Topic 4.5

What are series and parallel circuits and how are they different?

Key Concepts

- The current in a series circuit is the same at every point in the circuit.
- The current in each branch in a parallel circuit is less than the current through the source.
- The sum of the potential differences across each load in a series circuit equals the potential difference across the source.
- The potential difference across each branch in a parallel circuit is the same as the potential difference across the source.

Key Terms

series circuit
parallel circuit

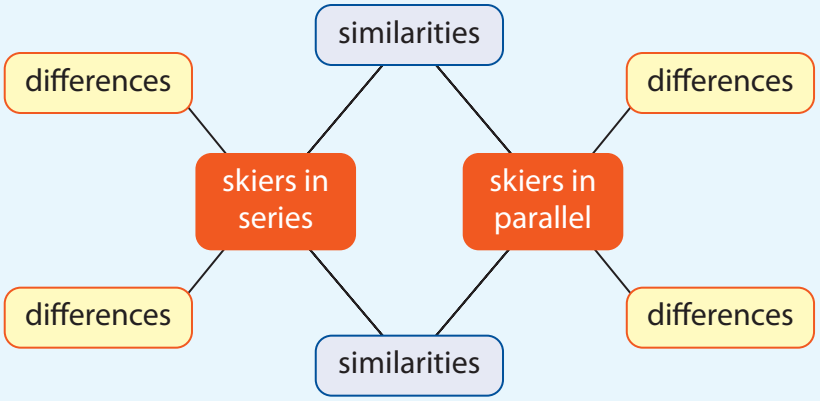
The skiers in Picture A are all following the same path. They are going up the ski lift one at a time. They are following each other down the ski run, one after the other. You could say that they are skiing in series. The word "series" refers to objects following along, one after the other, along a single path. With your finger, trace the path the skiers are taking to make sure that you see only one path they can follow.

The skiers in Picture B are not following the same path. They have a choice of three different runs to take while skiing down the hill. You could say that they are skiing in parallel. The word "parallel" refers to objects going side-by-side and in the same direction. All of the skiers are taking the same ski lift, but after they reach the top, they branch out onto the parallel runs.

Picture A

Starting Point Activity

Examine Picture A and Picture B closely. Use an organizer such as this one to compare all the features of the two pictures that are the same and all the features that are different.

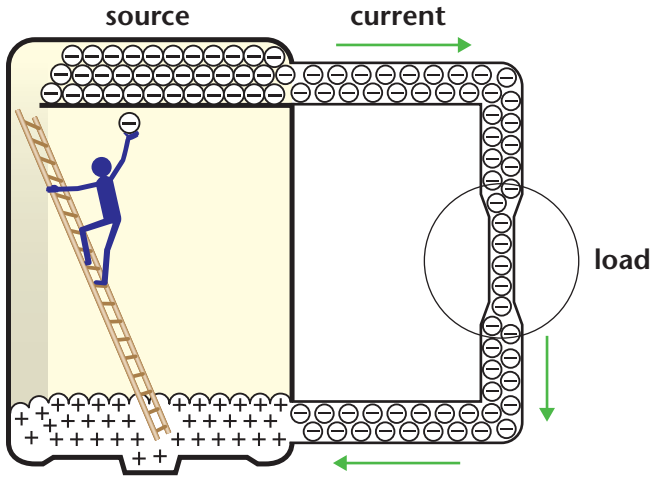


Picture B

The current in a series circuit is the same at every point in the circuit.

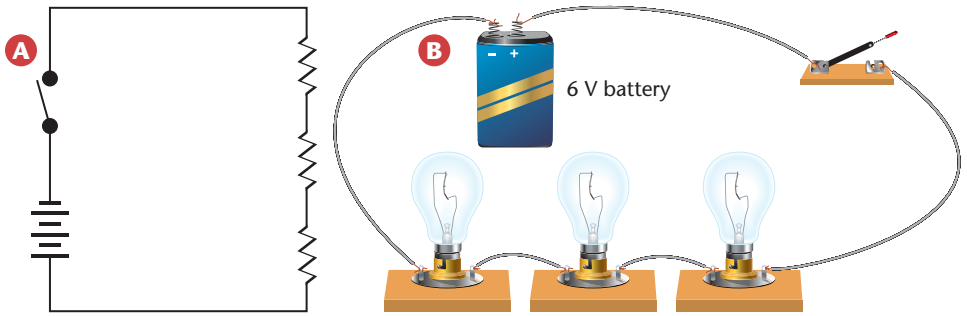
series circuit: a circuit that has only one path for current to follow

All of the circuits that you have worked with so far are series circuits. A **series circuit** has only *one path* for the current to follow. **Figure 4.25** reviews the circuit on page 280. You now know that it is a series circuit.



▶ **Figure 4.25** The current is the same at every point along a series circuit. Although a load resists the flow of current and the charges lose energy as they pass through, the current is still moving at the same rate after it leaves a load as it was when it entered the load.

Most of the circuits that you have analyzed in this unit had only one load. However, a series circuit can have several loads, as shown in **Figure 4.26**. You would describe this circuit as a 6 V battery with three loads (or light bulbs) and a switch that are all in series. When the switch is open, the light bulbs will all be off. If you close the switch, all of the light bulbs will go on. What do you think will happen if one of the light bulbs burns out?



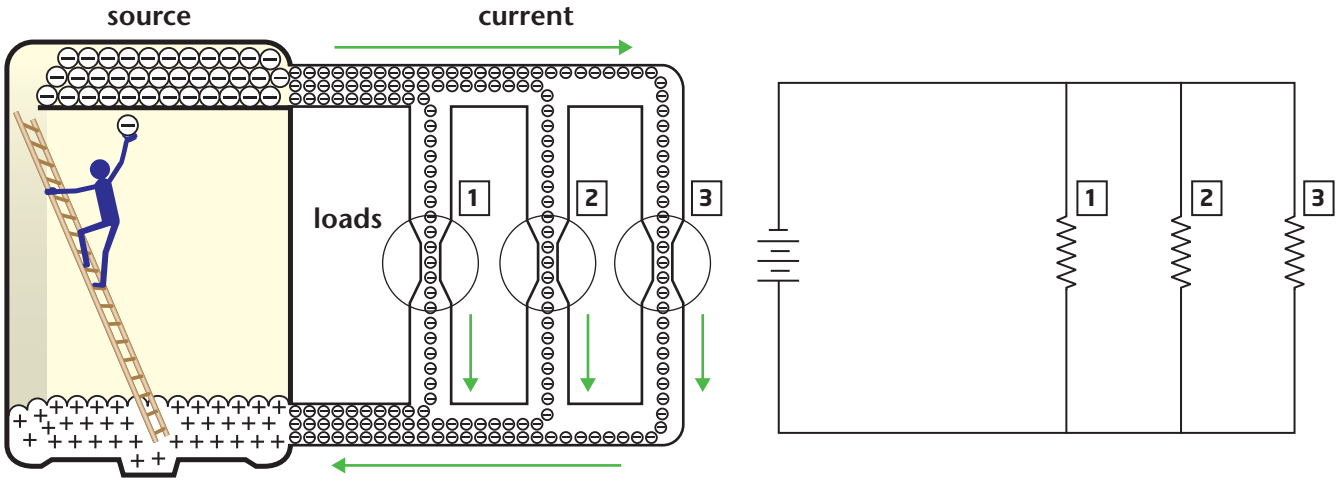
▶ **Figure 4.26** The circuit diagram (A) shows a battery, a switch, and three loads that have resistance. The circuit (B) shows a large 6 V battery, a switch, and three light bulbs. Study A and B until you can see that both types of diagrams represent the same circuit.

In a series circuit, all of the loads must be on and working at the same time. Why? Think of a burned-out light bulb. When a light bulb burns out, the filament breaks. The current can no longer flow through the filament. As a result, the current cannot flow anywhere in the circuit. The same thing would happen if you removed a light bulb from a series circuit. In a series circuit, all of the light bulbs, or other kinds of loads, must be on and working for charges to flow through the circuit.

The current in each branch in a parallel circuit is less than the current through the source.

Examine the circuit in Figure 4.27. With your finger, trace the paths of the negative charges leaving the source. Notice how similar these pathways are to the ski hill on page 293. The source is like the ski lift. Instead of lifting skiers to the top of the run, the source is raising negative charges to a higher level of energy. The charges are like the skiers. From the top of the hill, the skiers have a choice of three different runs to ski down. The negative charges have three different paths that they can follow to return to the positive end of the source. A circuit that has two or more paths for the current to follow is called a **parallel circuit**.

parallel circuit: a circuit that has two or more paths for current to follow



▲ **Figure 4.27** These two diagrams show the same parallel circuit. Compare them closely to be sure you recognize why they are the same.

Now think about what happens to the amount of current as it leaves the source and reaches a point where the current separates. Some of the current goes down toward the first load and the rest continues on. Then the current divides again and follows paths 2 and 3. The amount of current following each of the paths is less than the amount of current that left the source. Because the current separates before passing through the loads, there is *less current* passing through the loads than there is leaving or entering the source.

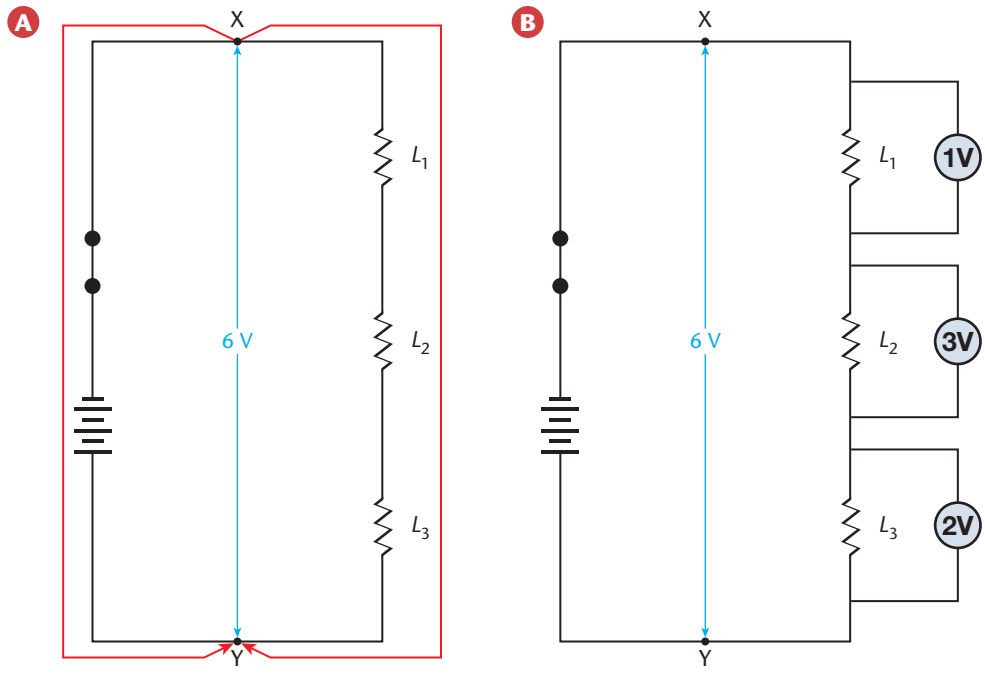
LEARNING CHECK

1. Refer to Figures 4.26 and 4.27. Draw and label a diagram of
   a) a series circuit with a source, a switch, and two lights
   b) a parallel circuit with a source, a switch, and two lights
2. Explain what you think would happen if you had 10 garden lights wired in series and one of the bulbs burned out.

The sum of the potential differences across each load in a series circuit equals the potential difference across the source.

Assume that you measure the potential difference between points A and B in the series circuit shown in **Figure 4.28**. If the meter reads 6 V, what does this really mean? It means two things. First, it means that the potential difference across the battery is 6 V. Second, it means that the potential difference across all three loads together (L_1, L_2, and L_3) is 6 V. It does not matter which path you follow from point A to point B. The potential difference between A and B must be the same.

As you know, when a charge passes through any load, it loses energy. So there is a potential difference across each of the three loads in **Figure 4.28**. If you measured the potential difference across each of the loads and added them together, the sum would be 6 V.



▲ Figure 4.28

A If you connect a voltmeter at points X and Y in the circuit, you are measuring both the potential difference across the battery and across all three of the loads.

B If, instead, you connect a voltmeter across each load separately, you could get readings such as 1 V, 3 V, and 2 V. The sum of the values on each meter would then be 1 V + 3 V + 2 V = 6 V. So the potential difference across each of the loads is lower than the potential difference across the source. But the sum of the potential differences across all the loads is equal to the potential difference across the source.

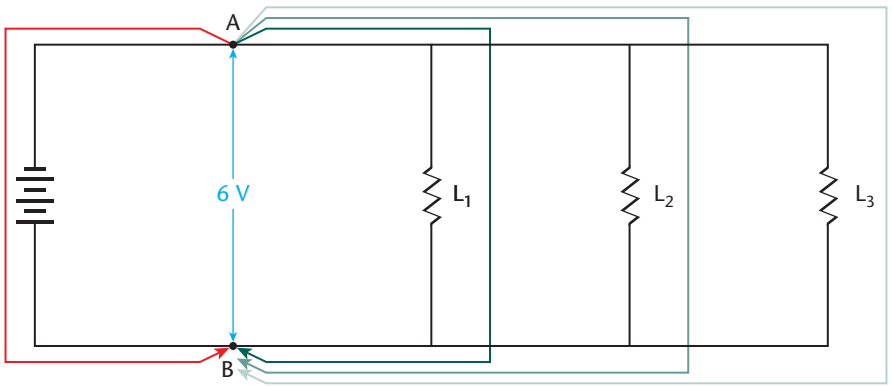
INVESTIGATION LINK

Investigation 4G, on page 298

The potential difference across each branch in a parallel circuit is the same as the potential difference across the source.

Examine the parallel circuit shown in **Figure 4.29**. If you measure the potential difference between points A and B, what are you really measuring? Notice that there are four different paths to get from A to B. The red path goes across the source. Each of the green paths goes across one of the loads. If the reading on the meter is 6 V, this means that the potential difference across the source and across each of the loads is 6 V. In a parallel circuit, the potential difference across the source and each of the branches is the same.

INVESTIGATION LINK
Investigation 4H, on page 300

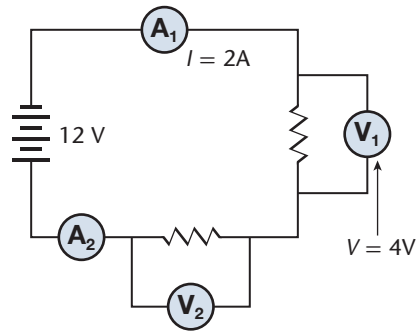


◀ **Figure 4.29** If you placed a voltmeter across the source and across each of the loads separately, you would get the following results. V_S = 6 V, V_1 = 6 V, V_2 = 6 V, and V_3 = 6 V.

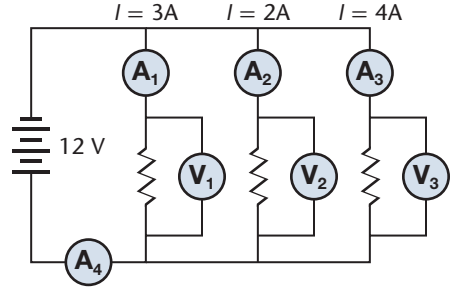
LEARNING CHECK

1. In Circuit 1, the battery provides a potential difference of 12 V. If the reading on voltmeter V_1 is 4 V, what is the reading on voltmeter V_2?
2. In Circuit 1, the reading on ammeter A_1 is 2 A. What is the reading on ammeter A_2?
3. In Circuit 2, the battery provides a potential difference of 12 V. What are the readings on voltmeters V_1, V_2, and V_3?
4. In Circuit 2, ammeter A_1 reads 3 A, ammeter A_2 reads 2 A, and ammeter A_3 reads 4 A. What is the reading on ammeter A_4?

Circuit 1



Circuit 2



Skill Check

Initiating and Planning

✓ **Performing and Recording**

✓ **Analyzing and Interpreting**

✓ **Communicating**

Observing Characteristics of Series Circuits

In this investigation, you will assemble series circuits and observe their characteristics. You will compare the current in the circuits and potential difference across the loads (flashlight bulbs) while you vary the number of loads.

Safety

- Disconnect any wire that gets too hot.
- When using a power supply, always follow your teacher's instructions.
- Always unplug or turn off a power supply before working on a circuit.

What You Need

power supply

switch

ammeter

3 flashlight bulbs with bases

3 voltmeters (or use one and move it for each measurement)

12 wire leads with alligator clips

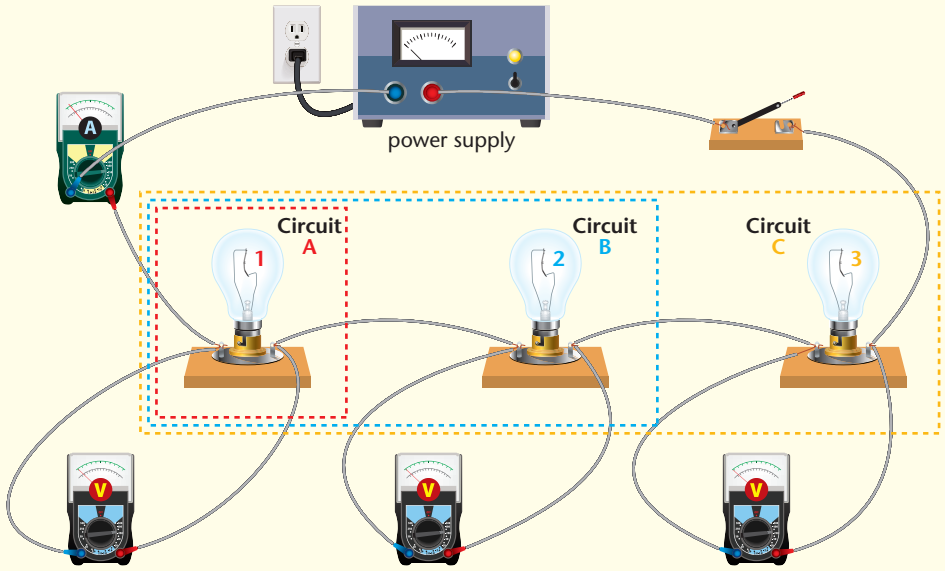
What To Do

1. Make a table like this one. Give it a suitable title.

Circuit	Current	Potential Difference			Brightness of Bulbs		
		Bulb 1	Bulb 2	Bulb 3	Bulb 1	Bulb 2	Bulb 3
A							
B							
C							

2. You are going to build three circuits. These circuits will be the same, except they will have different numbers of loads and voltmeters.
   - Circuit A will have one load (one bulb) and one voltmeter.
   - Circuit B will have two loads (two bulbs) and two voltmeters.
   - Circuit C will have three loads (three bulbs) and three voltmeters.

   Refer to the diagram on page 298 for the three circuits you will build.
3. Draw a circuit diagram for Circuit A (one bulb). With the power supply off and the switch open, build this circuit.
4. Turn on the power supply and set the potential difference to 6 V. Close the switch.
5. Observe and record the current on the ammeter and the potential difference across the bulb.
6. Observe the brightness of the bulb. Make a note in the table that will help you remember the brightness so you can compare the brightness of the bulbs in the next two circuits that you build.
7. Turn off the power supply and open the switch. Add a second bulb, in series with the first, and a second voltmeter. This is Circuit B. Draw a circuit diagram of Circuit B.



8. Repeat steps 4 to 6 with the new circuit. When describing the brightness of the two bulbs, note whether they are brighter, the same, or less bright than the bulb in Circuit A.
9. Turn off the power supply, and open the switch. Add a third bulb, in series with the first two bulbs, and a third voltmeter. This is Circuit C. Draw a circuit diagram of Circuit C.
10. Repeat steps 4 to 6 with Circuit C.
11. Turn off the power supply and open the switch. Remove one of the bulbs from its base, but leave the base in the circuit. Turn on the power supply and close the switch. Note what happens.

What Did You Find Out?

1. When you added more loads (bulbs) to your circuit, did the current reading go up, stay the same, or go down?
2. **a)** What happened to the brightness of the bulbs as you added more bulbs to the circuit?
   b) What is the relationship between the current through the bulbs and their brightness?
3. When you added more loads (bulbs) to your circuit, did the potential difference across each individual bulb go up, stay the same, or go down?
4. In step 11, you removed one bulb from its base and turned the power supply back on and closed the switch. What happened? Explain why it happened.
5. Write a statement describing how practical it would be to put many loads in a series circuit.

Skill Check

Initiating and Planning

✓ **Performing and Recording**

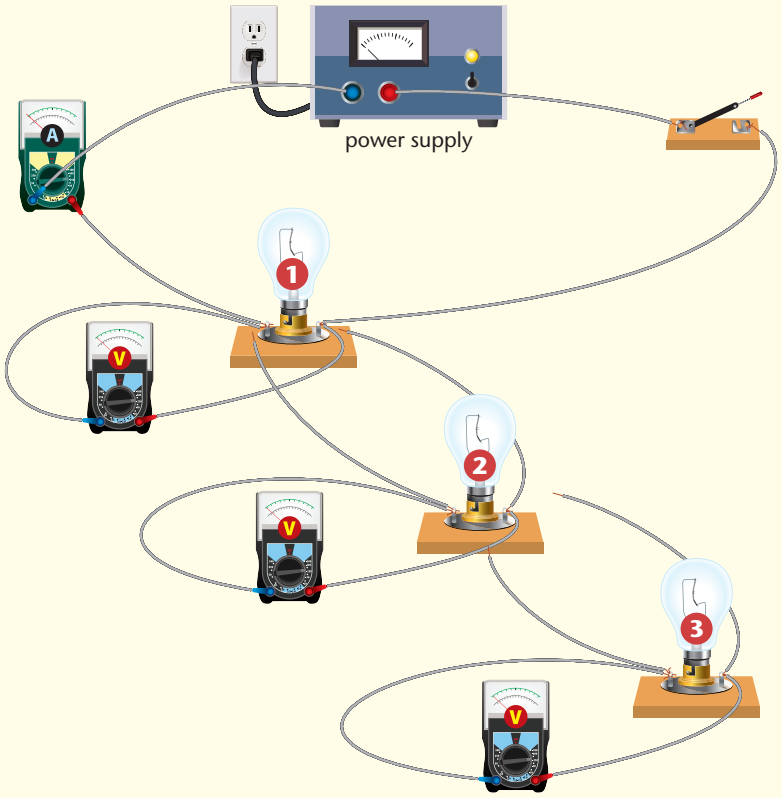
✓ **Analyzing and Interpreting**

✓ **Communicating**

Observing Characteristics of Parallel Circuits

In this investigation, you will start with a simple parallel circuit with one load (bulb), and then you will add two more loads, one at a time, in parallel with the bulb or bulbs already present. You will observe and measure the current near the source and the potential difference across each load.

Examine the circuit shown here. Notice that loads 2 and 3 are not yet connected to the first load and the power supply. This is the arrangement for your first measurements. You will add the second and third loads in parallel and make measurements after adding each one to the circuit.



Safety

- Disconnect any wire that gets too hot.
- When using a power supply, carefully follow your teacher's instructions.
- Always unplug or turn off a power supply before working on a circuit.

What You Need

power supply

switch

ammeter

3 flashlight bulbs with bases

3 voltmeters (If there are not enough, use one and move it for each measurement.)

13 leads with alligator clips

What To Do

1. Make a table like this one. Give it a suitable title.

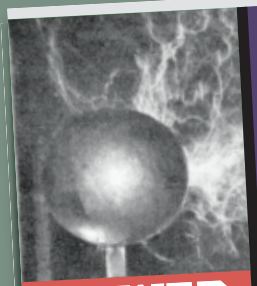
Circuit	Current	Potential Difference			Brightness of Bulbs		
		Load 1	Load 2	Load 3	Load 1	Load 2	Load 3
A							
B							
C							

2. Examine the circuit shown in the diagram. With the power supply off and the switch open, build this circuit.
3. Turn on the power supply and set the potential difference to 6.0 V. Close the switch.
4. Observe and record the current reading on the ammeter and the potential difference across the bulb.
5. Observe the brightness of the bulb. Make a note in the table that will help you remember the brightness so you can compare the brightness of the bulbs in the next two circuits that you build.
6. Turn off the power supply and open the switch. Add a second bulb and voltmeter to your circuit so they are in parallel with the first. You can do this by connecting the two ends of the leads from bulb 2 to the sides of bulb 1.
7. Repeat steps 3 to 5 with the new circuit. When describing the brightness of the two bulbs, note whether they are brighter, the same, or less bright than the bulb in the first circuit.
8. Turn off the power supply and open the switch. Add a third bulb and voltmeter to your circuit in parallel with the first two. Once again, study the diagram and connect the ends of the leads from bulb 3 to the sides of bulb 2.
9. Repeat steps 3 to 5 with the third circuit.
10. Turn off the power supply and open the switch. Remove one of the bulbs from its base but leave the base in the circuit. Turn on the power supply and close the switch. Note what happens.

What Did You Find Out?

1. When you added more loads (bulbs) in parallel to your circuit, did the current beside the power supply go up, stay the same, or go down?
2. Is the amount of current that is passing through the power supply the same, higher, or lower than the current that is passing through an individual bulb? Explain.
3. What happened to the brightness of the bulbs as you added more bulbs to the circuit?
4. When you added more loads (bulbs) to your circuit, did the potential difference across each individual bulb go up, stay the same, or go down?
5. In step 10, you removed one bulb from its base and then turned the power supply back on and closed the switch. Explain what happened.
6. Write a statement describing how practical it would be to connect many loads in a parallel circuit.

Strange Tales of Science



POWER SERIES

PREMIUM ISSUE

SPARKS OF GENIUS

There are some images that immediately "spark" our curiosity, and this is one of them. Who is the man reading in this image, seemingly without a care in the world? Shouldn't he at least be a little "shocked" by the electrical currents that are electrifying the air around him? The man's name is Nikola Tesla. Tesla was a genius when it came to electricity, but it turns out that not getting shocked was one of the least weird things about him!

Nikola Tesla (1856–1943) has over 500 inventions to his credit, most of which revolve around electricity. His inventions rank with those of Thomas Edison, inventor of the light bulb, who was Tesla's main rival and possible arch-enemy.

So... What do you think?

1. Find out why Tesla was perfectly safe while posing for this photograph!
2. Tesla would only stay in a hotel room with a number that could be divided by three. Find out three other really weird things about Tesla's life.
3. Tesla's contributions to the world of electricity may have even surpassed those of his rival Thomas Edison. Find out three things Tesla invented.
4. The machines generating the sparks in this photo are called Tesla coils. What are Tesla coils and how do they generate electricity?

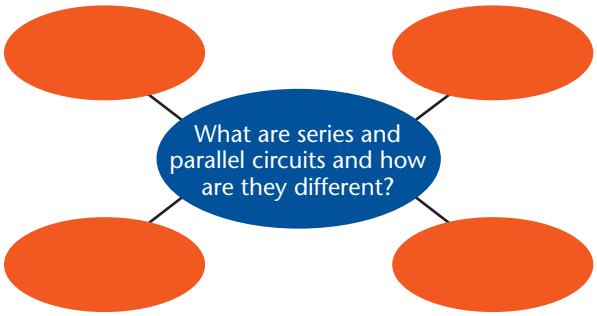
Topic 4.5 Review

Key Concept Summary

- The current in a series circuit is the same at every point in the circuit.
- The current in each branch in a parallel circuit is less than the current through the source.
- The sum of the potential differences across each load in a series circuit equals the potential difference across the source.
- The potential difference across each branch in a parallel circuit is the same as the potential difference across the source.

Review the Key Concepts

1. K/U Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



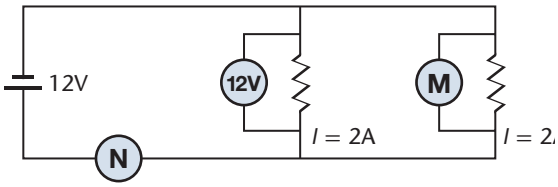
2. C Use a double bubble organizer to compare the properties of parallel circuits and series circuits in terms of current and potential difference.

3. K/U Look at the circuit diagram below.

a) Describe this circuit and identify all of its components.

b) Identify the meter labelled "M" in this circuit, describe what it measures, and determine the reading you would expect to see on this meter.

c) Identify the meter labelled "N" in this circuit, describe what it measures, and determine the reading you would expect to see on this meter.

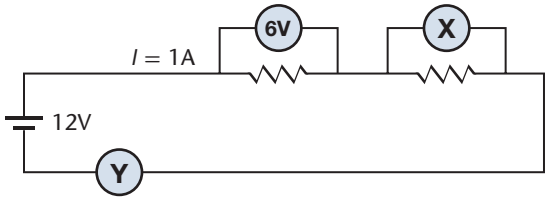


4. K/U Look at the circuit diagram below.

a) Describe the circuit and identify all of its components.

b) Identify the meter labelled "X" in this circuit, describe what it measures, and determine the reading you would expect to see on this meter.

c) Identify the meter labelled "Y" in this circuit, describe what it measures, and determine the reading you would expect to see on this meter.



5. T/I Assume the loads in the diagram above are light bulbs. Predict what would happen to the brightness of the bulbs if you added a third bulb to this circuit. Justify your answer.

6. K/U Examine pictures A and B below. Decide whether each picture shows a series circuit or a parallel circuit. Explain the evidence you used to make your decision.