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BASIC ELECTRICITY KIT

CAT NO. BKEPH2010

Experiment Guide

GENERAL BACKGROUND:

The basic electricity kit is an excellent start to your classroom's investigation of electricity and simple circuits. Appropriate for grades 6 – 12, this kit provides four complete kits with which to do all included activities. Further study of circuits is possible with the purchase of additional kits. Basic electricity kit “B” (BKE PH2012) is a teachers' kit containing spares, motors, buzzers and other items that will increase student understanding and learning.

The components of this kit are designed so that every component can be connected using 4mm plugs. Banana plug wires that fit into these components are included with this kit.

Each component is labeled with a number so that students who are just learning do not confuse similar components. Also included on each component is a circuit diagram symbol for the component so students can easily draw their circuits using the provided symbols.

REQUIRED COMPONENTS (INCLUDED):

Lamp holder (component 1)	20
Cell holder (component 2)	12
Fixed/variable resistor (component 3)	4
Push switch (component 4)	8
Universal clip (component 5)	4
Alligator clips	8
Resistors (15 Ω +/- 5%)	4
Diodes (1N4007)	4
Steel wool pad	1
Electrode holders (component 6)	4
Carbon electrodes	12
Metal plated carbon electrodes	8
Copper sheet	1
Changeover switch (component 7)	4
Short 4mm banana plug leads	24
Long 4mm banana plug leads	8
20 swg copper wire reel	1
34 swg eureka (constantan) wire reel	1
Plastic coated wire	1

REQUIRED COMPONENTS (NOT INCLUDED):

Multi-meter or voltmeter and ammeter	4
D cell batteries	12
Wire cutter and stripper	1

RECOMMENDED COMPONENTS (NOT INCLUDED):

Various materials for testing resistance (steel, wood, glass, polythene, aluminum, copper, iron, cotton, paper,Several samples carbon rod, glass, rubber, cardboard, Styrofoam, rubber, etc.)	Several samples
Liquids for conductivity of liquids experiment: tap water, distilled water, lemon juice, ethanol, sugar solution, copper sulfate solution, dilute sulfuric acid, acetone (nail polish remover), salt solution, vinegar, nickel ammonium sulfate solution, etc.)	Several samples
Multicore solder	
50/50 nitric acid	
Access to a fume cupboard	
9V transistor radio battery	1
Salt (NaCl)	
Vinegar	
Dilute sulfuric acid	
Copper strip	4
Magnesium strip	4
Aluminum strip	4
Iron strip	4
Zinc strip	4
Brass key	4
250 mL Beakers	Several
Lemons	16
Pennies	16
Zinc plated nail	16
Flat blade screwdriver	1
Hot water bath/Hot air dryer	1 per class
6.0V lantern battery	1 per class

SAFE HANDLING OF APPARATUS:

- **Warning:** Creating a short circuit and leaving it connected for even a short amount of time can cause the wires and battery to heat up. This can cause burns, start fires, and even cause battery acid to leak. Do not allow students to leave a circuit connected for a long while. Insist on using a switch to connect and disconnect circuits.

- **Breakable Warning:** The light bulbs are glass and should be treated with care. If too much current is supplied to the bulbs the filament will burn and the bulb will be useless. Use only three batteries maximum to light the bulb.

COMPONENTS:

Component 1: The Lamp Holder

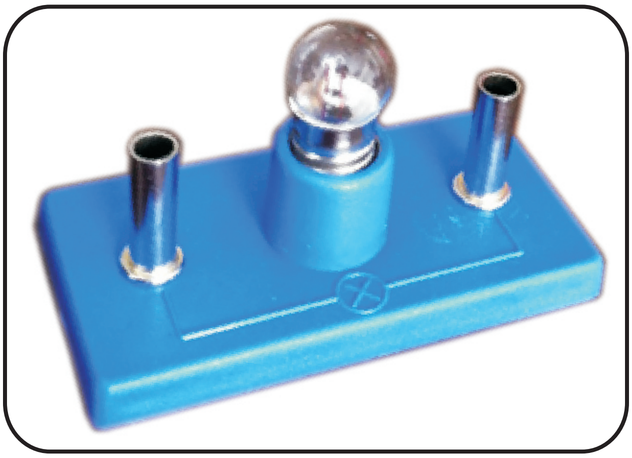


Diagram 1

The light bulbs supplied must be screwed in completely to the holder in order to work as shown in diagram 1.These bulbs were specially designed for this kit to minimize the number of replacement bulbs necessary. The bulbs will not “blow” (the filament will not overheat and break) when connected in series to up to three 1.5 volt batteries. However, the light bulb will give off light with only one battery in the circuit. This allows students to compare the brightness of bulbs as a means of comparing current without using an ammeter.

Component 2: The Cell Holder

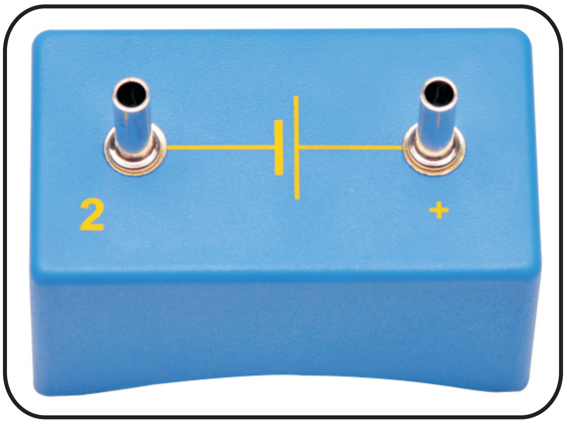


Diagram 2

Requires the use of D cells.

We call this a cell holder and not a battery holder to help students differentiate between a battery and a cell. A cell has only one positive and negative end. A series of cells makes up a battery. Even though we often call cells batteries in common day language, separating the two terms here will help students to more fully understand and appreciate what is going on. Have students think of the phrase “A battery of questions” which is several questions working together, or battery used in the military is two or more pieces of artillery used for combined action.

Note: It is important to fit the cell in the holder the correct way, with the positive end corresponding to the '+' on the holder. Cells that are reversed will work against each other instead of adding voltage together.

Component 3: The Fixed/Variable Resistor

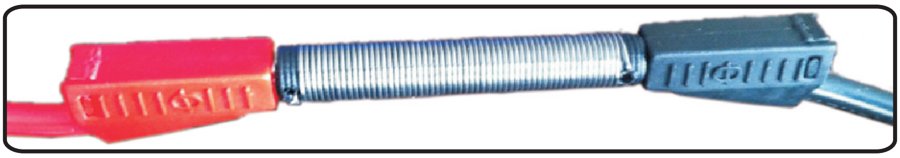


Diagram 3

To use as a fixed resistor, remove the coil from the holder and plug a 4mm plug into each end of the coil as shown in diagram 3.

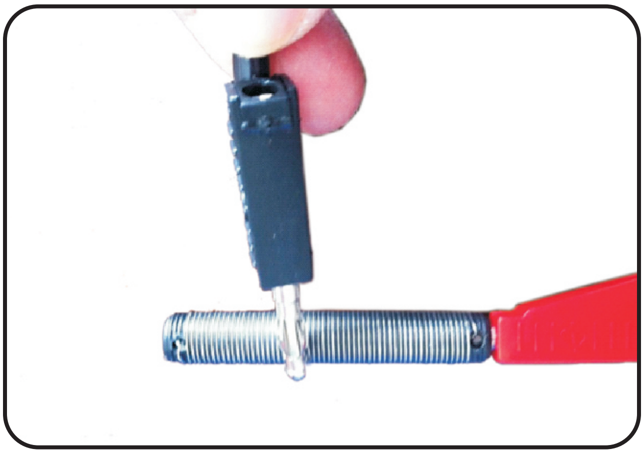


Diagram 4

The resistance can be varied by removing one of the plugs from the end of the resistor and sliding it up and down the resistor as shown in diagram 4. This will produce a noticeable change in brightness as the plug slides up and down the resistor.

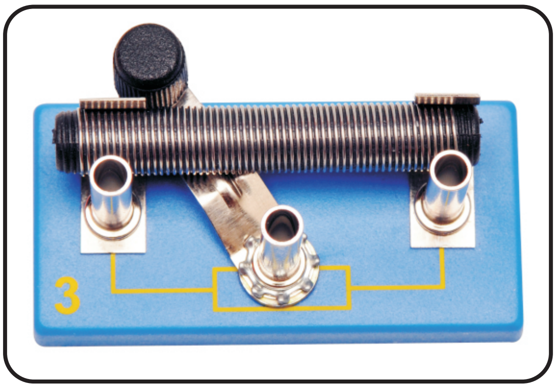


Diagram 5

Finally this component can be popped back into the holder and used as a rheostat as shown in diagram 5. This can be used to change the speeds in motors or to brighten and dim the bulb. The resistor also warms up when connected in series with a lamp and will illustrate how resistors use electrical energy and convert it to heat energy.

When using this component as a resistor, plug the 4mm leads into the two end receptors. When using this component as a rheostat, plug one 4mm plug into the end and the other into the middle receptor.

Component 4: The Push Switch

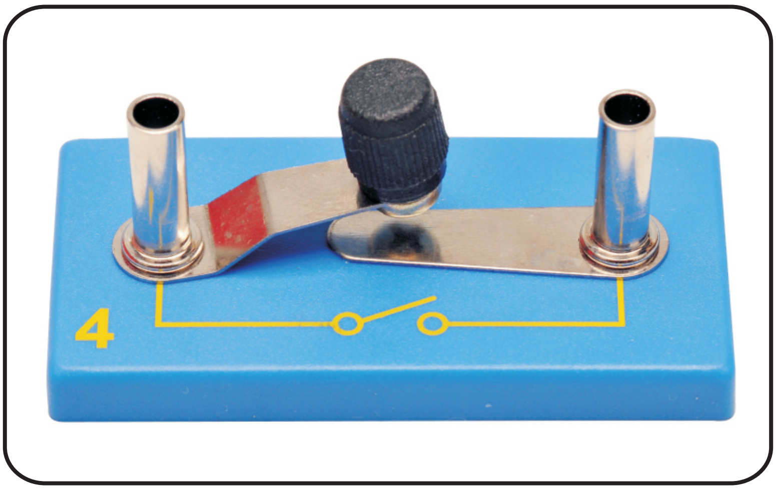


Diagram 6

The push switch adds a break in the circuit so that the circuit is only on when a student is pushing the button down to make contact between the two metal components. Encourage students to use this switch in all of their circuits as it will increase battery life and decrease the dangers of creating a short circuit.

Component 5: The Universal Clip

Diagram 7

Diagram 8

The alligator clips in this component are to be used with other loose components such as the included resistors and diodes. Depending on the components being used, the universal clip can be connected to a circuit in two ways.

The first is shown in diagram 7 and the second is shown in diagram 8. In order to get the banana plug leads to fit into the universal clip as shown in diagram 7, remove the small screw with a flat blade screwdriver.

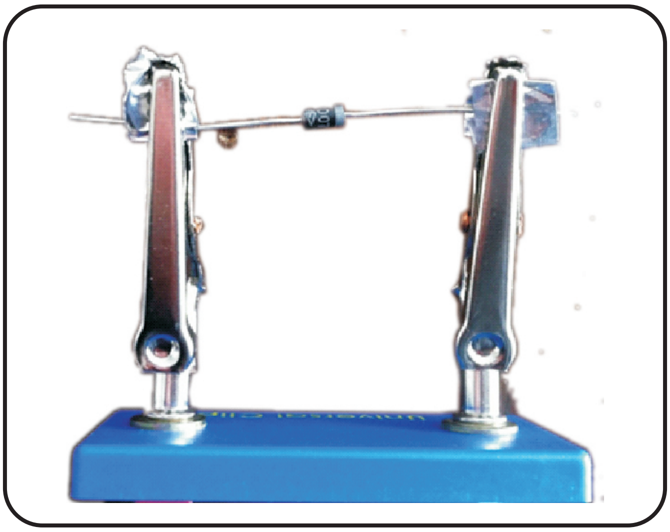


Diagram 9

If there is a poor connection between the alligator clip and the thin wires of a resistor or some other component, a small folded piece of aluminum foil will help improve the connection as shown in diagram 9.

Component 6: The Electrode Holder

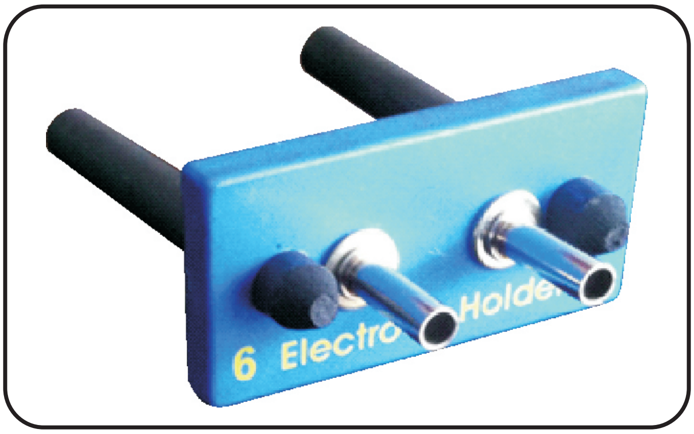


Diagram 10

Attach either the carbon rods or the metal coated carbon rods into the electrode holder as shown in diagram 10. It would be helpful to use a beaker that will allow the electrode holder to rest across the top of the beaker while conducting experiments.

The solutions used in electrolysis experiments can corrode the conductors. To delay this from happening, rinse the entire component, including the electrodes in water immediately after use.

Metal coated carbon rods should be cleaned after use by dipping them in a 1:1 concentrated nitric acid to water mix. Remember always add acid to water when mixing the two. Use a fume cupboard to rinse the electrodes and mix the acid. After dipping the electrodes in water, rinse the electrodes in water as well.

Component 7: The Changeover Switch

Diagram 11

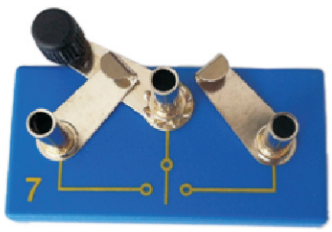


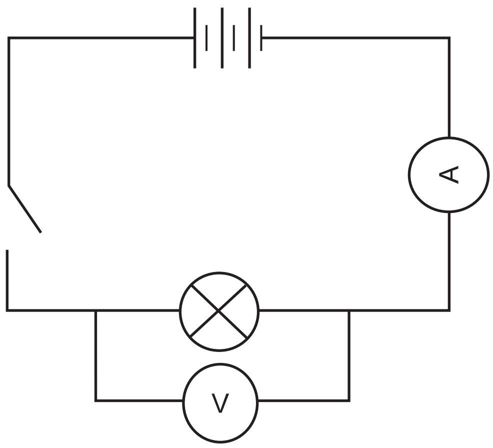
Diagram 12

The changeover switch has three leads on it. The middle lead is usually connected to some power source and then the two outside leads are connected to two separate circuits. It is possible that the two metal pieces connected to the lead can rotate so they both touch the center lead at the same time as shown in diagram 11. This can cause a short in your circuit. Make sure before adding this component to your circuit that the metal tabs are rotated far enough away from the center lead that the switch is in contact with only one tab at a time as shown in diagram 12.

MEASURING CURRENT AND VOLTAGE

The current in any part of a circuit can be measured with an ammeter, digital ammeter, or multi-meter. The device measuring current must be wired in series. An ammeter is able to measure current within a part of a circuit because it has very little resistance. The presence of the ammeter does not substantially affect the current of the circuit.

The voltage or voltage drop of any part of a circuit can be measured with a voltmeter, digital voltmeter, or multi-meter. The device measuring voltage must be wired in parallel. A voltmeter is able to measure the voltage between two points in a circuit because it has very high resistance. The voltmeter does not allow charge to flow through it, which would create a new circuit.



ACTIVITY 1: How to Light a Light Bulb

Teacher Instructions

Purpose: To establish the requirements of a working electric circuit.

This lab is designed as a student centered discovery activity. Give students minimal support while attempting this lab. Have students work with a partner and have them come up with the requirements of a circuit.

In order for charge to flow, there must be a potential difference established within the circuit. An energy source is required to separate charge, which establishes the potential difference. A battery supplies energy in the form of a chemical reaction. A battery can be thought of as a "charge escalator". Imagine positive charge* being pumped "up" toward the positive terminal. The work done by the battery transfers energy to the charge in the form of electric potential energy. The amount of electrical energy gained per amount of charge is referred to as voltage. The voltage V is given by the formula

$$V = \frac{W}{q}$$

Equation 1 - 1: Voltage

Where W is the electrical energy and q is the amount of charge.

Meanwhile, this will leave the "bottom", or negative terminal, with negative charge. Now that the positive charge is separated from the negative charge, it will want to move toward the negative charge. The easiest way for the positive charge to do this is to flow through the external circuit losing its electric potential energy along the way. The second requirement of a circuit is the circuit must consist of a closed loop. The positive and negative terminal and the resistor (light bulb) must be within the closed loop.

*The flow of positive charge was chosen to coincide with the idea of conventional current.

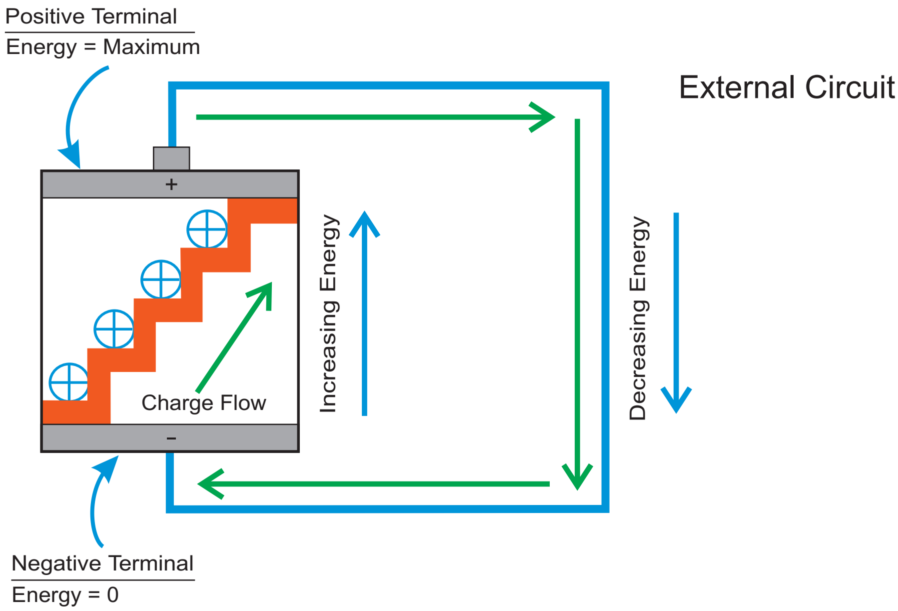


Diagram 1 – 1: Charge Escalator Model

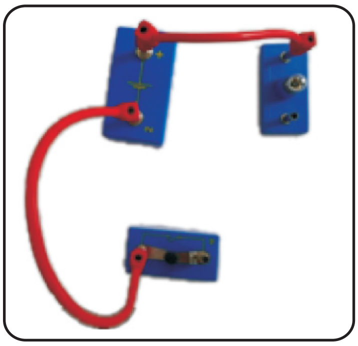
Question: What are the two requirements of a working electric circuit?

Materials: lamp holder (component 1), light bulb, D cell, cell holder (component 2), push switch (component 4), and 4 banana plug leads.

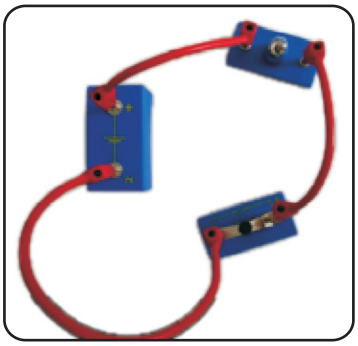
Part 1:

Examine the following circuit arrangements. Predict which circuit configurations will make the light bulb light up when the push switch is depressed.

Configuration A: Yes or ***No***

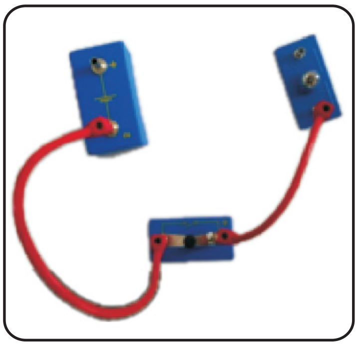


Configuration B: ***Yes*** or No

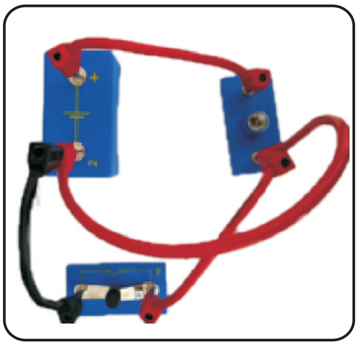


Configuration C: Yes or ***No***

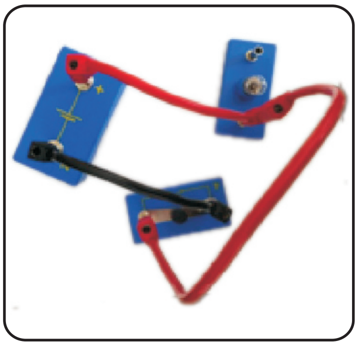
Configuration D: Yes or ***No***



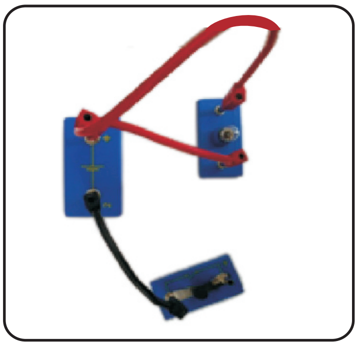
Configuration E: ***Yes*** or No



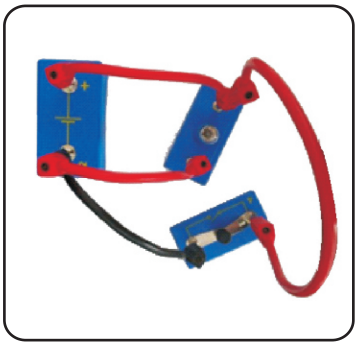
Configuration F: Yes or ***No***



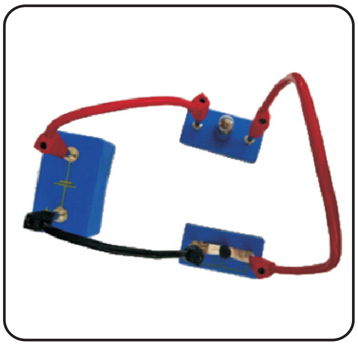
Configuration G: Yes or ***No***



Configuration H: ***Yes*** or No



Configuration I: ***Yes*** or No



Configuration J: Yes or ***No***

Part 2:

Build each of the circuits to verify your prediction. Set up the circuit first and then depress the switch for only a few seconds. Do not leave the circuits connected for more than a few seconds. Record the results below.

A. Yes or ***No*** B. ***Yes*** or No C. Yes or ***No*** D. Yes or ***No*** E. ***Yes*** or No

F. Yes or ***No*** G. Yes or ***No*** H. ***Yes*** or No I. ***Yes*** or No J. Yes or ***No***

Analysis Questions:

1. Describe in detail what the working circuits have in common.

   Each of the working circuits consist of a loop shaped path that connects the positive and negative terminals of the cell and forces the path to go through the light bulb.

2. Describe in detail what the non-working circuits have in common.

   Each of the non-working circuits are either missing the positive or negative terminals within the closed loop or the light bulb within the closed loop.

Conclusion: State the two requirements of a working circuit.

The first requirement of a circuit is a source of energy. The positive and negative terminal must be apart of the circuit in order to provide energy. The second requirement of a circuit is that the energy source and light bulb must be wired in a closed loop.

Name:______________________________________ Date:______________________

Activity 1

How to Light a Light Bulb

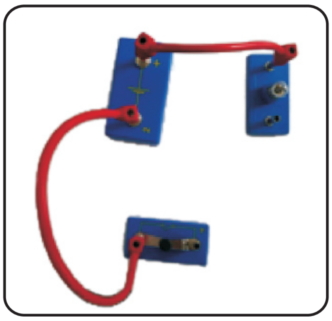
Question: What are the two requirements of a working electric circuit?

Materials: lamp holder (component 1), light bulb, D cell, cell holder (component 2), push switch (component 4), 4 banana plug leads

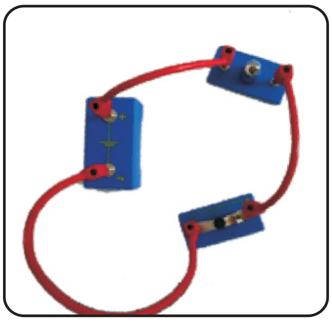
Part 1:

Examine the following circuit arrangements. Predict which circuit configurations will make the light bulb light up when the push switch is depressed.

Configuration A: Yes or No

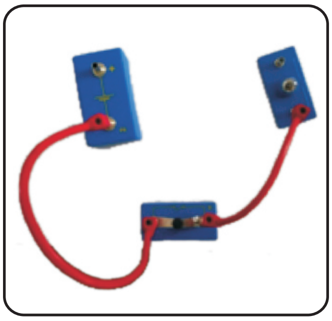


Configuration B: Yes or No

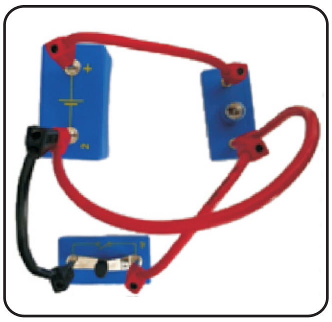


Configuration C: Yes or No

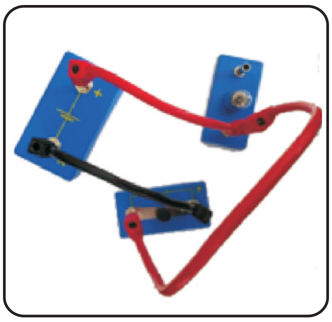
Configuration D: Yes or No



Configuration E: Yes or No

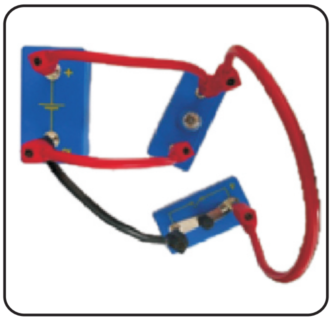


Configuration F: Yes or No



Configuration G: Yes or No

Configuration H: Yes or No



Configuration I: Yes or No

Configuration J: Yes or No

Part 2:

Build each of the circuits to verify your prediction. Set up the circuit first and then depress the switch for only a few seconds. Do not leave the circuits connected for more than a few seconds. Record the results below.

A. Yes or No	B. Yes or No	C. Yes or No	D. Yes or No	E. Yes or No
F. Yes or No	G. Yes or No	H. Yes or No	I. Yes or No	J. Yes or No

Analysis Questions:

1. Describe in detail what the working circuits have in common.

2. Describe in detail what the non-working circuits have in common.

Conclusion: State the two requirements of a working circuit.

ACTIVITY 1 EXTENSION: Drawing Circuit Diagrams

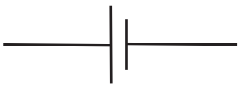
Teacher Instructions

The chart below shows symbols for various components of a circuit. When drawing a circuit diagram, it is convenient to use the symbols versus trying to draw a detailed version of the circuit.

In this kit, there are symbols on each component. This is the symbol that electricians would use to represent that component when drawing a circuit diagram. Look at the symbol for the “cell”.Notice that one vertical line is longer than the other. This longer line represents the positive terminal of the cell. This end of the cell usually has a small knob on it. The shorter line represents the negative terminal of the cell. More than one cell connected together is called a “battery”. The numbers of cells in a battery are denoted by the number of pairs of short and long vertical lines. For example, the battery below is made up of three cells, with the positive terminal on the left-hand side.

Circuit Symbols:

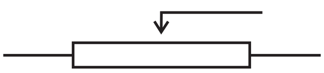
Cell



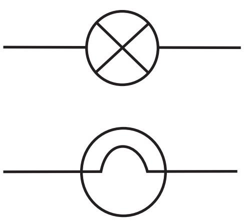
Battery

Resistor

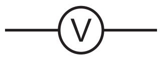
Variable Resistor



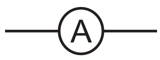
Lamp/bulb



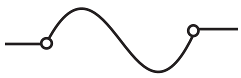
Voltmeter



Ammeter



Fuse



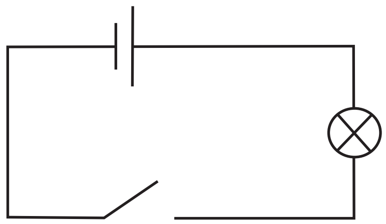
Switch

Electrical Wire

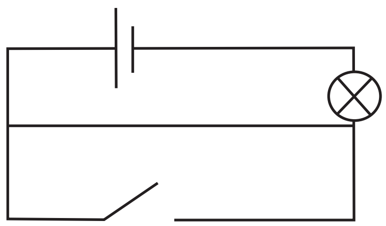
Teacher Key

Activity 1 Extension

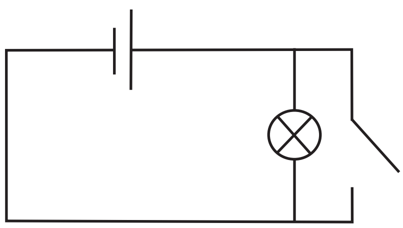
Configuration B:



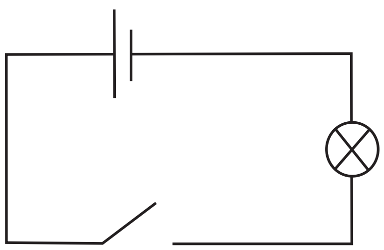
Configuration E:



Configuration H:



Configuration I:



Name:____ Date:______________________

Activity 1 Extension

Drawing Circuit Diagrams

Draw a circuit diagram using the correct symbols to represent each of the circuits that allowed the light bulb to light.

ACTIVITY 2: Make it Brighter

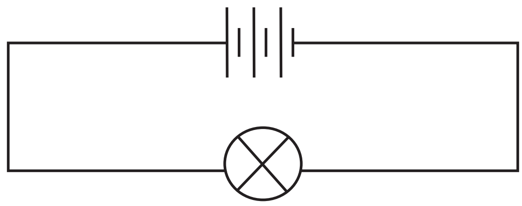
Teacher Instructions

Purpose: Appropriately add cells to make a battery that will increase the voltage of the circuit.

Propose the following scenario to your students:

The power goes out while you are in science class and your classroom has no windows. You need to find your phone to call for help, but you don't remember where you put it and you can't see a thing. Luckily you can reach your battery and bulb kit to make operate a light bulb. Unfortunately, the bulb is so dim it doesn't help you much. Using the materials in your kit, make the light bulb brighter.

1. Draw a circuit diagram of your circuit that contains the brightest bulb.



2. Cells connected one after another are called a battery. When making a battery, does it matter if you connect the negative terminal of one cell to the negative terminal of another cell or the negative terminal of a cell to the positive terminal of another cell? Cite evidence from your experiment.

   When connecting the battery together, the negative end of one battery needs to be connected to the positive end of the next battery. Otherwise the batteries will work against each other and not add more voltage to the circuit. I know this because when I connected two cells together positive to positive, the bulb did not light at all, and when I connected three cells together, but one was backwards, the bulb only burned as bright as using one cell.

Name:________________________________ Date:____________________

Activity 2

Make it Brighter

Mission: The power goes out while you are in science class and your classroom has no windows. You need to find your phone to call for help, but you don't remember where you put it and you can't see a thing. Luckily you can reach your battery and bulb kit typewrote a light bulb. Unfortunately, the bulb is so dim it doesn't help you much. Using the materials in your kit, make the light bulb brighter.

1. Draw a circuit diagram of your circuit that contains the brightest bulb.

2. Cells connected one after another are called a battery. When making a battery, does it matter if you connect the negative terminal of one cell to the negative terminal of another cell or the negative terminal of a cell to the positive terminal of another cell? Cite evidence from your experiment.

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ACTIVITY 3: Will It Conduct?

Teacher Instructions

Purpose: To determine whether certain solid and liquid materials can conduct electricity.

An appropriate discussion before this activity might be on the type of materials used in specific circuits. Ask students what criteria electrical engineers need to consider when building an electrical device. Some other questions to consider are what are the wires in power lines made of, do only solids conduct electricity or can liquids?

A conductor is any material that allows charge to flow freely, while an insulator does not allow charge to flow. In solids, the conductivity of a material is dependent upon how tightly the material holds on to its outer electrons. Once a potential difference is established, outer electrons in a solid conductor will move freely through the material because they are loosely bound to the atoms of the material. Figure 3 – 1 shows a cross section of a conducting wire. Once electrons begin moving, nearby neighboring electrons are repelled due to having the same charge. This domino effect occurs throughout the material at the speed of light. On the other hand, insulators hold on tightly to their outer electrons and do not allow them to flow throughout the material. How well a given material conducts electricity is known as resistivity.

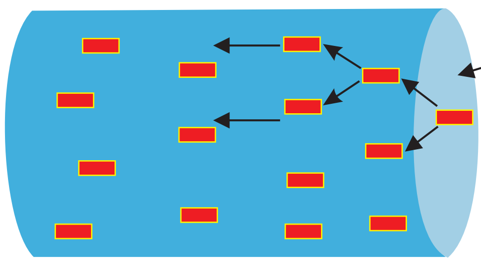


Figure 3 – 1: Electron Flow within a Conductor

The conductiblity of a liquid does not depend on the nature of the outer electrons, but on the presence of ions. An ion is a charged particle. An ion can be positively or negatively charged. A liquid that contains ions will be able to conduct electricity, and those that do not contain ions will not be able to conduct electricity. The amount of ions per volume within the liquid will determine how well of a conductor the liquid is. The more ions per volume, the better the conductor.

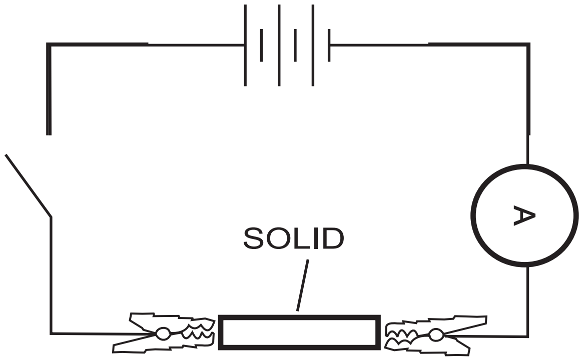
Circuit Materials: light bulb holder (component 1), light bulb, 3 cell holders (component 2), 3 D cells, push switch (component 4), electrode holder (component 6), 2 electrodes, 6 banana plug leads, 2 alligator clips, ammeter, and beaker.
Give students the list of materials to be used prior to the lab. If an ammeter or multi-meter is unavailable, a light bulb can be used to determine if a current is present within the circuit. An ammeter or multi-meter is recommended because some materials do conduct electricity, but the current is too low to allow the light bulb to light.

Tested Materials (Suggested):
Solids: Steel, wood, glass, polythene (saran wrap), aluminum, copper, cotton, paper, iron, cardboard, Styrofoam, rubber, and nickel.
Liquids: tap water, distilled water, sugar solution, lemon juice, acetone (nail polish remove), ethanol, olive oil, vinegar, copper sulfate solution, dilute sulfuric acid, and nickel ammonium sulfate solution.

Part 1: Solids

1. List the solids to be tested under the column labeled substance in data table 3 – 1. For each substance, predict whether each object is a conductor or insulator. Place an “X” in the appropriate column.

2. Construct the following circuit using the listed materials:



3. Press the push switch and determine whether the liquid conducts electricity. Place an “X” in the appropriate column of data table 3 – 1.

4. Repeat steps 3 – 5 for the remaining solids to be tested.

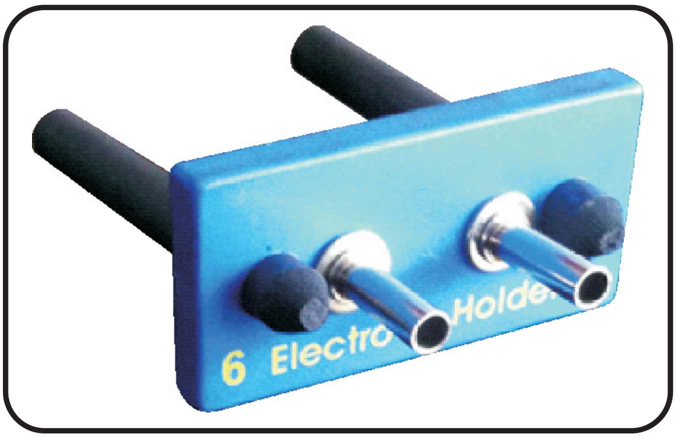
Solids	Prediction		Results	
	Conductor	Insulator	Conductor	Insulator
Steel			X	
Wood				X
Glass				X
Polythene				X
Aluminum			X	
Copper			X	
Cotton				X
Paper				X
Iron			X	
Cardboard				X
Styrofoam				X
Rubber				X
Nickel			X	

Data Table 3 – 1

Part 2: Liquids

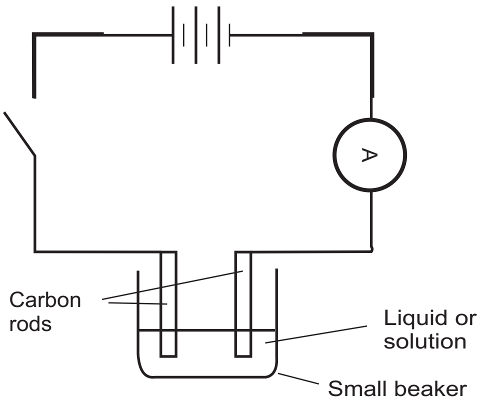
1. List the liquids to be tested under the column labeled substance in data table 3 – 2. For each substance, predict whether each object is a conductor or insulator. Place an "X" in the appropriate column.

2. Place a carbon rod through each of the holes of the electrode holder. The set up should look like the following:



3. Fill a small beaker with enough liquid so that the electrodes are able to be immersed in the fluid.

4. Construct the following circuit using the listed materials:



5. Press the push switch and determine whether the liquid conducts electricity. Place an "X" in the appropriate column of data table 3 – 2.

6. Repeat steps 3 – 5 for the remaining liquids to be tested.

Liquids	Prediction		Results	
	Conductor	Insulator	Conductor	Insulator
Tap water			X	
Distilled water				X
Sugar solution				X
Lemon juice			X	
Acetone				X
Ethanol				X
Olive oil				X
Vinegar			X	
Copper sulfate solution			X	
Dilute sulfuric acid			X	
Nickel ammonium sulfate solution			X	

Data Table 3 – 2

Name:________________________________ Date:____________________

Activity 3

Will It Conduct?

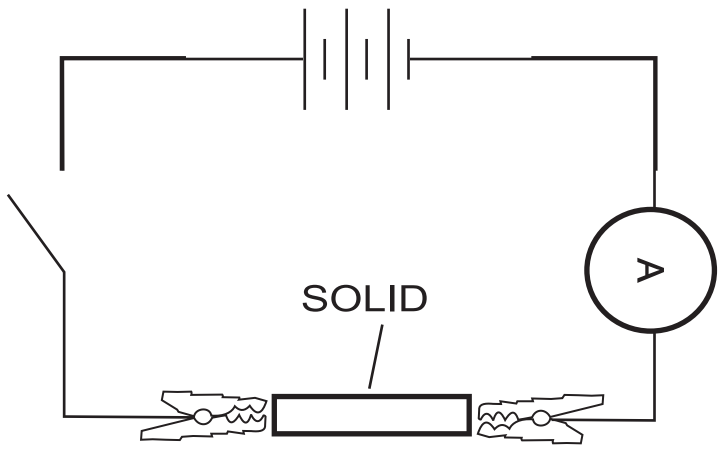
Purpose: To determine whether certain solid and liquid materials can conduct electricity.

Materials: 3 cell holders (component 2), 3 D cells, push switch (component 4), electrode holder (component 6), 2 electrodes, 6 banana plug leads, 2 alligator clips, ammeter, and beaker.

Part 1: Solids

1. List the solids to be tested under the column labeled substance in data table 3 – 1. For each substance, predict whether each object is a conductor or insulator. Place an "X" in the appropriate column.

2. Construct the following circuit using the listed materials:



3. Press the push switch and determine whether the liquid conducts electricity. Place an "X" in the appropriate column of data table 3 – 1.

4. Repeat steps 3 – 5 for the remaining solids to be tested.

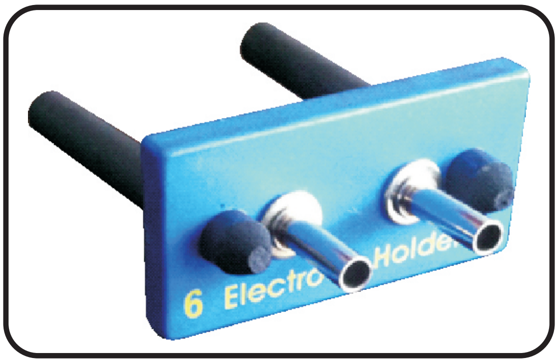
Solids	Prediction		Results	
	Conductor	Insulator	Conductor	Insulator

Data Table 3 – 1

Part 2: Liquids

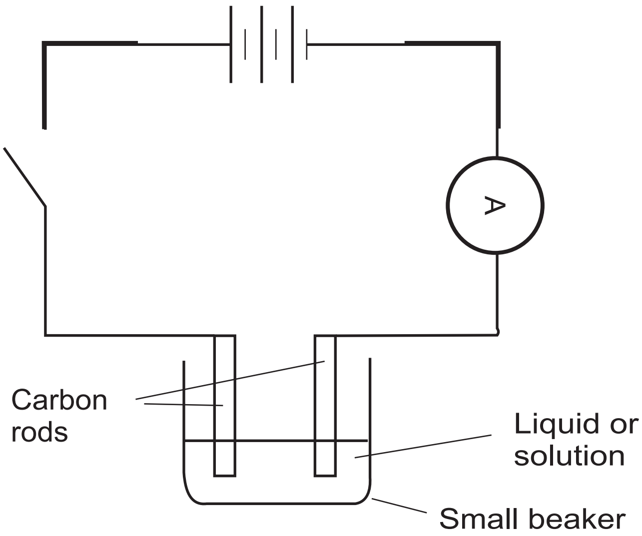
1. List the liquids to be tested under the column labeled substance in data table 3 – 2. For each substance, predict whether each object is a conductor or insulator. Place an "X" in the appropriate column.

2. Place a carbon rod through each of the holes of the electrode holder. The set up should look like the following:



3. Fill a small beaker with enough liquid so that the electrodes are able to be immersed in the fluid.

4. Construct the following circuit using the listed materials:



5. Press the push switch and determine whether the liquid conducts electricity. Place an “X” in the appropriate column of data table 3 – 2.

6. Repeat steps 3 – 5 for the remaining liquids to be tested.

Liquids	Prediction		Results	
	Conductor	Insulator	Conductor	Insulator

Data Table 3 – 2

ACTIVITY 3 EXTENSION: Electroplating

Teacher Instructions

Purpose: To investigate the mass changes at each electrode during electroplating.

Electroplating is a common industrial practice that deposits a layer of metal, such as copper, chromium, nickel, or zinc, onto another metal. This can be done for protective and/or decorative reasons. For example, steel bumpers on cars become more corrosion resistant after they are electroplated and electroplating is used to make jewelry brighter. This activity will deposit a copper coating onto a key.

When the copper sulfate is dissolved in water it dissociates to forms ions.

$$CuSO_4(s) + H_2O\ (l) \rightarrow\ Cu^{2+}(aq) + {SO_4}^{2-}(aq) +\ H_2O(l)$$

Equation 3 - 1

To begin the electroplating process, the brass key is immersed in the aqueous solution containing the copper ions. The key is then connected to the negative terminal of the battery. A strip of copper, which acts as an electrode, is connected to the positive terminal of the battery. Now that the circuit is completed, the key becomes negatively charged from the battery pulling electrons away from the copper strip at the positive electrode. The key, now being negatively charged, will attract the positively charged copper ions in the solution. For each Cu^{2+} ion, two electrons are required to reduce it to a neutral atom of copper metal, which gets deposited on the key.

$$Cu^{2+}(aq) +\ 2e^{-}\ \rightarrow Cu\ (\mathrm{s})$$

Equation 3 – 2

The amount of mass gained by the key and lost by the copper strip will depend on the current in the circuit and the length of time the circuit is allowed to run. For a current of 0.25 A over 30 minutes, about 0.120 g of mass was transferred.

Analysis Question:

1. Compare the change in mass of the key and the copper electrode. Explain this outcome.

   The change in mass for the key and copper strip are about the same. A small difference is due to copper flaking off of the key.

Name:_________________________________ Date:_____________________

Activity 3 Extension

Electroplating

Purpose: To investigate the mass changes at each electrode during electroplating.

Materials: 3 cell holders (component 2), 3 D cells, brass key, copper strip, copper sulfate, water, 250 mL beaker, 3 alligator clips, multi-meter, steel wool, safety goggles, soap and water, and digital balance.

Part 1: Prepping the solution

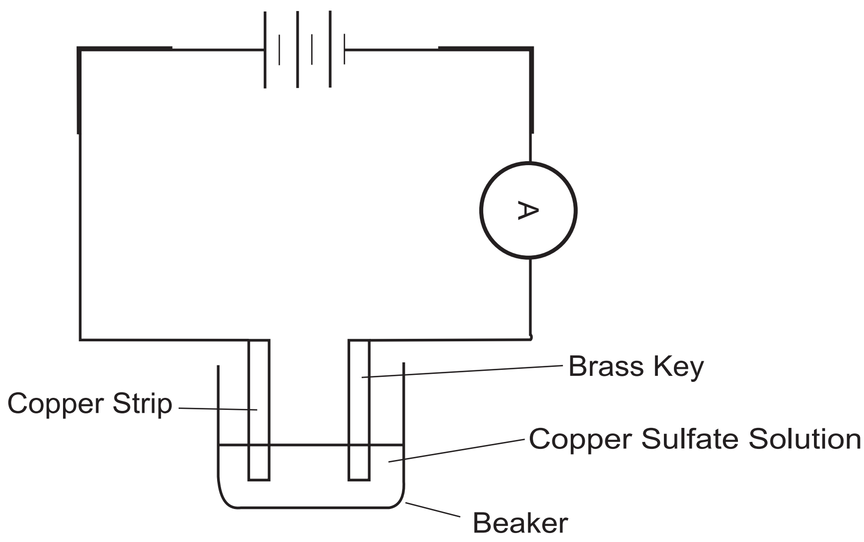
1. Put on safety goggles.
2. Fill a 250 mL beaker with 200 mL of hot water.
3. While stirring, slowly add copper sulfate until no more of it will dissolve. The solution should be dark blue.
4. Allow the water to cool.

Part 2: Cleaning the key

1. Scrub the key and copper electrode with steel wool.
2. Wash the key and copper electrode with soap and water.
3. Dry each with a paper towel.

Part 3: Electroplating

1. Determine the mass of the key and copper strip. Record the masses in data table 3 – 3.
2. Construct the following circuit using the given materials:



Make sure :

- the copper strip is attached to the positive terminal
- the brass key is attached to the negative terminal
- neither alligator clip is touching the solution
- the copper strip does not touch the key (the farther apart, the better)

3. Allow the circuit to run for 20 – 30 minutes. Make sure there is a current.
4. Disconnect the circuit and remove the key and copper strip from the solution.
5. Determine the new mass of the key and the copper strip. Record the masses in data table 3 – 3.

Mass of Brass Key		Mass of Copper Strip	
Before		Before	
After		After	

Data Table 3 – 3

Analysis Question:

1. Compare the change in mass of the key and the copper strip. Explain this outcome.

ACTIVITY 4: How Much "Juice" Can You Get Out Of A Lemon?

Teacher Instructions

Purpose: To examine the chemistry of a cell and to determine the effect of adding cells in series.

Background: A lemon can become a source of potential difference through oxidation and reduction reactions involving a zinc plated nail and a penny.

Oxidation: When a zinc plated nail comes into contact with the acid of a lemon, the acid removes the zinc atoms from the plating of the nail. Two electrons are then removed from each zinc atom, leaving the zinc atoms with a relative charge of +2.

$$Zn \rightarrow Zn^{2+} + 2e^{-}$$

Equation 4 - 1: Oxidation

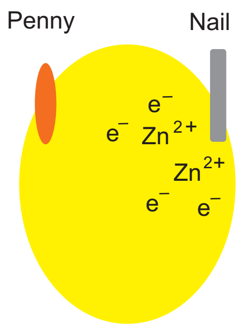


Figure 4 – 1: Oxidation

Reduction: Positively charged hydrogen atoms within the acid of the lemon accept the electrons released by the oxidation reaction and form hydrogen gas.

$$2H^{+} + 2e^{-} \rightarrow H_2$$

Equation 4 – 2: Reduction

When the penny is placed in the lemon, the copper on the penny will attract many of the available electrons from the zinc as long as there is a conductive pathway. Connecting the penny to the nail by means of a wire allows the electrons to move. This movement of charge is electric current and can be used operate an electrical device.

Because electrons flow out of the nail, the nail is considered to be the anode. The copper, which is what the electrons flow into, is considered to be the cathode.

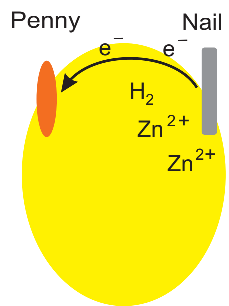


Figure 4 – 2: Flowing Charge

If the lemons are added in series, the combined effect is the same as adding cells in series. As lemons are added in series, the overall voltage amongst the lemons increases. As in activity 2, the negative electrode of one lemon must be connected to the positive electrode of another lemon.

The amount of voltage obtained by each lemon will vary. You should expect around 0.5 V per lemon. A small 1.5 LED light may be used to show that the lemons can be used to operate an electrical device. It is not likely that the light bulbs included in this kit will light while connected to the lemons.

Name:______________________________________ Date:______________________

Activity 4

How Much "Juice" Can You Get Out Of A Lemon?

Purpose: To determine the effect of adding cells in series.

Materials: 4 Lemons, 4 zinc plated nail,4 pennies, 6 alligator clips, small knife, and multi meter.

Part 1:

1. Gently squeeze each of your lemons until they become squishy. This helps release the juice inside the lemon.
2. Insert the nail about 1/3 of the way from the end of the lemon. Leave enough of the nail out of the lemon to connect an alligator clip.
3. Carefully cut a small slit (about 1 cm) with the knife about 1/3 of the way from the other end of the lemon.
4. Insert the penny into the slit.
5. Connect the nail and the penny with an alligator clip.
6. Measure the voltage between the nail and penny. Record the voltage in data table 4 – 1.
7. Repeat steps 1 – 4 for a second lemon.
8. Connect the two lemons in such a way to increase the voltage provided by the lemons.
9. Measure the voltage of the two lemons. Record the voltage in data table 4 – 1.
10. Repeat steps 1 – 4 for a third lemon.
11. Connect the three lemons in such a way to increase the voltage provided by the lemons.
12. Measure the voltage of the three lemons. Record the voltage in data table 4 – 1.
13. Repeat steps 1 – 4 for a fourth lemon.
14. Connect the four lemons in such a way to increase the voltage provided by the lemons.
15. Measure the voltage of the four lemons. Record the voltage in data table 4 – 1.

Number of Lemons	Voltage (V)
1	
2	
3	
4	

Data Table 4 – 1

ACTIVITY 5: Ohm's Law

Teacher Instructions

Purpose: To determine the relationship between voltage and current.

The relationship between voltage, current, and resistance is known as Ohm's law. Ohm's law states that the resistance across an electrical device is directly proportional to the voltage across it and inversely proportional to the current that moves through it.

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

Equation 5 – 4: Ohm's Law

Purpose: To determine the relationship between voltage and current.

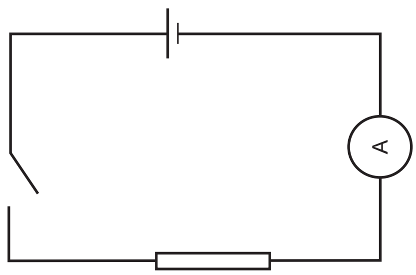
Materials: 5 cell holders (component 2), 5 D cells, resistor (component 3), push switch (component 4), 5 banana plug leads, 2 alligator clips, and multi-meter.

*Note: When measuring current within the circuit, press down on the push switch and quickly record the reading. Do not leave the push switch down longer than necessary. The temperature of the resistor increases the longer the circuit is connected. The longer the circuit is connected, the more the temperature change in the resistor will change the resistance of the resistor.

Procedure:

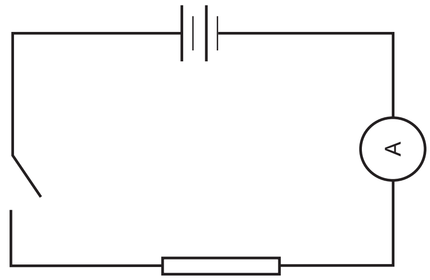
1. Starting with a single cell holder and D cell, construct an operational circuit that includes the resistor, push switch, and multi-meter.When connecting the resistor, use the right and left leads. Do not use the middle lead. Draw the circuit diagram below. Check your circuit with your teacher before moving on.

   Make sure the ammeter is wired in series



2. Press down on the push switch and record the reading on the ammeter in the data table.
3. Connect a second cell in series with the initial cell in your circuit. Draw the circuit diagram below. Check your circuit with your teacher before moving on.

Make sure the ammeter is wired in series



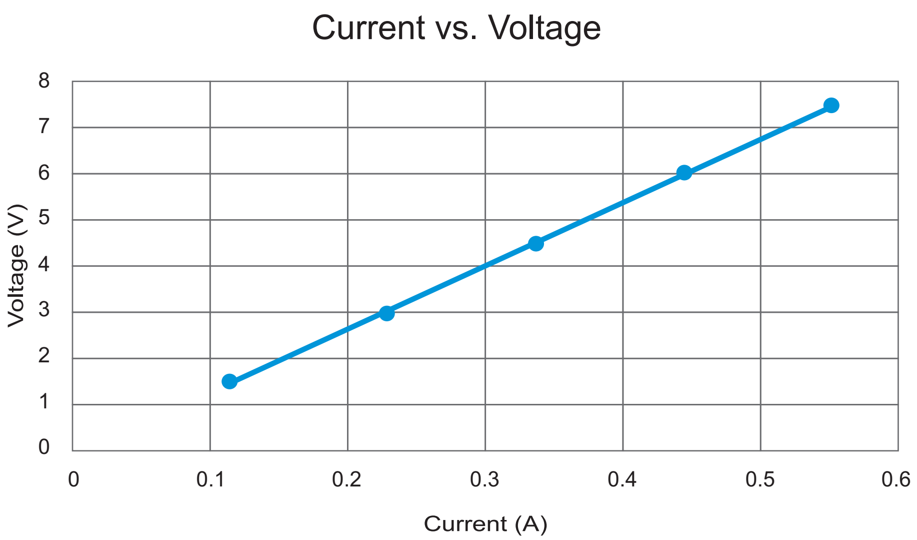
4. Press down on the push switch and record the reading on the ammeter in the data table.
5. Construct a circuit that includes three, four, and five cells in series. Press down on the push switch each time and record the reading on the ammeter in the data table.

Data Table:

Number of Cells	Voltage (V)	Current (A)
1	1.5	0.114
2	3.0	0.228
3	4.5	0.336
4	6.0	0.444
5	7.5	0.552

Data Analysis:

1. Construct a current vs. voltage graph.



2. Find the slope of your graph.

   Slope = 13.7 Ω

Analysis Questions:

1. What is the relationship between the current and voltage in a circuit?

   As the voltage of the circuit is increased, the current moving through the circuit increases. More specifically, this is a direct relationship.

2. What is the physical significance of the slope of the current vs. voltage graph?

   The physical significance is the resistance of the resistor.

3. Develop an equation that calculates the resistance of a resistor and illustrates the relationship between current and voltage. Use your graph.

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

Name:___________________________________ Date:____________________

Activity 5

Ohm's Law

Purpose: To determine the relationship between voltage and current.

Materials: 5 cell holders (component 2), 5 D cells, resistor (component 3), push switch (component 4), 5 banana plug leads, 2 alligator clips, and multi-meter.

*Note: When measuring current within the circuit, press down on the push switch and quickly record the reading. Do not leave the push switch down longer than necessary. The temperature of the resistor increases the longer the circuit is connected. The longer the circuit is connected, the more the temperature change in the resistor will change the resistance of the resistor.

Procedure:

1. Starting with a single cell holder and D cell, construct an operational circuit that includes the resistor, push switch, and multi-meter. When connecting the resistor, use the right and left leads. Do not use the middle lead. Draw the circuit diagram below. Check your circuit with your teacher before moving on.

2. Press down on the push switch and record the reading on the ammeter in the data table.

3. Connect a second cell in series with the initial cell in your circuit. Draw the circuit diagram below. Check your circuit with your teacher before moving on.

4. Press down on the push switch and record the reading on the ammeter in the data table.

5. Construct a circuit that includes three, four, and five cells in series. Press down on the push switch each time and record the reading on the ammeter in the data table.

Data Table:

Number of Cells	Voltage (V)	Current (A)
1	1.5	
2	3.0	
3	4.5	
4	6.0	
5	7.5	

Data Analysis:

1. Construct a current vs. voltage graph and attach this to this booklet.

2. Find the slope of your graph. Show all work including formula and substitution with units.

Analysis Questions:

1. What is the relationship between the current and voltage in a circuit?

____

____

____

2. What is the physical significance of the slope of the current vs. voltage graph?

____

____

____

3. Develop an equation that calculates the resistance of a resistor and that illustrates the relationship between current and voltage. Use your graph.

ACTIVITY 6: The Effect of Length on Resistance

Teacher Instructions

Purpose: To determine the effect of length on the resistance of a resistor.

Students should be familiar with at least voltage and current before doing these activities. If resistance has not been covered, these activities can also be used to introduce resistance.

Voltage (V): The amount of electrical potential energy per amount of charge. Unit: voltage (V)

$$V = \frac{W}{q}$$

Equation 5 – 1: Voltage

Current (I): The amount of charge (q) that passes a given area per amount of time (t). Unit: amps (A)

$$I = \frac{q}{t}$$

Equation 5 – 2: Current

Resistance (R): The opposition of charge flow. Unit: ohms (Ω)

The geometrical factors that affect an electrical devices resistance are length (L), cross-sectional area (A), and resistivity (ρ), which is a measure of the conductibility of a given material.

$$R = \frac{\rho L}{A}$$

Equation 5 – 3: Resistance

The temperature of an electrical device will also affect the device's resistance. Generally, as the temperature increases, the resistance increases.
Activity 6

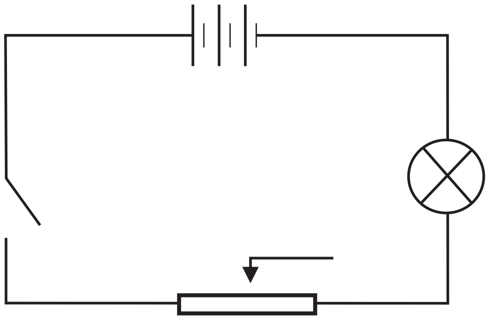
Purpose: To determine the effect of length on the resistance of a resistor.

Materials: lamp holder (component 1), light bulb, 3 cell holders (component 2), 3 D cells, variable resistor (component 3), push switch (component 4), 6 banana plug leads, 2 alligator clips, and multi-meter.

*__Note:__ When measuring current within the circuit, press down on the push switch and quickly record the reading. Do not leave the push switch down longer than necessary. The temperature of the resistor increases the longer the circuit is connected and will change the resistance of the wire.

Part 1:

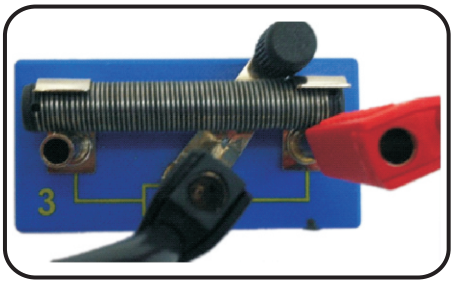
1. Construct the following circuit using the list materials.



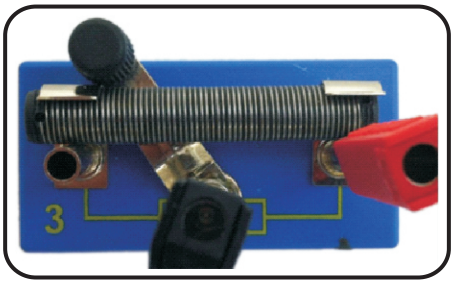
Note: When connecting the variable resistor, use the right and middle leads.

2. Adjust the variable resistor and observe the brightness of the light bulb.

Short Setting



Long Setting

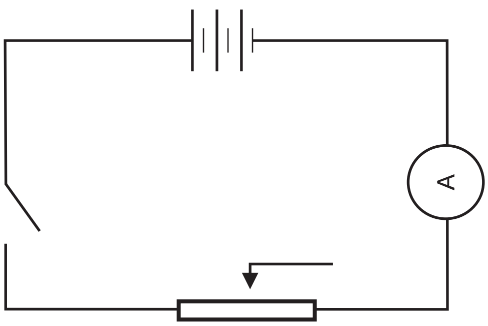


How does the brightness of the bulb when the resistor is long compared to when the resistor is short? How do you think the voltage, current, and resistance compare in each case.

The light bulb is less bright when the resistor is long compared to when the resistor is short. The resistance is greater when the resistor is long. The current is less when the resistor is long. The voltage does not change because the geometry of the resistor does not affect voltage.

Part 2:

1. Construct the following circuit using the listed materials.



Note: When connecting the variable resistor, use the right and middle leads.

2. With the variable resistor in the short position, record the reading of the ammeter in the data table.
3. Gradually increase the length of the resistor and record the reading of the ammeter in the data table.
4. Repeat step 3 for a total of seven trials. Make sure to cover the entire span of the resistor.

Data Table:

Length	Current (A)	Resistance (Ω)
1 (short)		
2		
3		
4		
5 (long)		

Analysis Questions:

1. Using Ohm's law, determine the resistance of the circuit at each length. Record these values in the data table. Note: Since three cells were used, assume the voltage is 4.5 V.

   Length 1:

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

$$R = \frac{4.5\ V}{0.173}$$

$$R = 26.2\ \Omega$$

2. What is the relationship between the length of a resistor and its resistance?

   As the length of a resistor increases, the resistance of the resistor increases.

Name:____ Date:_______________________

Activity 6

The Effect of Length on Resistance

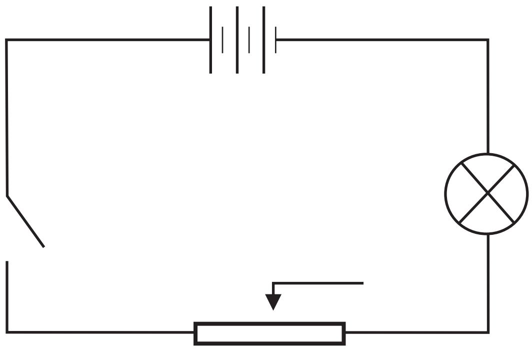
Purpose: To determine the effect of length on the resistance of a resistor.

Materials: lamp holder (component 1), light bulb, 3 cell holders (component 2), 3 D cells, variable resistor (component 3), push switch (component 4),6 banana plug leads, 2 alligator clips, and multi-meter.

*Note: When measuring current within the circuit, press down on the push switch and quickly record the reading. Do not leave the push switch down longer than necessary. The temperature of the resistor increases the longer the circuit is connected and this will change the resistance of the wire.

Part 1:

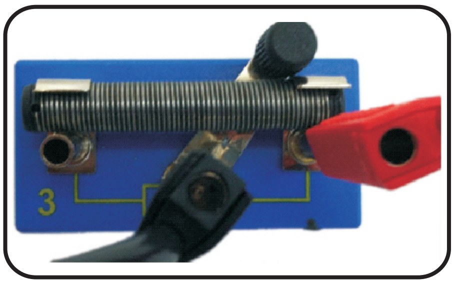
1. Construct the following circuit using the list materials.



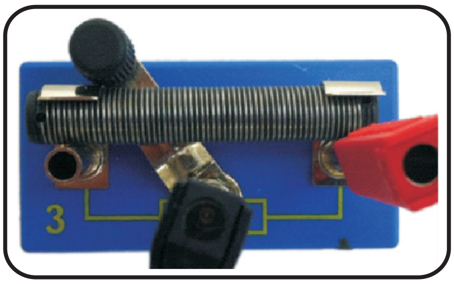
Note: When connecting the variable resistor, use the right and middle leads.

2. Adjust the variable resistor and observe the brightness of the light bulb.

Long Setting



Short Setting



How does the brightness of the bulb when the resistor is long compared to when the resistor is short? How do you think the voltage, current, and resistance compare in each case.

____

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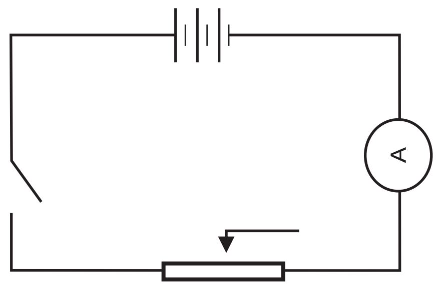
Part 2:

1. Construct the following circuit using the listed materials.

   Make sure the ammeter is wired in series



Note: When connecting the variable resistor, use the right and middle leads.

2. With the variable resistor in the short position, record the reading of the ammeter in the data table.
3. Gradually increase the length of the resistor and record the reading of the ammeter in the data table.
4. Repeat step 3 for a total of seven trials. Make sure to cover the entire span of the resistor.

Data Table:

Length	Current (A)	Resistance (Ω)
1 (short)		
2		
3		
4		
5 (long)		

Analysis Questions:

1. Using Ohm's law, determine the resistance of the circuit at each length. Record these values in the data table. Note: Since three cells were used, assume the voltage is 4.5 V.

2. What is the relationship between the length of a resistor and its resistance?

____

____

____

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ACTIVITY 7: Series Circuits

Teacher Instructions

This lab can be done with the intention of students developing the rules for resistance, current, and voltage for series circuits, or as a way to reinforce those rules.

Background:

One method of connecting two or more electrical devices in a circuit is to connect them in series. This means the charge within the circuit will pass through each one of the electrical devices in consecutive fashion. In other words, all the devices in a series circuit are on one loop. Older strings of holiday lights are wired in series. One effect of being wired in series is that if one bulb was broken or unscrewed, the entire string of lights would not work. The means by which the electrical devices are connected will impact the overall resistance, the current, and energy distribution of the circuit. This is one disadvantage of series circuits, another disadvantage is that the more components that are added to the circuit, the more resistance in the circuit.

As resistors are added in series, the total (equivalent) resistance of the circuit increases. The total resistance of a series circuit is the sum of the individual resistance of each resistor.

$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$

Equation 7 - 1: Total Resistance of a Series Circuit

A circuit wired in series has only one path for the charge to travel. Therefore, the current in a series circuit must be the same everywhere. Each resistor will have the same current moving through it. This means that an ammeter can be placed anywhere in the circuit and have the same reading.

$$I_T = I_1 = I_2 = I_3 = \ldots$$

Equation 7 – 2: Current in a Series Circuit

Short Circuits:

If the ends of a wire are connected to the positive and negative terminals of a battery, the wire quickly becomes hot. This is an example of a short circuit. Since there is not an electrical device to use the energy gained by the charge from the battery, the wires become hot in order to transfer the energy from the charge. This happens because the charge must return to the battery with no energy. The amount of energy used per unit of charge is called the voltage. The strength of a cell or a series of cells (a battery) is typically measured in volts. In other words, charge gains energy from the battery and loses it to the external circuit. When there is more than one resistor wired in a series circuit, each resistor will divide up the energy according to its resistance. The total voltage of a series circuit is related to the voltage drop of each component is the circuit by the equation

$$V_T = V_1 + V_2 + V_3 + \ldots$$

Equation 7 – 3: Total Voltage of Series Circuit

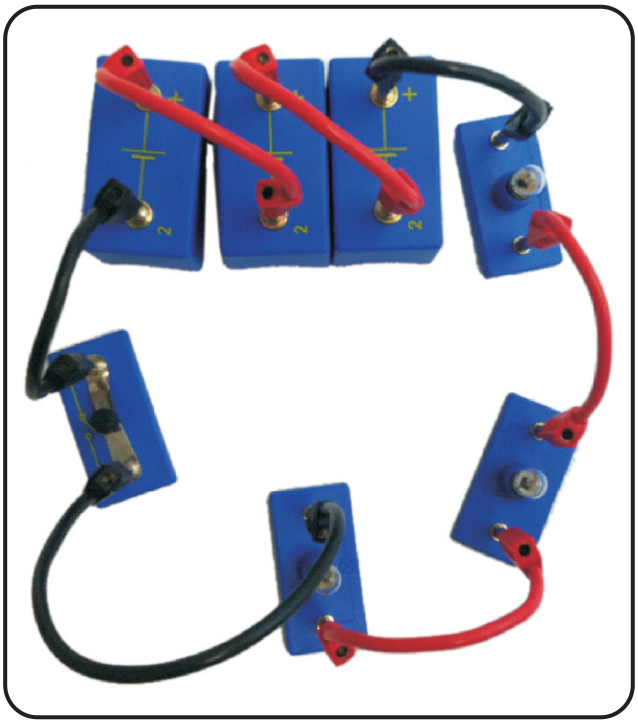


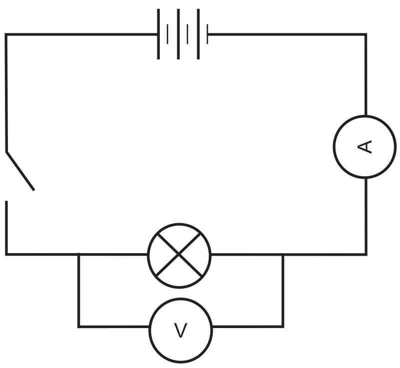
Figure 7 – 1: Three Bulb Series Circuit

Purpose: To measure the current and voltage at various points in a series circuit to determine how the flow of charge and energy are distributed in the circuit.

Materials: 3 lamp holders (component 1), 3 light bulbs, 3 cell holders (component 2), 3 D cells, push switch (component 4), 7 banana plug leads, 2 alligator clips, and multi-meter.

One Component Circuit

1. Construct a simple circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of the light bulb.



2. Measure the current through the light bulb. Record the measurement in data table 7 – 1.
3. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 7 – 1.

4. Measure the voltage drop across the light bulb. Record the measurement in data table 7 – 1.
5. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 7 – 1.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1	*4.69*	*0.185*	*25.4*
Battery (Total Circuit)	*4.78*	*0.185*	*25.8*

Data Table 7 – 1

6. Using Ohm's law, calculate the resistance of the light bulb and of the total circuit. Record each resistance in data table 7 – 1.

Bulb 1:

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

$$R = \frac{4.69\ V}{0.185}$$

$$R = 25.4\ \Omega$$

Battery (Total Circuit):

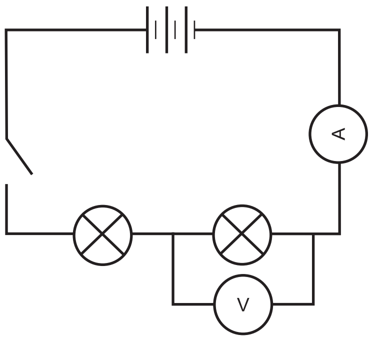
$$R = \frac{V}{I}$$

$$R = \frac{4.78\ V}{0.185}$$

$$R = 25.8\ \Omega$$

Two Component Series Circuit

1. Construct a two light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of one of the light bulbs.



2. Measure the current through the first light bulb. Record the measurement in data table 7 – 2.
3. Measure the current through the second light bulb. Record the measurement in data table 7 – 2.
4. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 7 – 2.
5. Measure the voltage drop across the first light bulb. Record the measurement in data table 7 – 2.
6. Measure the voltage drop across the second light bulb. Record the measurement in data table 7 – 2.
7. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 7 – 2.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1	*2.35*	*0.129*	*18.2*
Bulb 2	*2.37*	*0.129*	*18.4*
Battery (Total Circuit)	*4.78*	*0.129*	*37.1*

Data Table 7 – 2

8. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 7 – 2.

Bulb 1:

$$R = \frac{V}{I} = \frac{2.35\,V}{0.129\,A} = 18.2\,\Omega$$

Bulb 2:

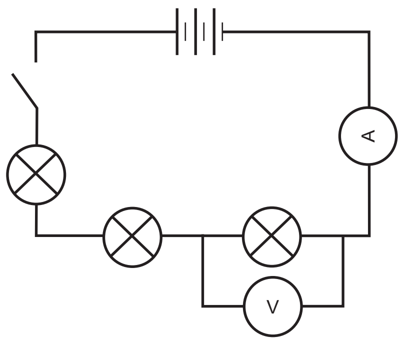
$$R = \frac{V}{I} = \frac{2.37\ V}{0.129\ A} = 18.4\ \Omega$$

Battery (Total Circuit):

$$R = \frac{V}{I} = \frac{4.78\ V}{0.129\ A} = 37.1\ \Omega$$

Three Component Series Circuit

1. Construct a three light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of one of the light bulbs.



2. Measure the current through the first light bulb. Record the measurement in data table 7 – 3.
3. Measure the current through the second light bulb. Record the measurement in data table 7 – 3.
4. Measure the current through the third light bulb. Record the measurement in data table 7 – 3.
5. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 7 – 3.
6. Measure the voltage drop across the first light bulb. Record the measurement in data table 7 – 3.
7. Measure the voltage drop across the second light bulb. Record the measurement in data table 7 – 3.
8. Measure the voltage drop across the third light bulb. Record the measurement in data table 7 – 3.
9. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 7 – 3.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1	1.50	0.105	14.3
Bulb 2	1.64	0.105	15.6
Bulb 3	1.59	0.105	15.1
Battery (Total Circuit)	4.78	0.105	45.5

Data Table 7 – 3

10. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 7 – 3.

    Bulb 1:

    $$R = \frac{V}{I} = \frac{1.50\ V}{0.105\ A} = 14.3\ \Omega$$

    Bulb 2:

    $$R = \frac{V}{I} = \frac{1.64\ V}{0.105\ A} = 15.6\ \Omega$$

    Bulb 3:

    $$R = \frac{V}{I} = \frac{1.59\ V}{0.105\ A} = 15.1\ \Omega$$

    Battery (Total Circuit):

    $$R = \frac{V}{I} = \frac{4.78\ V}{0.105\ A} = 45.5\ \Omega$$

Analysis Questions:

1. If one of the light bulbs is unscrewed in a series circuit, what would happen to the other light bulbs? Try this with your three light bulb circuit and explain the outcome.

   If one of the light bulbs is unscrewed, the complete loop necessary for a circuit to work is broke because a series circuit only has one path of charge flow.

2. How does the total voltage of the circuit compare to the voltage drop across each light bulb? Cite evidence from your data. Write an equation that relates the two.

   Two Bulb Circuit

   Bulb 1: 2.35 V　　*Bulb 2: 2.37 V*

   The sum of the voltage of each light bulb is 4.72 V and the total voltage measured 4.78 V.*

   Three Bulb Circuit

   Bulb 1: 1.5 V　　*Bulb 2: 1.64 V*　　*Bulb 3: 1.59 V*

   The sum of the voltage of each light bulb is 4.73 V and the total voltage measured 4.78 V.*

   Equation $: V_T = V_1 + V_2 + V_3 + ...$

   **The small difference is due to the internal resistance of the battery and resistance in the wires.*

3. How does the total current of the circuit compare to the current through each light bulb? Write an equation that relates the two.

   Two Bulb Circuit

   Bulb 1: 0.129 A　　*Bulb 2: 0.129 A*

   Three Bulb Circuit

   Bulb 1: 0.150 A　　*Bulb 2: 0.150 A*　　*Bulb 3: 0.150 A*

   The total current measured 0.129 A. The total current is the same as the current through each light bulb.

   Equation $: I_T = I_1 = I_2 = I_3 = ...$

4. How does the total resistance of the circuit compare to the resistance of each light bulb. Write an equation that relates the two.

   Two Bulb Circuit

   Bulb 1: 18.2 Ω　　*Bulb 2: 18.4 Ω*

   The sum of the resistance of each light bulb is 36.6 Ω and the total resistance was 37.1 Ω.*

Three Bulb Circuit

Bulb 1: 14.3 Ω *Bulb 2: 15.6 Ω* *Bulb 3: 15.1 Ω*

The sum of the resistance of each light bulb is 45.0 Ω and the total resistance was 45.5 Ω.*

Equation : $R_{eq} = R_1 + R_2 + R_3 + \ldots$

**The small difference is due to the internal resistance of the battery and resistance in the wires.*

5. What happens to the total resistance as you add light bulbs in series? Cite evidence from your data.

   As you add light bulbs in series, the total resistance increases. The total resistance for the one bulb circuit was 25.8 Ω. The total resistance for the two bulb circuit was 37.1 Ω and the total resistance for the three bulb circuit was 45.5 Ω.

Name:_________________________________ Date:____________________

Activity 7

Series Circuits

Purpose: To measure the current and voltage at various points in a series circuit to determine how the flow of charge and energy are distributed in the circuit.

Materials: 3 lamp holders (component 1), 3 light bulbs, 3 cell holders (component 2), 3 D cells, push switch (component 4), 7 banana plug leads, 2 alligator clips, and multi-meter.

One Component Circuit

1. Construct a simple circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of the light bulb.

2. Measure the current through the light bulb. Record the measurement in data table 7 – 1.
3. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 7 – 1.
4. Measure the voltage drop across the light bulb. Record the measurement in data table 7 – 1.
5. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 7 – 1.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1			
Battery (Total Circuit)			

Data Table 7 – 1

6. Using Ohm's law, calculate the resistance of the light bulb and of the total circuit. Record each resistance in data table 7 – 1.

Two Component Series Circuit

1. Construct a two light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of one of the light bulbs.

2. Measure the current through the first light bulb. Record the measurement in data table 7 – 2.
3. Measure the current through the second light bulb. Record the measurement in data table 7 – 2.
4. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 7 – 2.
5. Measure the voltage drop across the first light bulb. Record the measurement in data table 7 – 2.
6. Measure the voltage drop across the second light bulb. Record the measurement in data table 7 – 2.
7. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 7 – 2.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1			
Bulb 2			
Battery (Total Circuit)			

Data Table 7 – 2

8. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 7 – 2.

Three Component Series Circuit

1. Construct a three light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of one of the light bulbs.

2. Measure the current through the first light bulb. Record the measurement in data table 7 – 3.
3. Measure the current through the second light bulb. Record the measurement in data table 7 – 3.
4. Measure the current through the third light bulb. Record the measurement in data table 7 – 3.
5. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 7 – 3.

6. Measure the voltage drop across the first light bulb. Record the measurement in data table 7 – 3.
7. Measure the voltage drop across the second light bulb. Record the measurement in data table 7 – 3.
8. Measure the voltage drop across the third light bulb. Record the measurement in data table 7 – 3.
9. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 7 – 3.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1			
Bulb 2			
Bulb 3			
Battery (Total Circuit)			

Data Table 7 – 3

10. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 7 – 3.

Analysis Questions:

1. If one of the light bulbs is unscrewed in a series circuit, what would happen to the other light bulbs? Try this with your three light bulb circuit and explain the outcome.

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2. How does the total voltage of the circuit compare to the voltage drop across each light bulb? Cite evidence from your data. Write an equation that relates the two.

3. How does the total current of the circuit compare to the current through each light bulb? Write an equation that relates the two.

4. How does the total resistance of the circuit compare to the resistance of each light bulb. Write an equation that relates the two.

5. What happens to the total resistance as you add light bulbs in series? Cite evidence from your data.

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ACTIVITY 8: Parallel Circuits

Teacher Instructions

This lab can be done with the intention of students developing the rules for resistance, current, and voltage for parallel circuits, or as a way to reinforce those rules.

Background:

A different method of connecting two or more electrical devices in a circuit is to connect them in parallel. A parallel circuit is two or more series circuits connected to the same power source. This means the charge within a circuit has “a choice” as to which of the electrical devices it will pass through. Unlike a series circuit, where the charge passes through every electrical device, the charge in a parallel circuit will only pass through one electrical device. The wiring in your house is done in parallel. One effect of being wired in parallel is that if one of the electrical devices is turned off, the other devices can still function. For example, the toaster in your kitchen can still work if the coffee maker is turned off.

As resistors are added in parallel, the total (equivalent) resistance of the circuit decreases. The total resistance of a parallel circuit is given by the equation

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ \ldots$$

Equation 8 – 1: Total Resistance of a Parallel Circuit

Charge within a parallel circuit will divide itself up amongst the resistors. The total current of the circuit is the sum of the current through each individual resistor.

$$I_T = I_1 + I_2 + I_3 + \ \ldots$$

Equation 8 – 2: Total Current in a Parallel Circuit

Since the charge within a circuit will divide itself up amongst the resistors and only move through one, the voltage drop across each resistor must be equal to that of the energy source (battery).

$$V_T = V_1 = V_2 = V_3 = \ \ldots$$

Equation 8 – 3: Voltage in a Parallel Circuit

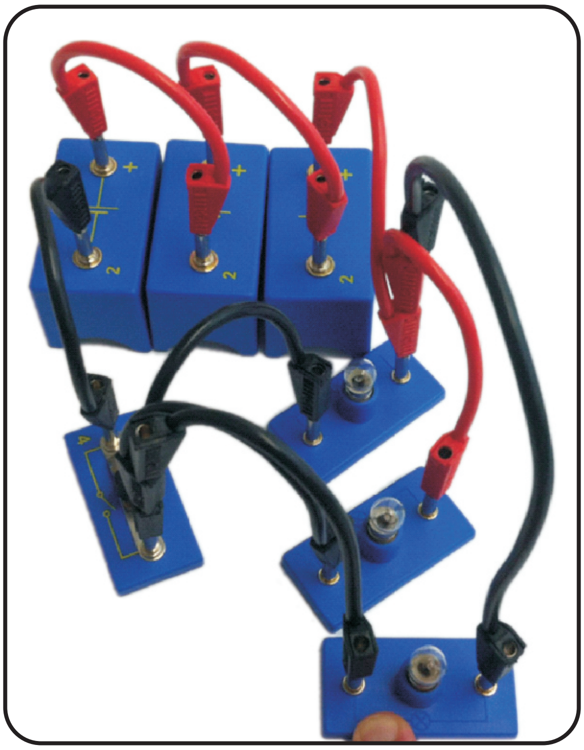


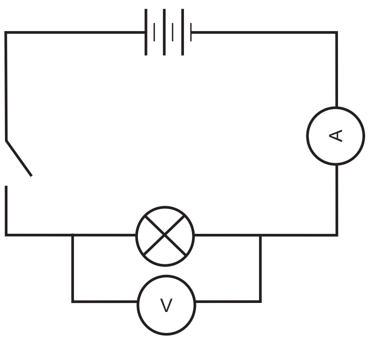
Figure 8 – 1: Three Bulb Parallel Circuit

Purpose: To measure the current and voltage at various points in a parallel circuit to determine how the flow of charge and energy are distributed in the circuit.

Materials: 3 lamp holders (component 1), 3 light bulbs, 3 cell holders (component 2), 3 D cells, push switch (component 4), 7 banana plug leads, 2 alligator clips, and multi meter.

One Component Circuit

1. Construct a simple circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of the light bulb.



2. Measure the current through the light bulb. Record the measurement in data table 8 – 1.

3. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 8 – 1.

4. Measure the voltage drop across the light bulb. Record the measurement in data table 8 – 1.
5. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 8 – 1.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1	4.69	0.185	25.4
Battery (Total Circuit)	4.78	0.185	25.8

Data Table 8 – 1

6. Using Ohm's law, calculate the resistance of the light bulb and of the total circuit. Record each resistance in data table 8 – 1.

Bulb 1:

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

$$R = \frac{4.69\ V}{0.185\,\mathrm{A}}$$

$$R = 25.4\ \Omega$$

Battery (Total Circuit):

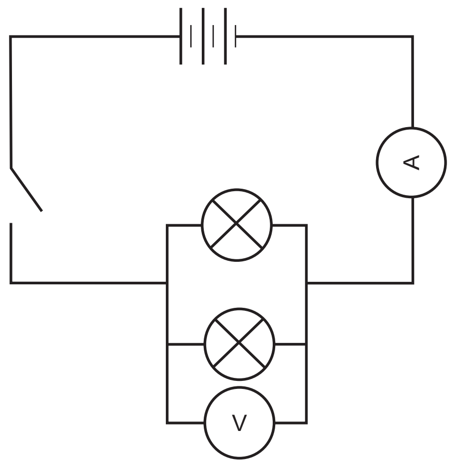
$$R = \frac{V}{I}$$

$$R = \frac{4.78\ V}{0.185\,\mathrm{A}}$$

$$R = 25.8\ \Omega$$

Two Component Parallel Circuit

1. Construct a two light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the ammeter that will measure the total current of the circuit and the voltmeter that will measure the voltage drop of one of the light bulbs.



2. Measure the current through the first light bulb. Record the measurement in data table 8 – 2.
3. Measure the current through the second light bulb. Record the measurement in data table 8 – 2.
4. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 8 – 2.
5. Measure the voltage drop across the first light bulb. Record the measurement in data table 8 – 2.
6. Measure the voltage drop across the second light bulb. Record the measurement in data table 8 – 2.
7. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 8 – 2.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1	4.64	0.181	25.6
Bulb 2	4.64	0.179	25.9
Battery (Total Circuit)	4.78	0.362	13.2

Data Table 8 – 2

8. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 8 – 2.

Bulb 1:

$$R = \frac{V}{I} = \frac{4.64\ V}{0.181\ A} = 25.6\ \Omega$$

Bulb 2:

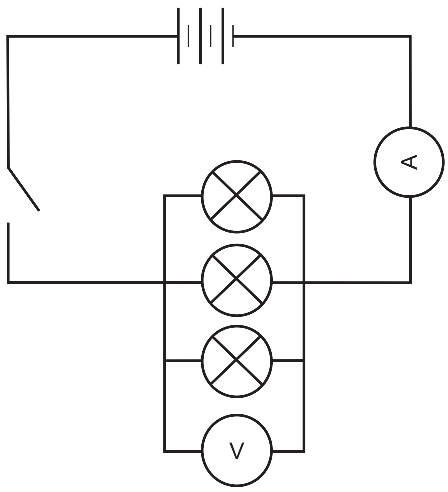
$$R = \frac{V}{I} = \frac{4.64\ V}{0.179\ A} = 25.9\ \Omega$$

Battery (Total Circuit):

$$R = \frac{V}{I} = \frac{4.78\ V}{0.362\ A} = 13.2\ \Omega$$

Three Component Parallel Circuit

1. Construct a three light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeters and ammeters necessary to measure the current and voltage drop of one of the light bulbs.



2. Measure the current through the first light bulb. Record the measurement in data table 8 – 3.
3. Measure the current through the second light bulb. Record the measurement in data table 8 – 3.
4. Measure the current through the third light bulb. Record the measurement in data table 8 – 3.
5. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 8 – 3.
6. Measure the voltage drop across the first light bulb. Record the measurement in data table 8 – 3.
7. Measure the voltage drop across the second light bulb. Record the measurement in data table 8 – 3.
8. Measure the voltage drop across the third light bulb. Record the measurement in data table 8 – 3.

9. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 8 – 3.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1	4.57	0.179	25.5
Bulb 2	4.57	0.180	25.4
Bulb 3	4.57	0.180	25.4
Battery (Total Circuit)	4.78	0.537	8.9

Data Table 8 – 3

10. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 8 – 3.

Bulb 1:

$$R = \frac{V}{I} = \frac{4.57\ V}{0.179\ A} = 25.5\ \Omega$$

Bulb 2:

$$R = \frac{V}{I} = \frac{4.57\ V}{0.180\ A} = 25.4\ \Omega$$

Bulb 3:

$$R = \frac{V}{I} = \frac{4.57\ V}{0.180\ A} = 25.4\ \Omega$$

Battery (Total Circuit):

$$R = \frac{V}{I} = \frac{4.78\ V}{0.537\ A} = 8.9\ \Omega$$

Analysis Questions:

1. If one of the light bulbs is unscrewed in a parallel circuit, what would happen to the other light bulbs? Try this with your three light bulb circuit and explain the outcome.

   If one of the light bulbs is unscrewed, the complete loop necessary for a circuit to work remains intact through the other two light bulbs. The other two light bulbs remain lit.

2. How does the total voltage of the circuit compare to the voltage drop across each light bulb? Cite evidence from your data. Write an equation that relates the two.

   Two Bulb Circuit

   Bulb 1: 4.64 V *Bulb 2: 4.64 V*

   The voltage drop of each light bulb is 4.64 V and the total voltage measured 4.78 V.*

   Three Bulb Circuit

   Bulb 1: 4.57 V *Bulb 2: 4.57 V* *Bulb 3: 4.57 V*

   The voltage drop of each light bulb is 4.57 V and the total voltage measured 4.78 V.*

   The voltage drop of each light bulb is approximately equal to the voltage of the battery.

   Equation : $V_T = V_1 = V_2 = V_3 = ...$

   **The small difference is due to the internal resistance of the battery and resistance of the connecting wires.*

3. How does the total current of the circuit compare to the current through each light bulb? Write an equation that relates the two.

   Two Bulb Circuit

   Bulb 1: 0.181 A *Bulb 2: 0.179 A*

   The sum of the current through each bulb is 0.36 A, and the total current measured 0.362 A.

   Three Bulb Circuit

   Bulb 1: 0.179 A *Bulb 2: 0.180 A* *Bulb 3: 0.180 A*

   The sum of the current through each bulb is 0.539 A, and the total current measured 0.537 A.

   Equation : $I_T = I_1 + I_2 + I_3 + ...$

4. How does the total resistance of the circuit compare to the resistance of each light bulb. You do not have to write an equation that relates the two.

   Two Bulb Circuit

   Bulb 1: 25.6 Ω *Bulb 2: 25.9 Ω*

   The total resistance of the circuit is 13.2Ω, which is less than the resistance of the individual resistors.

   Three Bulb Circuit

   Bulb 1: 25.5 Ω *Bulb 2: 25.4 Ω* *Bulb 3: 25.4 Ω*

   The total resistance of the circuit is 8.9 Ω, which is less than the resistance of the individual resistors.

5. What happens to the total resistance as you add light bulbs in series? Cite evidence from your data.

   As you add light bulbs in parallel, the total resistance decreases. The total resistance for the one bulb circuit was 25.8 Ω. The total resistance for the two bulb circuit was 13.2 Ω and the total resistance for the three bulb circuit was 8.9 Ω.

Name:_________________________________ Date:____________________

Activity 8

Parallel Circuits

Purpose: To measure the current and voltage at various points in a parallel circuit to determine how the flow of charge and energy are distributed in the circuit.

Materials: 3 lamp holders (component 1), 3 light bulbs, 3 cell holders (component 2), 3 D cells, push switch (component 4), 7 banana plug leads, 2 alligator clips, and multi-meter.

One Component Circuit

1. Construct a simple circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeter and ammeter necessary to measure the current and voltage drop of the light bulb.

2. Measure the current through the light bulb. Record the measurement in data table 8 – 1.
3. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 8 – 1.
4. Measure the voltage drop across the light bulb. Record the measurement in data table 8 – 1.
5. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 8 – 1.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1			
Battery (Total Circuit)			

Data Table 8 – 1

6. Using Ohm's law, calculate the resistance of the light bulb and of the total circuit. Record each resistance in data table 8 – 1.

Two Component Series Circuit

1. Construct a two light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the ammeter that will measure the total current of the circuit and the voltmeter that will measure the voltage drop of one of the light bulbs.

2. Measure the current through the first light bulb. Record the measurement in data table 8 – 2.
3. Measure the current through the second light bulb. Record the measurement in data table 8 – 2.
4. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 8 – 2.
5. Measure the voltage drop across the first light bulb. Record the measurement in data table 8 – 2.
6. Measure the voltage drop across the second light bulb. Record the measurement in data table 8 – 2.
7. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 8 – 2.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1			
Bulb 2			
Battery (Total Circuit)			

Data Table 8 – 2

8. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 8 – 2.

Three Component Series Circuit

1. Construct a three light bulb series circuit using the listed materials. Using circuit symbols, draw a diagram of your circuit below. Include the correct position of the voltmeters and ammeters necessary to measure the current and voltage drop of one of the light bulbs.

2. Measure the current through the first light bulb. Record the measurement in data table 8 – 3.
3. Measure the current through the second light bulb. Record the measurement in data table 8 – 3.
4. Measure the current through the third light bulb. Record the measurement in data table 8 – 3.
5. Measure the current through the battery. This is the total current in the circuit. Record the measurement in data table 8 – 3.

6. Measure the voltage drop across the first light bulb. Record the measurement in data table 8 – 3.
7. Measure the voltage drop across the second light bulb. Record the measurement in data table 8 – 3.
8. Measure the voltage drop across the third light bulb. Record the measurement in data table 8 – 3.
9. Measure the voltage drop across the battery. This is the total voltage of the circuit. Record the measurement in data table 8 – 3.

	Voltage (V)	Current (A)	Resistance (Ω)
Bulb 1			
Bulb 2			
Bulb 3			
Battery (Total Circuit)			

Data Table 8 – 3

10. Using Ohm's law, calculate the resistance of each light bulb and of the total circuit. Record each resistance in data table 8 – 3.

Analysis Questions:

1. If one of the light bulbs is unscrewed in a parallel circuit, what would happen to the other light bulbs? Try this with your three light bulb circuit and explain the outcome.

____

____

____

2. How does the total voltage of the circuit compare to the voltage drop across each light bulb? Cite evidence from your data. Write an equation that relates the two.

3. How does the total current of the circuit compare to the current through each light bulb? Write an equation that relates the two.

4. How does the total resistance of the circuit compare to the resistance of each light bulb. You do not have to write an equation that relates the two.

5. What happens to the total resistance as you add light bulbs in series? Cite evidence from your data.

ACTIVITY 9: The Switch Game

Teacher Instructions

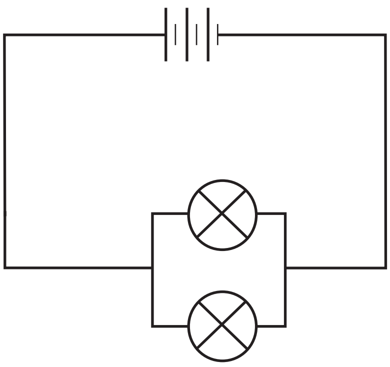
Purpose: To solve various circuit problems involving switches.

Once students are familiar with series and parallel circuits, have students attempt these switch problems.

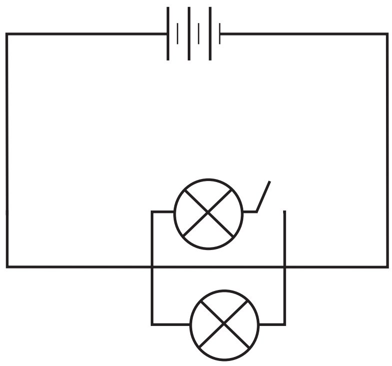
Materials: 3 lamp holders (component 1), 3 light bulbs, 3 cell holders (component 2), 3 D cells, 2 push switches (component 4), and 9 banana plug leads.

Directions: Each circuit below is paired with a switch problem. Construct the circuit that meets the criteria of the problem and redraw the circuit diagram with the included switches.

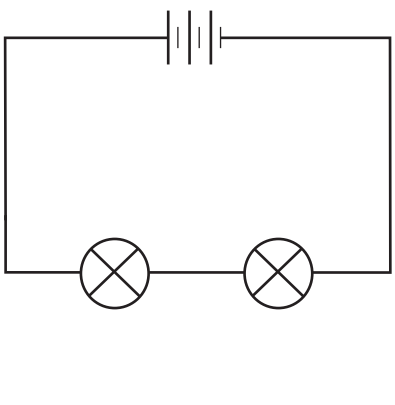
1. Include a switch that allows one light bulb to stay on all of the time, but when pressed, the switch allows the other light bulb to light up.



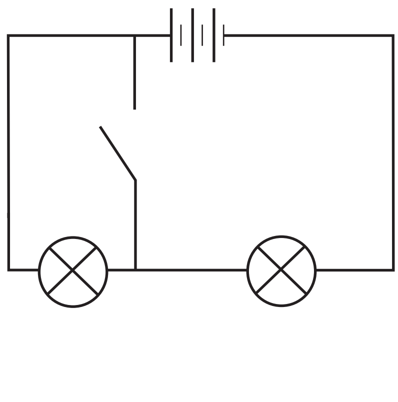
Answer:



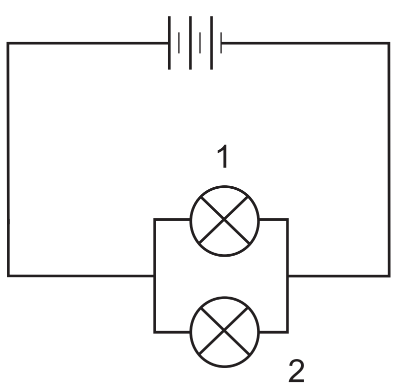
2. Include a switch that allows both light bulbs to remain on while the switch is not pressed, and when pressed, one of the light bulbs goes out.



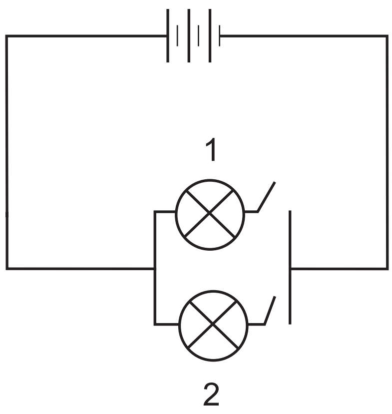
Answer:



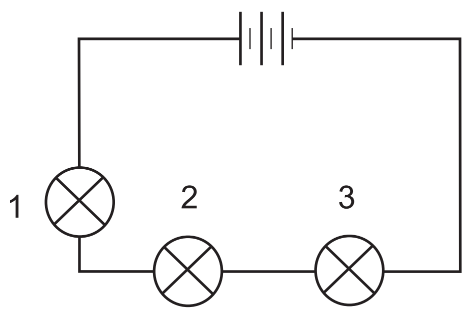
3. Include two switches so that when one switch is pressed, light bulb 1 lights up, and when the other switch is pressed, light bulb 2 lights up.



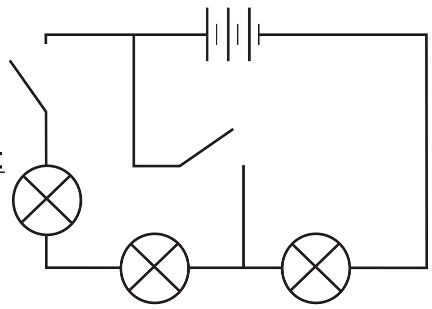
Answer:



4. Include two switches so that when one switch is pressed all of the light bulbs light up, but if the other switch is pressed, only light bulb 3 lights up.



Answer:



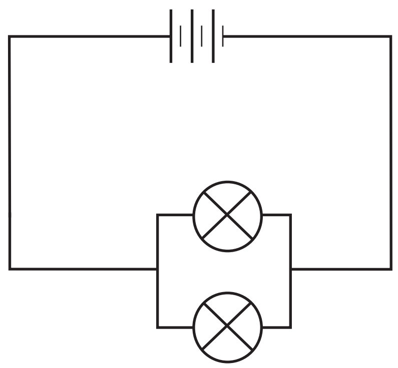
Name:_______________________________________ Date:______________________

Activity 9

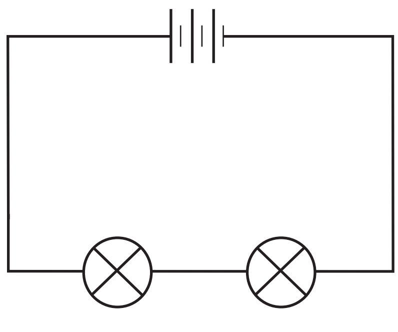
The Switch Game

Directions: Each circuit below is paired with a switch problem. Construct the circuit that meets the criteria of the problem and redraw the circuit diagram with the included switches.

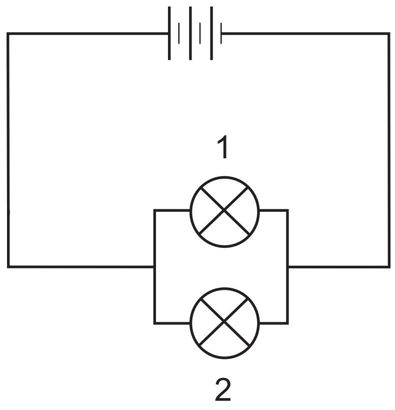
1. Include a switch that allows one light bulb to stay on all of the time, but when pressed, the switch allows the other light bulb to light up.



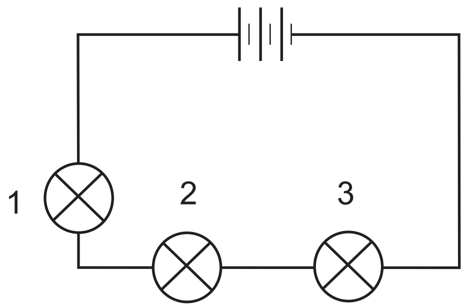
2. Include a switch that allows both light bulbs to remain on while the switch is not pressed, and when pressed, one of the light bulbs goes out.



3. Include two switches so that when one switch is pressed, light bulb 1 lights up, and when the other switch is pressed, light bulb 2 lights up.



4. Include two switches so that when one switch is pressed all of the light bulbs light up, but if the other switch is pressed, only light bulb 3 lights up.



ACTIVITY 10: Eureka Wire Resistance Investigation

Teacher Instructions

In addition to the materials supplied in the Basic Electricity Kit, each student pair will need 1 meter lengths of copper and eureka (constantan) wire. Reels of 20 swg copper and 34 swg eureka wire are supplied with the kit. If the resistivity of the materials is to be compared, samples of 20 swg eureka or 34 swg copper will be needed. Pupils also need small pieces of aluminum cooking foil to put in the clips. Pre-cutting the length of wire and wrapping it around pieces of hardboard before the students start the experiment will prevent wire from being wasted. Eureka is an alloy of two metals: copper and nickel. It is made by mixing molten copper with molten nickel then forming the “mixed metals” in to a wire.

Purpose: To determine what variables affect the resistivity of wire.

Materials: 1universal clip (component 5), 1 light bulb (component 1), 3 cell holders (component 2), 3 D cells, 1 push switches (component 4), and 5 banana plug leads, 1 meter Eureka wire 34 swg, 1 meter copper wire 20 swg, 10 meter Eureka wire 20 swg or 1 meter copper wire 34 swg, boiling hot water bath

Directions:

1. First fit crocodile clips on to the universal clip and put a V-shaped piece of aluminum foil into each clip as shown in figure 10-1 below.

Figure 10

2. Push a connecting lead in to each hole. (The left hand hole is shown with the connecting lead properly inserted on figure 10-1.)

3. Now put your universal clips in to a circuit as shown in figure 10-2.

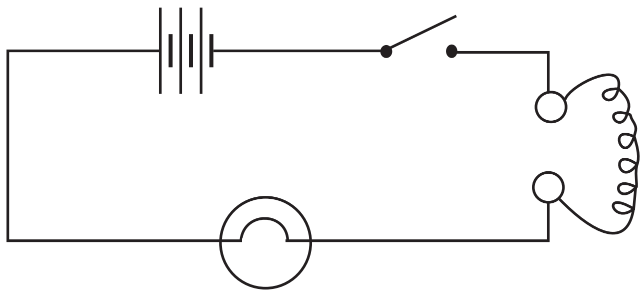


Figure 10-2

4. Test the circuit to make sure it by connecting a lead across the crocodile clips. If the circuit is properly connected, the lamp should light when you press the switch.
5. To make lengths of wire easy to handle, you can wind them in to long coils around a pencil or piece of board. Make sure the wire is wrapped around an insulating material and that bare wires do not touch one another.
6. Put your copper wire across the clip as shown in figure 10-2 and note the brightness of the bulb.
7. In the space provided below, make a list of things you can change about the wire.

   The length of the wire, the thickness of the wire, the material the wire is made out of, the temperature of the wire.

8. Try changing one variable listed above at a time and see how it affects the brightness of the bulb. Record your observations in a neat data table below

Data:

Variable Changed	**How Variable Was Changed**	**Effect on Brightness of Bulb**
Length of wire	*Shorter*	*Brighter*
Thickness of wire	*Thicker*	*Brighter*
Temperature (copper)	*Hotter*	*Dimmer*
Temperature (eureka)	*Hotter*	*None*
Material	*Copper vs. Eureka*	*Copper was brighter*

***Notes**: Students must change only one variable at a time. For example, when comparing copper and eureka wire, the temperature, length, and thickness of the wire must be the same. It is difficult to see how resistance changes with length with the copper wire as the resistance is so small, eureka wire is better suited for this. Eureka wire does not notably change resistance based on change in temperature. Dunking the 34 swg copper wire in a boiling hot water bath will change almost double the resistance.

This might not be enough to see the brightness of the bulb dim, but it should show up on an ohmmeter. **Make sure that all necessary precautions including eye wear and gloves are used around boiling water to avoid burns.**

Data Analysis:

1. What is a better conductor of electricity, copper wire or Eureka wire? Explain your reasoning using your observations from your experiment.

   The copper wire is a better conductor of electricity because the same length of copper wire made the light bulb burn brighter than when the Eureka wire was used.

2. What is a better conductor of electricity, thin Eureka wire or thick Eureka wire? Explain your answer using your observations to support your answer.

   Thick Eureka wire is a better conductor of electricity because the light bulb burned brighter when the thicker Eureka wire was used.

3. The current running through a circuit is reflected by how bright the light bulb burned during the circuit. Using this information, describe the length, thickness, temperature, and type of wire that would have the most current running through it.

   A copper wire that was thick, short, and cold would have the most current running through it.

4. Describe the thickness, temperature, type of wire and length of wire that would draw a very low current.

   A Eureka wire that was thin, and long would have the least current running through it. The temperature would have little effect on the current.

5. If making a device that needs electrical wiring, which type of wire would you use, copper or Eureka wire? Explain your reasoning.

   I would use Eureka wire because I could get a more reliable resistance. As the wire is connected to a circuit for a length of time, it heats up. The resistance of my device would change if I used copper wire and might affect how my device worked.

Name:_______________________________________ Date:______________________

ACTIVITY 10

Eureka Wire Resistance Investigation

Purpose: To determine what variables affect the resistivity of wire.

Materials: 1 universal clip (component 5), 1 light bulb (component 1), 3 cell holders (component 2), 3 D cells, 1 push switches (component 4), and 5 banana plug leads, 1 meter Eureka wire 34 swg, 1 meter copper wire 20 swg, 1 meter Eureka wire 20 swg or 1 meter copper wire 34 swg.

Directions:

1. First fit crocodile clips on to the universal clip and put a V-shaped piece of aluminum foil into each clip as shown in figure 10-1 below.

Figure 10-1

2. Push a connecting lead in to each hole. (The left hand hole is shown with the connecting lead properly inserted on figure 10-1.)

3. Now put your universal clips in to a circuit as shown in figure 10-2.

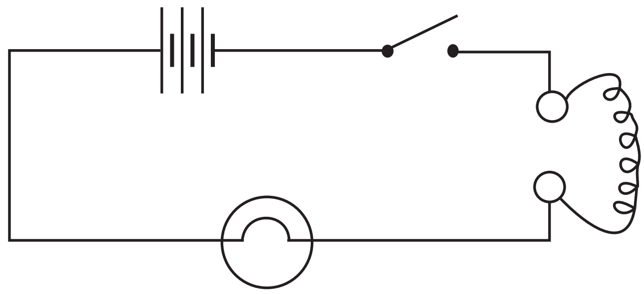


Figure 10-2

4. Test the circuit to make sure it by connecting a lead across the crocodile clips. If the circuit is properly connected, the lamp should light when you press the switch.
5. To make lengths of wire easy to handle, you can wind them in to long coils around a pencil or piece of board. Make sure the wire is wrapped around an insulating material and that bare wires do not touch one another.
6. Put your copper wire across the clip as shown in figure 10-2 and note the brightness of the bulb.
7. In the space provided below, make a list of things you can change about the wire.

____

____

____

____

8. Try changing one variable listed above at a time and see how it affects the brightness of the bulb. Record your observations in a neat data table below

Data:

Variable Changed	**How Variable Was Changed**	**Effect on Resistance of Wire/Brightness of Bulb**
Length of wire		
Thickness of wire		
Temperature (copper)		
Temperature (eureka)		
Material		

Data Analysis:

1. What is a better conductor of electricity, copper wire or Eureka wire? Explain your reasoning using your observations from your experiment.

____

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____

2. What is a better conductor of electricity, thin Eureka wire or thick Eureka wire? Explain your answer using your observations to support your answer.

____

____

____

3. The current running through a circuit is reflected by how bright the light bulb burned during the circuit. Using this information, describe the length, thickness, temperature, and type of wire that would have the most current running through it.

____

____

____

4. Describe the thickness, temperature, type of wire and length of wire that would draw a very low current.

____

____

____

5. If making a device that needs electrical wiring, which type of wire would you use, copper or Eureka wire? Explain your reasoning.

____

____

____

ACTIVITY 11: The Diode

Teacher Instructions

The diode is by far the simplest new circuit element that we will be encountering in these experiments. Its job is to restrict current flow to one direction.

The symbol of the diode then has a straightforward meaning: the arrow and the bar instructs placement according to the flow of current in the circuit. When the arrow points in the direction of current flow, the diode is said to be *forward-biased*. Oppositely when the diode points against current flow, the diode is now *reverse-biased*. That is not to say that current will always flow when in the forward-bias direction. One must also overcome the characteristic "diode drop" by supplying the diode with a minimum voltage.

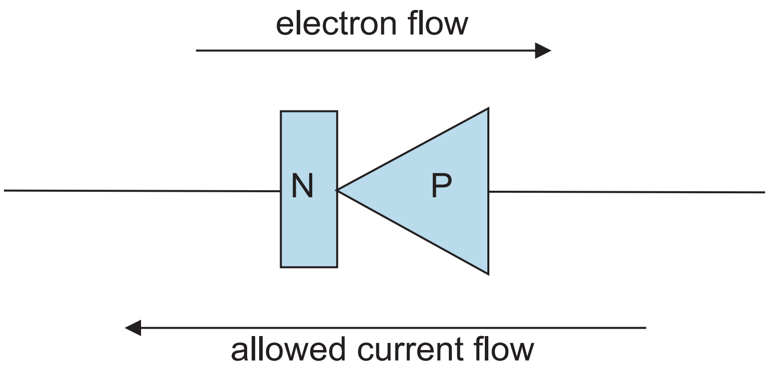


Figure 11.1

The diode is made up of a crystal lattice with two types of regions: an N-type region and a P-type region. The N-type region has an excess of electrons while the P-type region has a lack of electrons, sometimes referred to as "holes". It is the behavior of these two types of regions which gives the diode its useful properties. When in forward-bias direction and current is applied, electrons are injected into the N-type substance and positive charge carriers move into the P-type region. These two charge carriers migrate to the junction of the two regions where they combine to net zero charge and thus allow forward current to continue flowing. When in reverse-bias condition, the electrons are attracted to the positive terminal of the voltage source, and the holes are attracted to the negative terminal. As the positive and negative charge carriers are swept away from the junction, current is not allowed to flow through the diode. See figure 11-2 below.

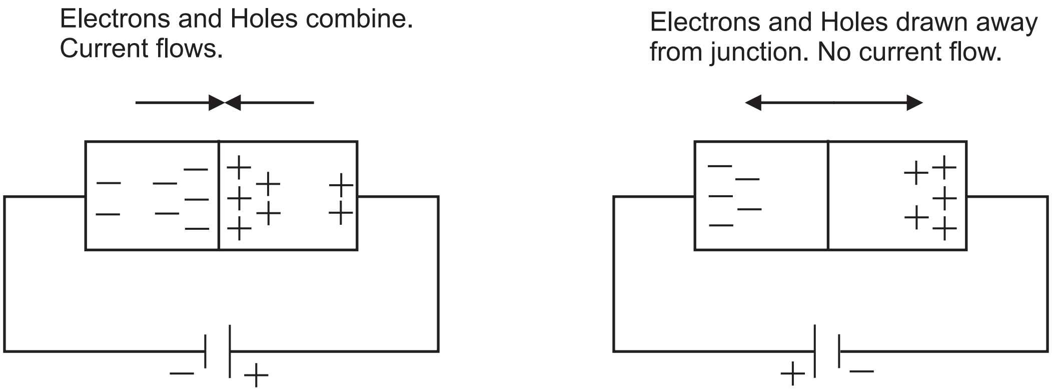
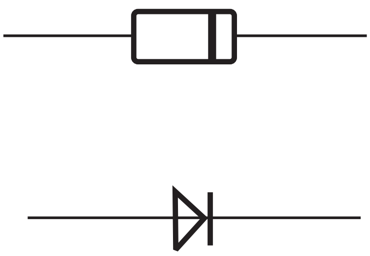


Figure 11-2

Purpose: To observe the forward and reverse-bias properties of the diode.

Materials: 1 universal clip (component 5), 1 light bulb (component 1), 3 cell holders (component 2), 3 D cells, 1 push switches (component 4), and 5 banana plug leads, 1 diode, aluminum foil

The symbol for a diode is shown below the sketch of the diode:



Directions:

1. First fit crocodile clips on to the universal clip and put a V-shaped piece of aluminum foil into each clip and add the diode as shown in figure 11-3 below.

Figure 11-3

2. Push a connecting lead in to each hole. (The left hand hole is shown with the connecting lead properly inserted on figure 11-3.)
3. Now put your universal clips in to a circuit as shown in figure 11-4.

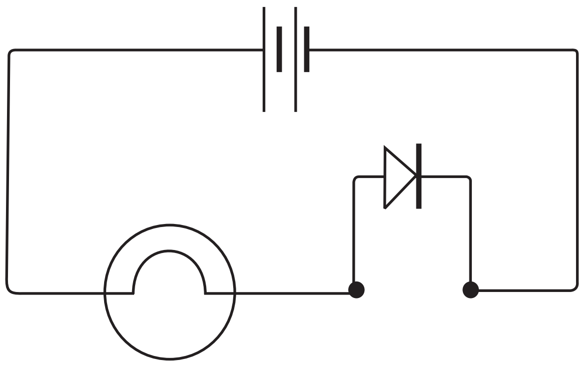


Figure 11-4

4. Test the circuit to make sure it by connecting a lead across the crocodile clips. If the circuit is properly connected, the lamp should light when you press the switch.
5. In the space provided below describe what has happened to the current.

   The light bulb lights and the circuit is functioning properly.
6. Reverse the leads from the DC source so the current flows in the reverse direction. Now your diode is in what is called reverse-bias direction.
7. Before pushing the switch voltage, what do you expect will happen when voltage is applied to the circuit? Record your hypothesis in the space provided below.

   Bulb will not light, current will not flow.
8. Now push down the switch and record your results in the space below.

   The light bulb did not light. The diode only allows current to flow through the circuit in one direction.

Name:______________________________________ Date:_____________________

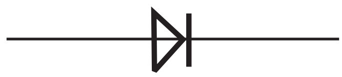
Experiment 11

The Diode

Purpose: To observe the forward and reverse-bias properties of the diode.

Materials: 1 universal clip (component 5), 1 light bulb (component 1), 3 cell holders (component 2), 3 D cells, 1 push switches (component 4), and 5 banana plug leads, 1 diode, aluminum foil

The symbol for a diode is shown below the sketch of the diode:



Directions:

1. First fit crocodile clips on to the universal clip and put a V-shaped piece of aluminum foil into each clip and add the diode as shown in figure 11-3 below.

Figure 11-3

2. Push a connecting lead in to each hole. (The left hand hole is shown with the connecting lead properly inserted on figure 11-3.)
3. Now put your universal clips in to a circuit as shown in figure 11-4.

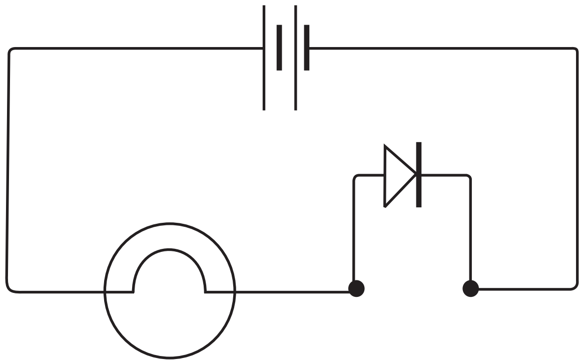


Figure 11-4

4. Test the circuit to make sure it by connecting a lead across the crocodile clips. If the circuit is properly connected, the lamp should light when you press the switch.
5. In the space provided below describe what has happened to the current.

6. Reverse the leads from the DC source so the current flows in the reverse direction. Now your diode is in what is called reverse-bias direction.
7. Before pushing the switch voltage, what do you expect will happen when voltage is applied to the circuit? Record your hypothesis in the space provided below.

8. Now push down the switch and record your results in the space below.

ACTIVITY 12: The Fuse

Teacher Instructions

This activity is a demonstration with no student capture sheet. Now that students understand series and parallel circuits, they know that as more components get added in parallel, the energy source gets used up more quickly, and that if a component in a series circuit breaks, that the whole circuit won't work. Students also know what a short circuit is. It should be stressed that short circuits are dangerous because they cause wires to heat up and can cause an electrical fire and burn down houses. Fuses are installed in houses to prevent fires. If too many appliances are turned on, or there is a short circuit, there could be a lot of current going through the wires. A fuse breaks the circuit and turns all the circuits off before a fire can get started.

Demonstration:

Use a 6.0 volt lantern battery, the steel wool, and some electrician's gloves. Have a small container of water to place the burning wool in after it lights on fire and of course take appropriate safety precautions such has having an extinguisher on hand and removing all dangling objects such as ties and/or hair from the area.

Hold the steel wool across both terminals of the battery. In a matter of a few seconds, the steel wool will light on fire and begin to smoke.

ACTIVITY 13: The Electromagnet

Teacher Instructions

The source of all magnetic fields is moving charge. The orientation of the electrons spinning around the nuclei affects whether or not certain materials become magnetic. In order for a material, such as iron to be magnetic, the electrons must spin in the same direction. This change happens when such a material is in the presence of another strong magnetic field. Such a material is known as a temporary magnet.

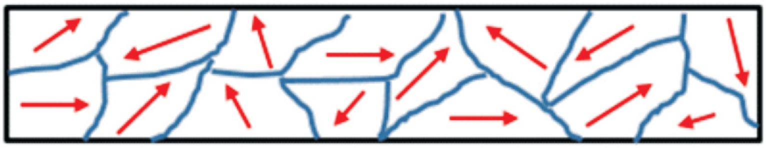


Figure 13 – 1: Magnetic Domains Unaligned

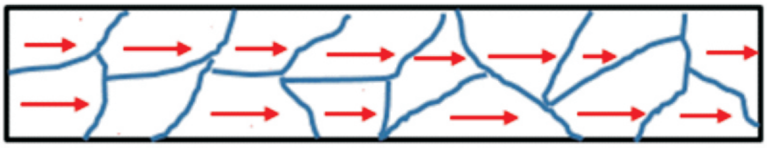


Figure 13 – 2: Magnetic Domains Aligned

Current, which is moving charge, produces a magnetic field. So, if the above mentioned material is placed within the magnetic field produced by the current, the material becomes magnetic. Figure 13 – 3 shows a piece of iron wrapped with wire connected to an energy source. This is what is known as an electromagnet. When current passes though the looped wire, the electron spin of the iron lines up in the same direction. The iron now acts as a magnet. Often times it is convenient to increase the strength of this magnet. The stronger the magnetic field the iron is placed in, the stronger magnet the iron becomes. There are two ways to do this. One method is to increase the number of loops around the iron. The second method is to increase the current that moves through the loops of wire. This can be done by increasing the voltage of the energy source.

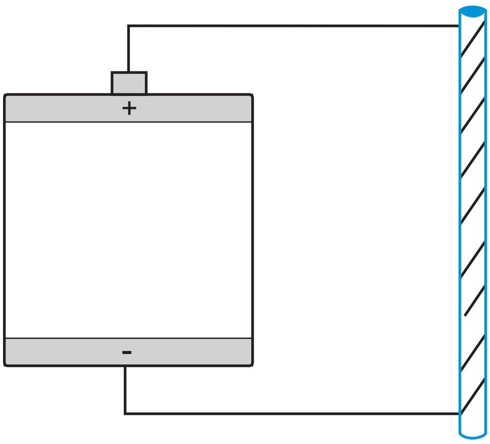


Figure 13 – 3: Electromagnet

A series of wire loops placed along a common axis is known as a solenoid. When connected in a circuit, there is a magnetic field inside and outside of the solenoid. Inside the solenoid, the magnetic field is relatively strong and nearly uniform. Outside of the solenoid, the magnetic field is relatively weak and divergent. A compass can be used to determine the polarity of each end of the solenoid. A compass can be thought of as a tiny magnet. When placed within another magnetic field, the compass will orient itself to line up with the magnetic field it's in. Since unlike poles attract, the north end of the compass will point toward the south pole of the magnet. One feature of magnetic field lines is that they always point away from the north pole of a magnet and toward the south pole of a magnet.

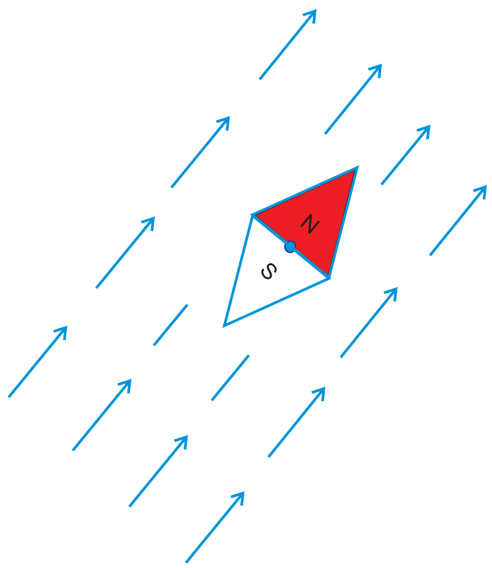


Figure 13 – 4: Compass within Magnetic Field

Purpose: To explore the connection between electricity and magnetism and to determine the variables that determine the strength of an electromagnet.

Materials: 5 cell holders (component 2), 5 D cells, push switch (component 4), 3 banana plug leads, 2 alligator clips, large iron nail, insulated wire, several paper clips, compass, and wire cutter.

*Prior to the activity, cut each group approximately 70 cm of wire. Strip approximately 1 cm of insulation away from each end of each wire.

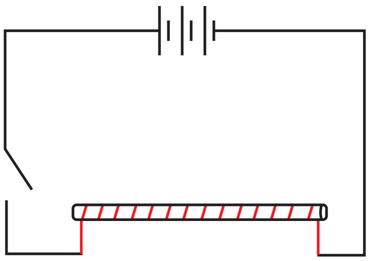
Note:

- When wrapping the wire around the nail, make certain that you wrap the wire in one direction.
- When picking up paper clips, it is suggested that you use the flat end of the nail.

Part 1:

In this section of the activity you will examine the relationship between the number of loops of the electromagnet and the magnetic force created. In order to examine the effect the number of loops has, other variables must be held constant.

1. Create the following circuit using the listed materials. Loop the wire around your nail for a total of three loops. Spread your loops out of the entire nail and do your best to space them evenly.



2. Once the nail is wrapped, press the push switch and see how many paper clips the electromagnet can pick up. Record the number of paper clips in table 13 - 1.

3. Increase the number of loops wrapped around the nail seeing how many paper clips the electromagnet can pick up. Record the number of paper clips in table 13 – 1.

Number of loops	Number of paper clips picked up
3	2
6	4
9	7
12	8
15	10
18	12
21	13
24	15

Data Table 13 – 1

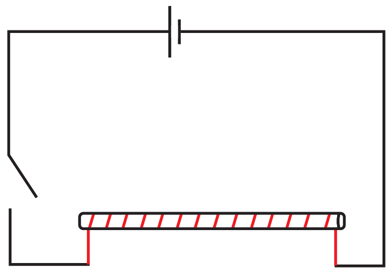
What happens to the strength of the electromagnet as the number of loops increased?

As the number of loops is increased, the number of paper clips picked up increases. This suggests that the strength of the electromagnet increases as the number of loops increases.

Part 2:

In this section of the activity you will examine the relationship between the amount of current in the loops of wire and the magnetic force created. In order to examine the effect the current has, other variables must be held constant. Decide on a set number of loops you want to use and stick with that for the remainder of this section of the activity. The amount of current flowing in the wire will be changed by altering the potential difference in the energy source.

1. Create the following circuit using the listed materials. Loop the wire around your nail for the set number of loops. Spread your loops out of the entire nail and do your best to space them evenly.



2. Once the nail is wrapped, press the push switch and see how many paper clips the electromagnet can pick up. Record the number of paper clips in table 13 – 2.

3. Construct a similar circuit using two, three, four, and, five cells seeing how many paper clips the electromagnet can pick up. Record the number of paper clips in table 13 – 2.

DATA FOR 25 LOOPS

Number of Cells	Potential Difference (V)	Number of paper clips picked up
1	1.5	*6*
2	3.0	*12*
3	4.5	*16*
4	6.0	*23*
5	7.5	*29*

Data Table 13 – 2

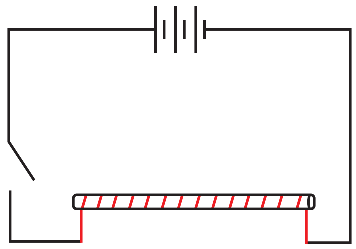
What happened to the strength of the electromagnet as the current through the wire increased?

As the current through the wire is increased, the number of paper clips picked up increases. This suggests that the strength of the electromagnet increases as the current through the wire increases.

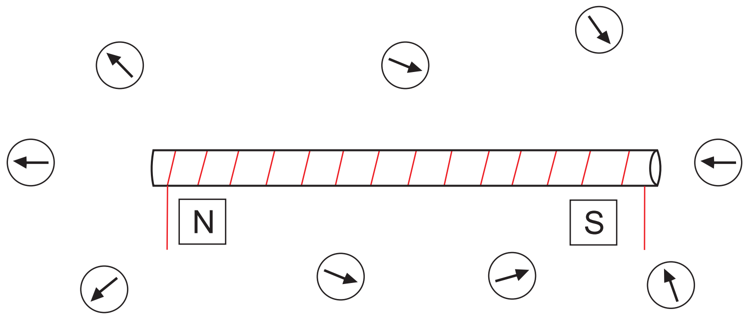
Part 3:

In this section of the activity you will examine the magnetic field around the electromagnet created.

1. Create the following circuit using the listed materials. Make sure there are several loops wrapped around the nail.



2. Place the compass at each of the circled positions indicated below. Press down on the push switch and observe the direction that the compass points. Draw the direction of the north end of the compass inside the circle.



3. Use the information from step 2 to determine the polarity of the electromagnet. Put N in the square that indicates the north end of the electromagnet and S in the square that indicates the south end.

Name:____________________________________ Date:_____________________

Activity 13

The Electromagnet

Purpose: To explore the connection between electricity and magnetism and to determine the variables that determine the strength of an electromagnet.

Materials: 5 cell holders (component 2), 5 D cells, push switch (component 4), 3 banana plug leads, 2 alligator clips, iron nail, insulated wire, several paper clips, and compass.

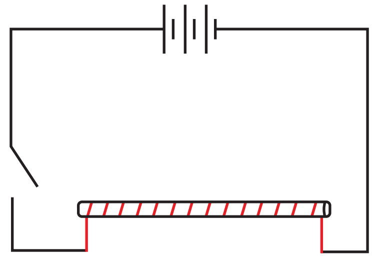
Note:

- When wrapping the wire around the nail, make certain that you wrap the wire in one direction.
- When picking up paper clips, it is suggested that you use the flat end of the nail.

Part 1:

In this section of the activity you will examine the relationship between the number of loops of the electromagnet and the magnetic force created. In order to examine the effect the number of loops has, other variables must be held constant.

1. Create the following circuit using the listed materials. Loop the wire around your nail for a total of three loops. Spread your loops out of the entire nail and do your best to space them evenly.



2. Once the nail is wrapped, press the push switch and see how many paper clips the electromagnet can pick up. Record the number of paper clips in table13 – 1.
3. Increase the number of loops wrapped around the nail seeing how many paper clips the electromagnet can pick up. Record the number of paper clips in table 13 – 1.

Number of loops	Number of paper clips picked up
3	
6	
9	
12	
15	
18	
21	
24	

Data Table 13 – 1

What happens to the strength of the electromagnet as the number of loops increased?

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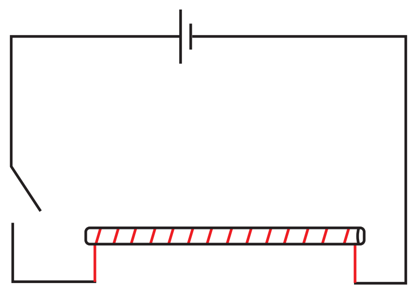
Part 2:

In this section of the activity you will examine the relationship between the amount of current in the loops of wire and the magnetic force created. In order to examine the effect the current has, other variables must be held constant. Decide on a set number of loops you want to use and stick with that for the remainder of this section of the activity. The amount of current flowing in the wire will be changed by altering the potential difference in the energy source.

1. Create the following circuit using the listed materials. Loop the wire around your nail for the set number of loops. Spread your loops out of the entire nail and do your best to space them evenly.



2. Once the nail is wrapped, press the push switch and see how many paper clips the electromagnet can pick up. Record the number of paper clips in table 13 - 2.

3. Construct a similar circuit using two, three, four, and, five cells seeing how many paper clips the electromagnet can pick up. Record the number of paper clips in table 13 – 2.

Number of Cells	Potential Difference (V)	Number of paper clips picked up
1	1.5	
2	3.0	
3	4.5	
4	6.0	
5	7.5	

Data Table 13 – 2

What happened to the strength of the electromagnet as the current through the wire increased?

____

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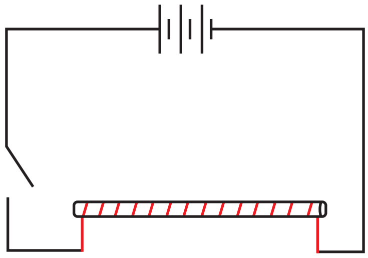
____

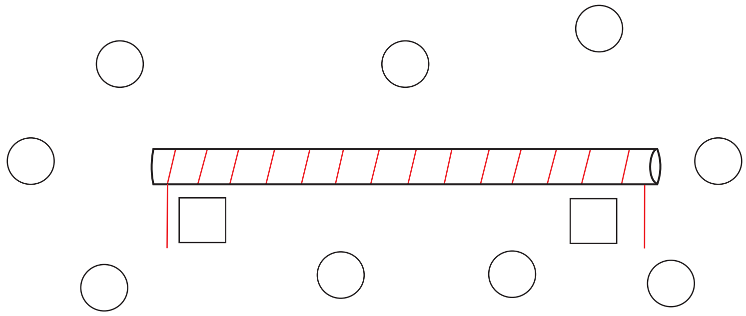
Part 3:

In this section of the activity you will examine the magnetic field around the electromagnet created.

1. Create the following circuit using the listed materials. Make sure there are several loops wrapped around the nail.



2. Place the compass at each of the circled positions indicated below. Press down on the push switch and observe the direction that the compass points. Draw the direction of the north end of the compass inside the circle.



3. Use the information from step 2 to determine the polarity of the electromagnet. Put N in the square that indicates the north end of the electromagnet and S in the square that indicates the south end.

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