0.30 \text{ A}; \quad I_1 = 0.30 \text{ A}; \]

\[ I_2 = 0.10 \text{ A}; \quad I_3 = 0.10 \text{ A}; \quad I_4 = 0.20 \text{ A}; \quad V_1 = 3.6 \text{ V}; \]

\[ V_2 = 1.2 \text{ V}; \quad V_3 = 1.2 \text{ V}; \quad V_4 = 2.4 \text{ V} \]

(d)

Step 1. Find the total resistance of the circuit. Start by finding the equivalent resistance for the resistors in series in the parallel part of the circuit. Find $R_{\text{series}1}$, the equivalent of $R_2$ and $R_3$:

\[ R_{\text{series}1} = R_2 + R_3 = 12.0 \Omega + 12.0 \Omega \]

\[ R_{\text{series}1} = 24.0 \Omega \]

Find $R_{\text{series}2}$, the equivalent of $R_4$ and $R_5$:

\[ R_{\text{series}2} = R_4 + R_5 = 12.0 \Omega + 12.0 \Omega \]

\[ R_{\text{series}2} = 24.0 \Omega \]

Now find the equivalent resistance for the parallel part of the circuit.

\[ \frac{1}{R_{\text{parallel}}} = \frac{1}{R_{\text{series}1}} + \frac{1}{R_{\text{series}2}} \]

\[ \frac{1}{R_{\text{parallel}}} = \frac{1}{24.0 \Omega} + \frac{1}{24.0 \Omega} \]

\[ R_{\text{parallel}} = 12.0 \Omega \]

Now find the total resistance.

$r_{\text{parallel}}$ is in series with $R_1$, so

\[ R_{\text{total}} = R_1 + R_{\text{parallel}} = 12.0 \Omega + 12.0 \Omega \]

\[ R_{\text{total}} = 24.0 \Omega \]

Step 2. Find $I_{\text{source}}$ using Ohm’s law written as $I = \frac{V}{R}$.

\[ I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}} = \frac{6.0 \text{ V}}{24.0 \Omega} \]

\[ I_{\text{source}} = 0.25 \text{ A} \]

Step 3. Apply KCL to find $I_1$. Note that the source is in series with $I_1$ and the parallel part $I_{\text{parallel}}$.

\[ I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = 0.25 \text{ A} \]

Step 4. Find $V_1$ using Ohm’s law written as $V = IR$.

\[ V_1 = I_1 R_1 = (0.25 \text{ A})(12.0 \Omega) \]

\[ V_1 = 3.0 \text{ V} \]

Step 5. Apply KVL to find $V_{\text{parallel}}$.

\[ V_{\text{source}} = V_1 + V_{\text{parallel}} \]

\[ V_{\text{parallel}} = V_{\text{source}} - V_1 = 6.0 \text{ V} - 3.0 \text{ V} \]

\[ V_{\text{parallel}} = 3.0 \text{ V} \]

Step 6. Apply KVL to find $V_{2,3}$ and $V_{4,5}$.

\[ V_{\text{parallel}} = V_{2,3} = V_{4,5} = 3.0 \text{ V} \]
Step 7. Find \(I_{2,3}\) and \(I_{4,5}\) using Ohm’s law written as \(I = \frac{V}{R}\). Note that \(I_{2,3}\) represents the current going through the path that contains \(I_2\) and \(I_3\), and \(I_{4,5}\) represents the current going through the path that contains \(I_4\) and \(I_5\).

\[
I_{2,3} = \frac{V_{2,3}}{R_{\text{series1}}}
= \frac{3.0 \text{ V}}{24.0 \Omega}
= 0.125 \text{ A} \quad \text{(one extra digit carried)}
\]

The same amount of current goes through both \(I_2\) and \(I_3\), so:

\(I_{2,3} = I_2 = I_3 = 0.125 \text{ A} \quad \text{(one extra digit carried)}\)

\[
I_{4,5} = \frac{V_{4,5}}{R_{\text{series2}}}
= \frac{3.0 \text{ V}}{24.0 \Omega}
= 0.125 \text{ A} \quad \text{(one extra digit carried)}
\]

The same amount of current goes through both \(I_4\) and \(I_5\), so:

\(I_{4,5} = I_4 = I_5 = 0.125 \text{ A} \quad \text{(one extra digit carried)}\)

Step 8. Find all other missing values using Ohm’s law.

\[
V_2 = I_2 R_2
= (0.125 \text{ A})(12.0 \Omega)
= 1.5 \text{ V}
\]

\[
V_3 = I_3 R_3
= (0.125 \text{ A})(12.0 \Omega)
= 1.5 \text{ V}
\]

\[
V_4 = I_4 R_4
= (0.125 \text{ A})(12.0 \Omega)
= 1.5 \text{ V}
\]

\[
V_5 = I_5 R_5
= (0.125 \text{ A})(12.0 \Omega)
= 1.5 \text{ V}
\]

Step 9. Final answers:

\[
R_{\text{source}} = 24.0 \Omega; \quad I_{\text{source}} = 0.25 \text{ A}; \quad I_1 = 0.25 \text{ A};
I_2 = 0.13 \text{ A}; \quad I_3 = 0.13 \text{ A}; \quad I_4 = 0.13 \text{ A}; \quad I_5 = 0.13 \text{ A};
V_1 = 3.0 \text{ V}; \quad V_2 = 1.5 \text{ V}; \quad V_3 = 1.5 \text{ V}; \quad V_4 = 1.5 \text{ V};
V_5 = 1.5 \text{ V}
\]
Step 1. Apply KVL to any complete pathway. In this case, one complete pathway involves the source and resistor 1.
\[ V_{\text{source}} = V_1 \]
\[ V_1 = 1.5 \text{ V} \]

Step 2. Apply KVL to any complete pathway. In this case, another complete pathway involves the source and resistor 2.
\[ V_{\text{source}} = V_2 \]
\[ V_2 = 1.5 \text{ V} \]

Step 3. Apply KVL to any complete pathway. In this case, another complete pathway involves the source and resistor 3.
\[ V_{\text{source}} = V_3 \]
\[ V_3 = 1.5 \text{ V} \]

Step 4. Find \( I_2 \) and \( I_3 \) using Ohm’s law written as
\[ I = \frac{V}{R}. \]
\[ I_2 = \frac{V_2}{R_2} \]
\[ = \frac{1.5 \text{ V}}{7.5 \text{ } \Omega} \]
\[ I_2 = 0.20 \text{ A} \]

\[ I_3 = \frac{V_3}{R_3} \]
\[ = \frac{1.5 \text{ V}}{5.0 \text{ } \Omega} \]
\[ I_3 = 0.30 \text{ A} \]

Step 5. Final answers:
\[ V_1 = 6.0 \text{ V}; \quad V_3 = 5.0 \text{ V}; \quad I_1 = 0.20 \text{ A}; \quad I_3 = 0.20 \text{ A}; \quad I_{\text{source}} = 0.20 \text{ A}; \quad R_2 = 2.0 \times 10^3 \text{ } \Omega; \quad R_3 = 25 \text{ } \Omega; \quad R_{\text{total}} = 75 \text{ } \Omega \]

Step 5. Apply KCL to find the missing current values.
Find \( I_{\text{source}} \):
\[ I_{\text{source}} = I_1 + I_2 + I_3 \]
\[ = 0.10 \text{ A} + 0.20 \text{ A} + 0.30 \text{ A} \]
\[ I_{\text{source}} = 0.60 \text{ A} \]

Step 6. Find all other missing values using Ohm’s law.
\[ R_1 = \frac{V_1}{I_1} \]
\[ = \frac{1.5 \text{ V}}{0.10 \text{ A}} \]
\[ R_1 = 15 \text{ } \Omega \]

\[ \frac{R_{\text{total}}}{I_{\text{source}}} = \frac{V_{\text{source}}}{I_{\text{source}}} \]
\[ = \frac{1.5 \text{ V}}{0.60 \text{ A}} \]
\[ R_{\text{total}} = 2.5 \text{ } \Omega \]

Step 7. Final answers:
\[ V_1 = 1.5 \text{ V}; \quad V_2 = 1.5 \text{ V}; \quad V_3 = 1.5 \text{ V}; \quad I_2 = 0.20 \text{ A}; \quad I_3 = 0.30 \text{ A}; \quad I_{\text{source}} = 0.60 \text{ A}; \quad R_1 = 15 \text{ } \Omega; \quad R_{\text{total}} = 2.5 \text{ } \Omega \]

4. 
Step 1. Find \( V_4 \) using Ohm’s law written as \( V = IR \).
\[ V_4 = I_4 R_4 \]
\[ = (0.10 \text{ A})(70.0 \text{ } \Omega) \]
\[ V_4 = 7.0 \text{ V} \]

Step 2. Apply KVL to any complete pathway. In this case, one complete pathway involves the source, resistor 1, resistor 3, and resistor 4.
\[ V_{\text{source}} = V_1 + V_3 + V_4 \]
\[ = 2.5 \text{ V} + 5.0 \text{ V} + 7.0 \text{ V} \]
\[ V_{\text{source}} = 14.5 \text{ V} \]

Step 3. Apply KVL to any complete pathway. In this case, another complete pathway involves the source, resistor 1, resistor 3, and resistor 5.
\[ V_{\text{source}} = V_1 + V_3 + V_5 \]
\[ V_5 = V_{\text{source}} - V_1 - V_3 \]
\[ = 14.5 \text{ V} - 2.5 \text{ V} - 5.0 \text{ V} \]
\[ V_5 = 7.0 \text{ V} \]
Step 4. Apply KVL to any complete pathway. In this case, another complete pathway involves the source, resistor 2, resistor 3, and resistor 4.

\[ V_{source} = V_2 + V_3 + V_4 \]
\[ V_2 = V_{source} - V_3 - V_4 \]
\[ V_2 = 14.5 \text{ V} - 5.0 \text{ V} - 7.0 \text{ V} \]
\[ V_2 = 2.5 \text{ V} \]

Step 5. Apply KCL to find the missing current values.

Find \( I_{source} \):
\[ I_{source} = I_1 \]
\[ I_{source} = 0.50 \text{ A} \]

Find \( I_1 \):
\[ I_{source} = I_1 + I_2 \]
\[ I_1 = I_{source} - I_2 \]
\[ I_1 = 0.50 \text{ A} - 0.30 \text{ A} \]
\[ I_1 = 0.20 \text{ A} \]

Find \( I_5 \):
\[ I_{source} = I_4 + I_5 \]
\[ I_5 = I_{source} - I_4 \]
\[ I_5 = 0.50 \text{ A} - 0.10 \text{ A} \]
\[ I_5 = 0.40 \text{ A} \]

Step 6. Find all other missing values using Ohm's law.

\[ R_1 = \frac{V}{I_1} \]
\[ R_1 = \frac{2.5 \text{ V}}{0.20 \text{ A}} \]
\[ R_1 = 13 \Omega \]

\[ R_2 = \frac{V_2}{I_2} \]
\[ R_2 = \frac{2.5 \text{ V}}{0.30 \text{ A}} \]
\[ R_2 = 8.3 \Omega \]

\[ R_3 = \frac{V_3}{I_3} \]
\[ R_3 = \frac{5.0 \text{ V}}{0.50 \text{ A}} \]
\[ R_3 = 1.0 \times 10^1 \Omega \]

\[ R_5 = \frac{V_5}{I_5} \]
\[ R_5 = \frac{7.0 \text{ V}}{0.40 \text{ A}} \]
\[ R_5 = 18 \Omega \]

\[ R_{total} = \frac{V_{source}}{I_{source}} \]
\[ R_{total} = \frac{14.5 \text{ V}}{0.50 \text{ A}} \]
\[ R_{total} = 29 \Omega \]

Step 6. Final answers:

\( V_{source} = 14.5 \text{ V} \); \( V_2 = 2.5 \text{ V} \); \( V_4 = 7.0 \text{ V} \);
\( V_5 = 7.0 \text{ V} \); \( I_{source} = 0.50 \text{ A} \); \( I_1 = 0.20 \text{ A} \);
\( I_5 = 0.40 \text{ A} \); \( R_1 = 13 \Omega \); \( R_2 = 8.3 \Omega \);
\( R_3 = 1.0 \times 10^1 \Omega \); \( R_5 = 18 \Omega \); \( R_{total} = 29 \Omega \)