Electric Circuits
Circuits and Current

CONCEPT EXPLORATION

Neutral objects can become electrically "charged" by gaining electrons or by losing electrons.

1. What kind of charge does an object have if it has more electrons than protons? . . . less electrons than protons?

In the last lesson you learned about static charges. **Static** means unchanging or stable. In this lesson you will learn about electrical systems that are changing because the charge carriers (electrons) are moving in a particular direction.

Engagement Question

2. What can exert a force on an electron to make it move?

3. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

<u>Student A</u>

"If an unmoving electron was hit by another electron, the first electron would begin to move."

<u>Student B</u>

"An electron could never touch another electron since they would repel each other. A moving electron's electric field would make an unmoving electron move."

Check your work with your teacher ☐

A light bulb will light up when electrons are induced to continuously move through the filament of the light bulb. The moving electrons have energy and this energy is passed on to the molecules that make up the filament of the light bulb. This energy is given off in the form of both heat and light. How can you get electrons to move through the filament of a light bulb?

The Challenge

You will experiment with materials that will allow you to light up a light bulb.

Your Ideas about the Challenge

4. If you were given a light bulb, what additional materials would you need to make the light bulb light up?

At each lab station you will find the following:
a light bulb, a battery, and a single wire

The Investigation

a. Use the materials that are provided to get the light bulb to light up.
b. In the first space provided below make a drawing of how the materials were oriented and connected when the light bulb lit. Make sure that you label the polarity of the battery (positive and negative terminals) in your drawing.
c. Find another arrangement, of your materials, that will cause the light bulb to light up.
d. Make another drawing of the new arrangement that allowed you to light the bulb.

First Arrangement	Second Arrangement

5. What was similar about the two different ways that you managed to get the bulbs to light? In your answer be sure to mention the two different terminals of the battery as well as the two metal contacts of your light bulb (threaded part and the end contact).

6. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

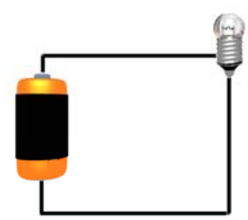
"Both times that our bulb lit there was a complete path that started with the wire touching either the negative or positive terminal of the battery and then went to one of the contacts of the light bulb, and finally ended where the other contact of the light bulb touched the other terminal of the battery."

Student B

"Our light bulb lit whenever we made any kind of a circle with the materials."

Check your work with your teacher ☐

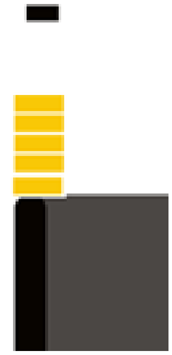
If you had two wires, in addition to your light bulb and battery, you could have used the arrangement shown to the right to get the light bulb to light.



The complete path between the positive and negative terminals of the battery that passes through the light bulb, is referred to as an **electrical circuit**.

By connecting a wire to each terminal of the light bulb, the circuit passes through the filament of the light bulb. The complete circuit, between the terminals of the battery, causes electrons to "flow" through the filament. This flow of electrons is called electric **current**.

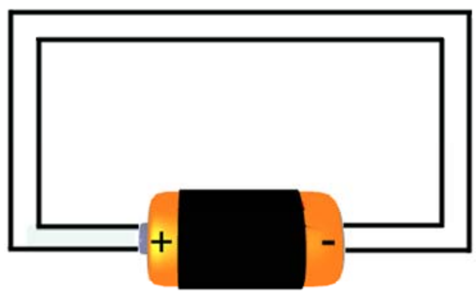
A chemical reaction inside of the battery causes a separation of charge between the two terminals of the battery. One terminal becomes positive while the other terminal becomes negative.



When a wire is connected between the terminals of a battery an electric field is created inside of the wire. This electric field goes from one terminal of the battery, through the wire, and then into the other terminal of the battery.

The diagram shown below represents the cross section of a very fat wire that is connected to the positive and negative terminals of a battery.

7. On the diagram, draw the direction of the electric field that is created inside of the wire. Remember that the direction of an electric field is the direction that a positive charge would experience a force due to the presence of the electric field.



8. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

"The direction of the electric field inside of the wire must be clockwise, in the circuit shown here, since positive charges would be repelled by the positive terminal of this battery and attracted to the negative terminal of this battery."

Student B

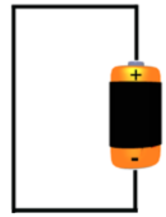
"The electrons inside of this wire must move in the same direction as the electric field inside of the wire."

Check your work with your teacher ☐

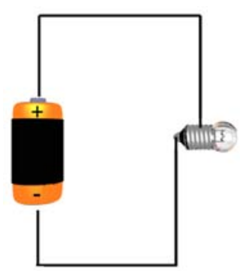
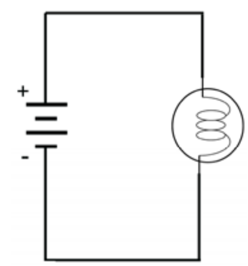
The direction of electric current is in the same direction as the direction of the electric field. However, electrons would move in the opposite direction. Even though electric current results from the movement of electrons, electric current can be thought of as a flow of positive charge "carriers".

9. What would be the direction for the electric current in the circuit shown to the right? Is it clockwise or counter clockwise?

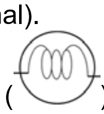
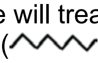
10. What would be the direction for the electron flow in the circuit shown to the right? Is it clockwise or counter clockwise?



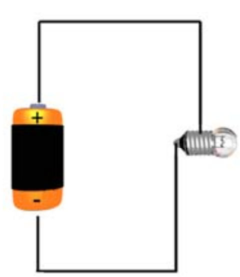
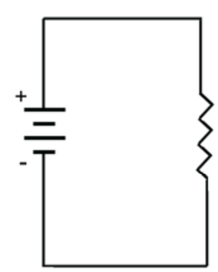
For practical purposes circuits are drawn using symbols rather than pictures of the actual circuit elements. For example: the circuit shown below, on the left, could be drawn as shown on the right.

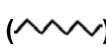
Picture of circuit	Traditional circuit diagram
	

The traditional representation of voltage sources, such as batteries, is an alternating series of long and short lines (). The number of pairs of long and short lines is not important as long as one end of the battery is represented by a long line (the positive terminal) and the other end by a short line (the negative terminal).

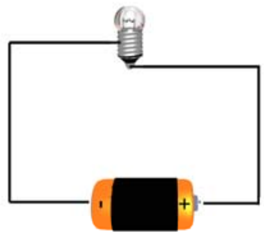
There are a variety of traditional symbols used to represent light bulbs in circuit diagrams ().
For simplicity sake we will treat light bulbs as resistance devices and the traditional symbol used for a resistor is a series of zigzag lines ().

Therefore the simple circuit that we have been using could be drawn as seen below:

Picture of circuit	Traditional circuit diagram
	

11. Make a traditional circuit diagram for the circuit shown below. Use the resistance symbol () to represent the light bulb in the circuit. Be sure to correctly label the terminals of your battery.

Picture of Circuit	Traditional Circuit Diagram

Check your work with your teacher

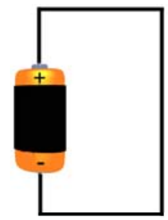
Electric Circuits
Circuits and Current

CONCEPT DEVELOPMENT

In order to create an electric current you need a complete electrical circuit. You also need a voltage source and the circuit needs to consist of a complete "conductive" path.
In addition to what was mentioned in the preceding paragraph it is important, for safety reasons, to have a sufficient "resistive load" in an electrical circuit. What happens in your house when you have too many things plugged into the same circuit?

Engagement Question

1. If there was zero-electrical resistance in the circuit that you see to the right, what do you think would happen to the electrical current?



The Challenge

You will measure the voltage and the current in a simple circuit. From the data that you collect you will be able to determine the resistance of a lit light bulb.

Your Ideas about the Challenge

2. A 1.5-volt battery is used in a simple circuit. If the 1.5-volt battery is replaced by a 6-volt battery, would the current in the circuit change? If so, would it increase or decrease?

The technical definition for "voltage" involves the concept of potential difference. **Potential difference** is defined as the amount of work (or energy) required to move a quantity of charge a distance through an electric field. For our purposes we will define potential difference (commonly referred to as **voltage**) as the amount of energy that is given to a unit of charge by the voltage source.
Voltage is measured in volts (V). A volt is a measurement of energy per unit charge.

3. What is a volt (V) equivalent to? What is the unit breakdown for a volt?

4. Is the relationship between current and voltage a direct proportion or an inverse proportion? Explain how you know.

5. What do you think would happen to the current in a simple electrical circuit, if the "electrical resistance" in the circuit was doubled? Would the current change? If so, would you expect it to increase or decrease?

Resistance (**R**) can be defined as the opposition to the flow of electric current in a circuit.
6. Is the relationship between current and resistance a direct proportion or an inverse proportion? Explain how you know.

The equation that describes the relationship between electrical current (I), voltage, and resistance can be derived from the proportional relationship between electric current, voltage, and resistance. Also the units for electrical current can be derived from this relationship.

Electrical current and voltage are directly proportional.	$I \propto V$
Electrical current and resistance are inversely proportional.	$I \propto \frac{1}{R}$
If you put these two proportions together you get the relationship that you see to the right.	$I \propto \frac{V}{R}$
If the proper units are used this becomes the equation that you see to the right.	$I = \frac{V}{R}$

The final equation, seen above, is known as Ohm's law in honor of the 19th century physicist George Ohm who is credited with being the first to express this relationship between current, voltage, and resistance.

There are two variations of this equation. The first variation is the equation solved for voltage (V).

$$\mathbf{V = IR}$$

The second variation is the original equation solved for resistance (R).

$$R = \frac{V}{I}$$

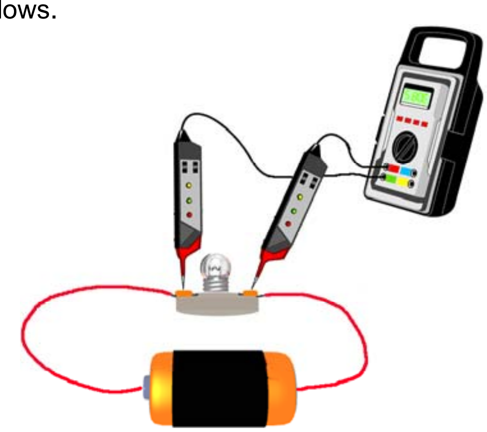
The units of electrical resistance are called Ohms (Ω) in honor of George Ohm.

7. What are Ohms equal to? What is the unit breakdown for an Ohm? Hint: look at the version of Ohm's law that is solved for resistance.

At each lab station you will find the following:
a light bulb, a battery, two wires, a voltmeter, and an ammeter

The Investigation

a. Use the materials that are provided to get the light bulb to light up.
b. Touch the two probes of your voltmeter to opposite sides (the terminals) of the light bulb. Record the voltage that you measure in the data table that follows.



c. Repeat part "b" after you reverse which probe that you originally touched to each terminal.

Data Table

First Voltage Measurement (V)	**Reversed Probe Measurement (V)**

8. What was different about the two voltage measurements that you made? How do you explain this difference?

9. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

"The voltage was positive the first way that we measured it and then it was negative when we reversed the probes. I think that there must be less voltage going one way in the circuit and more voltage going the other way."

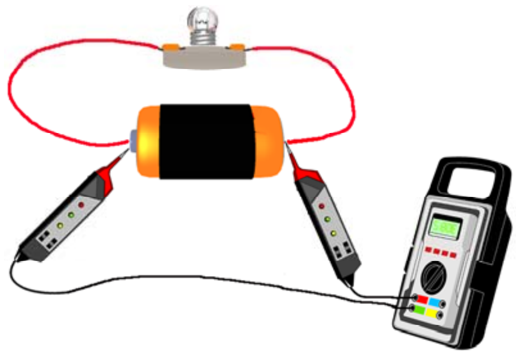
Student B

"The voltage measurement was the same when we reversed the probes. The difference in signs was due to the direction of the current. The voltage increased going one way and it decreased going the other way."

Check your work with your teacher ☐

The Investigation (continued)

a. With the light bulb lit up, touch the two probes on opposite sides (the terminals) of your battery. Make sure that you get a positive voltage measurement.



b. Record the voltage that you measure in the data table that follows.

Data Table

Battery Voltage Measurement (V)

10. Was the voltage that you measured from the battery significantly different from the voltage that you measured across the light bulb?

11. Was the voltage that you measured from the battery higher or lower than the voltage that you measured across the light bulb? How can you explain this?

12. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

"The voltage that we measured across the battery was almost exactly the same as the voltage that we measured across the light bulb. All we really did was to measure the voltage at opposite ends of the wires which have no resistance."

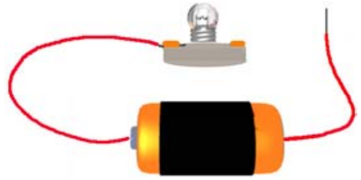
Student B

"The wires did have a little resistance. That's why we got a slightly higher voltage measurement from the battery. The tiny amount of voltage was used up by the wires."

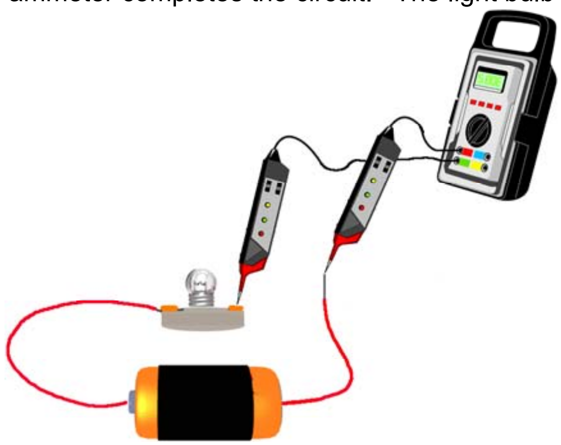
Check your work with your teacher ☐

The Investigation (continued)

a. Open up your circuit, so that the light bulb goes out, by disconnecting one of the wires from one side of the light bulb.



b. Touch one probe of your ammeter to the end of the disconnected wire and the other probe to the unconnected terminal of the light bulb so that the ammeter completes the circuit.   The light bulb should light up once again.



c. Record the current measurement in Amperes (A) in the data table that follows.

d. Reverse the probes of your ammeter and take the measurement again. Record this reading this reading in the data table that follows.

Data Table

First Current Measurement (A)	Reversed Probe Measurement (A)

13. How did the second current measurement compare to the first current measurement? How can you explain the different readings?

14. Evaluate the following student statement about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

<u>Student A</u>

"We got a positive current measurement one way and a negative current measurement the other way. I think that the current must be flowing backwards through the ammeter when we got the negative measurement."

Check your work with your teacher ☐

You can use the version of Ohm's law, solved for resistance (R), to find the resistance of the lit light bulb: $R = \frac{V}{I}$.

Be sure to use the positive voltage that you measured across the light bulb as well as the positive current in your calculations.

15. Calculate the resistance of the lit light bulb. Be sure to use the appropriate units in your calculations and to label the answer with appropriate units.

Check your work with your teacher ☐

Electric Circuits
Circuits and Current

CONCEPT REFINEMENT

Review

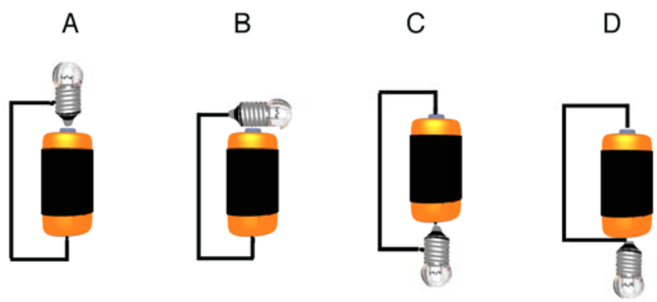
In order to have an active electrical circuit you must have a voltage source and a closed conductive path that includes the voltage source. It is important to have sufficient resistance in the circuit so that the current doesn't become too big.

Voltage, current, and resistance are related mathematically by Ohm's law: V = IR. If you know any two components of this equation, for a particular circuit element, then you can solve for the third.

It is important to know each of the electrical concepts along with the units with which they are measured. The table below shows the name and symbol for each concept as well as the symbol for the units and the unit breakdown for each electrical concept that you have been introduced to so far.

Electrical concept	Symbol for the concept	Units for the concept	Symbol for the Units	Unit breakdown
Quantity of charge	Q or q	Coulombs	C	C
Current	I	Amperes or Amps	A	C/s
Voltage	V	Volts	V	J/C
Resistance	R	Ohms	Ω	V/A

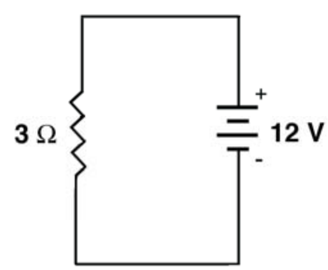
1. Which of the following circuit arrangements would <u>not</u> light up the light bulb? Explain why this arrangement would not light up the light bulb.



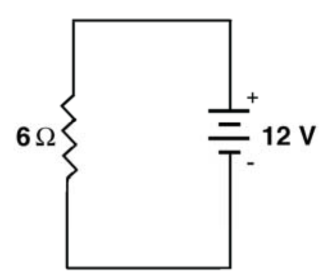
2. Does the current flow clockwise or counter-clockwise in the circuit shown to the right?

3. Do the electrons flow clockwise or counter-clockwise in the circuit shown to the right?

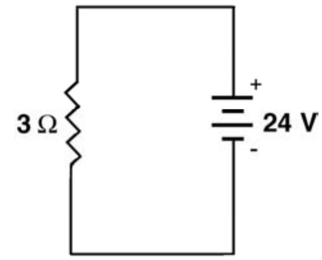
4. Calculate the current for the circuit shown to the right. Be sure to use appropriate units.



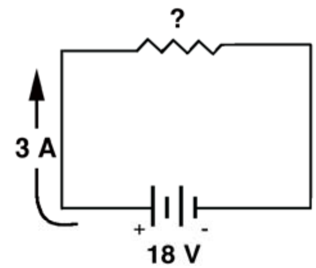
5. Calculate the current for the circuit shown to the right. Be sure to use appropriate units.



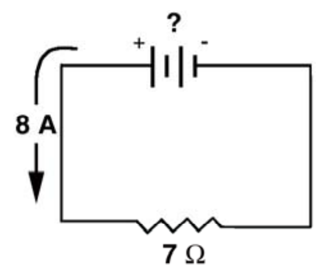
6. **Calculate the current for the circuit shown to the right. Be sure to use appropriate units.**



7. **Calculate the resistance of the unknown resistor shown in the circuit to the right.**



8. **Calculate the voltage of the unknown battery shown in the circuit to the right.**



9. **Draw a simple circuit that consists of a single resistor ( ) and a single 6-Volt battery ( ) along with a voltmeter (V) and an ammeter (A). Be sure to appropriately label the battery and to use as many wires as necessary in your diagram in order to correctly connect the two meters in your circuit.**

10. **In the diagram that you drew above indicate which way the current (I) flows in the circuit by drawing an arrow in the diagram. Label the arrow "I".**