Section 11.6: Kirchhoff's Laws

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1. Separate the circuit in Figure 7 into sections that are connected in parallel and sections that are connected in series. Doing this shows how to view the circuit as three complete paths: the path passing through the source, lamp 1, lamp 2, and lamp 3; the path passing through the source, lamp 1, lamp 2, and lamp 4; and the path passing through the source, lamp 1, lamp 2, and lamp 5. Using this approach of three separate paths, you can think of three completely independent series circuits.

Using KVL for a series circuit, you can solve for V_2:

$$V_{\text{source}} = V_1 + V_2 + V_3$$
$$60.0 \text{ V} = 20.0 \text{ V} + V_2 + 15 \text{ V}$$
$$60.0 \text{ V} = 35 \text{ V} + V_2$$
$$V_2 = 25 \text{ V}$$

If you apply the same thinking to the next path, you can solve for V_4:

$$V_{\text{source}} = V_1 + V_2 + V_4$$
$$60.0 \text{ V} = 20.0 \text{ V} + 25 \text{ V} + V_4$$
$$60.0 \text{ V} = 45 \text{ V} + V_4$$
$$V_4 = 15 \text{ V}$$

If you apply the same thinking to the third path, you can solve for V_5:

$$V_{\text{source}} = V_1 + V_2 + V_5$$
$$60.0 \text{ V} = 20.0 \text{ V} + 25 \text{ V} + V_5$$
$$60.0 \text{ V} = 45 \text{ V} + V_5$$
$$V_5 = 15 \text{ V}$$

So, $V_2 = 25$ V, $V_4 = 15$ V, and $V_5 = 15$ V.

2. The current in a series circuit is constant and the same as the source current. The source, lamp 1, and lamp 2 are in series, and $I_1 = 0.70$ A. Using these values and KCL, you can find I_{source} and I_2:

$$I_{\text{source}} = I_1 = I_2$$
$$I_{\text{source}} = 0.70 \text{ A} = I_2$$

Therefore, $I_{\text{source}} = 0.70$ A and $I_2 = 0.70$ A.

The amount of current entering a junction is equal to the amount of current exiting the junction. This can be used to find I_4:

$$I_{\text{parallel}} = I_3 + I_4 + I_5$$
$$0.70 \text{ A} = 0.10 \text{ A} + I_4 + 0.20 \text{ A}$$
$$0.70 \text{ A} = 0.30 \text{ A} + I_4$$
$$I_4 = 0.40 \text{ A}$$

So, I_4 is equal to 0.40 A.

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1. (a) Kirchhoff's current law (KCL) states that the current entering a junction is equal to the current exiting a junction in a circuit, but the current going into the parallel circuit is listed as 0.50 A and the current coming out of the parallel circuit is listed as 0.30 A, which are not equal.

(b) Kirchhoff's voltage law (KVL) states that the voltage gains are equal to the voltage drops in a complete path in a circuit, but the student has measured that the series circuit has one voltage gain of 10 V from the source, and a voltage drop of 10 V from each of the three loads, for a total voltage drop of 30 V.

(c) Kirchhoff's voltage law (KVL) states that the voltage gains are equal to the voltage drops in a complete path in a circuit. The source and the first lamp form one complete path in the circuit, and the source and the second lamp form another complete path in the circuit, so the voltage drop of the first lamp and the voltage drop of the second lamp must both equal the voltage gain of the source. The student has measured that the voltage drop of the first lamp is 20 V and the voltage drop of the second lamp is 10 V, which are not equal, so the student's measurements must be incorrect.

(d) Kirchhoff's current law (KCL) states that the current entering a junction is equal to the current exiting a junction in a circuit. Since there is no junction in a series circuit, only one complete path, the current must be the same for all the loads. Since the lamps have different currents, they cannot be connected in series.

2. (a)

Item	*V* (V)	*I* (A)
source	**3.0**	**3.0**
lamp 1	2.0	3.0
lamp 2	1.0	1.5
lamp 3	**1.0**	**1.5**

Using KVL for a series circuit, you can solve for V_{source}:

$$V_{source} = V_1 + V_2$$
$$= 2.0\text{ V} + 1.0\text{ V}$$
$$V_{source} = 3.0\text{ V}$$

So V_{source} = 3.0 V.

If you apply the same thinking to the other path, you can solve for V_3:

$$V_{source} = V_1 + V_3$$
$$3.0\text{ V} = 2.0\text{ V} + V_3$$
$$V_3 = 1.0\text{ V}$$

So V_3 = 1.0 V.

The current in a series circuit is constant and the same as the source current. The source and lamp 1 are in series, and I_1 = 0.70 A. Using these values and KCL, you can find I_{source}:

$$I_{source} = I_1$$
$$I_{source} = 3.0\text{ A}$$

So I_{source} = 3.0 A.

The amount of current entering a junction is equal to the amount of current exiting the junction. This can be used to find I_3:

$$I_{parallel} = I_2 + I_3$$
$$3.0\text{ A} = 1.5\text{ A} + I_3$$
$$I_3 = 1.5\text{ A}$$

So I_3 = 1.5 A.

(b)

Item	*V* (V)	*I* (A)
source	24.0	2.0
lamp 1	10.0	**2.0**
lamp 2	6.0	1.0
lamp 3	**6.0**	**1.0**
lamp 4	**8.0**	**2.0**

Using KVL for a series circuit, you can solve for V_4:

$$V_{source} = V_1 + V_2 + V_4$$
$$24.0\text{ V} = 10.0\text{ V} + 6.0\text{ V} + V_4$$
$$24.0\text{ V} = 16.0\text{ V} + V_4$$
$$V_4 = 8.0\text{ V}$$

So V_4 = 8.0 V.

If you apply the same thinking to the other path, you can solve for V_3:

$$V_{source} = V_1 + V_3 + V_4$$
$$24.0\text{ V} = 10.0\text{ V} + V_3 + 8.0\text{ V}$$
$$24.0\text{ V} = 18.0\text{ V} + V_3$$
$$V_3 = 6.0\text{ V}$$

So V_3 = 6.0 V.

The current in a series circuit is constant and the same as the source current. Lamp 4, the source, and lamp 1 are in series, and I_{source} = 2.0 A. Using these values and KCL, you can find I_1 and I_4:

$$I_{source} = I_1 = I_4$$
$$2.0\text{ A} = I_1 = I_4$$

So I_1 = 2.0 A and I_4 = 2.0 A.

The amount of current entering a junction is equal to the amount of current exiting the junction. This can be used to find I_3:

$$I_{parallel} = I_2 + I_3$$
$$2.0\text{ A} = 1.0\text{ A} + I_3$$
$$I_3 = 1.0\text{ A}$$

So I_3 = 1.0 A.

(c)

Item	*V* (V)	*I* (A)
source	6.0	4.0
lamp 1	**3.0**	**4.0**
lamp 2	1.0	2.0
lamp 3	2.0	**2.0**
lamp 4	**3.0**	**2.0**

Using KVL for a series circuit, you can solve for V_1:

$$V_{source} = V_1 + V_2 + V_3$$
$$6.0\text{ V} = V_1 + 1.0\text{ V} + 2.0\text{ V}$$
$$6.0\text{ V} = V_1 + 3.0\text{ V}$$
$$V_1 = 3.0\text{ V}$$

So V_1 = 3.0 V.

If you apply the same thinking to the other path, you can solve for V_4:

$$V_{source} = V_1 + V_4$$
$$6.0\text{ V} = 3.0\text{ V} + V_4$$
$$V_4 = 3.0\text{ V}$$

So $V_4 = 3.0$ V.

The current in a series circuit is constant and the same as the source current. The source and lamp 1 are in series, and $I_{source} = 4.0$ A. Using these values and KCL, you can find I_1:

$$I_{source} = I_1$$
$$I_1 = 4.0\text{ A}$$

So $I_1 = 4.0$ A.

Lamp 2 and lamp 3 are in series, and $I_2 = 2.0$ A. Using these values and KCL, you can find I_3:

$$I_2 = I_3$$
$$I_3 = 2.0\text{ A}$$

So $I_3 = 2.0$ A.

The amount of current entering a junction is equal to the amount of current exiting the junction. The amount of current entering the junction is equal to I_2 (or I_3). This can be used to find I_4:

$$I_{parallel} = I_2 + I_4$$
$$4.0\text{ A} = 2.0\text{ A} + I_4$$
$$I_4 = 2.0\text{ A}$$

So $I_4 = 2.0$ A.