Electric Circuits

Part One: Electric Circuits

Lab Demo Video: Charges and the electroscope

- **Create charges and identify attractive and repulsive forces**
- **View Julius Sumner Miller electrostatics videos to see a multitude of electrostatic experiments for discussion**

Lab A-1 OBJECTIVES (ALL):

How many ways can you light a light bulb?

What is a battery and how does it work?

What are electrical symbols and why are they used?

Differentiate conductors and insulators.

- **Stop and do A-1 Lab**

Part 1. How many different combinations of the battery, bulb and wire completed the circuit?

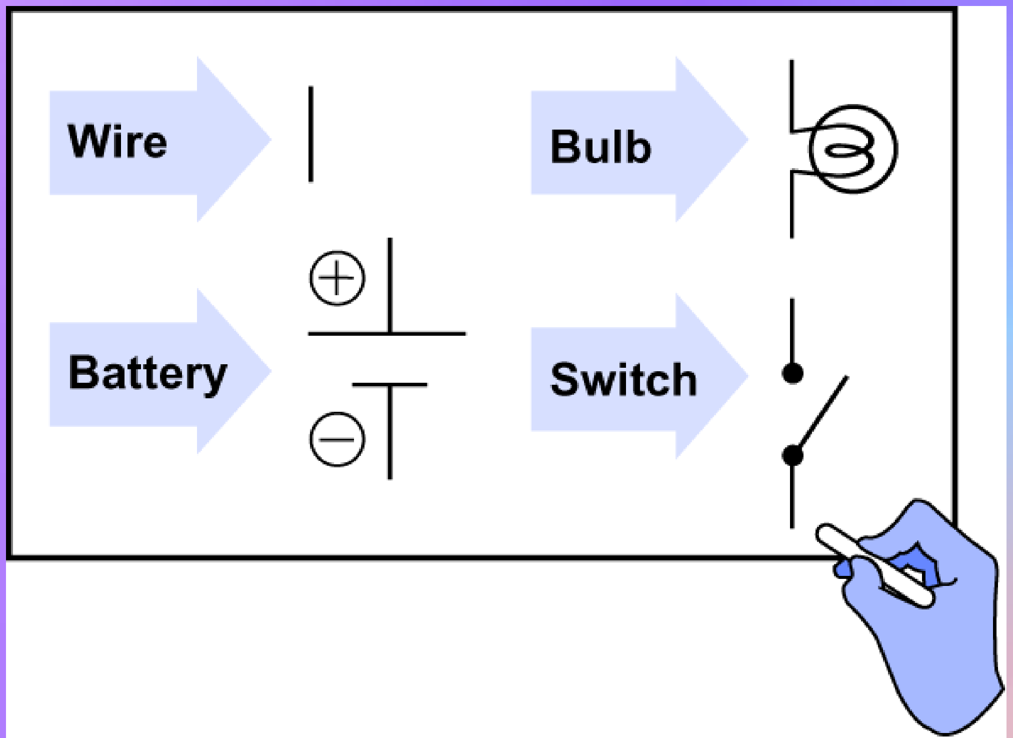
1. 1
2. 2
3. 3
4. ★ 4
5. None are correct

Parts of a Circuit –

check your lab A1-part 3

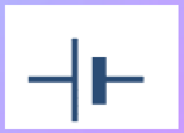
- **Wire**
- **Bulb**
- **Battery**
- **Switch**

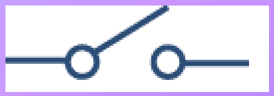
Symbols used for Diagramming

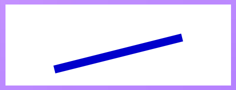


Part 3. a

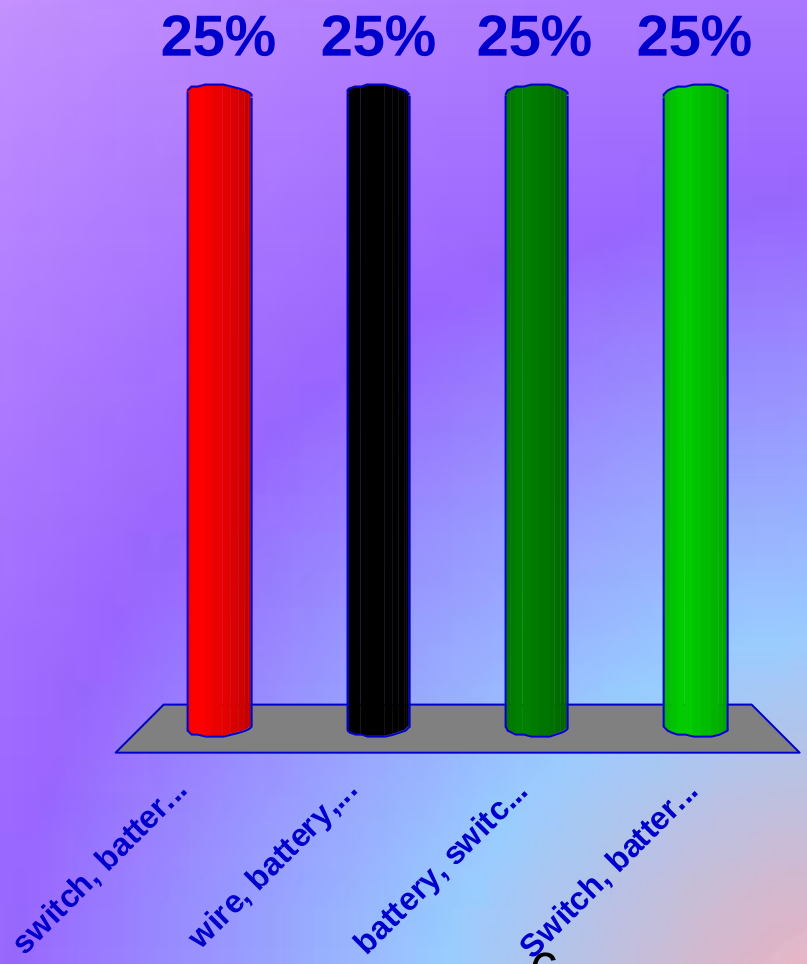
Identify each symbol correctly –







1. switch, battery, wire
2. wire, battery, switch
3. battery, switch, wire
4. Switch, battery, wire



Learning Goals

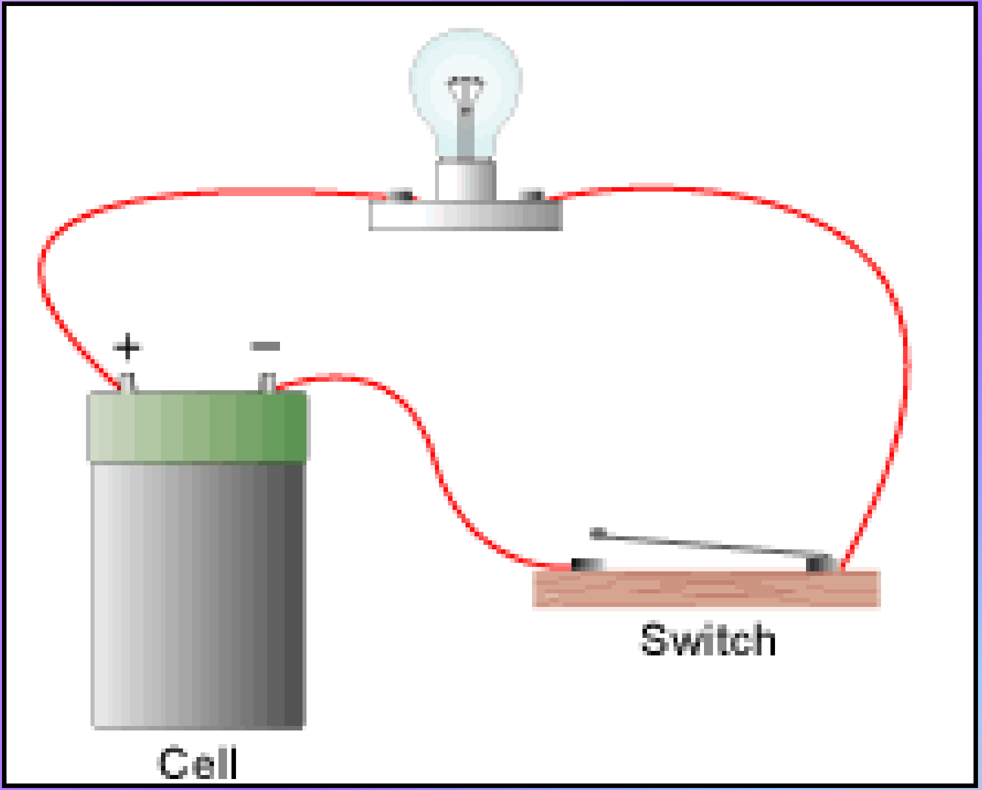
- Define electricity.
- Describe the components of an electric circuit.
- Explain the difference between a closed circuit and an open circuit.

Part 4.

Is the switch open or closed?

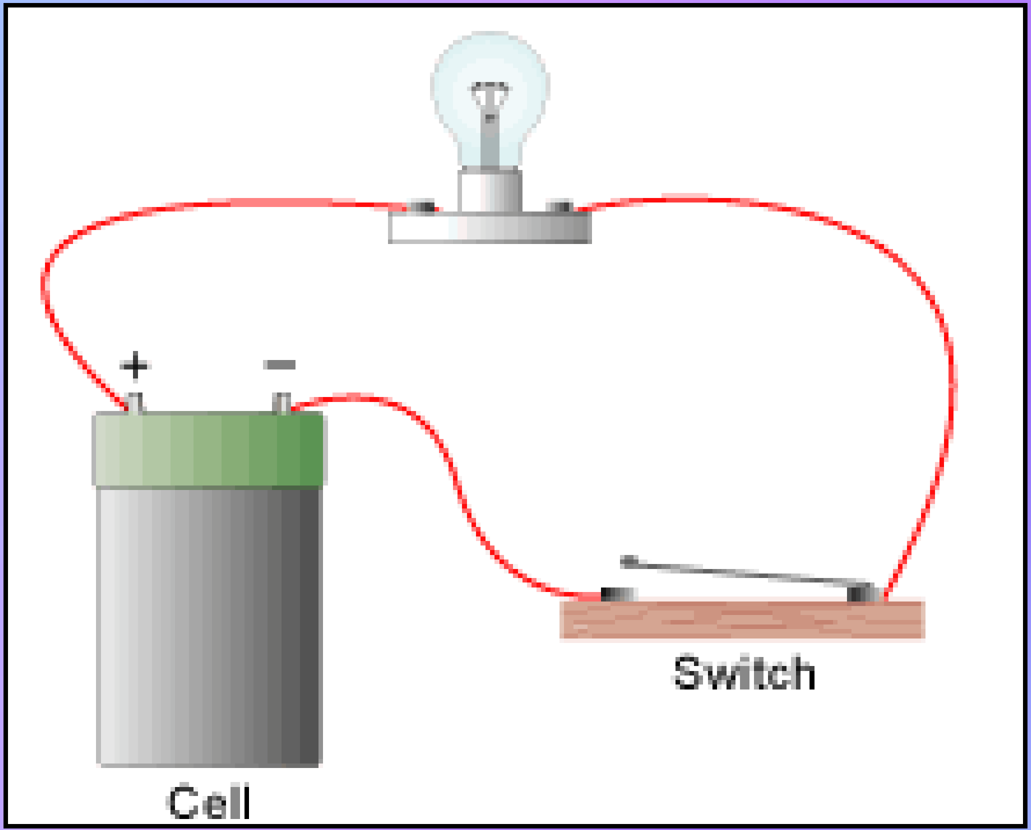
Would the light be on or off?

1. Open and On
2. ★ Open and Off
3. Closed and On
4. Closed and Off



Part 4.

The Switch works when the lever is down and touching the metal – this completes the circuit.



Part 5. a

Which of the following materials can electricity NOT travel through?

1. **metal**
2. **water**
3. **air**

What are conductors?

material through which electric current flows easily.

What are insulators?

material through which electric current cannot move

BACKGROUND

Key Questions before Voltage and Current lab

- **What “flow of understanding” provides the necessary foundation for an understanding of electricity?**

- **How does electricity behave?**

Electric Circuits

Provide a complete path through which electricity can travel

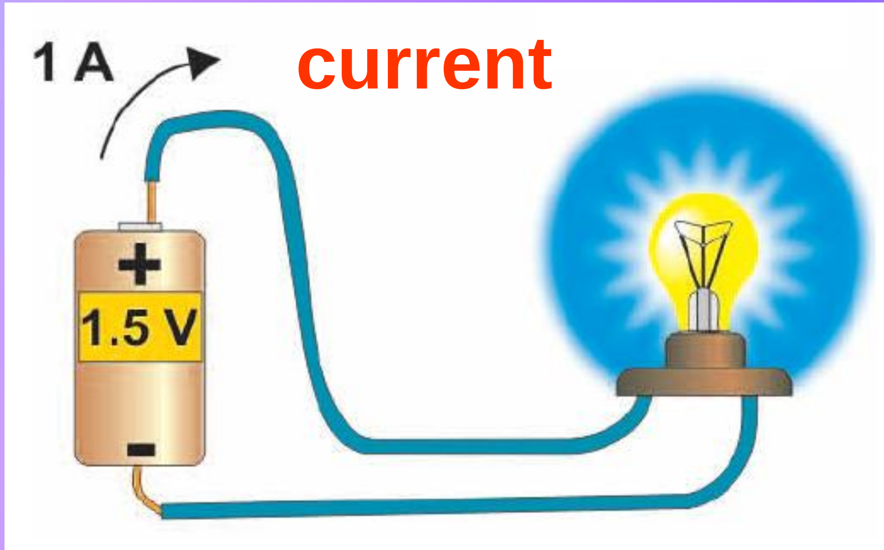
Electric Circuits aren't confined to appliances

wires and devices built by people

- **Nerves in body are an electric current connection between muscles and the brain**
- **Tail of the electric eel moves current when doing the "work" of stunning a fish it shocks**
- **Earth makes a giant circuit when lightning carries current between the clouds and the ground.**

Electric current

- *Electric current* **is caused by moving electric charge.**
- **Electric current comes from the motion of** ***electrons*****.**

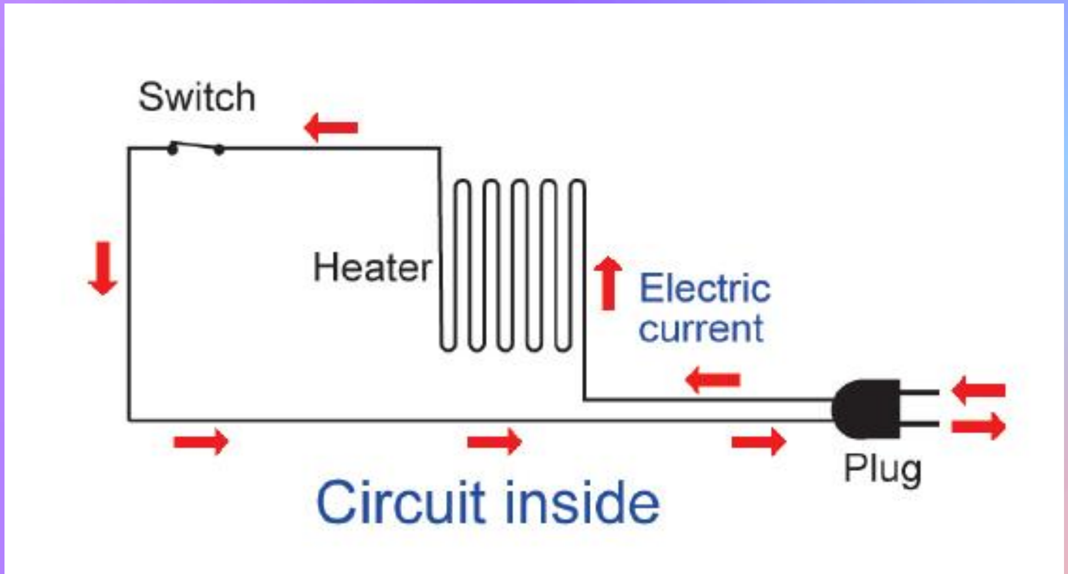


Electric current

- Electric current is similar in some ways to a current of water.
- Like electric current, water current can carry energy and do work.
- A waterwheel turns when a current of water exerts a force on it.

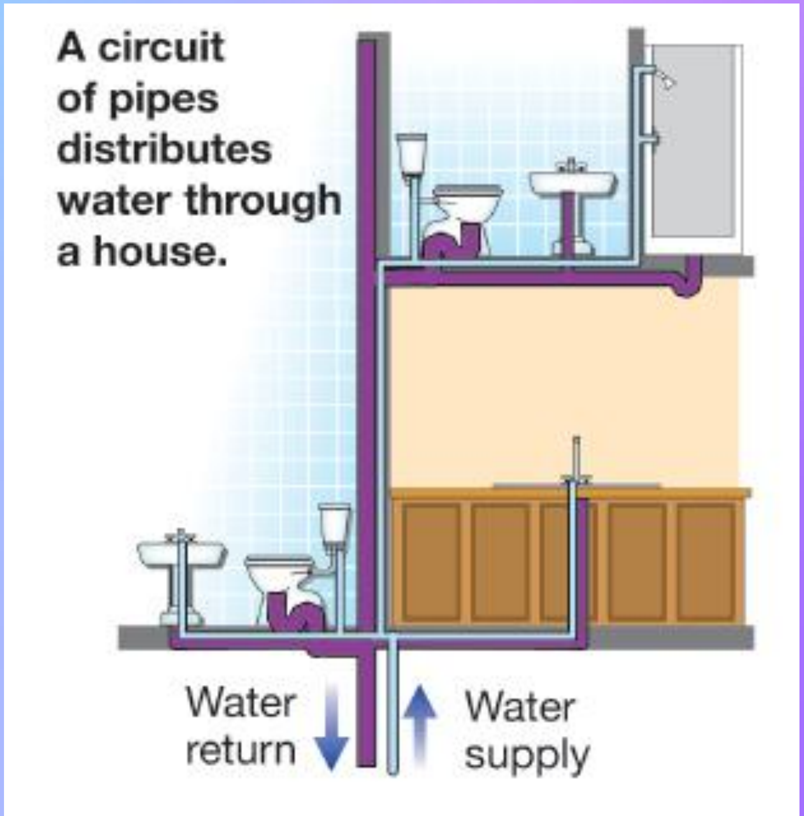
Electric Circuits

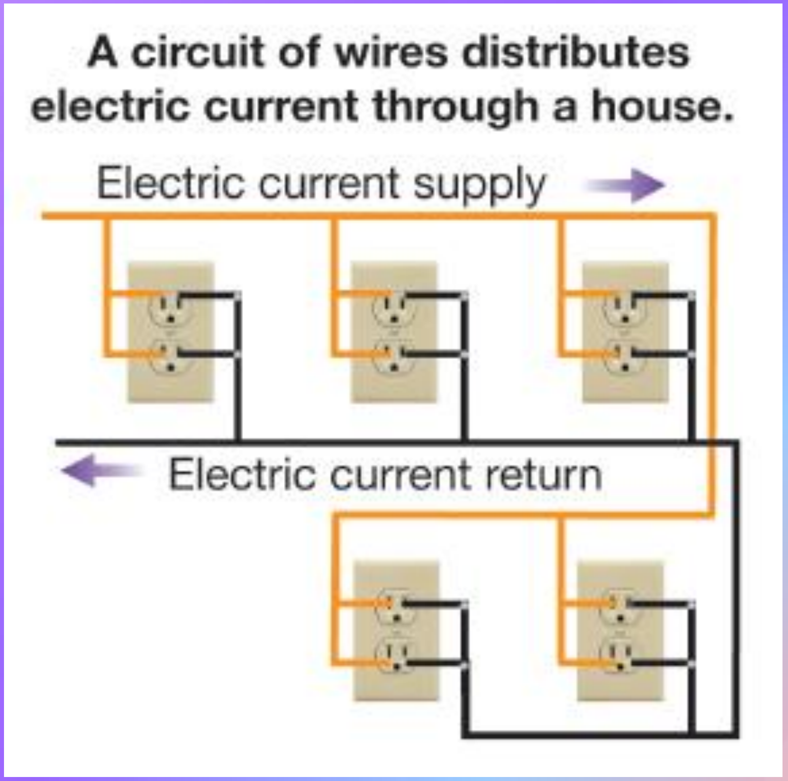
- An *electric circuit* is a complete path through which electric current travels.
- A good example of a circuit is the one found in an electric toaster.



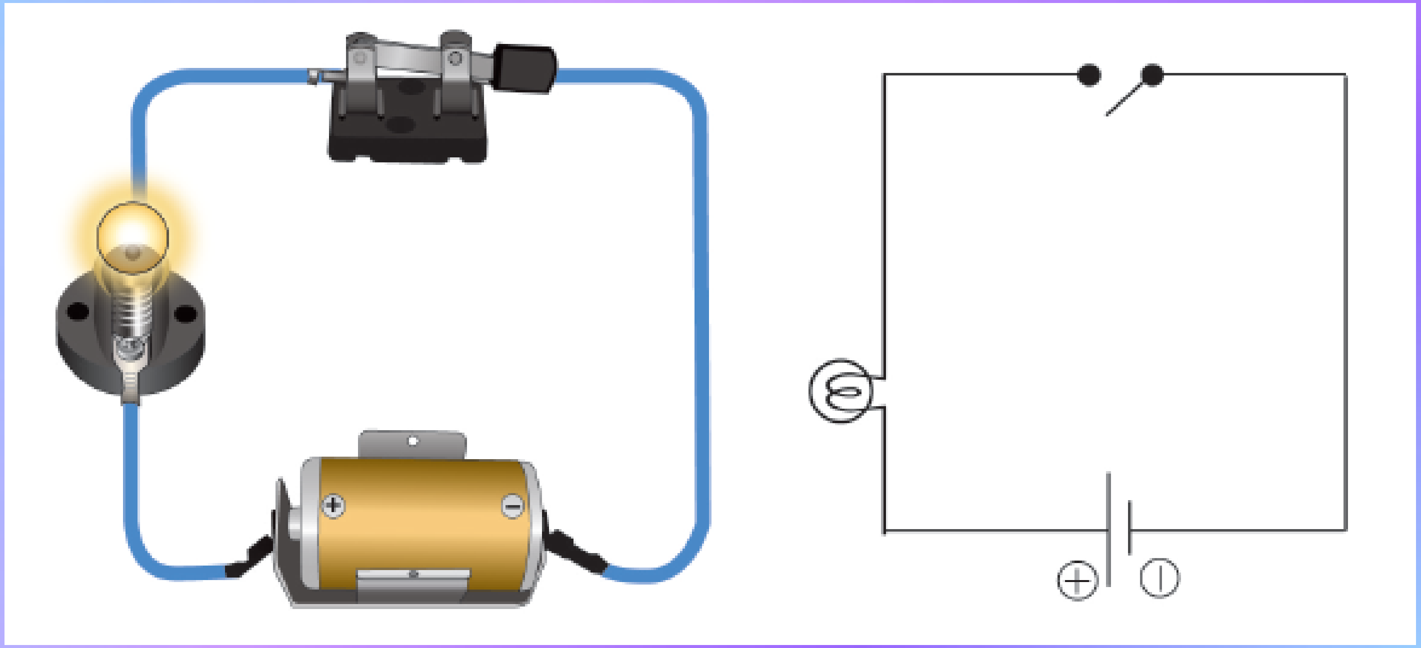
Electric Circuits

- **Wires in electric circuits are similar in some ways to pipes and hoses that carry water.**





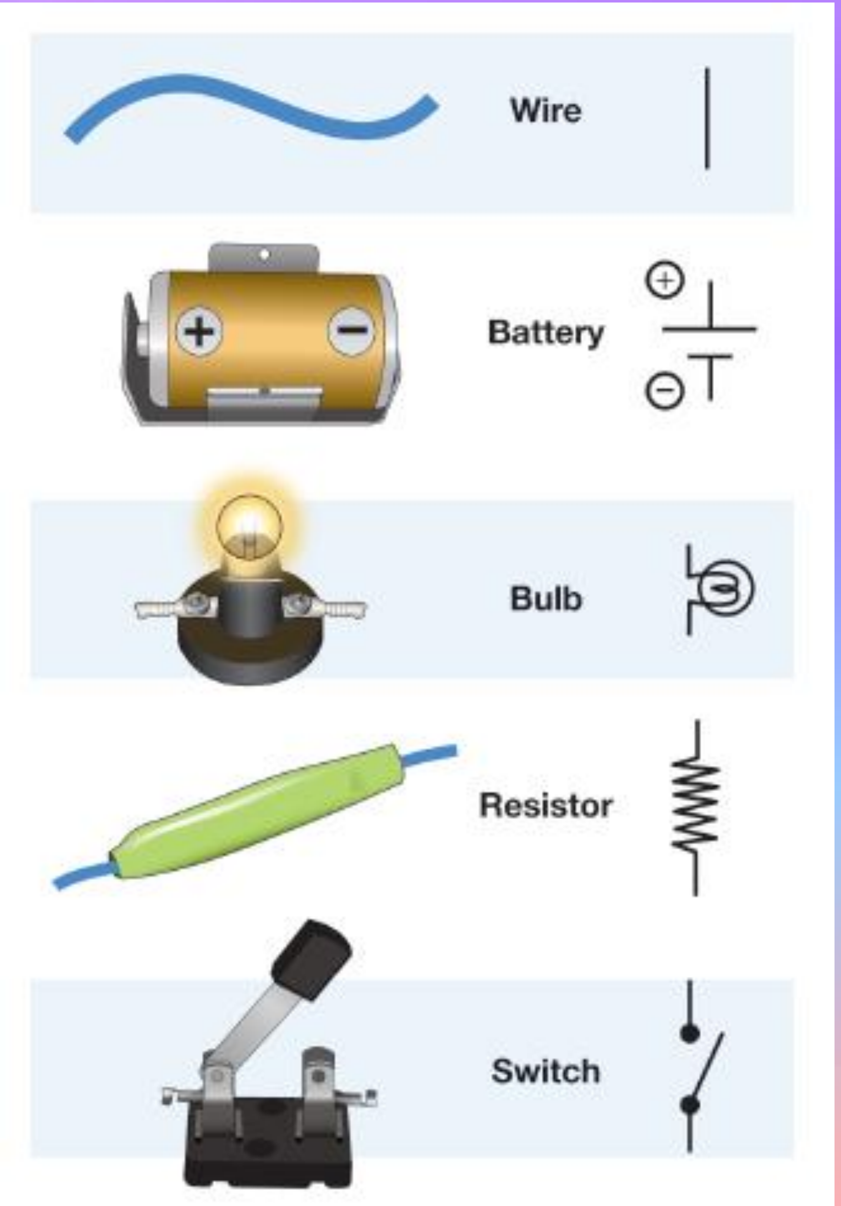
Electric Circuits



- When drawing a *circuit diagram*, symbols are used to represent each part of the circuit.

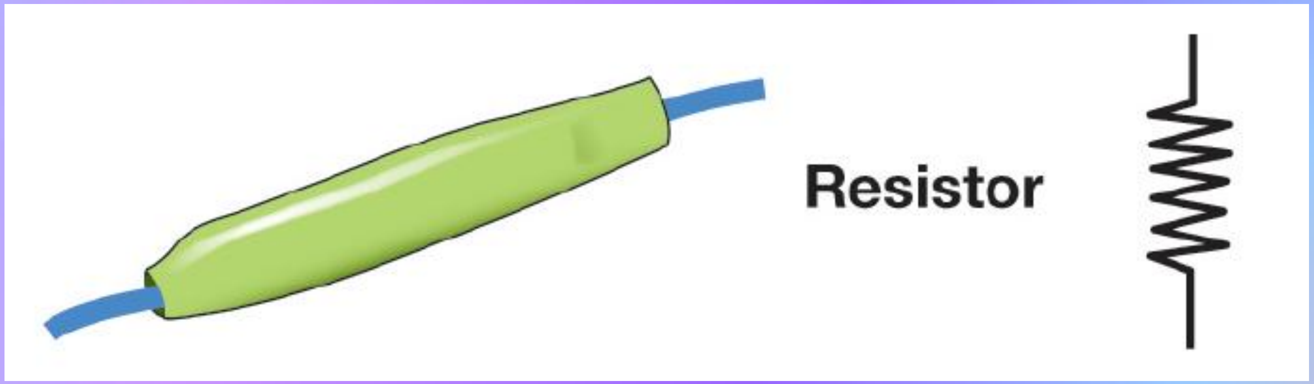
Electric Circuits

- ***Electrical symbols*** **are quicker and easier to draw than realistic pictures of the components.**

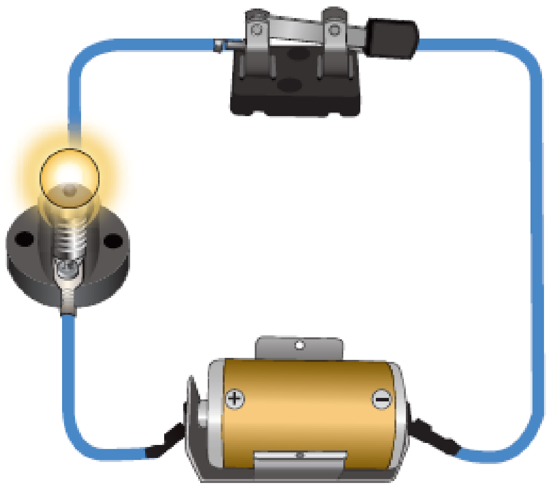


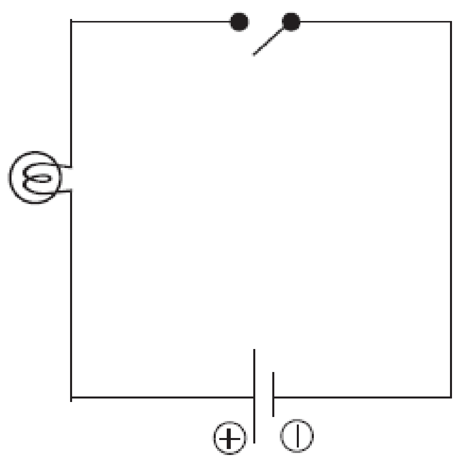
Resistors

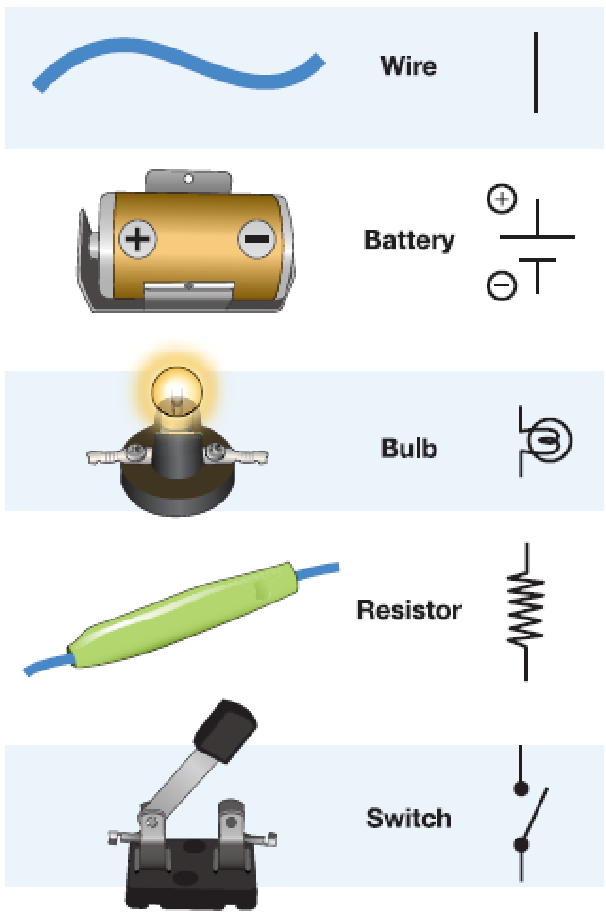
- A *resistor* is an electrical device that uses the energy carried by electric current in a specific way.
- Any electrical device that uses energy can be shown with a resistor symbol.



Circuit Diagrams and Electrical Symbols



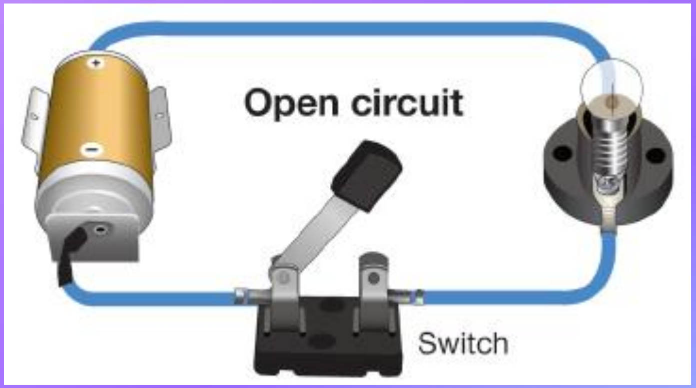


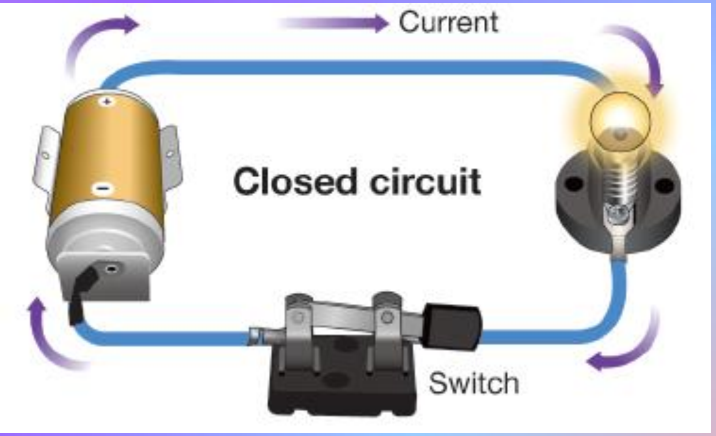


Current in a circuit

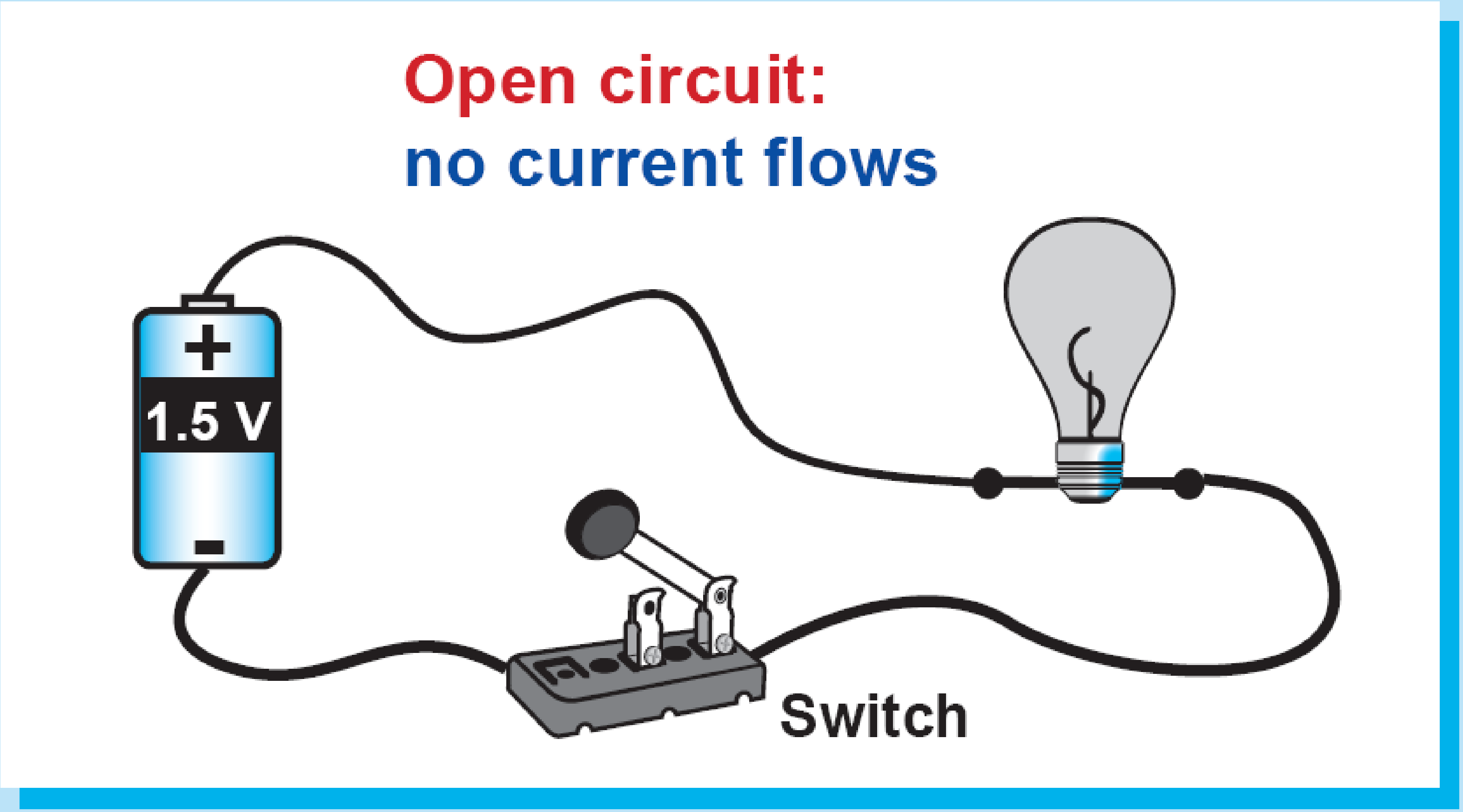
- **Current only flows when there is a complete and unbroken path, or a *closed circuit*.**

- **Flipping a switch to the “off” position creates an open circuit by making a break in the wire.**

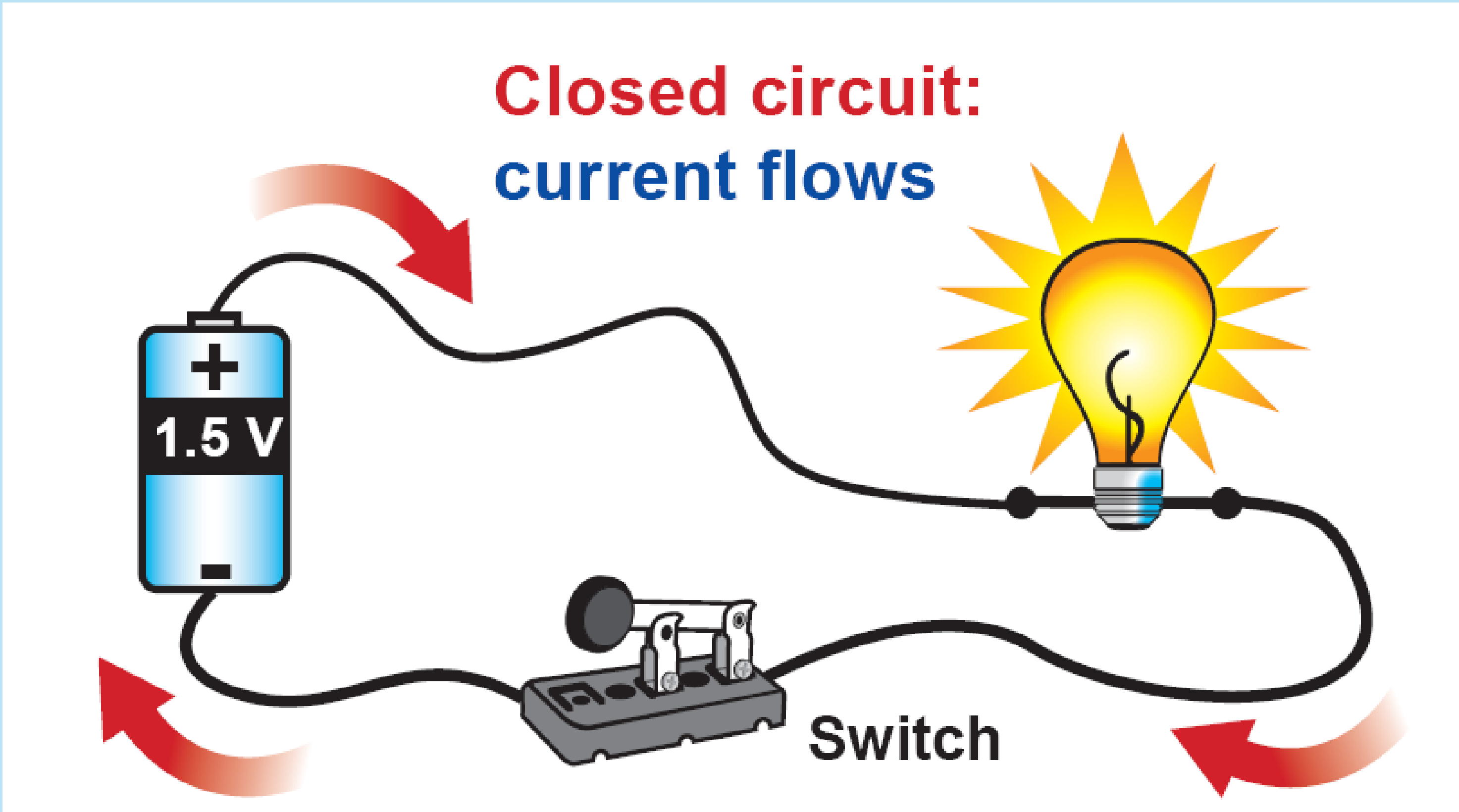




Open Circuit and Current



Closed Circuit and Current



Electric Circuits

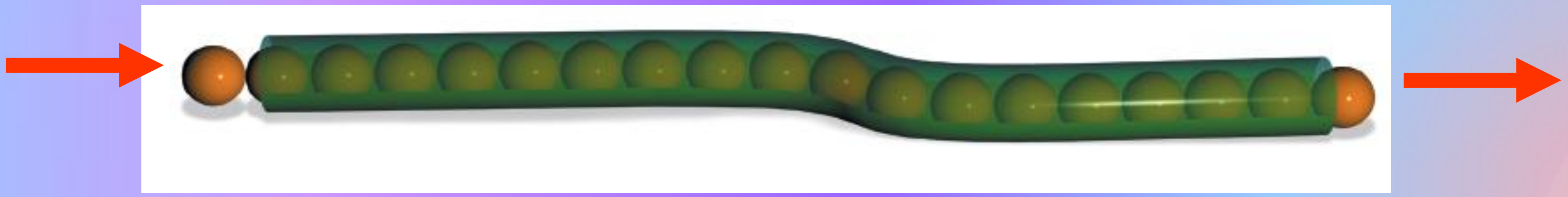
Part Two: Current and Voltage

Learning Goals

- **Explain how current flows in an electric circuit.**
- **Define voltage and describe how it is measured.**
- **Discuss the function of a battery in an electric circuit.**

Current and voltage

- *Electric current* is measured in units called *amperes*, or amps (A) for short.
- One amp is a flow of a certain quantity of electricity in one second.
- The amount of electric current entering a circuit always equals the amount exiting the circuit.

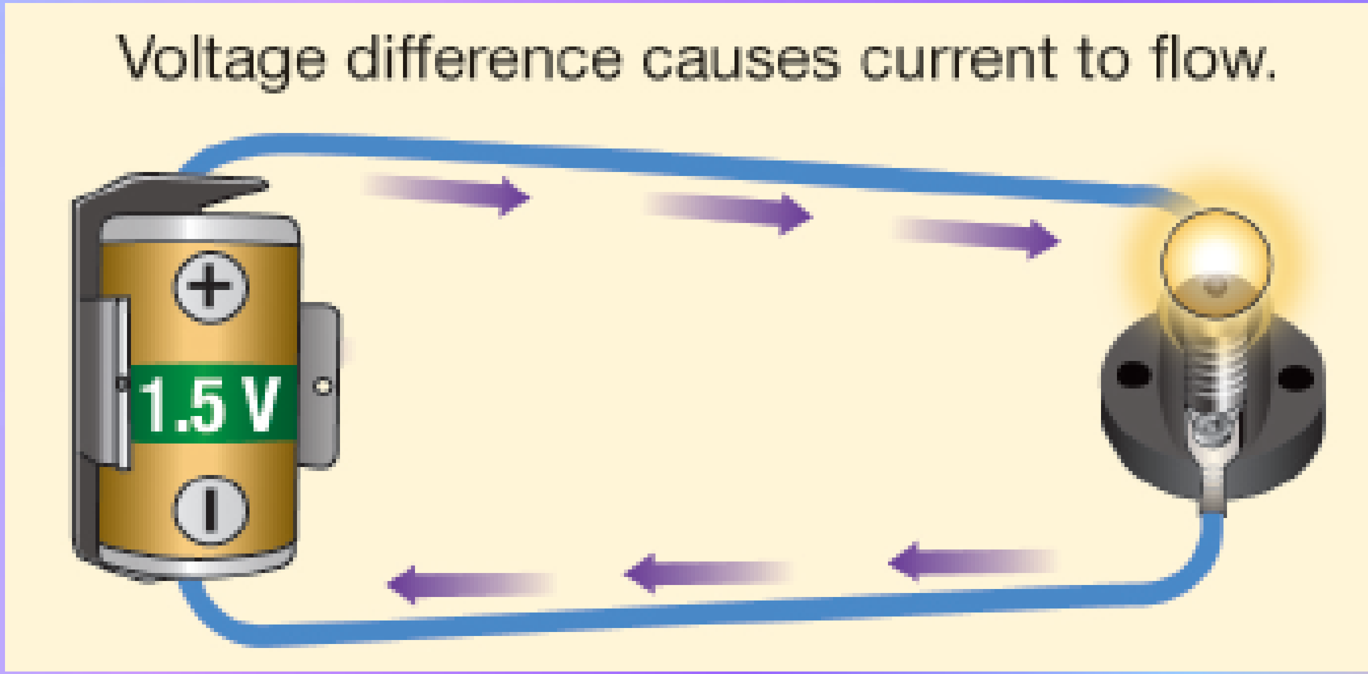


Voltage

- ***Voltage*** **is a measure of electric *potential energy*, just like height is a measure of gravitational potential energy.**
- **Voltage is measured in *volts* (V).**
- **A voltage difference of 1 volt means 1 amp of current does 1 joule of work in 1 second.**

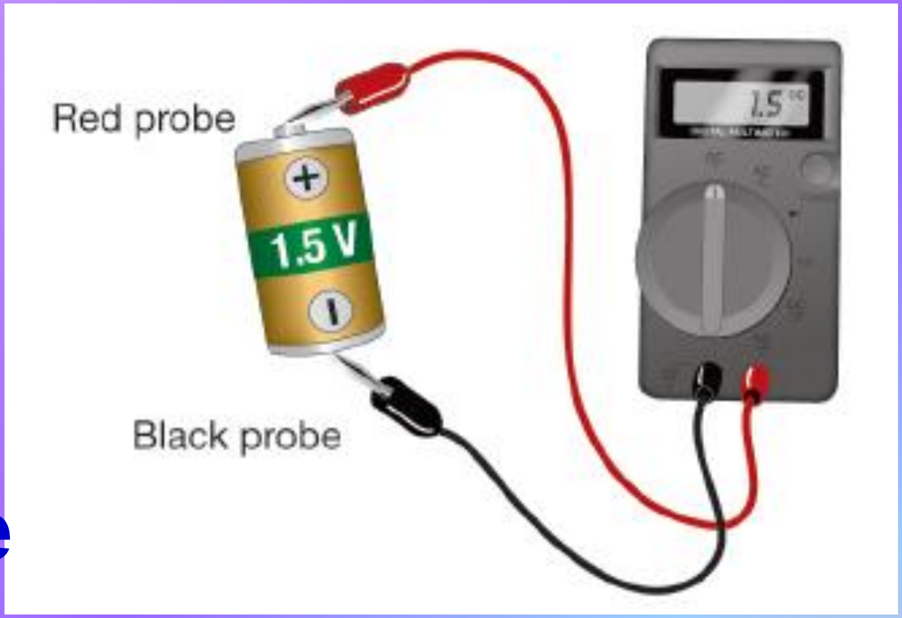
Voltage

- **A <u>difference</u> in voltage provides the energy that causes current to flow.**



Voltage

- A useful meter is a ***multimeter*, which can** measure voltage or current, and sometimes resistance.



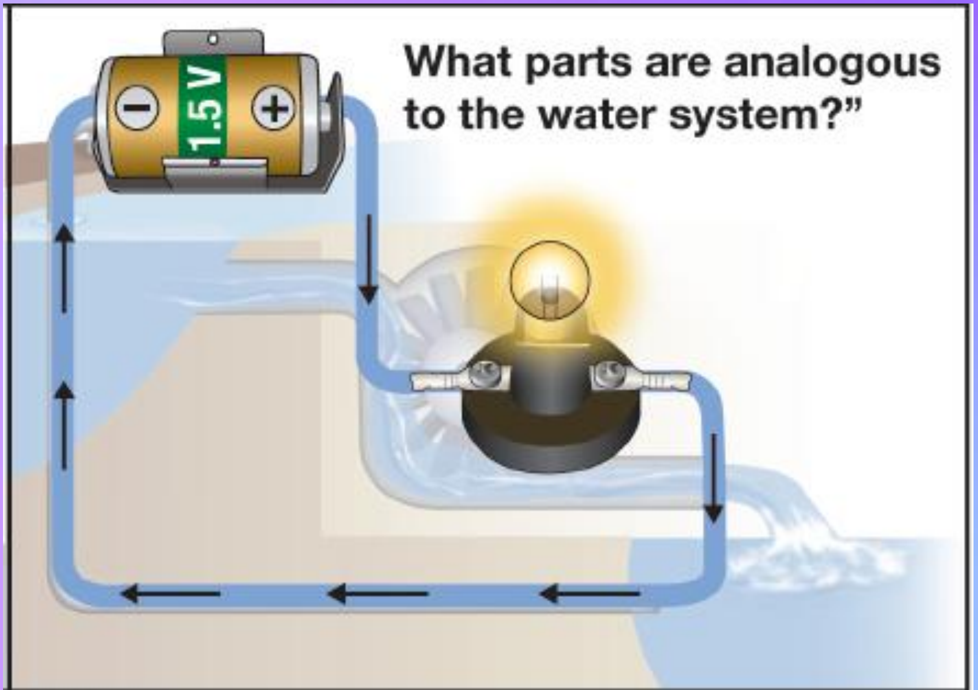
- To measure voltage, the meter's probes are touched to two places in a circuit or across a battery.

Batteries

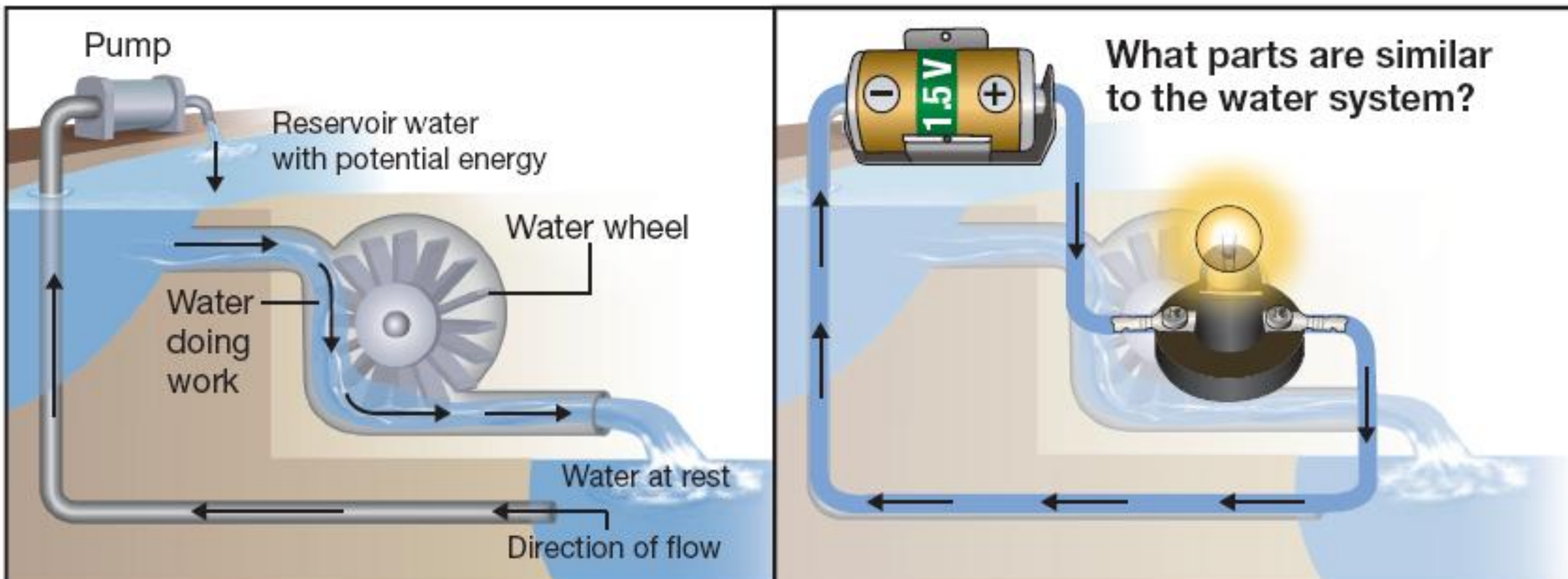
- A *battery* uses stored chemical energy to create the voltage difference.
- Three 1.5-volt batteries can be stacked to make a total voltage of 4.5 volts in a flashlight.

Batteries

- **A pump is like a battery because it brings water from a position of low energy to high energy.**



Water/Electric Circuit Analogy

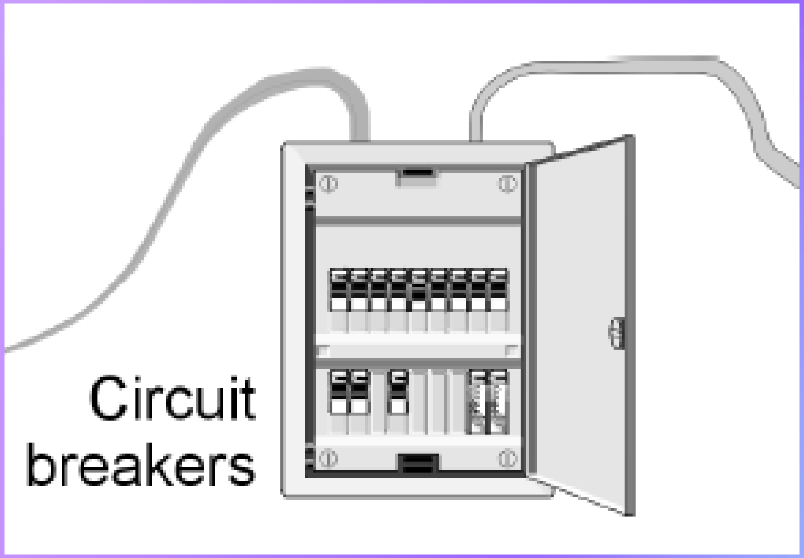


Measuring current

- If you want to measure current you must force the current to pass *through* the meter.
- Multimeters can measure two types of current: *alternating current* (AC) and *direct current* (DC).

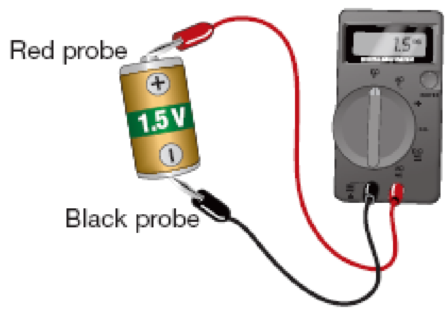
Measuring current

- Circuit breakers and fuses are two kinds of devices that protect circuits from too much current by making a break that stops the current.

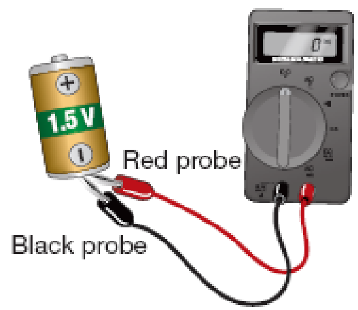


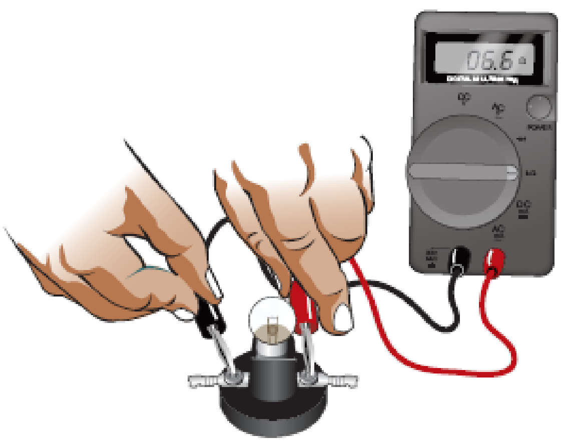
Measuring Voltage, Current, and Resistance

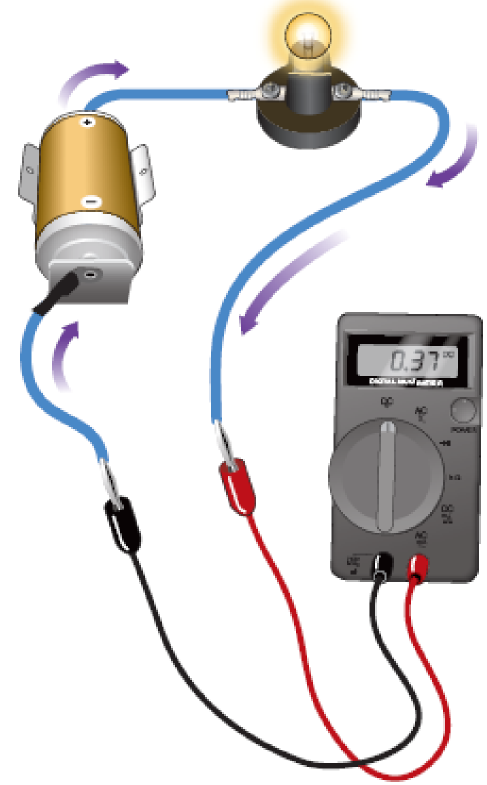
A multimeter can measure a battery's voltage if one probe touches each end.



The meter reads zero volts if both probes are connected at the same place.







Electric Circuits

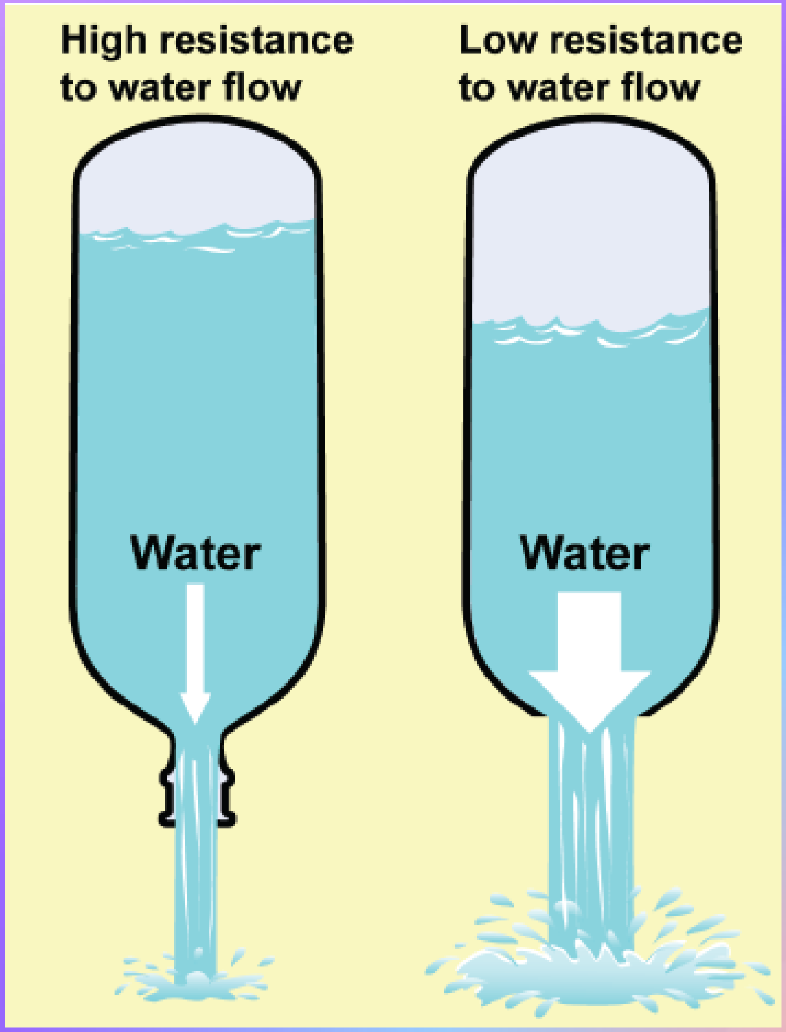
Part Three: Resistance and Ohm’s Law

Chapter Learning Goals

- **Use Ohm's law to relate current, voltage and resistance.**
- **Apply Ohm's law to solve problems.**
- **Classify materials as conductors, insulators, and semiconductors.**

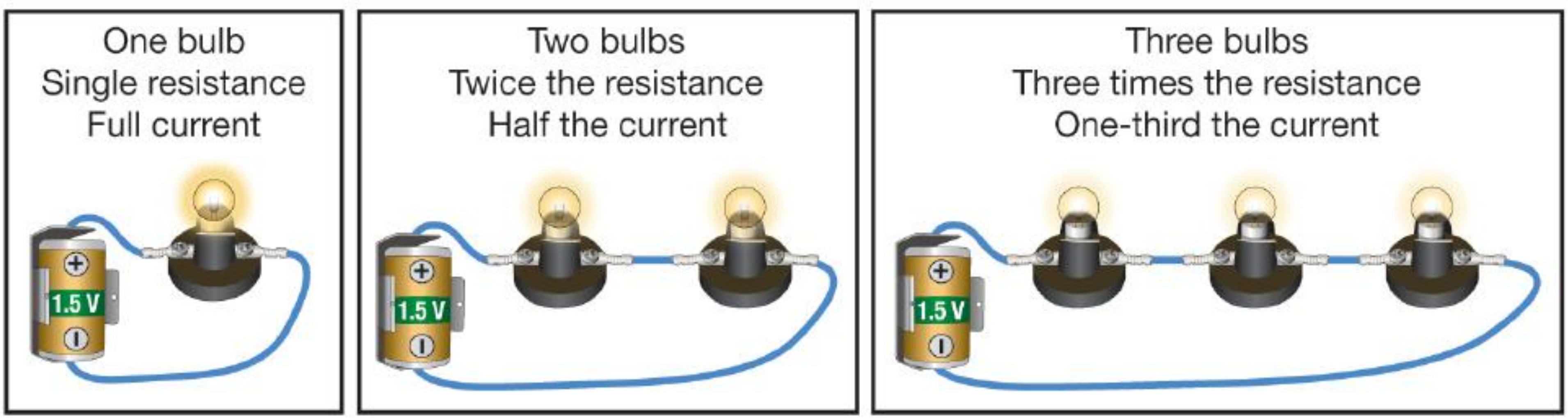
Resistance

- *Resistance* is the measure of how strongly an object resists current flowing through it.
- The relationship between electric current and resistance can be compared with water flowing from the open end of a bottle.



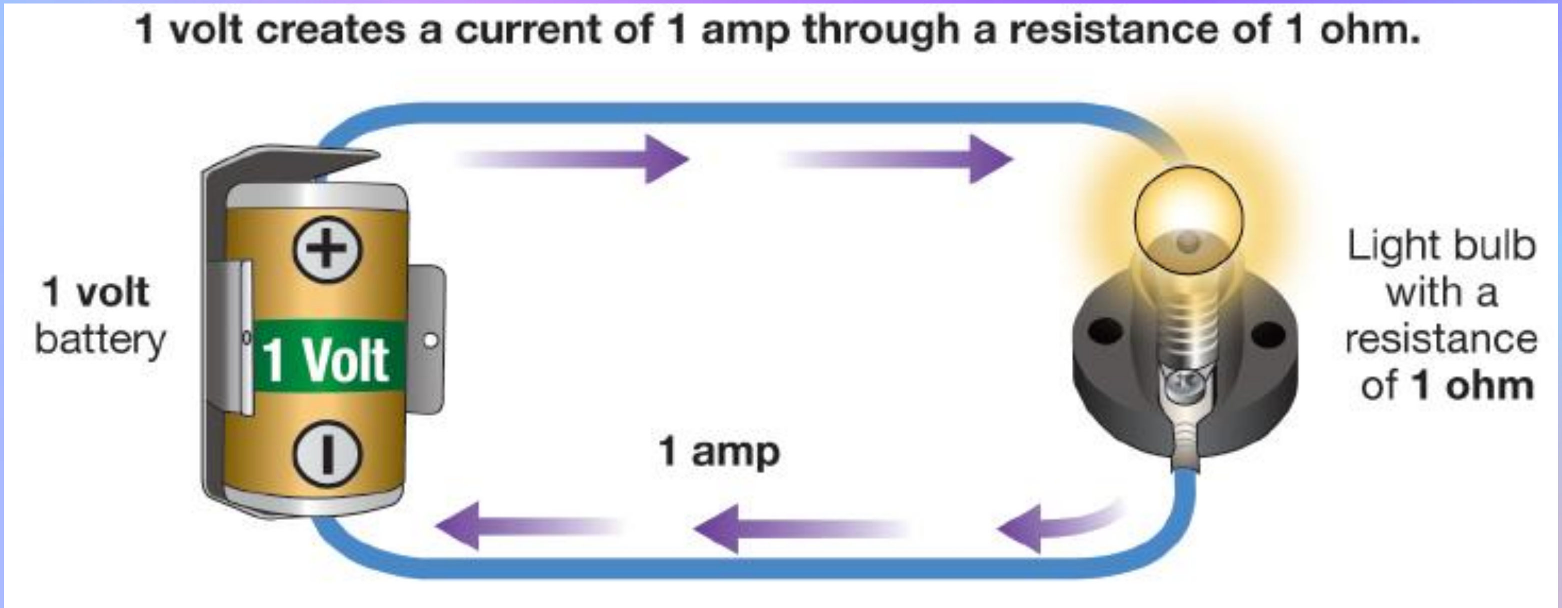
Resistance

- **The <u>total</u> amount of resistance in a circuit determines the amount of current in the circuit for a given voltage.**



Resistance

- **Electrical resistance is measured in units called *ohms*.**
- **This unit is abbreviated with the Greek letter *omega* (Ω).**



Ohm's Law INQUIRY→ you find the relationship

- **The current in a circuit depends on voltage and resistance.**
- ***Ohm's law*** **relates current, voltage, and resistance with one formula.**
- **Hint: If you know two of the three quantities, you can use Ohm's law to find the third.**
- **GO TO NEXT SLIDE AND STOP FOR LAB**

Ohm's Law INQUIRY→ you find the relationship

- *Ohm's law* **relates current, voltage, and resistance with one formula.**

STOP FOR LAB

- **Measure V, I,& R (blue)**
  …Find math relationships

- **Knowing V, measure I**
  …Then predict R
  ….. Then measure to confirm

- **Knowing V, Measure Green R**
  …. then predict I and confirm

Ohm's Law

- The current in a circuit depends on voltage and resistance.
- *Ohm's law* relates current, voltage, and resistance with one formula.

Equation	Gives you...	If you know...
$I = V/R$	current (I)	voltage and resistance
$V = IR$	voltage (V)	current and resistance
$R = V/I$	resistance (R)	voltage and current

Solving Problems: Ohm's Law

OHM'S LAW

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

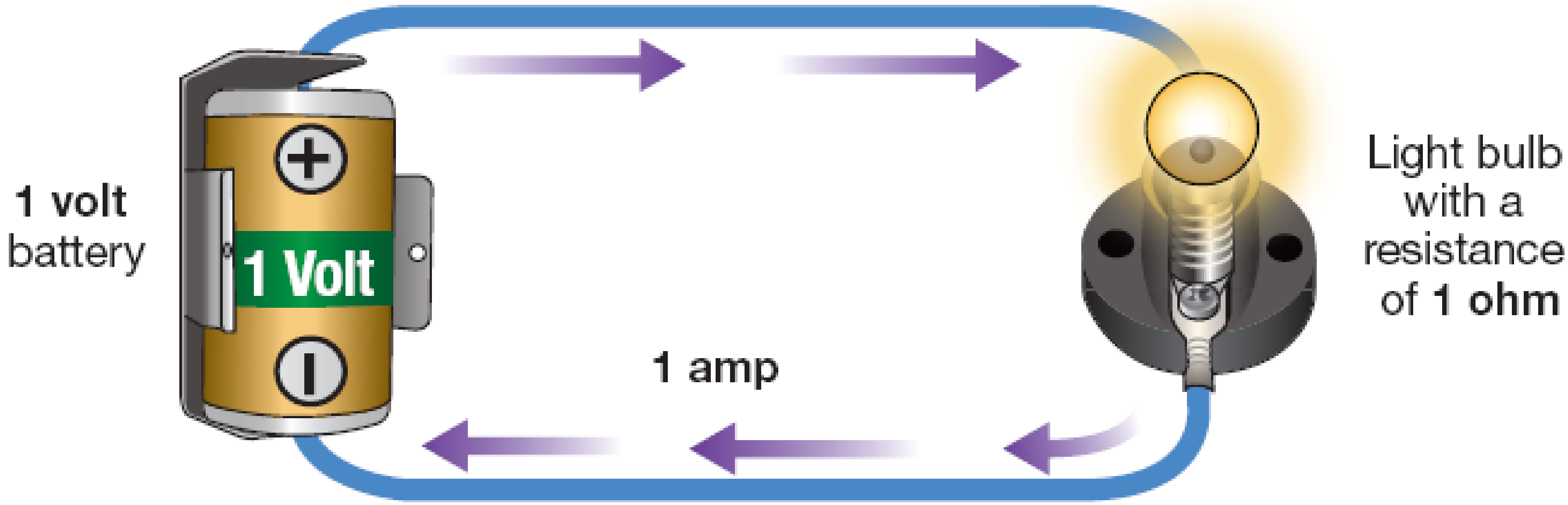
Current (amps, A)

Voltage (volts, V)

Resistance (ohms, Ω)

Volts, Amps, and Ohms

1 volt creates a current of 1 amp through a resistance of 1 ohm.



Solving Problems

- **A toaster oven has a resistance of 12 ohms and is plugged into a 120-volt outlet.**
- **How much current does it draw?**

Electric toaster

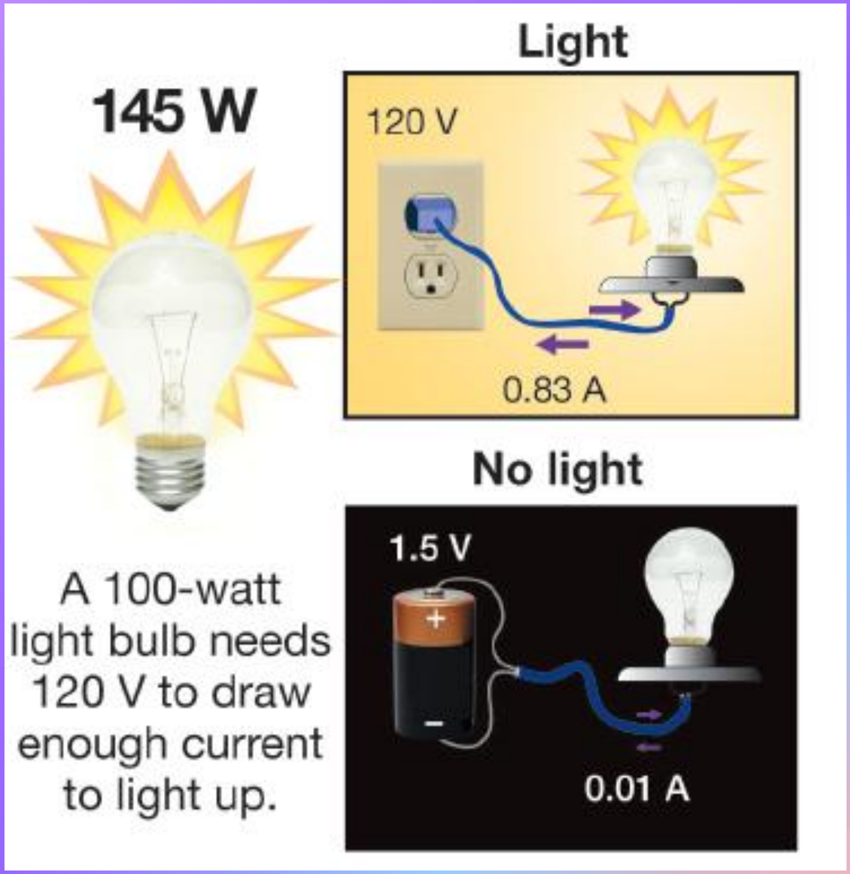
Solving Problems

1. **Looking for:**
   - …current in amps
2. **Given**
   - …R = 12 Ω; V = 120 V
3. **Relationships:**
   - $I = \frac{V}{R}$
4. **Solution**
   - $I = \frac{120\ V}{12\ \Omega}$ **= 10 A**

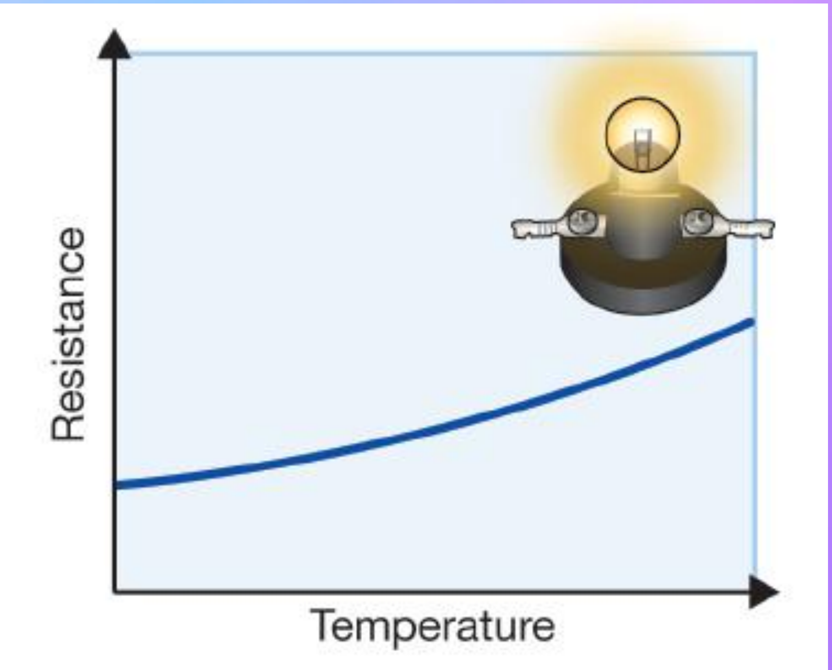
Electric toaster

Resistance of common objects

- **Every electrical device is designed with a resistor that causes the right amount of current to flow when the device is connected to voltage.**

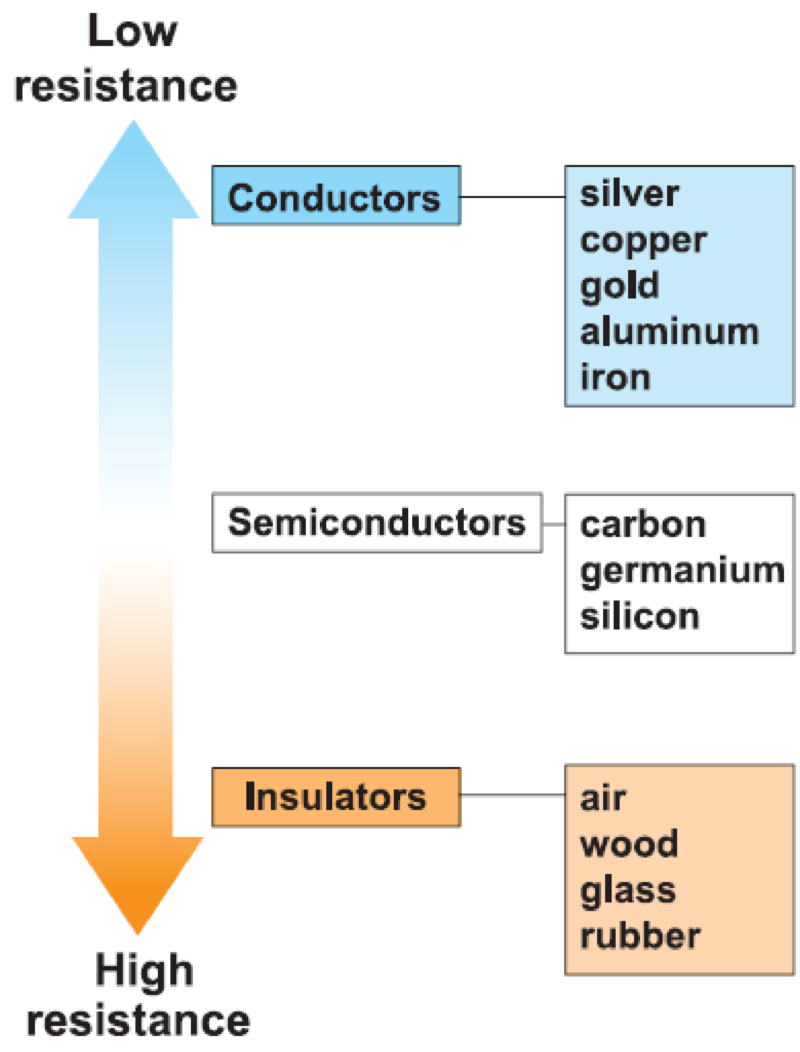


Resistance of common objects



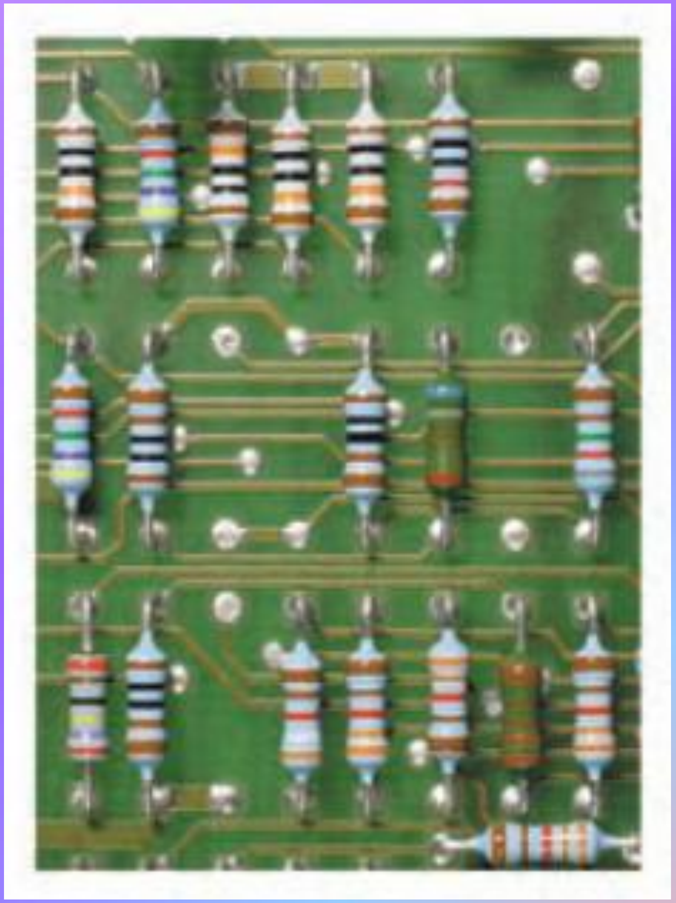
- The resistance of many electrical devices varies with temperature and current.
- A light bulb’s resistance increases when there is more current because the bulb gets hotter when more current passes through it.

Comparing Resistance of Materials

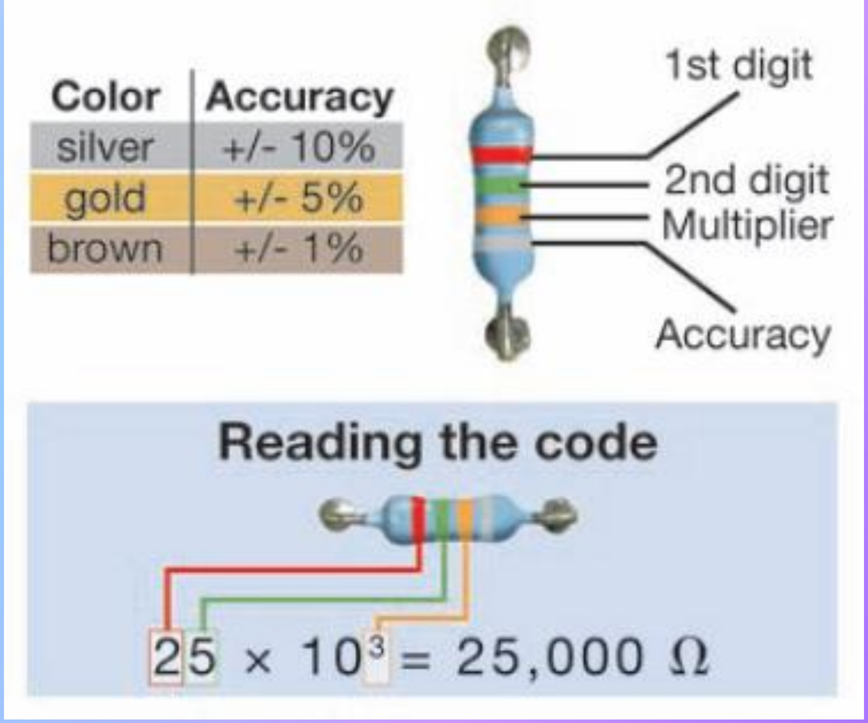


Resistors

- *Resistors* **are used to control the current in circuits.**
- **They are found in many common electronic devices such as computers, televisions, telephones, and stereos.**



Fixed Resistors



- *Fixed resistors* **have a resistance that cannot be changed.**
- **They are small skinny cylinders or rectangles with colored stripes that tells you the resistance on each one of them.**

Variable Resistors

- ***Variable resistors*, also called potentiometers, can be adjusted to have a resistance within a certain range.**
- **If you have ever turned a dimmer switch or volume control, you have used a potentiometer.**

Electric Circuits

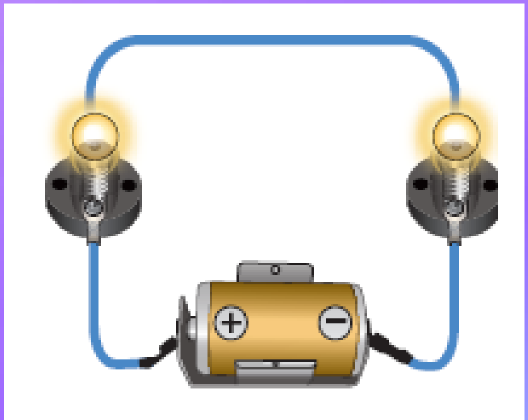
Part Four: Series Circuits

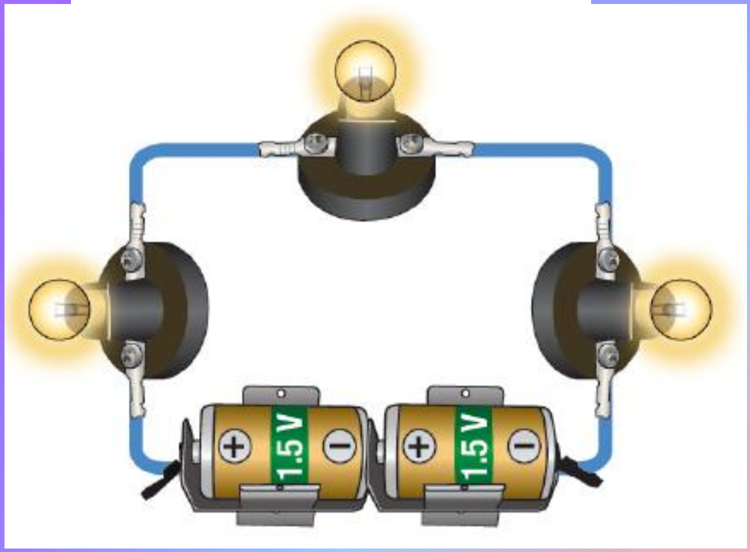
Chapter Learning Goals

- **Build and analyze series circuits.**
- **Apply Ohm's law to calculate the current in a series circuit.**
- **Explain how energy conservation applies to electric circuits.**

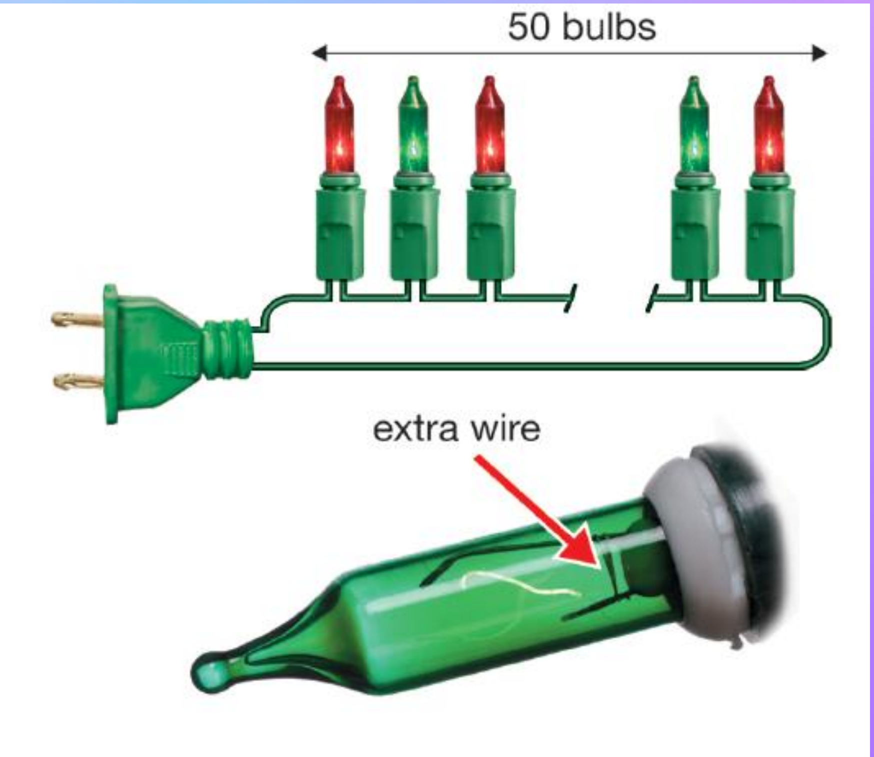
Series Circuits

- **In a *series* circuit, current can only take one path, so the current is the <u>same</u> at all points in the circuit.**





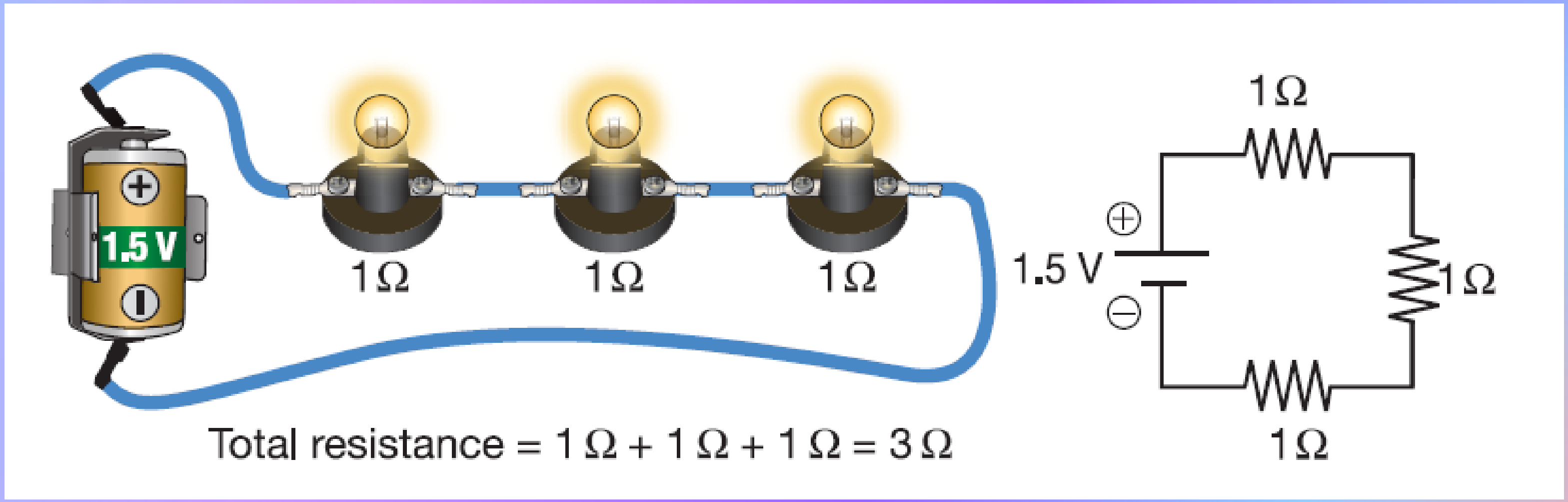
Electrical Systems



- Inexpensive strings of holiday lights are wired with the bulbs in series.
- If you remove one of the bulbs from its socket, the whole string of mini bulbs will go out.

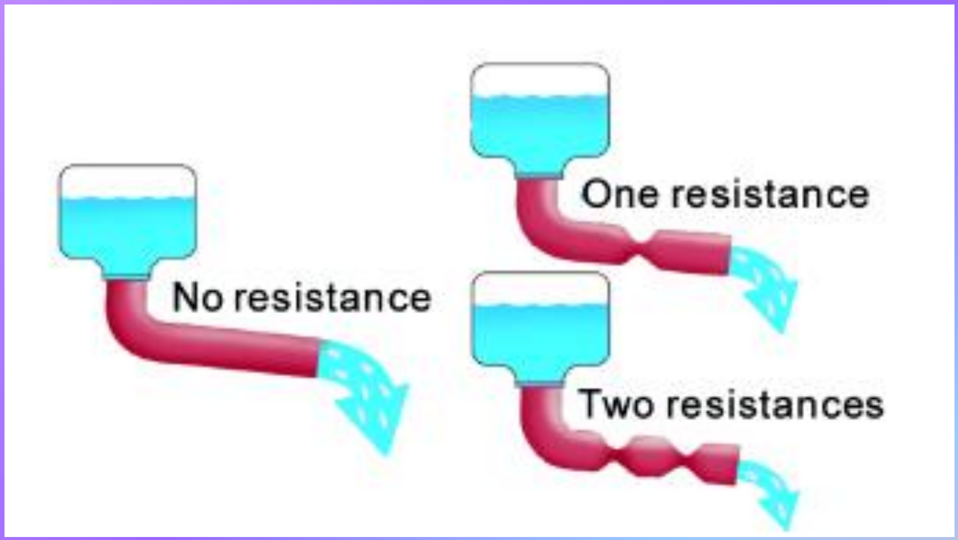
Current and resistance in series circuits

- **If you know the resistance of each device, you can find the total resistance of the circuit by adding up the resistance of each device.**



Current and resistance in series circuits

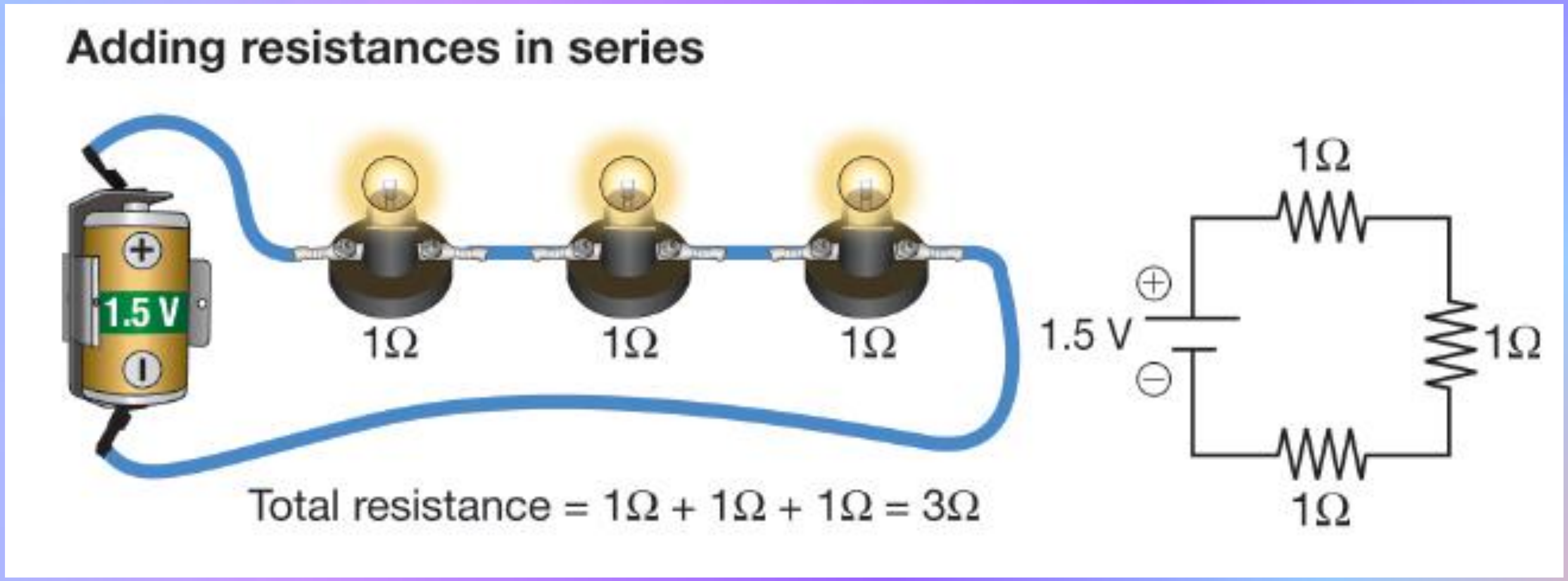
- Think of adding resistances like adding pinches to a hose.



- Each pinch adds some resistance.

Current and resistance in series circuits

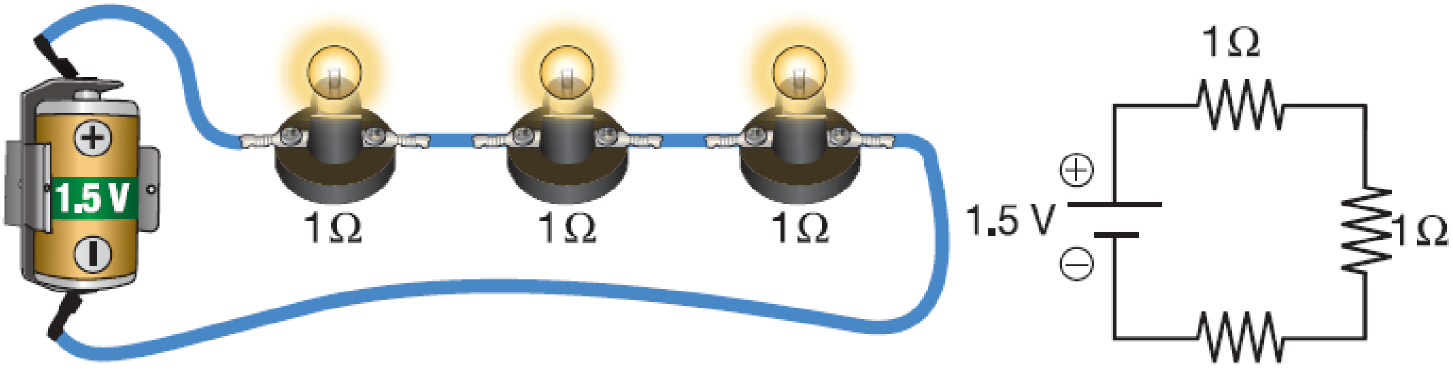
- **Everything has some resistance, even wires.**



Solving Problems: Current in a Series Circuit

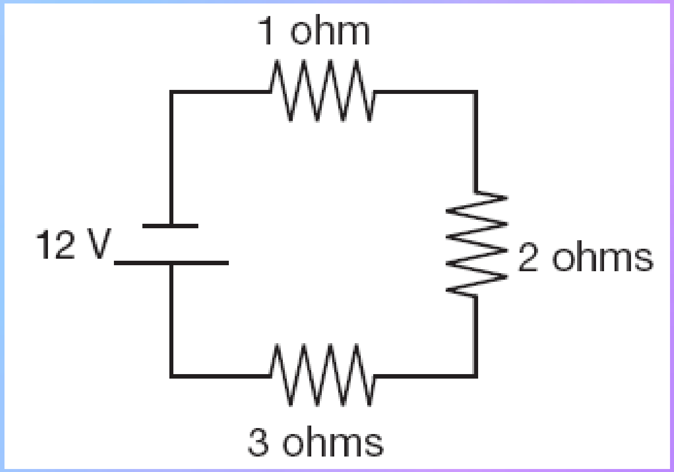
ADDING RESISTANCES IN A SERIES CIRCUIT

$$\underbrace{R_{total}}_{\text{Total resistance }(\Omega)} = \underbrace{R_1 + R_2 + R_3 + \ldots}_{\text{Individual resistances }(\Omega)}$$



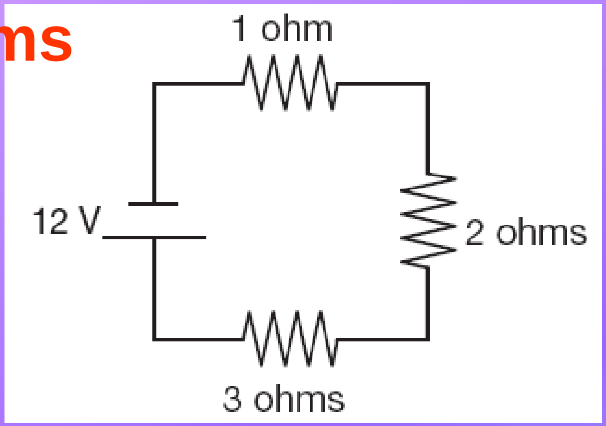
Total resistance = 1 Ω + 1 Ω + 1 Ω = 3 Ω

Solving Problems



- A series circuit contains a 12-V battery and three bulbs with resistances of1Ω, 2 Ω, and 3 Ω.
- What is the current in the circuit?

Solving Problems



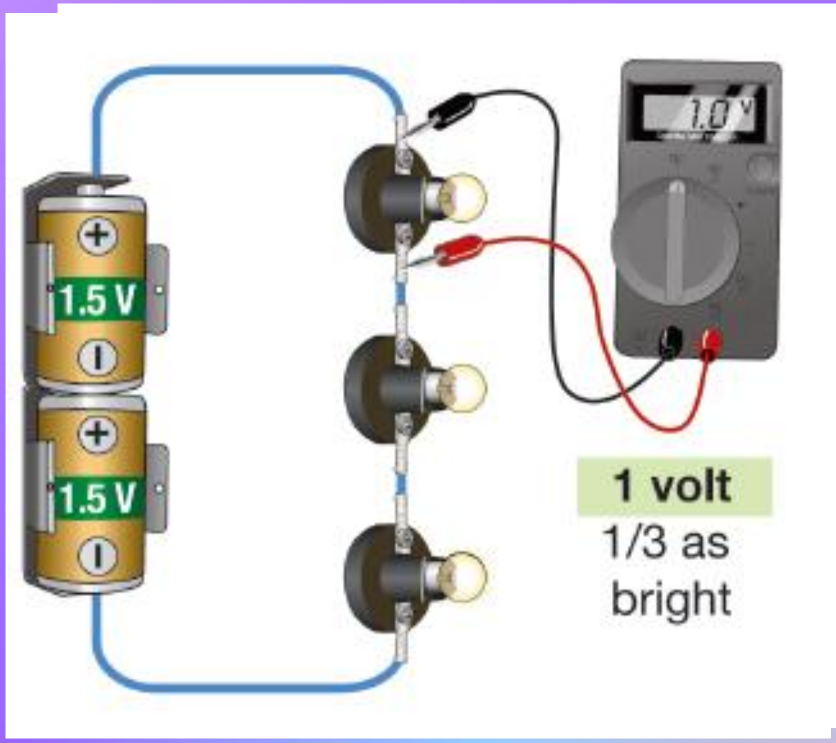
1. **Looking for:**
   - …current (amps)
2. **Given**
   - …Voltage = 12V; resistances = 1Ω, 2 Ω, 3 Ω.
3. **Relationships:**
   - $R_{tot} = R_1 + R_2 + R_3$
   - Ohm's Law $I = V \div R$
4. **Solution**
   - $R_{tot} = 6\ \Omega$
   - $I = 12\ V \div 6\ \Omega =$ **2 amps**

Energy and voltage in a series circuit

- Energy cannot be created or destroyed.
- The devices in a circuit convert electrical energy carried by the current into other forms of energy.
- As each device uses power, the power carried by the current is reduced.

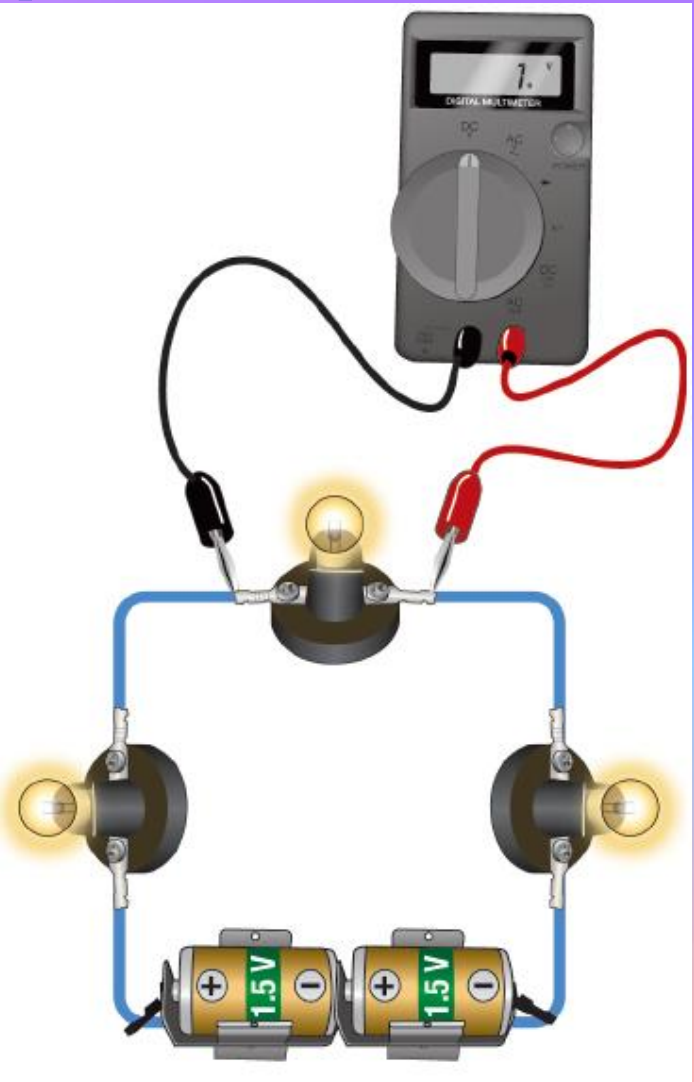
Voltage drop

- **As a result, the voltage is lower after each device that uses power.**
- **This is known as the *voltage drop*.**
- **The voltage drop is the difference in voltage across an electrical device that has current flowing through it.**

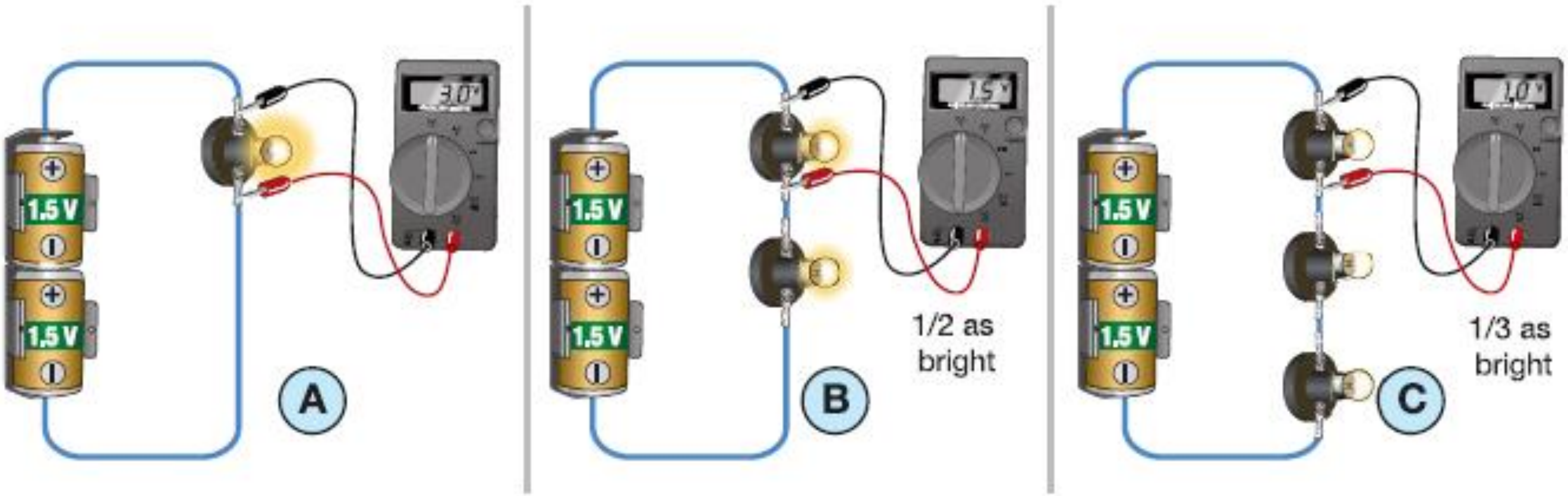


Voltage drop

- The law of conservation of energy also applies to a circuit.
- In this circuit, each bulb has a resistance of 1 ohm, so each has a voltage drop of 1 volt when 1 amp flows through the circuit.

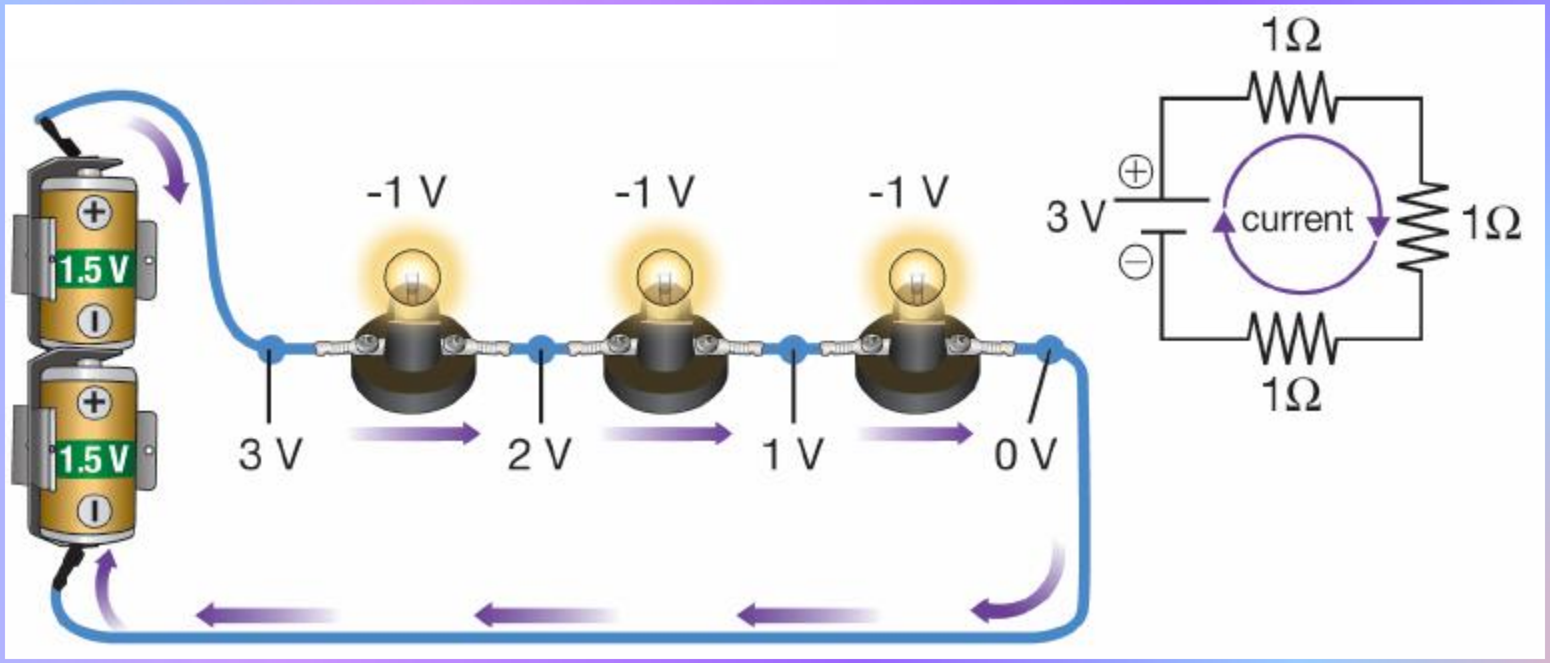


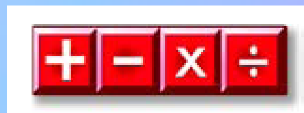
Voltage Drop



Voltage drop and Ohm's Law

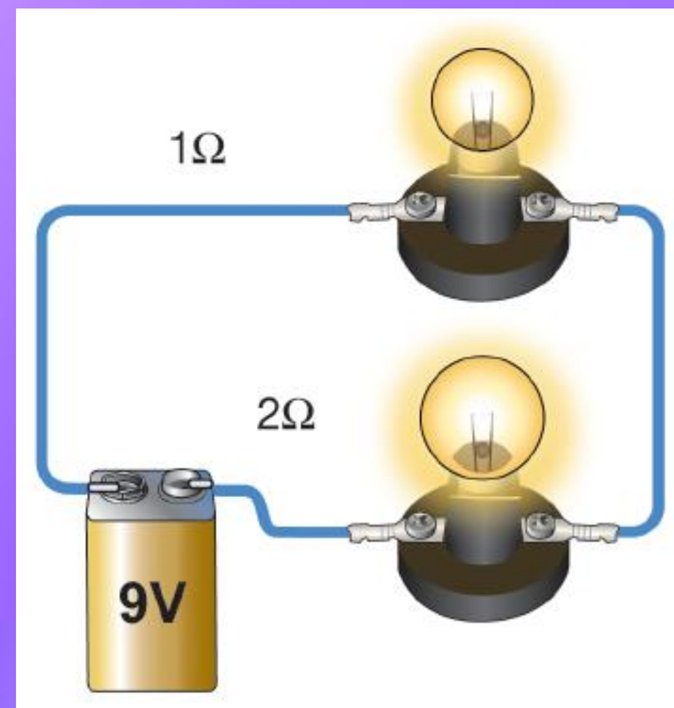
- ***Kirchhoff's voltage law*** **states that the total of all the voltage drops must add up to the battery's voltage.**





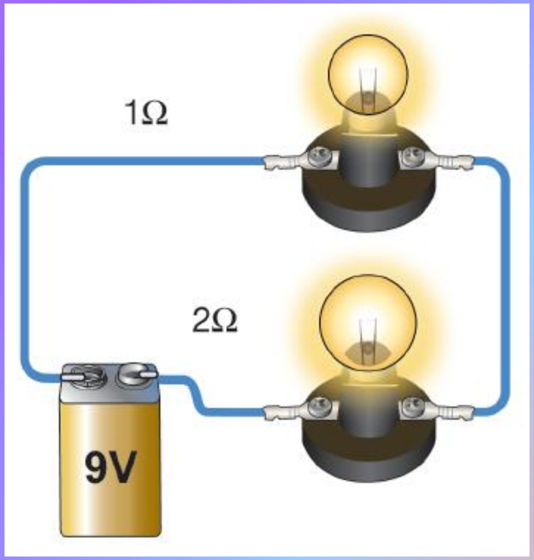
Solving Problems

- **The circuit shown contains a 9-volt battery, a 1-ohm bulb, and a 2-ohm bulb.**
- **Calculate the circuit's total resistance and current.**
- **Then find each bulb's voltage drop.**



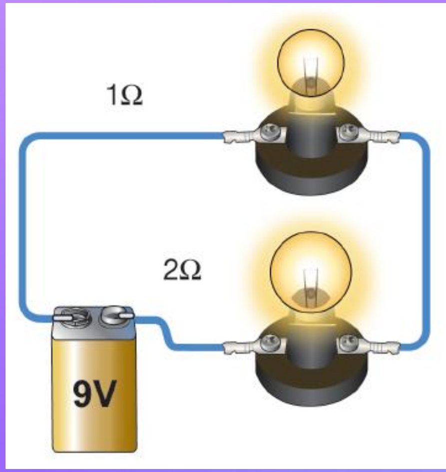
Solving Problems

1. **Looking for:**
   - …total resistance; voltage drop each bulb
2. **Given**
   - …Voltage = 9V; resistances = 1Ω, 2 Ω.
3. **Relationships:**
   - $R_{tot} = R_1 + R_2 + R_3$
   - Ohm's Law $I = V \div R$



4. **Solution- part 1**
   - $R_{tot} = 3\ \Omega$
   - $I = 9\ V \div 3\ \Omega =$ **3 amps**

Solving Problems



4. **Solution- part 2**
   - Use resistance to find current

     $I = 9\ V \div 3\ \Omega =$ **3 amps**

- **Solution- part 3**
   - Rearrange Ohm's law to solve for voltage
   - Use current to find each voltage drop

$V = I \times R$

$V_1 = (3\ A) \times (1\ \Omega) =$ **3 volts**

$V_2 = (3\ A) \times (2\ \Omega) =$ **6 volts** **(3 + 6) = 9 V**

Electric Circuits

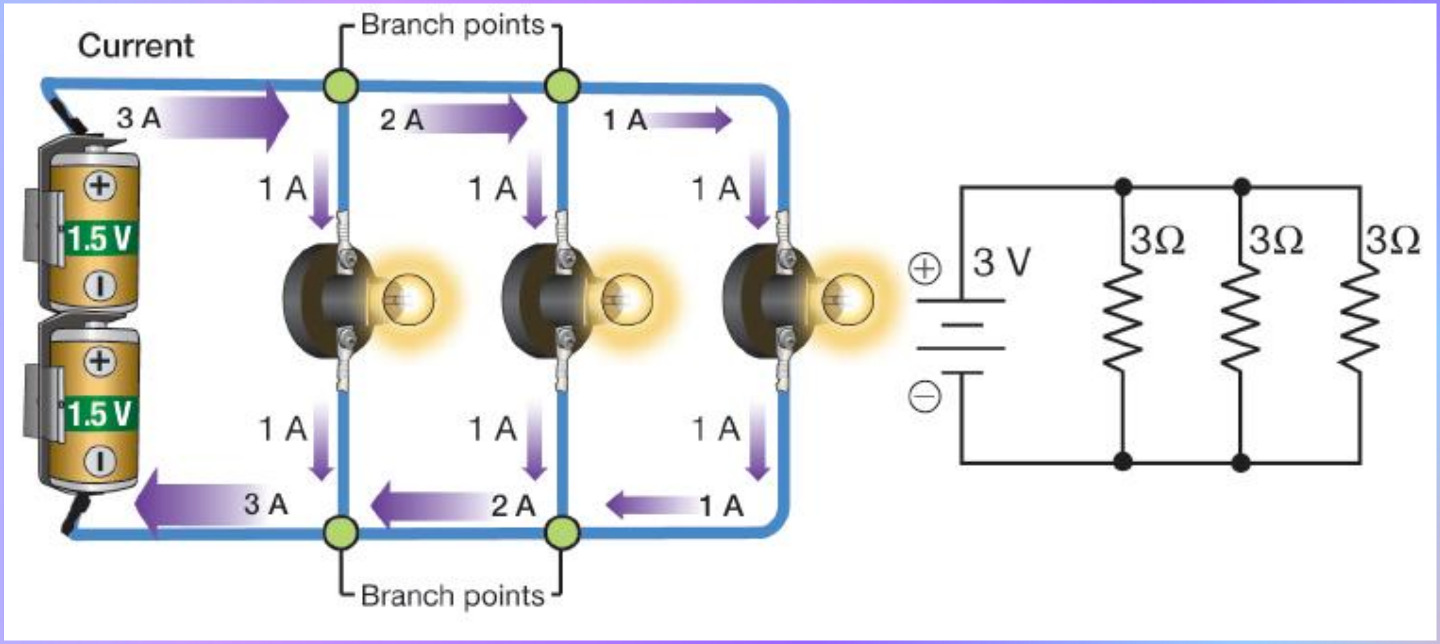
Part Five: Parallel Circuits

Chapter Learning Goals

- Build and analyze parallel circuits.
- Compare and contrast series and parallel circuits.
- Discuss advantages for using parallel circuits in homes.

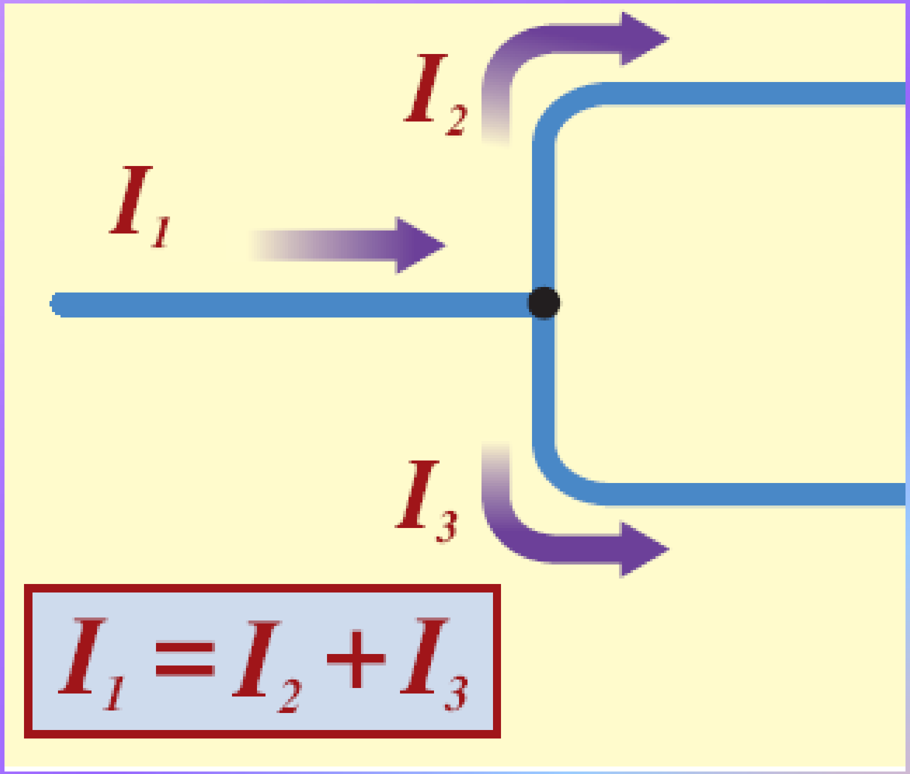
Parallel Circuits

- **In *parallel* circuits the current can take more than one path.**

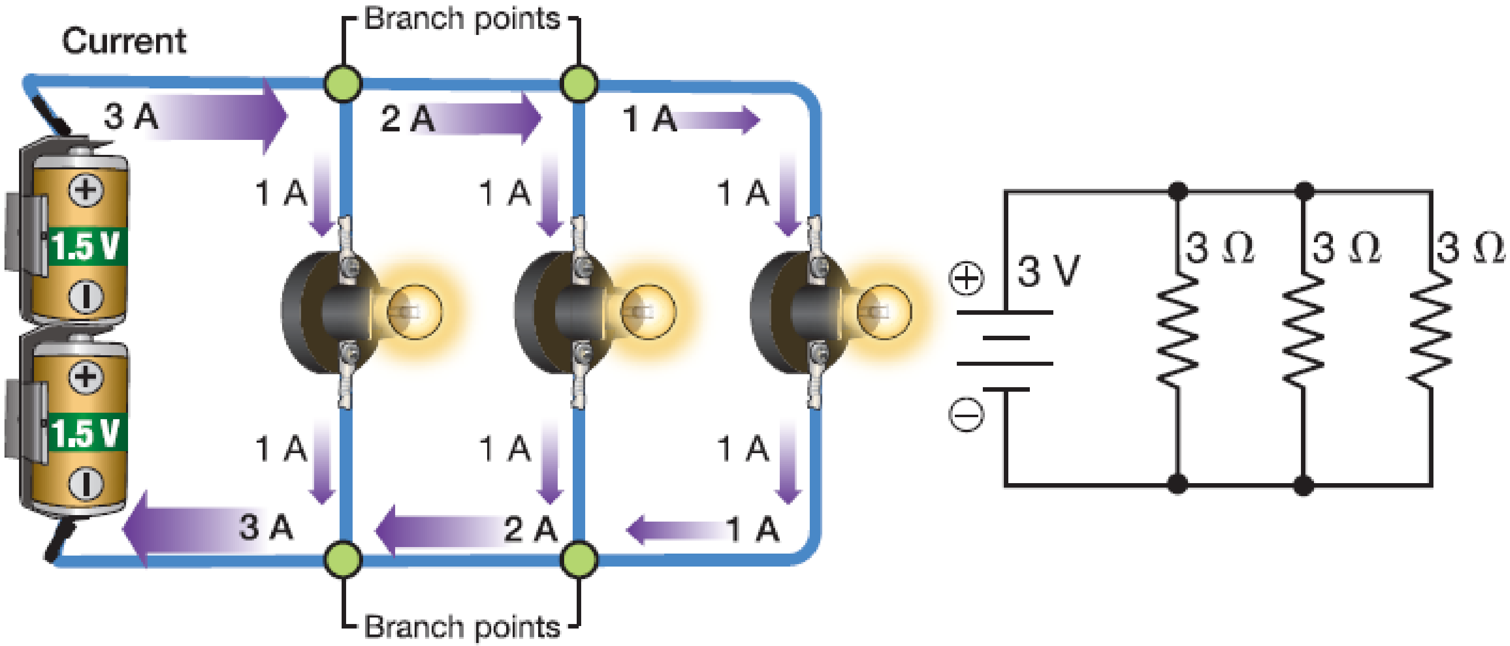


Kirchhoff's Current Law

- **All of the current entering a branch point must exit again.**
- **This is known as *Kirchhoff's current law.***

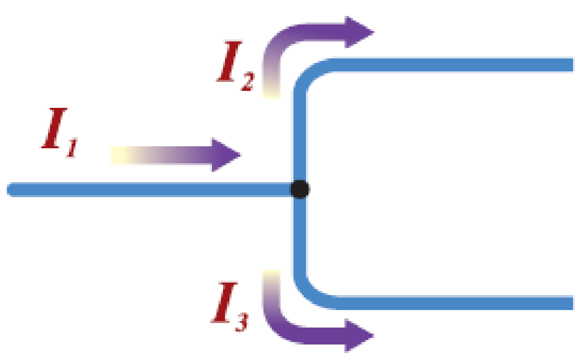


Parallel Circuits



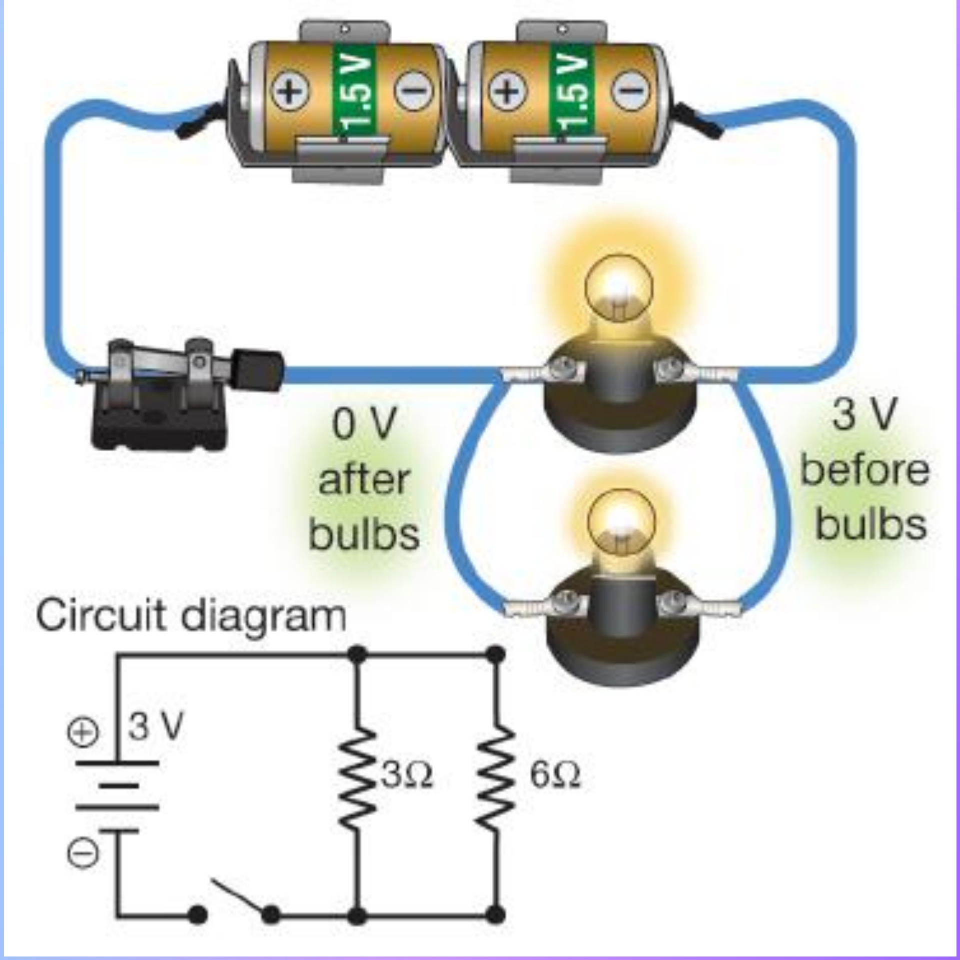
Kirchhoff's current law

All current flowing into a branch point must flow out again.



$$I_1 = I_2 + I_3$$

Voltage and parallel circuits



- **If the voltage is the same along a wire, then the same voltage appears across each branch of a parallel circuit.**

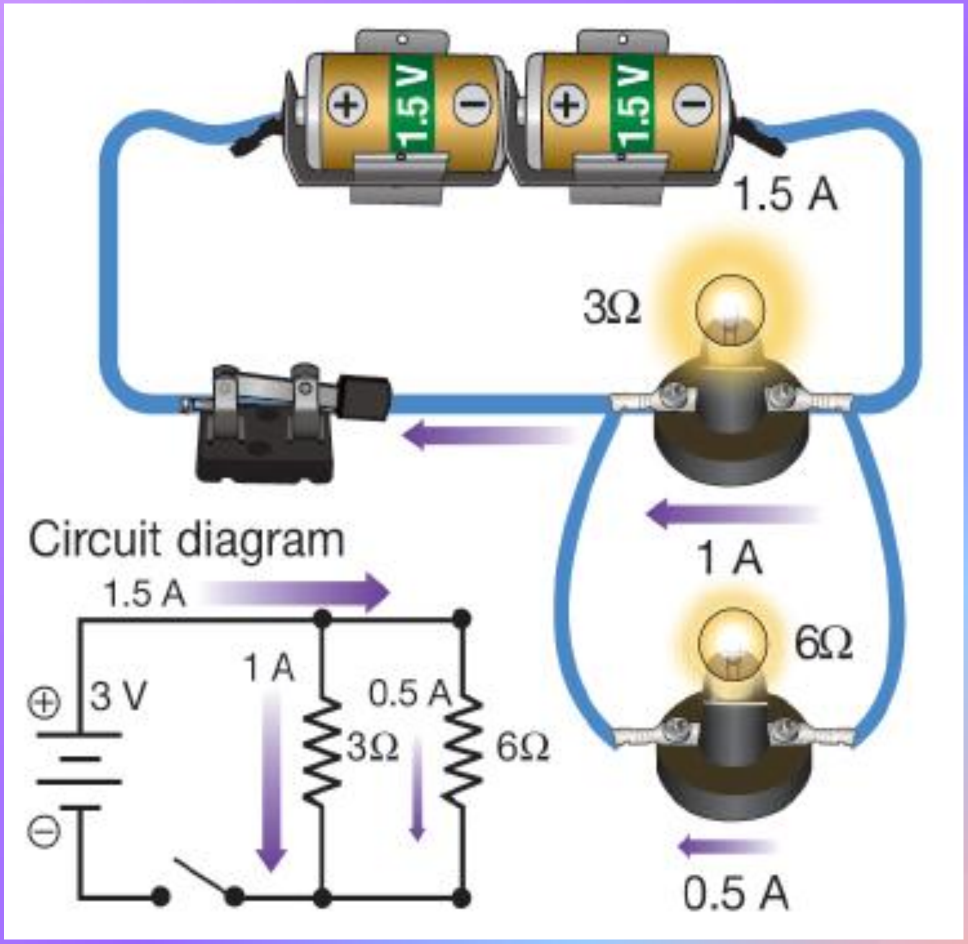
Voltage and parallel circuits

- **Parallel circuits have two advantages over series circuits.**

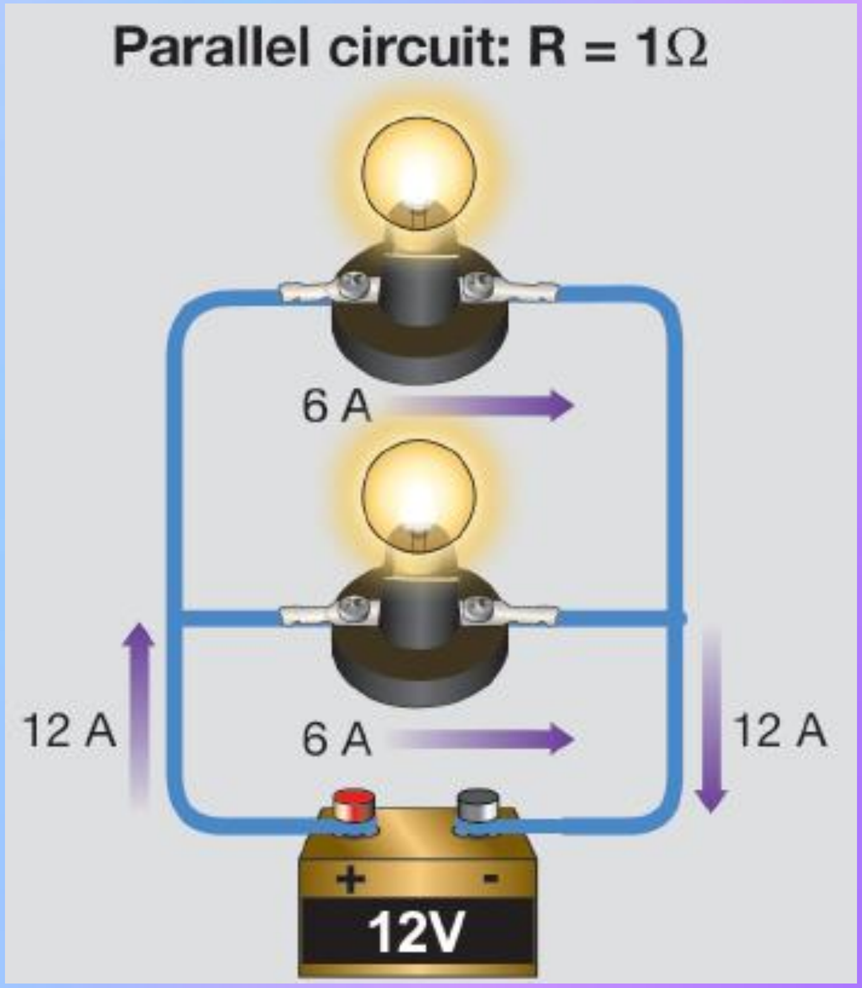
1. Each device in the circuit has a voltage drop equal to the full battery voltage.
2. Each device in the circuit may be turned off independently without stopping the current in the other devices in the circuit.

Current and parallel circuits

- **Each branch works independently so the total current in a parallel circuit is the sum of the currents in each branch.**

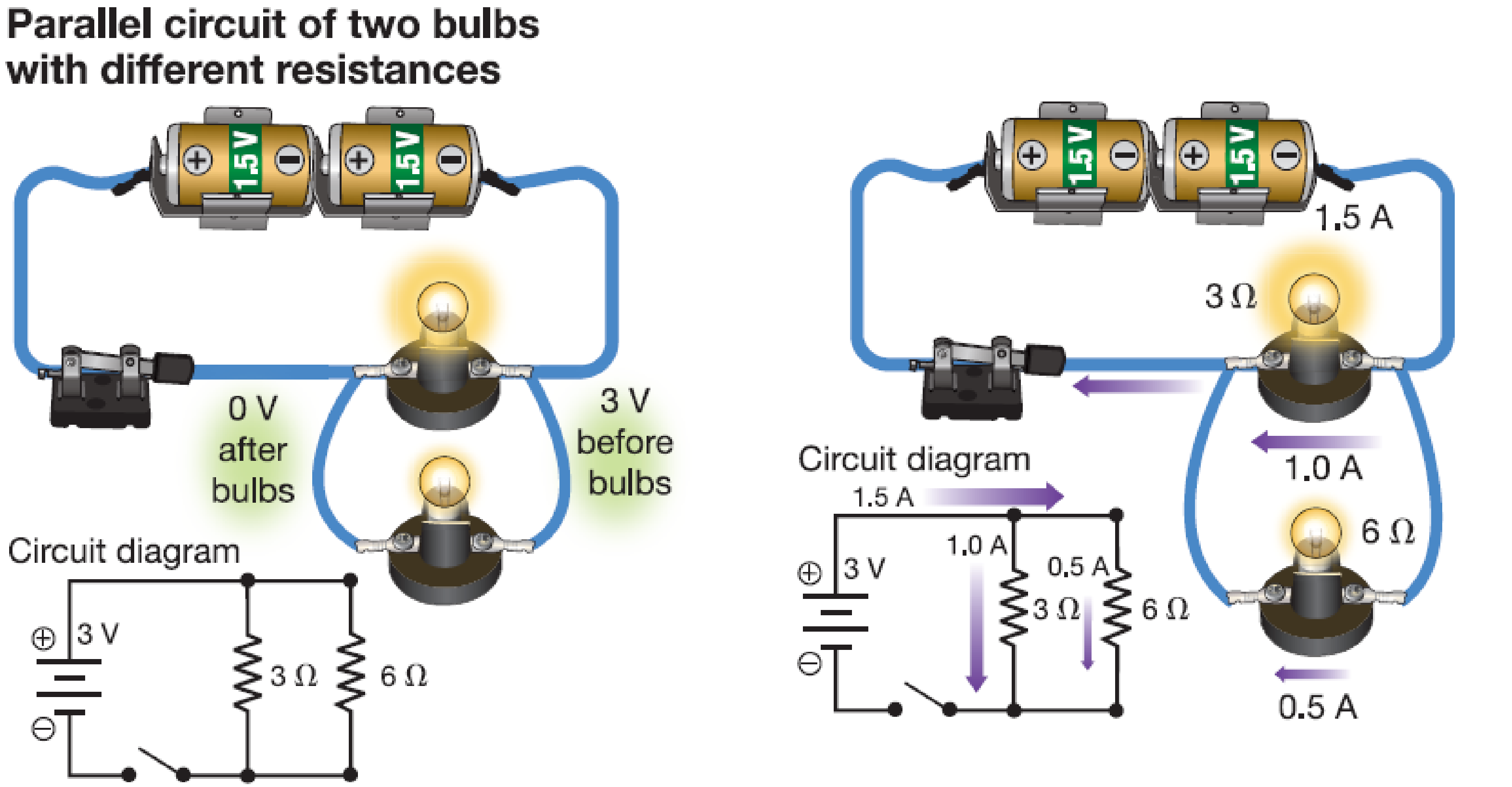


Calculating in circuits



- **In a series circuit, adding an extra resistor <u>increases</u> the total resistance of the circuit.**
- **In a parallel circuit, more current flows so the total resistance <u>decreases</u>.**

Voltage and Current in a Parallel Circuit



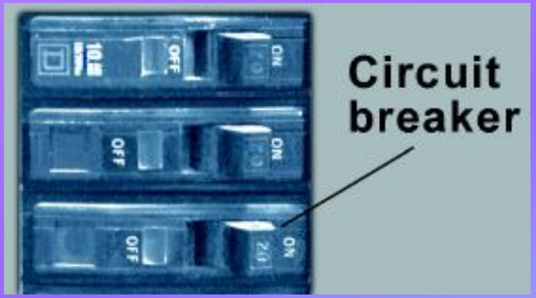
Parallel vs. Series

- **Remember: series/same/current; parallel/same/voltage.**
- **Use Ohm's law for both.**

	Voltage	Current	Resistance
Series	Resistors must "share" total voltage available	Current is the same everywhere in the circuit	Resistance increases as you add resistors in series
Parallel	Each branch sees the full voltage available	Branch current can vary within the same circuit; add up branch currents to get total current	Resistance decreases as you add resistors in parallel, because current increases

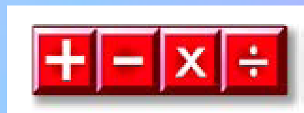
Solving Problems

- All of the electrical outlets in Jonah's living room are on one parallel circuit.



- The circuit breaker cuts off the current if it exceeds 15 amps.

- Will the breaker trip if he uses a light (240 Ω), stereo (150 Ω), and an air conditioner (10 Ω)?



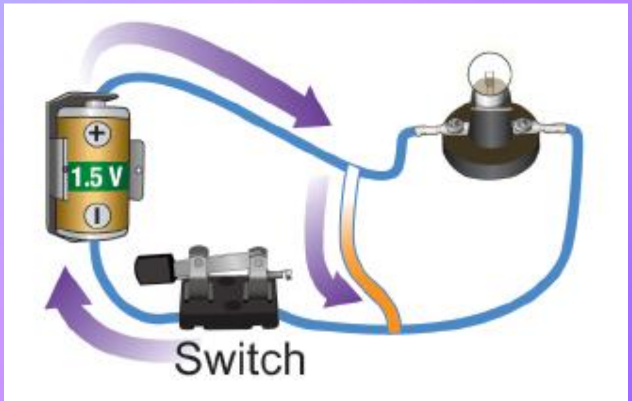
Solving Problems

1. **Looking for:**
   - whether current exceeds 15 amps
2. **Given:**
   - ……resistances = 240 Ω; 150 Ω; 10 Ω
3. **Relationships:**
   - Assume voltage for each branch = 120 V
   - Ohm's Law $I = V \div R$
   - Kirchhoff's Current Law $I_{total} = I_1 + I_2 + I_3$
4. **Solution:**
   - $I_{light} = 120\ V \div 240\ \Omega =$ **0.5 amps**
   - $I_{stereo} = 120\ V \div 150\ \Omega =$ **0.8 amps**
   - $I_{a/c} = 120\ V \div 10\ \Omega =$ **12 amps**

$$\begin{array}{r} 0.5 \\ 0.8 \\ \underline{+12.0} \\ 13.3 \end{array}$$

Breaker will not trip

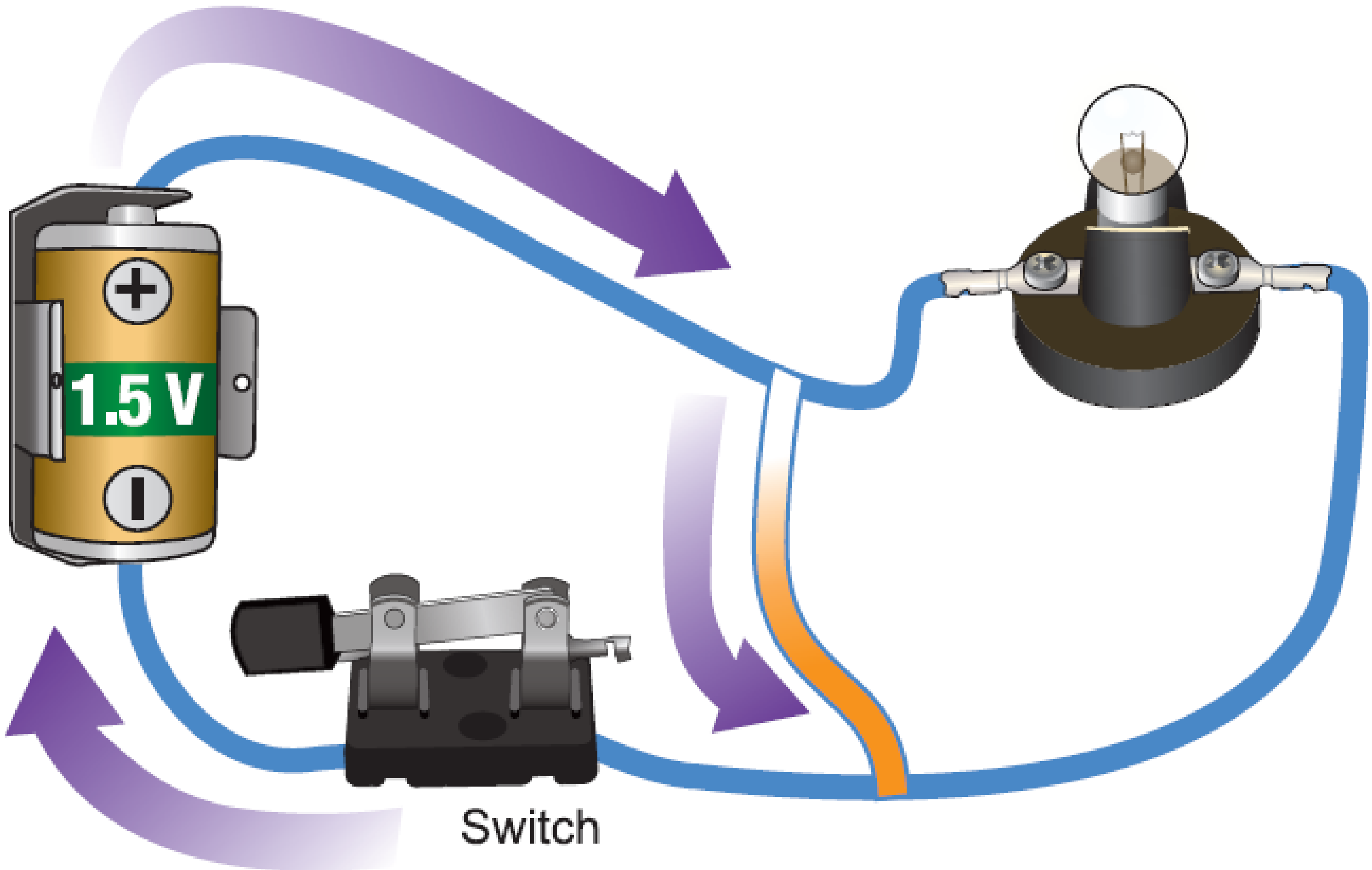
Short circuits



- A *short circuit* is a parallel path in a circuit with very low resistance.
- A short circuit can be created accidentally by making a parallel branch with a wire.

Short Circuit

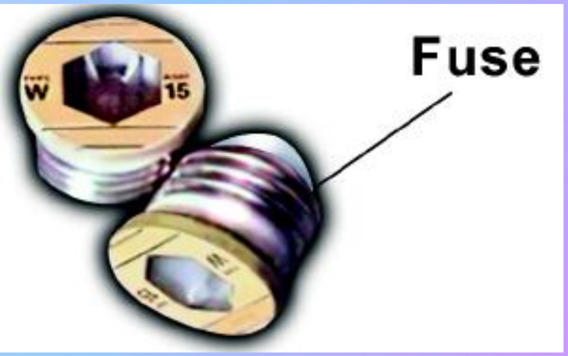
A large amount of current passes through the short circuit branch. Almost no current goes through the bulb.



Short circuits

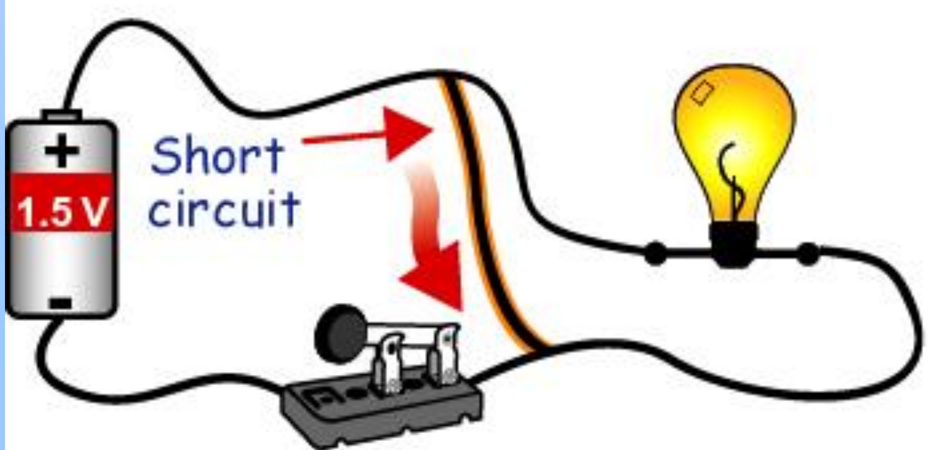
- **Each circuit has its own fuse or circuit breaker that stops the current if it exceeds the safe amount, usually 15 or 20 amps**
- **If you turn on too many appliances in one circuit at the same time, the circuit breaker or fuse cuts off the current.**
- **To restore the current, you must FIRST <u>disconnect</u> some or all of the appliances.**

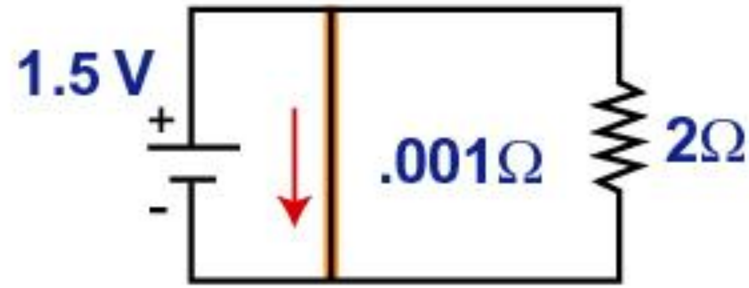
Fuses



- **In newer homes, flip the tripped circuit breaker.**
- **In older homes you must replace the blown fuse (in older homes).**
- **Fuses are also used in car electrical systems and in electrical devices such as televisions or in electrical meters used to test circuits.**

Circuits and Current





$$I = \frac{V}{R} = \frac{(1.5\ V)}{(0.001\ \Omega)} = 1{,}500\ \text{amps}$$

Warning! Wire gets hot - fire hazard!