Summer 2015 Workshop Labs

Components are in Toolbox
CSAAPT JMU 2023
151 pages

Lab 1
Basics of Energy Production I

Relevant SOLs: PS.1a, PS.1b, PS.1d, PS.1k, PS.1m, PS.2e, PS.2f, PS.5a, PS.5c, PS.6a, PS.6b, PS.6c, PS.7a, PS.7b, PS.9c, 3.1h, 3.1j, 3.11a, 3.11b, 4.3d, 5.3a, 5.4c, 6.1c, 6.1h, 6.2a, 6.2d, 6.2e, 6.5f

Overview

In science energy is often defined as the ability to do work. For instance, if you are going to push a heavy couch across your living room, you do work on the couch. The work you do transfers energy from you to the couch. Energy comes in different forms: chemical energy, electrical energy, light energy, thermal energy, mechanical energy, and nuclear energy.

Chemical energy is stored in chemical bonds. When you exercise, chemical energy stored in the fat cells in your body changes into your energy of motion.

Fig. 1.0.1 Calories are a unit for measuring the chemical energy stored in the food that we eat.

Electrical energy flows in wires and powers most of the devices that we use at home and at school. Light energy moves as waves. Visible light is one form of light energy, but so are microwaves, X-Rays, and harmful ultraviolet waves.

Thermal energy is generally called heat. Many processes create thermal energy due to friction. If you rub your two palms together, you can feel heat due to friction. Mechanical energy comes in two forms, kinetic and potential. Kinetic energy is the energy that a moving object has, just due to the movement. Potential energy is energy stored in an object either due to being elevated above the ground (like an acorn that will some day fall from a tree) or by being stretched or bent (like a stretched rubber band). Nuclear energy is energy stored in the nucleus of an atom. This energy is used in nuclear power plants and atomic weapons.

One of the reasons that energy is such an important topic in Science is that it is a *conserved* quantity. Conserved means that it can never be lost or gained. When a match is lit, however much thermal energy and light energy is created and is exactly balanced out by the amount of chemical energy that is lost. The total amount of energy stays constant.

Fig. 1.0.2 When a match is lit, chemical energy from the match changes into thermal energy and light energy. The total amount of energy does not change.

Activity 1 - 1: Energy Conversion Simulations

Objective: To explore energy conversions.

SOLs: PS.2e, PS.5a, PS.6a, PS.6b, PS.6c, PS.7a, PS.7b, PS.9c, 3.11a, 3.11b, 4.3d, 5.4c, 6.2a, 6.2d, 6.2e, 6.5f

Procedures[1]:

1. Open a browser and go to http://phet.colorado.edu/en/simulation/energy-forms-and-changes

2. The Intro tab shows a beaker of water, a piece of iron, piece of brick and two stations where you can heat or cool the water/iron/brick.

3. Is it possible to boil the water? Is it possible to freeze the water? (Make sure to attach the temperature gauge so you have a guide.) What do you need to do to make these changes?

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4. Chill the water as much as possible- then add heat and observe. List below at least three things you noticed (Make sure the energy symbols box is checked.)

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5. Place the brick on top of the iron and add heat. Describe what is happening in at least three sentences.

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6. Click on the Energy Systems Tab.

[1] *This activity is modified from one created by Elizabeth Hobbs from Washington High School, Missouri. That activity can be found in the PhET activities*

7. Click around and explore what the symbols mean make sure to click on the Energy symbols tab. What do the different symbols mean? What are the different types of energy circulating? For the source of energy- describe the picture and if there is any energy transfers that happen. Example: the teapot goes from thermal to mechanical. Make your lists below:

8. Compare the two types of light bulbs. How are the CFL's (compact fluorescent lamps) different than the incandescent bulbs? Which one releases more thermal energy- how is the process different?

9. The faucet is most similar to hydroelectric energy generation. Where do you think the mechanical energy of the water comes from?

10. Where does the Sun's energy come from?

11. Where does the bicycle's energy come from? (Hint, let the bicycle go for 30 seconds).

Activity 1- 2: Repeat the Heat [1]

Introduction:

The gel-heating pad used in this investigation is shown in Fig. 1.2.1a. It is manufactured for use in keeping hands warm inside gloves or for medical heat treatment purposes. Once activated, the pad will maintain therapeutic temperatures for 15-20 minutes and will be warmer than the surroundings for up to 30 minutes.

Fig. 1.2.1a. The “hot gel” and “warm mate” heat pads and a selection of triggers. Close up images of b the flexible disc and c the spring type trigger. The flexible disk trigger is 19 mm in diameter and is the type in your gel pad.

Once activated, heat pads can be re-used but will look very different than when they are new. Pads can be reused by submerging the pad in a hot water bath with a cloth on the bottom as a caution against sticking. Once cooled to room temperature the pad is ready to be used again. How does it work?

The pad contains a super-cooled liquid that, at the flex of a disk, crystallizes and releases heat. The substance inside the heat pad is sodium acetate, a salt hydrate that can be super-cooled far below its freezing point without undergoing a phase transition from liquid to solid. The super-cooled liquid is metastable because a nucleation barrier that prevents the growth of macroscopic particles of crystalline material hinders the spontaneous transition to the thermodynamically stable solid phase. Also contained in the heat pad is a trigger device that can be manipulated by the user to initiate the crystallization of the super-cooled liquid. (**Fig. 1.2.1b** and **Fig. 1.2.1c**) When the material crystallizes, the energy associated with the phase transition, the latent heat of fusion, is released and the temperature increases to the melting/freezing point temperature of the substance, which for sodium acetate trihydrate is 58 °C. Heat storing devices using supercooled salt hydrates such as sodium acetate date back over 100 years. The present form of the heat pad with the metallic trigger appeared in the late 1970s. How do these triggers work?

The flexing of the disk shown in **Fig. 1.2.1**c causes "a single molecule to crystallize. Proposed mechanisms include nucleation by friction, tearing at the ends of slits exposing a fresh metal surface, local compression of the solution confined in the slit, small particles broken off from slit surfaces acting as heterogeneous nucleation centers, and oscillation waves created by friction as the disk is snapped. In any case nucleation occurs if any of these happen.

Most heat pads contain sodium acetate trihydrate due to its convenient melting point, the large amount of latent heat it releases during crystallization, and its ability to remain in a supercooled state for months and even years. Sodium acetate trihydrate is, as its name implies, a salt hydrate. In liquid form the Na^+ and CH_3COO^- ions are soluble in water, and when it crystallizes, three moles of water for each mole of salt are incorporated into the crystalline structure: $Na^+(aq) + CH_3COO^-(aq) \rightarrow NaCH_3COO \cdot 3H_2O(s)$. The crystals grow quickly, approximately 5 mm/s, and the solid phase has a polycrystalline structure shown in **Fig. 1.2.2.**

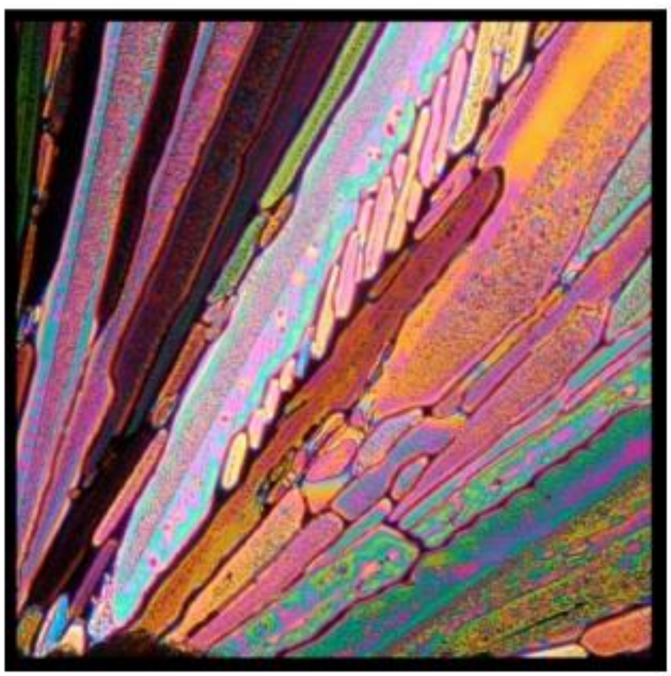

Fig.1.2.2 The art of sodium acetate trihydrate crystals. A drop of the solution was placed between two microscope slides, and crystallization of the supercooled liquid was seeded from one edge. The images show the polycrystalline structure observed between crossed polarizers in a microscope using a 5X objective.

Objective: To understand the energy transformations occurring in a gel heating pad and to measure the temperature of the gel as a function of time.

SOLs: PS.1b, PS.1d, PS.1k, PS.1m, PS.2f, PS.5c, PS.6b, PS.6c, PS.7a, 3.1h, 3.1j, 6.1c, 6.1h, 6.2e

Materials:

- Gel Heating Pad
- Thermometer
- Pan of boiling water
- Cloth

Procedure

1. Describe the contents of the pad. Are there liquids? Are there solids? What shapes do you see? What color are the contents?

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2. Hold your thermometer firmly against the center of the pad. Be sure to only hold the top part of the thermometer. Record the starting temperature of the pad.

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3. To start the heating pad, flex the metal disc up and down on the curved center until you hear a "click - click" sound.

4. In order to fully activate the pad you should mold and shape the gel to evenly distribute the contents.

   In **Table 1.2.1**, record the temperature of the pad every minute for 20 minutes. In between readings, record your observations about changes in the physical characteristics of the pad (color, texture, clarity, etc.).

Table 12.1

Time (minutes)	Temperature Degrees °C	Observations
0		
1		
2		
3		
4		
5		
6		
7		
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9		
10		
11		
12		
13		
14		
15		
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5. In words, describe how the temperature changes with time through the 20 minutes.

6. Where do you think the energy came from that resulted in the temperature of the pad increasing? Support your answer with your data and/or observations.

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7. Place the pad in a pot of water bath with a cloth on the bottom as a caution against sticking. Bring the water should be brought to a boil until the crystals have melted to a clear gel. Hold the pad against the light to check and shake the pad to dissolve the remaining crystals. Cool to room temperature so that the pad is ready to be used again. What energy transformations take place in order to put the pad back into a reusable condition?

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References

1. B. Sandness Am. J. Phys., Vol. 76, No. 6, June 2008

Activity 1 – 3: Dippy Duck

Introduction:

Dippy Duck is a toy, or in terms of physics, a heat engine that uses thermal energy from the air to make the bird heads bob up and down as if it were in a state of perpetual motion. Of course, there is no such thing as perpetual motion so what is going on here. The drinking bird consists of two glass bulbs joined by a glass tube (the bird's neck). The tube extends nearly all the way into the bottom bulb, and attaches to the top bulb but does not extend into it. The space inside the bird contains a fluid, usually colored. The fluid is typically dichloromethane, also known as methylene chloride (CH_2Cl_2). It is blue in Fig.1.3.1. The gas inside the bird above the fluid is Methylene Chloride vapor! The Methylene Chloride is a volatile liquid. This means that it has a boiling point very close to room temperature. As a result, the Methylene Chloride inside the bird is in, what we call, thermal equilibrium resulting in a coexistence of its gas phase and its liquid phase.

Fig. 1.3.1

Next, you need to know that the bird's head is a glass bulb (like the bottom) but the head is covered with a felt-like fabric that absorbs water. So, to start the drinking process the bird's head must be covered in water. Once this happens, the water on the head begins to evaporate and cools the head a little bit. This decrease in temperature causes some of the Methylene Chloride vapor in the head to condense into a liquid and fill up the neck a little bit. Since the liquid phase takes up much less space than the vapor phase, there is fewer vapors in the head to fill up practically the same volume. This means that the pressure in the head will *decrease*, causing a difference in pressure between the head and the base of the bird. A difference in pressure results in a net force from the higher-pressure area to the lower pressure area. This means that the little bit of vapor in the base of the bird forces the liquid up the neck and into the head. This gives the bird a heavy head, and forces it to dip. Once it dips, the liquid moves out of the way, letting the warmer vapor in the bottom move up the tube to the top warming the head a bit and starting the cycle all over again.

Objective: To understand the physics behind how dippy duck works.

Materials:

- Dippy Duck
- Glass of water

SOLs: PS.1b, PS.1d, PS.1k, PS.1m, PS.2f, PS.5c, PS.6b, PS.6c, PS.7a, 3.1h, 3.1j, 6.1c, 6.1h, 6.2e

Prediction:

Before you dip the head in water and release it, predict the behavior of dippy duck over the next few minutes.

Procedure:

1. Fill a glass cup with water to almost the top as shown in Fig.1.3.1 and arrange dippy duck so that its beak can strike the water when bent over. Now push the head in the water with your fingers and release it. Describe the behavior of the head of dippy duck and the fluid in the tube over a period of a few minutes.

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2. You will be asked several questions to help you understand what is going on**.** You may discuss these questions with your partner and/or Google for answers. Hold the bottom bulb in the palm of your hand as shown in Fig.1.3.2. Before you hold it, predict the behavior here.

3. Was your prediction correct? Describe your observations here.

Fig. 1.3.2

4. Using concepts of temperature and pressure of gases and fluids explain your observations here.

5. Slide the metal band shown in Fig. 1.3.3 up and down and see what effect it has on the action of dippy duck. Describe what role the metal band plays in the motion of dippy duck.

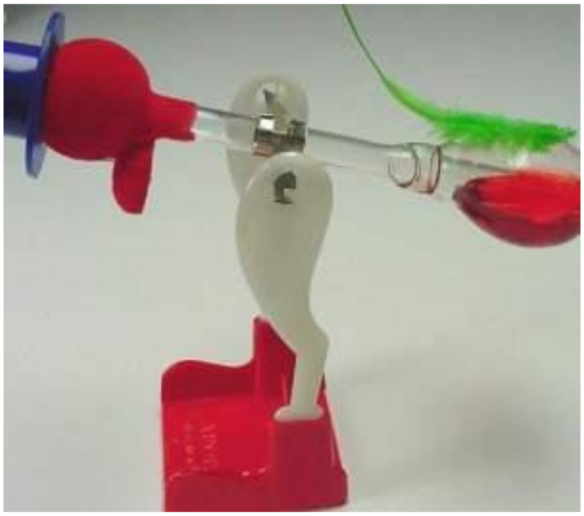

Fig. 1.3.3

6. Measure the temperature of the hot water coming out of the tap and determine if it makes any difference if you use hot water in the glass cup. Predict the behavior here.

7. Describe your observations here. Was your prediction correct?

8. Explain your observations here.

9. Replace the water in the cup with alcohol. Your Lab instructor will prepare this for you and you will share the alcohol with others. Predict how using alcohol instead of water will affect the motion of dippy duck.

10. Describe your observations here. Was your prediction correct?

11. Explain your observations here.

Name ________________________________ Date ___________________________

Lab 2
Basics of Energy Production 2

Relevant SOLs: PS.1a, PS.1k, PS.2f, PS.5a, PS.5c, PS.6a, PS.6b, PS.6c, PS.11a, 3.1a, 3.1j, 3.3b, 3.11a, 3.11b, 4.1a, 4.2d, 4.3a, 4.3b, 4.3c, 4.3d, 5.1b, 6.1c, 6.1h, 6.2a, 6.2d, 6.2e

Overview
Recall from Lab 1 that Mechanical Energy includes Kinetic Energy, Gravitational Potential Energy, and Elastic Potential Energy. Electrical Energy normally involves a flow of electrons, which we call an electric current.

Piezoelectricity
In Activity 1, you will be using a piezoelectric device to generate electrical energy. Some crystals demonstrate piezoelectric behavior, which means that when pressure is applied, a charge separation is induced, and they release electrons. There are many uses of piezoelectric behavior including quartz watches, barbecue lighters, and microphones.

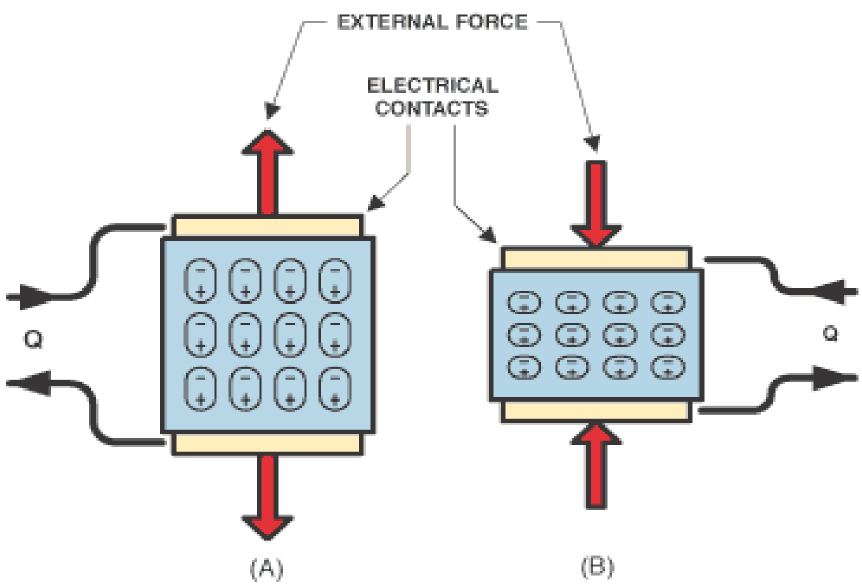

Fig. 2.0.1 Some crystal structures have a charge separation when the crystal undergoes tension (A) or compression (B). This charge separation can generate electrons to flow and convert mechanical energy into electric energy. (Image from http://archives.sensorsmag.com/articles/0203/33/main.shtml)

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In a gas lighter, when you depress the switch, a piezoelectric crystal is squeezed, generating a high enough voltage to generate a spark. This spark will ignite a combustible fluid and produce a flame.

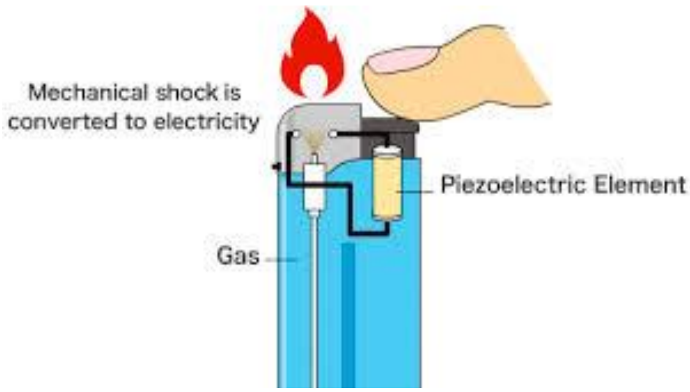

Fig. 2.0.2 A gas lighter uses piezoelectricity to produce a spark. (Image from global.kyocera.com)

Solar Energy

Solar Energy refers to energy from the Sun that reaches the Earth. The energy primarily reaches us in the form of Visible Light, Infrared Light, and Ultraviolet Light. Solar Energy can be converted into Thermal Energy and Electrical Energy. Perhaps you have visited a swimming pool that has a solar cover. These covers are meant to convert Solar Energy into Thermal Energy in the pool water in order to increase the temperature of the water. See **Fig. 2.0.3**. Homes in sunny regions sometimes have special solar collectors that help to heat the house's water supply.

Fig. 2.0.3 These *Solar Sun Rings* are designed to convert Solar Energy from the Sun into Thermal Energy of the swimming pool water. Image from Leslie's Swimming Pool Supplies, http://www.lesliespool.com/.

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Photovoltaic (PV) panels can convert Solar Energy directly into Electrical Energy. These panels are traditionally made from Silicon, but are now made from other materials that exhibit the photoelectric effect. The photoelectric effect occurs when the energy from light causes an atom in a solid to emit an electron. If enough atoms are emitting enough electrons, Electrical Energy can be harvested. **Fig. 2.0.4** shows a typical residential solar photovoltaic panel arrangement.

Fig. 2.0.4. A typical rooftop arrangement of solar photovoltaic panels. Image from Advanced Energy Industries, http:// www.vaadvancedenergy.org/.

Energy Efficiency and Conservation

In addition to making more energy in power plants, there are two other ways to help meet our country's energy demands: energy efficiency and energy conservation. Energy efficiency refers to using less energy to provide the same service. For example, the three main types of light bulbs are LEDs (Light Emitting Diode), CFLs (Compact Fluorescent Lamp, and incandescent bulbs. Each bulb can provide the same amount of light energy but each uses a different amount of electrical energy. **Table 2.0.1** provides a comparison of the three bulbs. When comparing the input power to the bulb, it can be seen that an incandescent bulb is far less efficient and an LED bulb is the most efficient.

Type of Bulb	Power (Watts)	Light Output (lumens)
Light Emitting Diode	9-13	1100
Compact Fluorescent Lamp	18-25	1100
Incandescent Bulb	75	1100

Table 2.0.1 (data from http://www.designrecycleinc.com/led%20comp%20chart.html)

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Energy conservation refers to reducing energy consumption by having less energy service. For instance, even if using an LED bulb, it is wasteful to leave a lamp on if you aren't using it. In Activity 3, you will be using a meter to determine the energy use of different devices. These energy meters are sold to help you make decisions about both energy efficiency and energy conservation.

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Activity 2 - 1: Piezo-popper

Objectives: Initiate a transformation of mechanical energy to electrical energy and back again

SOLs: PS.1a, PS.2f, PS.5a, PS.5c, PS.6a, PS.6b, PS.6c, PS.11a, 3.1j, 3.3b, 4.1a, 4.2d, 4.3c, 4.3d, 5.1b, 6.1c, 6.2a, 6.2e

Materials

- piezo popper
- rubbing alcohol (From Home)
- safety goggles (From Home)
- eye dropper or disposable pipet (From Home)

Introduction

The piezo-popper works similar to a barbecue lighter. A small hammer inside the popper strikes a quartz crystal and generates a large voltage spark. How does the igniter work? The igniter is a piezoelectric generator. The word *piezo* comes from the Greek word for *press*. A piezoelectric substance is something that makes electricity when you press on it. The igniter holds this ceramic element in a plastic case, with a steel hammer attached to a spring and a catch. As you push down the plunger, the spring is compressed until it hits the catch, which releases the spring, pushing the hammer quickly down on the ceramic. The electricity runs through the wires to the spark gap, which it jumps across, igniting the fuel-air mixture. The spark occurs inside a canister with a removable top. As the name implies, the cannister can pop off from the top.

Fig. 2.1.1 The piezo popper uses piezoelectricity. (Image from teachersource.com)
A closer view of the spark gap is shown here in **Fig. 2.1.2**

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Fig. 2.1.2 Closer view of end of wire in canister

Types of air-fuel mixtures

While perfume (which is mostly alcohol) works pretty well, the best fuels are hair spray and Binaca. Hair spray has alcohol in it also, but it also contains large amounts of propane, butane, and isobutane as propellants (gases under so much pressure that they are liquids in the can, and turn to gas at the nozzle). These gases are excellent fuels. The Binaca is alcohol and isobutane, and comes in a very convenient dispenser. It fits easily in a pocket, and delivers just the right amount of fuel in a single push of its button. (The hair spray keeps spraying, so it is harder to get just the right amount).

In order to make an explosion, you need a flammable gas, oxygen, and a source of heat to start things off. Solids like candle wax and liquids like alcohol only burn when they are heated enough to become gases. Then they need a little more heat to get them to break their chemical bonds so they can combine with the oxygen.

In our activity we will use alcohol, which when sprayed in a fine mist, produces a nice vapor, which will ignite with a small spark to start things burning.

The small film canister can only hold a small amount of air and fuel mixture, so it is safe to fire off in the house. The plastic can is soft and light, and can land on people without disturbing their hairdo. But it takes off rather quickly, and it is not recommended to have your head in the way during a launch.

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The amount of air that is required to be mixed with the fuel will vary with which fuel is used. The ratio of air to fuel (called surprisingly enough, the 'fuel-air ratio') must be just right for some fuels. Other fuels (such as hydrogen) have a wide range of ratios that will explode.

Hydrogen will burn in air at concentrations ranging from 4% to 75% by volume. Methane (natural gas) burns at 5.3% to 15%. Propane burns at 2.1% to 9.5%. Isobutane burns at 1.8% to 8.4%.

Hydrogen will explode in air at ratios of 13% to 59%. Methane explodes at a much narrower range between 6.3% and 14% (ratios are fuel to air).

It is easy to see how too little fuel will result in no explosion. But the ratios we saw in the preceding paragraphs show that the problem is more likely to be too *much* fuel. If your can won't go *Bang!*, try lifting it off the pad and putting it back. This will allow a little more air in, and you will probably get a bang out of the results.

As the fuel-air mixture burns, energy is released by the formation of chemical bonds between the oxygen in the air and the carbon and hydrogen in the fuel. This energy heats up the gasses that result from the burning. The gases are water vapor (H_2O) and carbon dioxide (CO_2). Since they are hot, they expand. The expansion pushes on all sides of the can and its lid. The can and the lid separate quickly, and the can goes skyward

Predict

1. Cite an instance when you were able to see an electric spark.

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2. Do you think that you will be able to see a spark inside the piezo-popper? Why or why not?

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3. In the end of the activity you will be combusting two drops of alcohol in order to launch the popper into the air. Predict how high the popper will rise.

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Observe

1. With the bottom of the film canister off, depress the trigger. Observe the spark carefully. If you can't see the spark, turns the lights off. Describe the spark. Descriptions will vary.

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2. Put your goggles on.

3. Place the bottom of the canister onto the popper. Be certain that your popper is not aimed at anybody or at anything breakable. Depress the trigger. Record your observations, including how high/far the canister was launched.

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4. Using the dropper, place two drops of alcohol inside the canister and place the bottom onto the popper. Hold the canister in your hands for at least two minutes in order to vaporize the alcohol.

5. Go outside, or to a gymnasium, or other room with high ceilings. Be certain that your popper is not aimed at anybody or at anything breakable. Depress the trigger. Record your observations, including how high/far the canister was launched.

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Explain

1. Describe how there was mechanical energy present before the spark of electrical energy was produced.

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2. We know that energy has to be conserved. What happened to the electrical energy from the spark in Step 1? Be specific.

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3. What happened to the electrical energy from the spark in Step 5? Be specific.

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Activity 2 - 3: Rookie Solar Racer

Objective: Construct a solar powered racer and investigate how it works

SOLs:

Materials:

- Screwdriver
- Lamp
- Long Nose Pliers
- Rookie Solar Racer Kit (See Fig. 11.1.1)

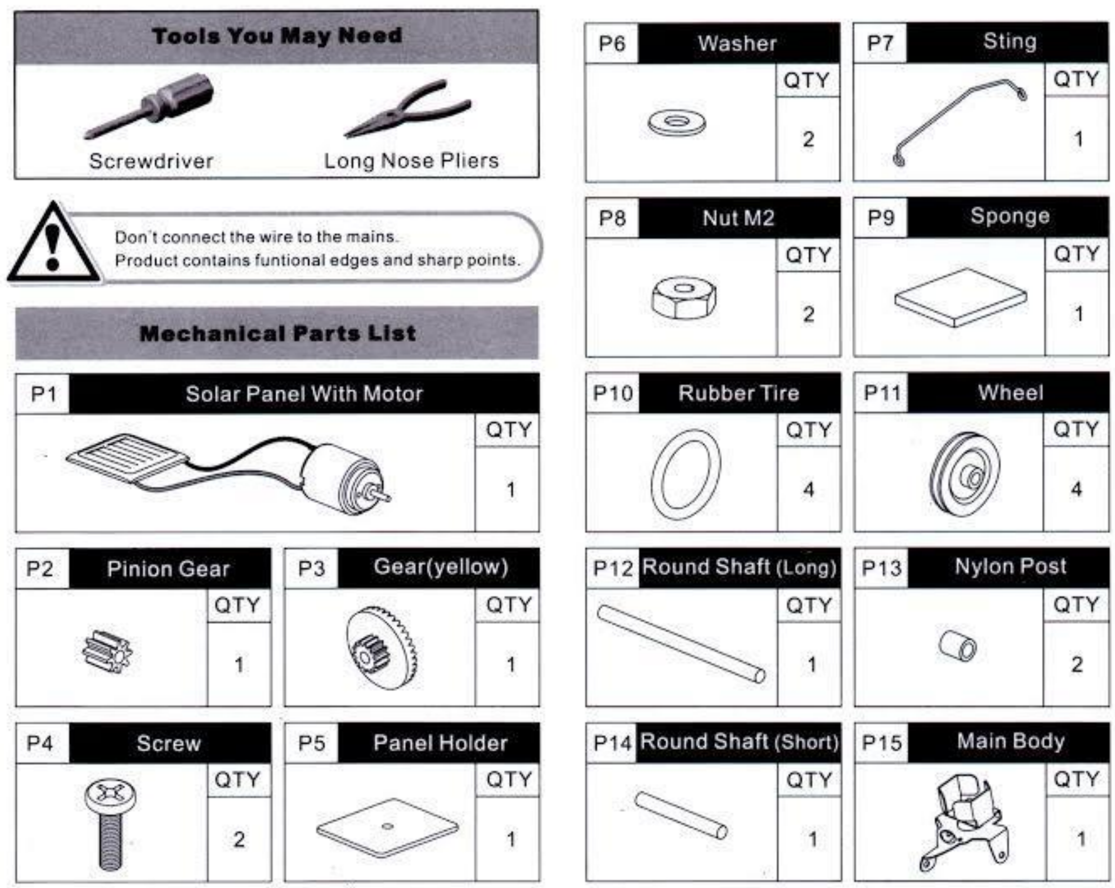

Fig. 11.1.1 Material list for the Rookie Solar Racer Kit

Prediction

1. Predict the behavior of the solar powered racer when one puts it outside in the sunlight. How about when one puts it under regular indoor lighting?

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2. Can heat be used to power the racer? If the racer was put up to a heat lamp instead of a regular lamp, would the racer move?

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Observation and Procedure

1. Attach the Pinion Gear to the metal bar on the Motor. Do so by setting the pinion gear down on a flat surface and then putting the metal bar inside. Make sure that the end of the pinion gear is flush with the end of the metal bar. See **Fig. 11.1.2**

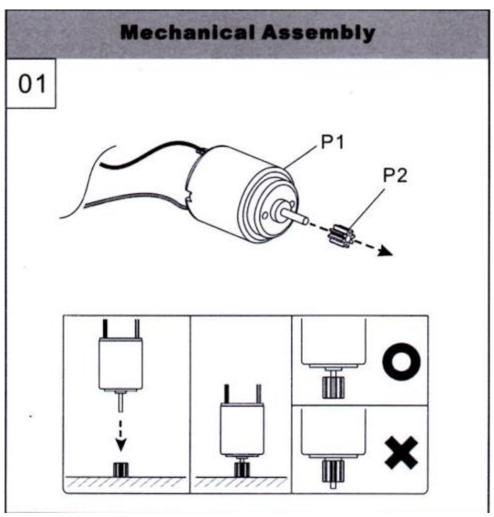

Fig. 11.1.2

2. Now put the solar panel with motor so that it is secure in the main body, with the wires and solar panel free. Press it down so that the main body is holding onto the motor firmly. See **Fig. 11.1.3**

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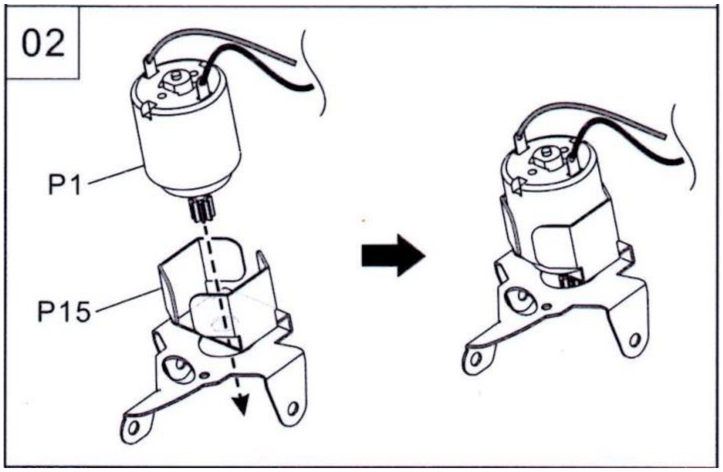

Fig. 11.1.3

3. Arrange the screw, panel holder, washer, sting, and bolt as shown in **Fig. 11.1.4.** Use your screwdriver and long nose pliers to carefully tighten the screw and nut. Then attach the sponge onto the top of the panel holder and then stick the solar panel on top of that. Remember to remove the plastic that adheres to the sponge.

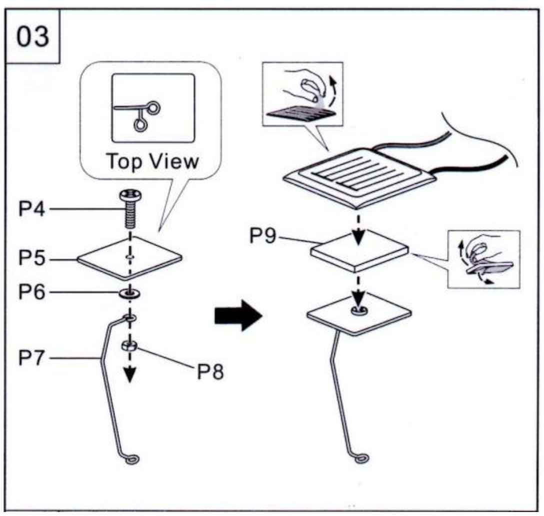

Fig. 11.1.5

4. Now, attach the sting to the base using a screw, washer and nut. See **Fig. 11.1.5**

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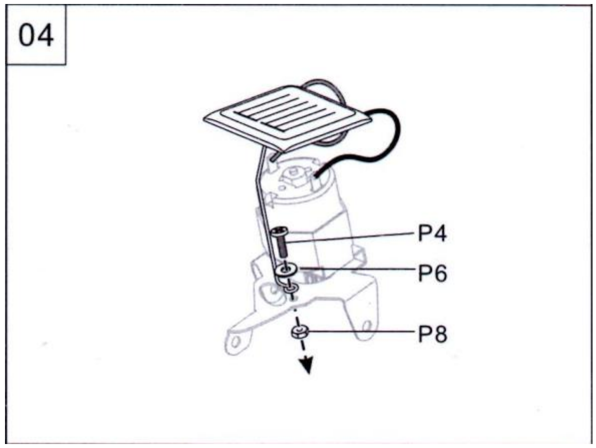

Fig. 11.1.6

5. Attach the two back wheels to the racer. First add the rubber circles to the wheels and then put the gear onto the long round shaft. Put the round shaft through the two holes with the gear in the middle and make sure the gear is touching the pinion gear and that it is not too loose or too tight. Then attach the wheels on either end with a 1mm clearance. See **Fig 11.1.6.** What would happen if the wheels were attached too tightly?

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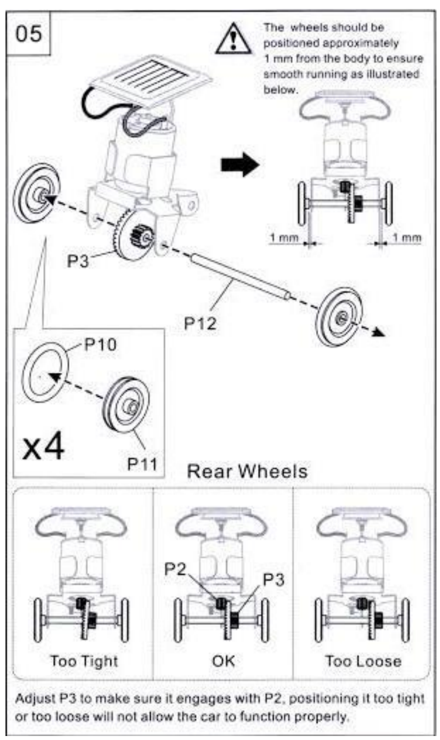

Fig. 11.1.7

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6. Attach the two front wheels, again leaving a 1mm clearance between the wheels and the mount. See **Fig. 11.1.8**

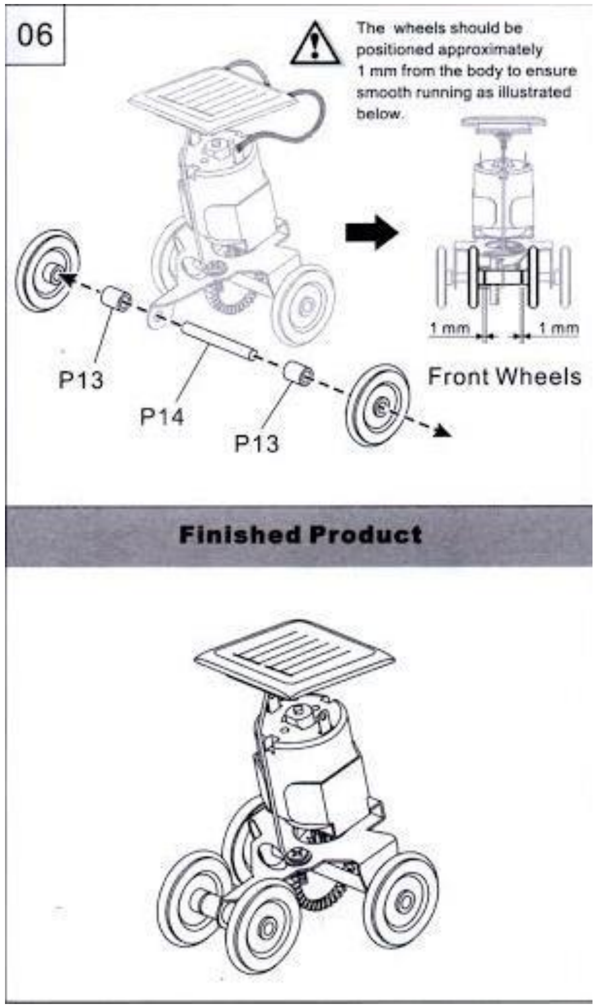

Fig 11.1.8 The finished solar racer

Explain

1. Does the speed of the racer depend on the brightness of the light. How could you test this idea?

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2. Why couldn't you use a red or green laser pointer to get the solar car to move?

Name ______________________________ Date __________________________

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3. Does the speed of the racer depend on the wavelength of light? How could you test it?

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4. What are the ways in which energy is transferred that make the racer move.

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Name ________________________________ Date ___________________________

Activity 2 - 3: Kill A Watt

Objective: Evaluate the energy demands of electrical devices.

Materials:

- Kill A Watt® EZ power meter
- Various devices that plug into electrical outlets

SOLs: PS.1k, PS.5a, PS.6a, PS.6b, PS.6c, 3.1a, 3.1j, 4.1a, 4.3d, 6.1c, 6.1h, 6.2e

Introduction

Power is the rate at which energy is converted. In the case of an electrical device that plugs into an outlet, power is the rate at which electrical energy is changed into other types. One way to limit the use of fossil fuels is by conserving energy. In this activity you will test the power consumption of various devices in your surroundings.

Prediction:

1. Make a list of all of the devices in your surroundings that plug in to an electrical outlet in the wall. Don't forget about chargers for cell phones and laptops.

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2. Rank the devices from highest to lowest in terms of how powerful they are. Explain your rankings.

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3. For each device listed, state what the electrical energy gets converted into.

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Name ________________________________ Date ___________________________

Observation and Procedure

1. Plug your power meter into an easily accessible power outlet.

2. Note in **Fig. 2.3.1** that the meter's default unit is V. All standard outlets in the US should have a Voltage of approximately 120 V.

Fig. 2.3.1 The power meter plugs directly into a standard electrical outlet.

3. Cycle through the meter read-outs by hitting the "up" or "down" button until you find the setting that measures Watts, the SI unit for power.

4. Plug one of the devices into the power meter and record the power of the device in **Table 2.3.1**

5. For a charger, you should make an entry for the charger both when it is actively charging and when it isn't actively charging. You should also make notes of any meter fluctuations or other observations that will help you analyze the data. Similarly, if any of your devices have multiple settings, you should test the power on at least a few different settings.

Name ________________________________ Date ___________________________

Fig. 2.3.2 The device plugged into the meter is converting electrical energy into other types at a rate of 3.9 Joules per second, or Watts.

Device	Power	Additional Observations

Table 2.3.1

Name ________________________________ Date ___________________________

Explain

1. Using your data, rank the devices from highest power to lowest power.

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____
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2. Comment on differences between your predicted ranking and your final ranking.

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3. Many people talk about phantom electricity, which refers to power consumption of devices like televisions when they are powered off or chargers being plugged in when they aren't being used. Does your data support or refute the notion of phantom electricity? Explain.

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Name ________________________________ Date ___________________________

Lab 3
Electrostatics: Charging Objects by Friction

Overview

Static electricity is the result of an imbalance of charge in materials. All material is made up of atoms. Atoms are extremely small and are made of even smaller components called electrons, protons, and neutrons. (Figure 3.2) Protons and neutrons are similar in size and mass to each other and are found in the nucleus of the atom. The main difference between protons and neutrons is that protons have a positive electric charge and neutrons have no electric charge. The electron is much smaller in size and mass than protons and neutrons. The electrons are found outside of the nucleus and have a negative electric charge.

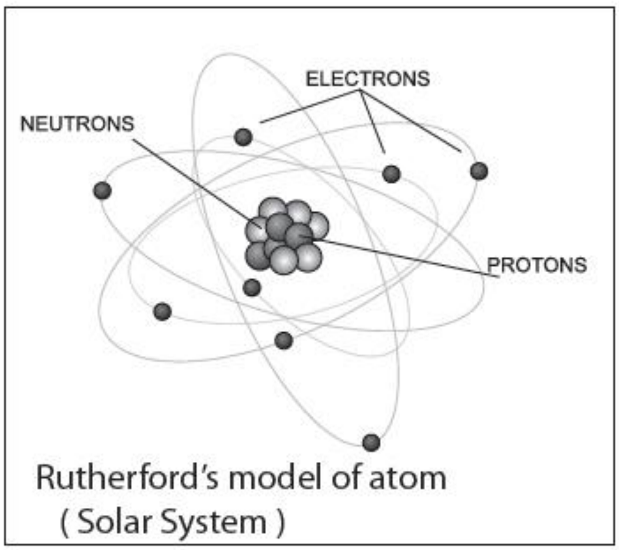

Fig. 3.1 Solar System Model (a.k.a Rutherford's Model of Atom) is the most common way to picture an atom. The model describes electrons orbiting around the nucleus in a fashion similar to planets orbiting the Sun. Just like planets have their orbits and are located at different distances from the Sun, the electrons have their own trajectory and distance from the nucleus. This model is still popular in teaching physics, as it is easier to visualize.

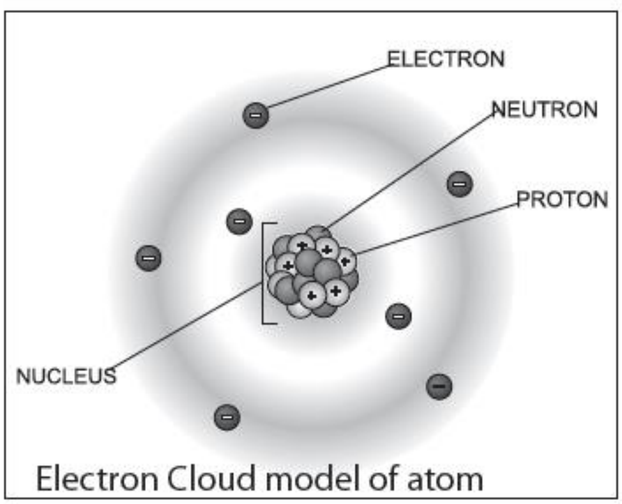

Fig. 3.2 The Electron Cloud Model claims that there are no orbitals. Instead, the electrons are located around the nucleus within certain boundaries or shells.

These shells are described as the most probable locations for electrons to be found. The boundaries are fuzzy and the precise locations of the electrons are unknown. This model, which is based on probability, is considered more advanced, and it is commonly used in chemistry and quantum mechanics.

Name ________________________________ Date ___________________________

Typically, the number of electrons is the same as the number of protons. The outer electrons are located farthest from nucleus and are held more loosely than the rest. On contact between two materials, electrons may migrate from one material to another. This migration will create an imbalance of charges. The object whose atoms lost electrons will be left with a positive charge on it and the object that received or "captured" the electrons will have a negative charge. This imbalance and transfer of charges between objects is what creates static electricity.

Insulators and Conductors

Materials made of atoms that hold on to their electrons very tightly are called *insulators*. Materials made of atoms that have a weak attraction to their electrons are called *conductors*. If you take a segment of electric wire, you will have both types of materials in it. The silicon that wraps around the metal is an insulator, and the metal inside is a conductor. Electrons inside conductors are free to move as influenced by various forces. They either move inside the conductor itself or can migrate to another conductor.

Electrons inside insulators can only move within atoms themselves and cannot move along the insulator. They may stretch the atoms or rotate them but never leave the atoms under normal circumstances.

The Triboelectric Series

Triboelectricity means electric charge generated by friction. It comes from the Greek word "tribos", which means rubbing. Historically, Benjamin Franklin identified the charge on glass as positive and the charge on silk as negative after he rubbed them against one another. When an insulator like glass is rod rubbed against an insulator like silk, a charge transfer occurs between the two materials. Silk attracts the loose electrons from the surface of glass and becomes negatively charged. Because charge is conserved, the glass rod is left positively charged. Transfer of electrons is responsible for charging; the protons in atoms remain where they are and do not contribute to static electricity.

Materials possess various tendencies to acquire or lose electrons; the ordering of these tendencies is referred to as the *triboelectric series*. The list below orders a number of common materials by their electrical nature. (**Fig. 3.3**) The tendency of a material to acquire charge determines is place in the triboelectric series. Materials toward the top of the list tend to give up electrons more easily (and thus acquire a positive charge) than those at the bottom of the list. The further apart in the series the two materials are, when rubbed together, the greater the charge acquired by each material. For example, when Teflon is rubbed with silk, Teflon acquires a negative charge and silk acquires a positive charge. Because they are quite far apart in the series, each acquires a large amount of negative (Teflon) or positive (silk) charge. Another example is when glass is rubbed with silk. The glass acquires a positive charge and the silk now acquires a negative charge. Because silk and glass are close together in the series, each acquires less charge and there is less charge imbalance.

Name ________________________________ Date ___________________________

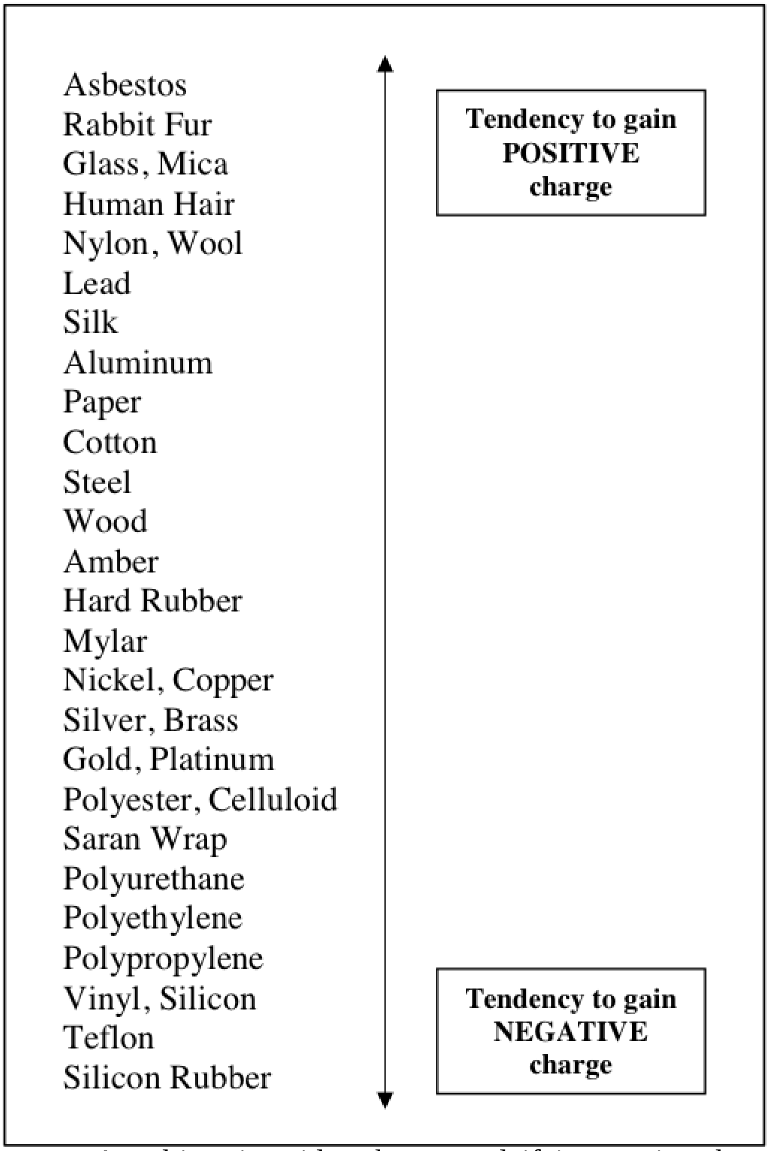

Fig. 3.3 The triboelectric series shows the relative tendencies of objects to gain positive (lose electrons) or negative charges (gain electrons) when rubbed against one another.

Neutral and Polarized Objects

An object is said to be neutral if it contains the same number of positive and negative charges. In **Fig. 3.4** below the material is neutral since each atom contains the same number of positive and negative charges. The arrangement of the charge in the atom is such that the center of negative charge is on one side and the center of the positive charge is on the other. Each atom is arranged randomly so that the orientation of the charges is different throughout the material.

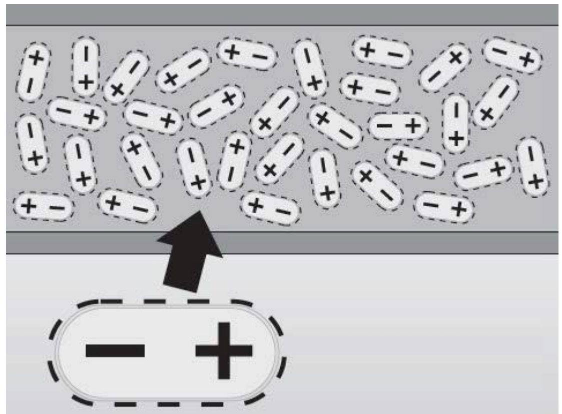

Fig. 3.4 Each oval represents an atom. Each neutral atom has an equal amount of negative charge (electrons) and positive charge (protons)

A neutral object can, however, produce some of the same phenomena as a charged object as a result of a process known as polarization. We already know that opposite charges attract and like charges repel. If we recall that charges are somewhat free to move within an object, we should not be surprised that a negatively charged object will cause a charge alignment in a neutral object so that the object's electrons are as far from the negatively charged object as possible. **(Fig 3.5)** As a result, the neutral object will appear to react to an electric force as though it were charged.

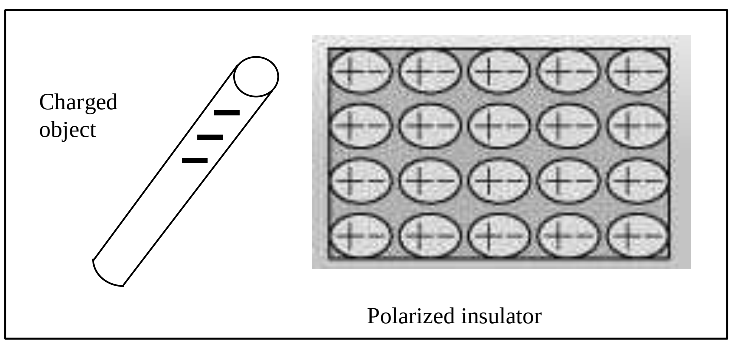

Fig. 3.5

The electrons and nuclei in the atoms that make up an object carry equal and opposite charges, so the whole object appears neutral. When a second, charged object comes close, it induces the electrons to align themselves slightly away from the nuclei. This process is known as polarization. For example, in **Fig 3.6** below, a plastic comb (negatively charged) attracts pieces of paper (neutral) after combing through hair.

Name ________________________________ Date ___________________________

Fig. 3.6 A charged comb causes polarization of charge within neutral pieces of paper

Different Ways to Obtain Charge

Materials can acquire charge through three different methods. These are friction (rubbing), conduction (touching), and induction.

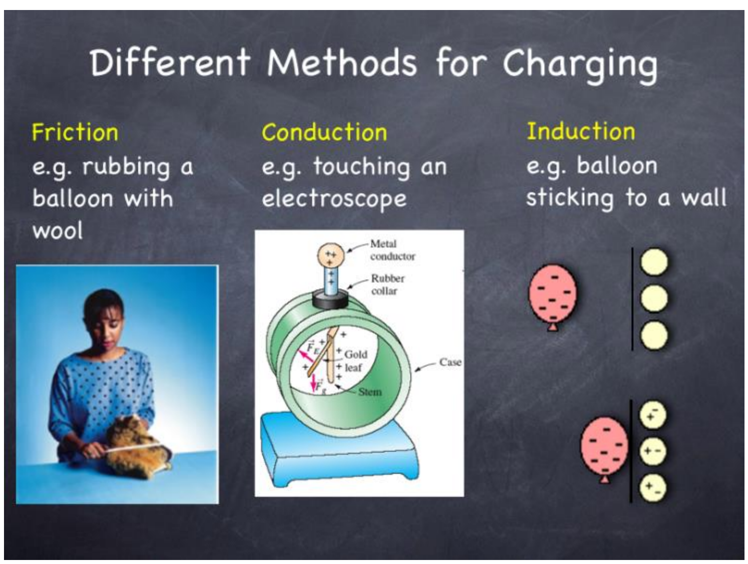

Fig. 3.7 The three primary ways to electrically charge an object

Name ________________________________ Date ___________________________

Activity 3 - 1: Charging Objects by Friction

Objective: Charge selected objects by rubbing them on silk; observe the effect of charge on small objects around it.

Materials:

- Acrylic Rod*
- Teflon Rod
- Silk
- Scrap Paper (confetti)

* We use acrylic rods instead of traditional glass rods for safety reasons. Acrylic ranks about the same as glass in the triboelectric series.

The materials except for the confetti are shown in **Fig 3.8**

SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 6.4a PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 6.4a

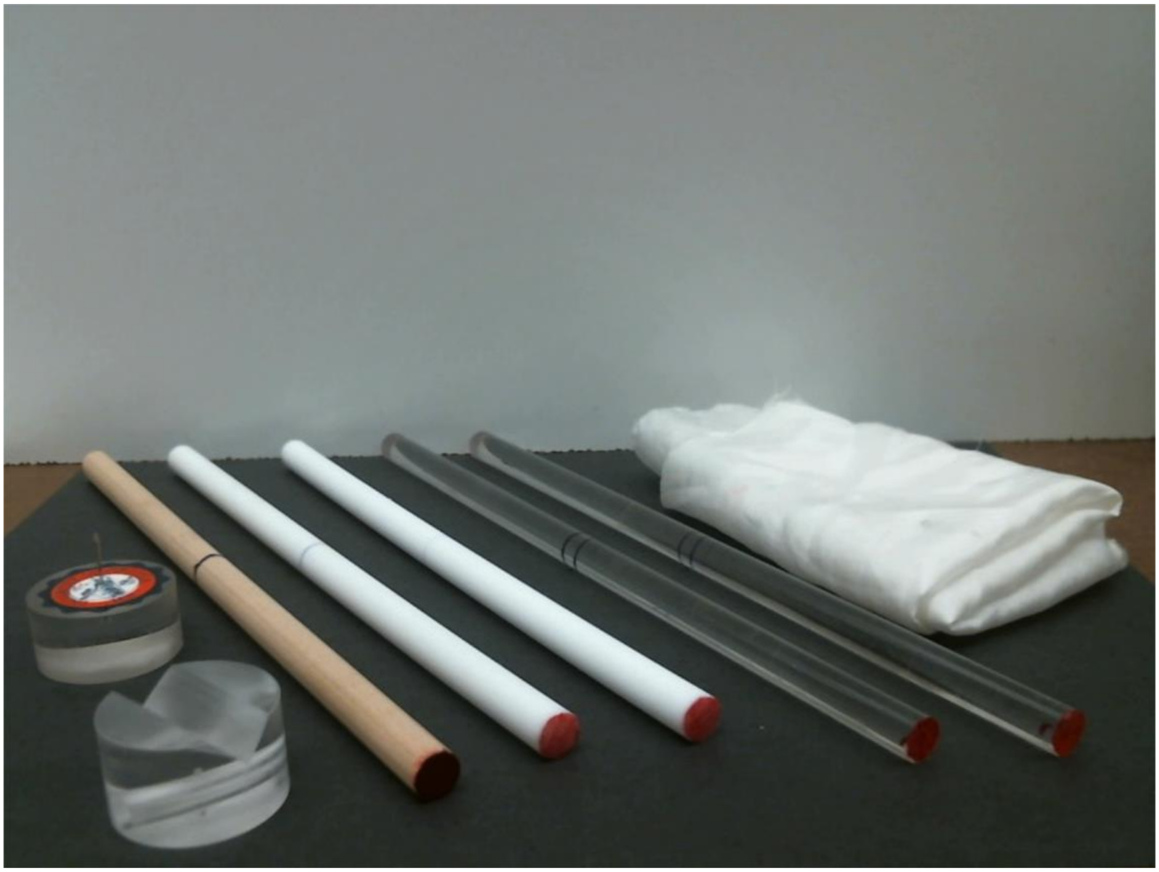

Fig. 3.8

Name ________________________________ Date ___________________________

Prediction

1. Using the triboelectric series in Figure 3.3, predict whether the rods will gain a positive charge or a negative charge after being rubbed with the silk. Explain your answer.

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2. Predict how small, neutral, pieces of paper will behave when a positively charged rod is brought near them. Explain your answer.

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3. Predict how small, neutral, pieces of paper will behave when a negatively charged rod is brought near them. Explain your answer.

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____
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Procedure:

1. Cut a piece of dry, scrap paper into a few quarter-inch squares.

2. Neutralize the Teflon rod by sliding it slowly across your palm. Move the rod towards the paper squares. Describe the behavior of the squares.

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____
____

3. Rub the Teflon rod with silk. Move the rod towards the paper squares. Describe the behavior of the squares.

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4. In the next step, you will repeat steps 2 and 3 but you will use the acrylic rod instead of the Teflon rod.

Name ________________________________ Date ___________________________

Explain

1. Why do you think the squares displayed the behavior that they did in Step 2?

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2. Explain the behavior of the squares in Step 3.

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____

3. Propose a general rule that will predict the behavior of small neutral objects that are near charged objects.

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Name _________________________________ Date ____________________________

Activity 3 - 2: Electrical Forces between Charged Objects

Objective: Show that charged objects could attract or repel each other, depending on the polarity of charges involved.

Materials:

- Acrylic Rod (2)
- Teflon Rod (2)
- Silk
- The Spinner*

* The "spinner" consists of two parts – the base and the cap. The base is a piece of acrylic with a protruding metal pin. A cork is placed over the metal pin during shipping and handling for safety reasons. Remove the cork only when the apparatus is in use. The cap is another piece of acrylic that is designed to rotate freely on the metal pin. See **Fig. 3.9** and **Fig. 3.10**

SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

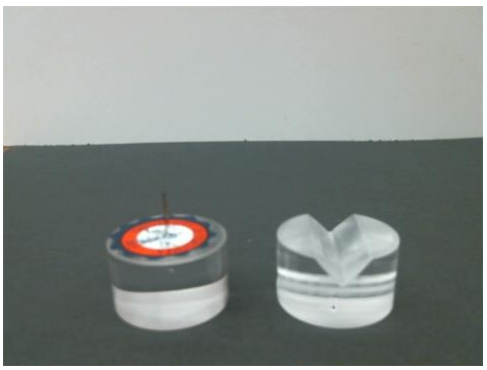

Fig 3.9

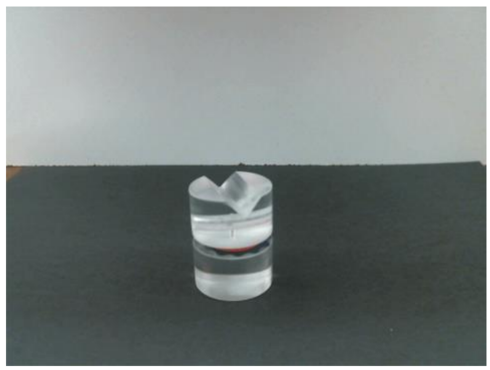

Fig 3.10

Prediction:

1. Two Teflon rods are charged by being rubbed against silk. Predict what will happen you hold one Teflon rod in your hand parallel to the Teflon rod on the spinner as shown in **Figure 3.11** and **Figure 3.12**.

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Name ________________________________ Date ____________________________

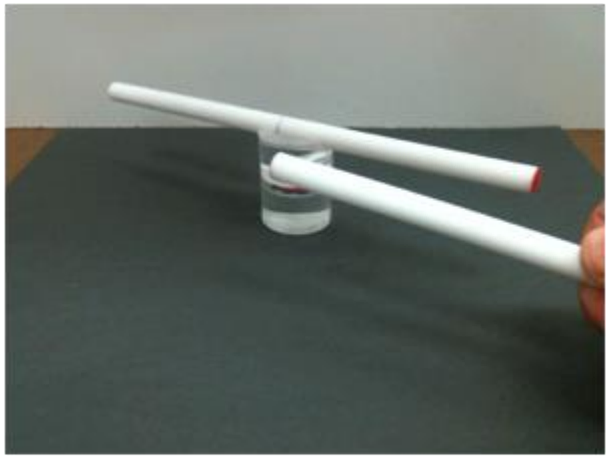

Fig 3.11

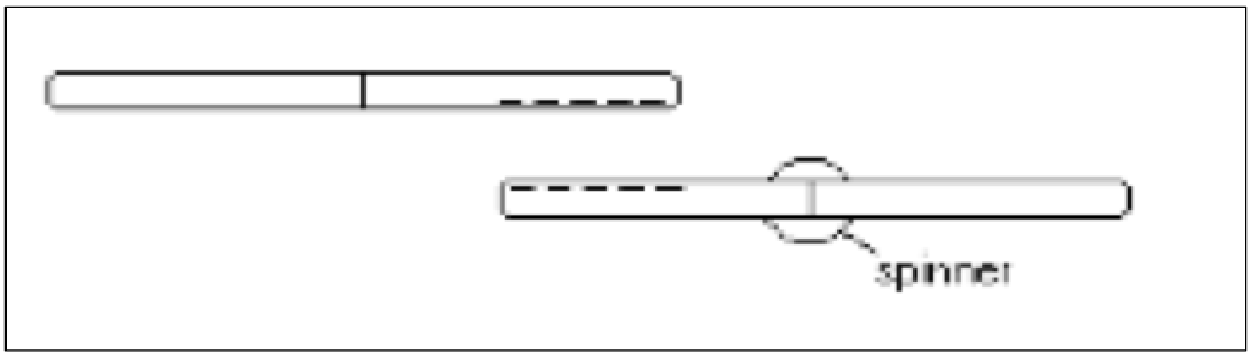

Fig 3.12

2. Predict what will happen when you replace the two, charged, Teflon rods with two acrylic rods that have been rubbed against the silk. Explain your answer.

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3. Predict what will happen when you have one charged acrylic rod and one charged Teflon rod and they are allowed to interact. Explain your answer.

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Name ________________________________ Date ___________________________

Procedure:

1. Charge one end of the first Teflon rod by striking it on the silk cloth and place this Teflon rod on the spinner. Now charge one end of the second Teflon rod.

2. Go ahead and hold the second charged rod next to the first one in order to ensure the greatest possible interaction between the two rods. Record the direction of the force (attract or repel) in **Table 3.1**.

3. Repeat steps 1 and 2 replacing the Teflon rods with the acrylic rods. Record the direction of the force in **Table 3.1**.

4. Repeat steps 1 and 2, but use one Teflon rod and one acrylic rod. Record the direction of the force in **Table 3.1**.

Direction of Electrical Forces Between Charged Objects		
	Teflon (-)	Acrylic (+)
Teflon (-)		
Acrylic (+)		

Table 3.1

5. Place the wooden rod in the slot on the spinner.

6. Hold the charged Teflon rod in your hand parallel to the wooden rod on the spinner as shown in Figure 3.13 to ensure the greatest possible interaction. Record the direction of the force in **Table 3.2.**

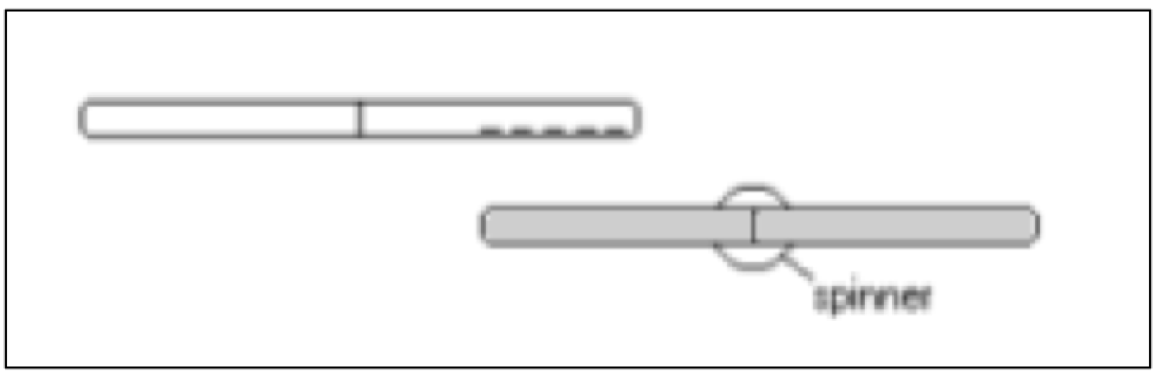

Fig 3.13 A wooden rod is placed on the spinner. A Teflon rod is then charged and used to rotate the wooden rod without touching it. Note the direction of the electric force between the two.

7. Hold the charged acrylic rod in your hand parallel to the wooden rod on the spinner as shown in **Figure 3.12** to ensure the greatest possible interaction. Record the direction of the force in **Table 3.2**.
8. Recall the description about how paper squares behave near charged acrylic and Teflon rods in Activity 1. If you are not sure, redo activity 1 to double check. Fill in **Table 3.2**.

Direction of Electrical Forces between a Charged Object and an Uncharged Object		
	Teflon (-)	Acrylic (+)
Wood (0)		
Paper (0)		

Table 3.2

Explain

1. Based on your data in **Table 3.1**, try to make a conclusion about the relationship between the charges of the object and whether they repel or attract each other.

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____
____

2. If opposite charges attract, then why does positive charge stay on silk and negative charge on Teflon after we rub them against one another? (Be sure to mention conductors and insulators in your answer)

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____
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3. Based on your data, what can you generalize about the direction of the electric force between a charged object and an uncharged object?

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____
____

Name ________________________________ Date ___________________________

Activity 3 - 3: Van de Graaf Generator

Overview

The Van de Graaff generator is a machine invented in 1929 by American physicist Robert J. Van de Graaff to generate static electric charge. A traditional VDG includes a motor-driven conveyor belt made of rubber going around a Teflon roller at the bottom and a metal roller at the top. Our handheld VDG has a small reservoir, which is the front tube made of cardboard. It carries a safe amount of charge to be used in the classroom. **Figure 3.14** is a picture of the handheld VDG.

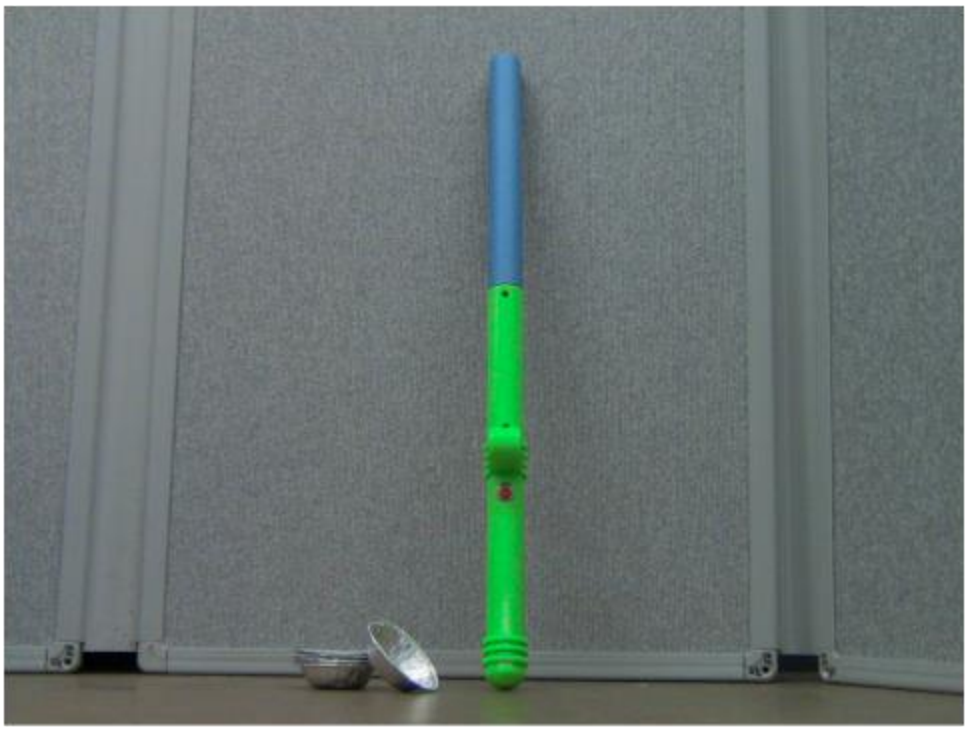

Figure 3.14

Objective: Determine whether positive or negative charge is generated by the handheld VDG.

Materials:

- Handheld VDG
- The Spinner
- Teflon Rod
- Acrylic Rod
- Silk
- Small Pie Tins (5) (from home)

SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 4.3d

Name ________________________________ Date ___________________________

Prediction

1. If you place an uncharged acrylic rod in the spinner, what do you think will happen if you bring the charged Van De Graaf Generator nearby? Explain.

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____
____

2. If you rub the acrylic rod with silk and then place the charged rod on the spinner, what do you think will happen if you bring the charged Van De Graaf Generator nearby? Explain.

____
____
____

Procedure

1. Set up the spinner as in Activity 2. Charge up the acrylic rod by rubbing it on silk. Place the acrylic rod on the spinner so that the center of mass falls close to the pivot. See **Figure 3.15**. What is the polarity of charge on the acrylic rod? Based on your observations, why do you think so?

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2. Press the button on the handheld VDG to start the charge generation process. Move it towards the acrylic rod from the side as shown in **Figure 3.15**. How does the acrylic rod react?

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____
____

Name ______________________________ Date _________________________

Figure 3.15

3. Remove the acrylic rod. Charge up the Teflon rod by rubbing it on silk. Place the Teflon rod on the spinner so that the center of mass falls close to the pivot. What is the polarity of charge on the Teflon rod? Based on your observations, why do you think so?

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____

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4. Press the button on the handheld VDG to start the charge generation process. Move it towards the Teflon rod from the side. How does the Teflon rod react?

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____

____

5. Get 5 small pie tins. Hold the handheld VDG pointing straight up. Stack the pie tins upside-down on the tip of the handheld VDG. Pie tins are shown in **Figure 3.14** on the bottom left side next to the handheld VDG.

6. Press the button on the handheld VDG to start the charge generation process. How do the pie tins react?

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____

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Figure 3.14

Explain

1. Based on your observations, what can you tell about the polarity of charge on the handheld VDG? Explain your reasoning.

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2. What do you think caused the reaction you observed in step 6? Describe the role of static electricity in the takeoff process.

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Name ________________________________ Date ___________________________

Lab 4 - Detection of Charge

Relevant SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Overview

An electroscope is an instrument that detects the presence of charge on an object, either through actual contact (conduction) or through induction. When the electroscope itself is charged, its two conductive components (which vary from electroscope to electroscope) will acquire like charge and deflect from the vertical position of gravitational equilibrium. See **Fig. 2.0.1** and **Fig. 2.0.2** for an illustration of the standard metal leaf electroscope and the UVa electroscope that we will use.

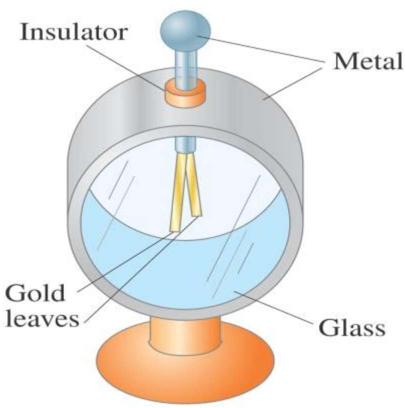

Fig. 4.1 Standard Electroscope

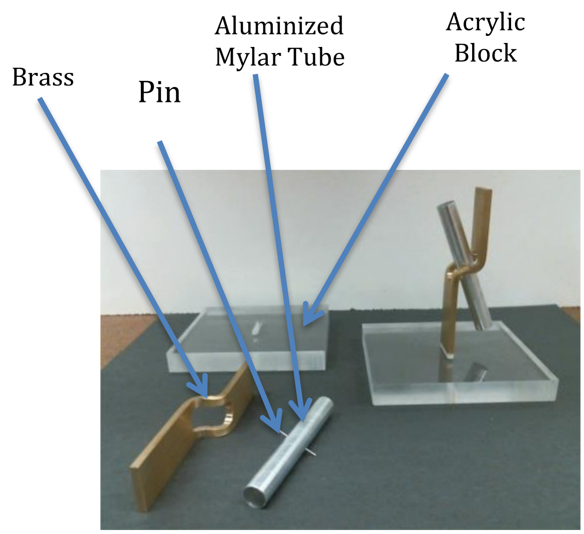

Fig. 4.2 UVa Electroscope disassembled on left, assembled on right

The base of the UVa electroscope in **Figure 4.2** is made of acrylic, an insulator, to eliminate charge leakage to the table. Both the brownish brass and the aluminized mylar tube are conductors. Electrical charge can easily move along the tube and brass support causing a repulsive force to separate them. The angle separating them is a measure of how much charge is present.

Name ________________________________ Date ___________________________

Activity 4-1: Using the UVa electroscope to detect the presence of charge

Objective: Use the electroscope to detect the presence of charge.

Materials:

- Electroscope
- Acrylic Rod
- Teflon Rod
- Silk

SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Prediction:

1. Predict the behavior of the electroscope when you touch the charged Teflon rod to the top of the brass support on the electroscope. (**Figure 4.3). Explain.**

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2. In what ways will a negatively charged electroscope look different from a positively charged electroscope? Explain.

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Procedure:

1. Assemble the electroscope according to **Figure 4.2**. Set the tube in the vertical position by touching the top of the brass support with your finger. Your finger is a conductor and therefore will drain any electric charge on the electroscope so it becomes neutral after you touch it.

2. Rub the Teflon rod on silk.

Name ______________________________ Date __________________________

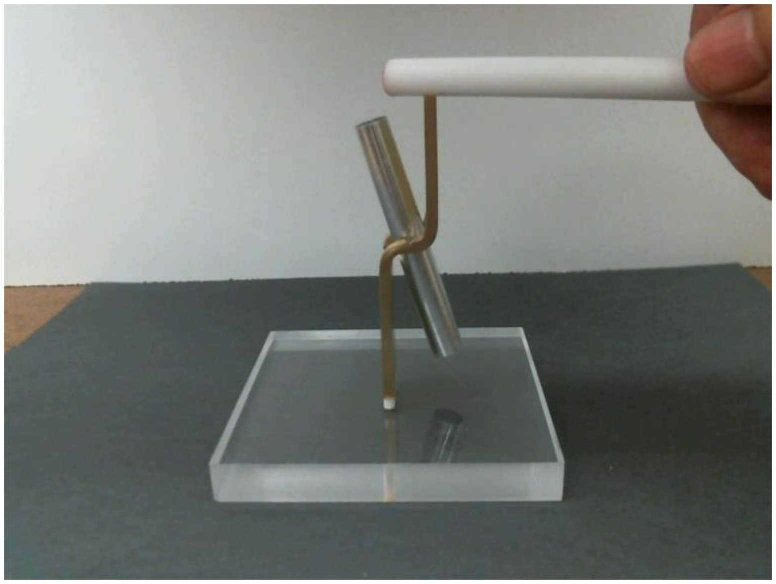

Fig. 4.3

3. Touch the charged Teflon rod to the top of the brass support on the electroscope. Describe the behavior of the electroscope.

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4. Repeat the process of charging the Teflon rod and touching the electroscope several times to accumulate more charge. Describe how the angle of the tube changes as you add charge. Is there a maximum angle?

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____
____

5. Touch the top of the brass support with your finger to make it become neutral. Now rub the acrylic rod with silk and repeat step 3 and 4. You may have to repeat the process a few times for the effect to be evident. Describe the behavior of the electroscope.

____
____
____

6. Touch the upper lip of the brass support to make it neutral. Then, using the Teflon rod, charge up the electroscope until the tube goes out as far as it can.

Name ________________________________ Date ____________________________

7. Rub the acrylic rod on silk. Then slowly slide the rod on the upper lip of the brass support while watching the movement of the tube very closely. Describe the behavior of the tube as more charge gets rubbed off the acrylic tube.

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____
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Explanation

1. Explain why the tube of the electroscope rotates when a charged rod touches the top of the brass support.

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____
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2. In Step 4, explain why there is a maximum angle that the tube of the electroscope will rotate through.

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____
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3. Compare the behavior of the electroscope after being charged by a Teflon rod and an acrylic rod. Explain the reasons for the similarities and differences.

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____
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4. When the polarity of the charge on the electroscope was negative what real particle was being transferred to or from the electroscope? When the polarity of the charge on the electroscope is positive what real particle was being transferred to or from the electroscope?

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____
____

5. What happens when an equal amount of positive charge meets an equal amount of negative charge?

____
____

Name ________________________________ Date ___________________________

Activity 4-2: Conductor or Insulator?

Introduction:

The main difference between a conductor and an insulator is that a conductor allows charge to move through it while an insulator doesn't. While the atoms in an object are stationary, the electrons can sometimes escape the grasp of the atomic nuclei and drift through the material. A material whose electrons can easily move through is said to conduct electricity. Conversely, a material whose atomic nuclei are strongly attached to all the electrons is an insulator since they are not allowed to move.

Objective: Determine whether an object is a conductor or insulator.

Materials:

- Teflon Rod
- Silk
- Electroscope
- 100% Metal Object such as Knife, Fork, or Spoon (from home)
- 100% Plastic Object such as a Plastic Knife, Fork, or Spoon (from home)
- Wooden Rod
- Acrylic Rod

SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Prediction:

1. Use **Table 4.1** to record your predictions as to whether certain materials are electrical conductors or insulators.

Table 4.1 Conductor/Insulator Predictions

Material	Conductor/Insulator?
Your Finger	
Wood	
Acrylic	
Teflon	
Metal object	
Plastic object	

Name ______________________________ Date ___________________________

2. Which predictions are you certain about? Why?

____

____

____

3. For the objects that you are uncertain about, state the reasons that contributed to your predictions.

____

____

____

Observation and Procedure:

1. Assemble the electroscope according to **Figure 4.2**. Set the tube in the vertical position by touching the top of the brass support with your finger. Your finger is a conductor and therefore will drain any electric charge on the electroscope so it becomes neutral after you touch it.

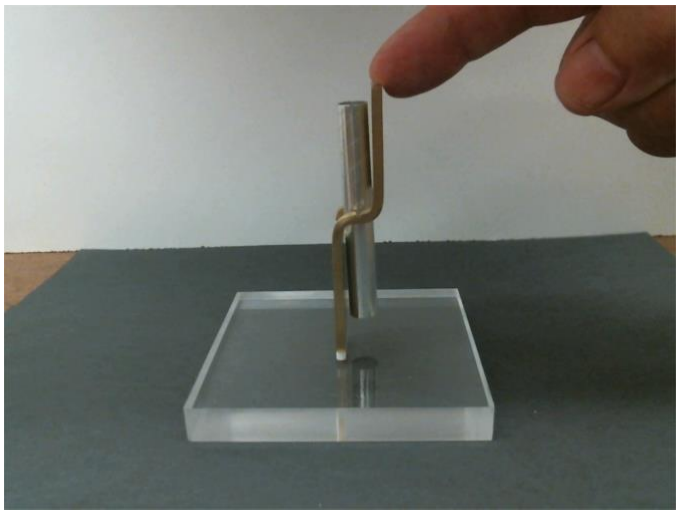

Fig. 4.4

2. Rub the Teflon rod on silk

Name ________________________________ Date ___________________________

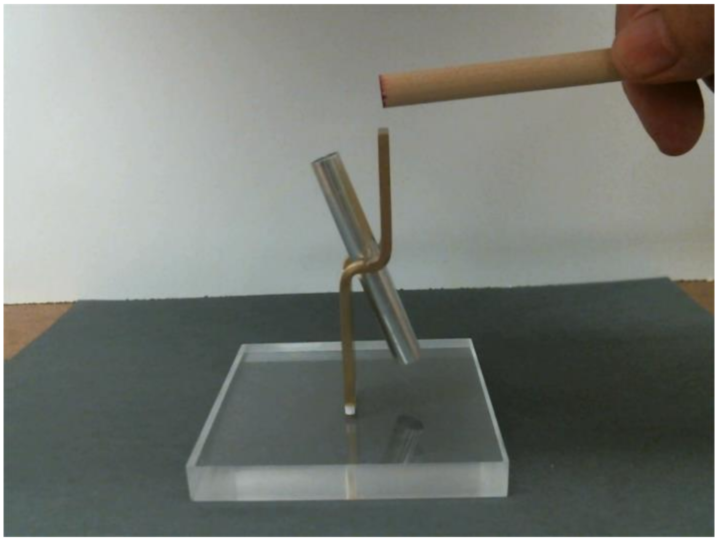

Fig. 4.5

3. Touch the charged Teflon rod to the top of the brass support on the electroscope. Describe the behavior of the electroscope.

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4. Repeat the process of charging the Teflon rod and touching the electroscope several times to accumulate more charge. Describe how the angle of the tube changes as you add charge. Is there a maximum angle?

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5. Touch the top of the brass support with your finger to make it become neutral. Now the rub the acrylic rod with silk and repeat step 3 and 4. You may have to repeat the process a few times for the effect to be evident. Describe the behavior of the electroscope.

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6. Touch the upper lip of the brass support to make it neutral. Then, using the Teflon rod, charge up the electroscope until the tube goes out as far as it can.

Name ________________________________ Date ___________________________

7. Rub the acrylic rod on silk. Then slowly slide the rod on the upper lip of the brass support while watching the movement of the tube very closely. Describe the behavior of the tube as more charge gets rubbed off the acrylic tube.

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Explanation

1. Explain why the tube of the electroscope rotates when a charged rod touches the top of the brass support.

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2. In Step 4, explain why there is a maximum angle that the tube of the electroscope will rotate through.

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3. Compare the behavior of the electroscope after being charged by a Teflon rod and an acrylic rod. Explain the reasons for the similarities and differences.

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4. When the polarity of the charge on the electroscope was negative what real particle was being transferred to or from the electroscope? When the polarity of the charge on the electroscope is positive what real particle was being transferred to or from the electroscope?

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Name ________________________________ Date ___________________________

5. What happens when an equal amount of positive charge meets an equal amount of negative charge?

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Name ________________________________ Date ___________________________

Activity 4 – 3: Movement of Charges in a Conductor

Introduction:

We already know that the fundamental characteristic of a conductor is that charges can move freely through it. If a charged object is placed close to a conductor, it will affect the spatial distribution of the charges in the conductor by attracting opposite charge while pushing similar charge away. See **Fig. 4.6 and Figure 4.7**

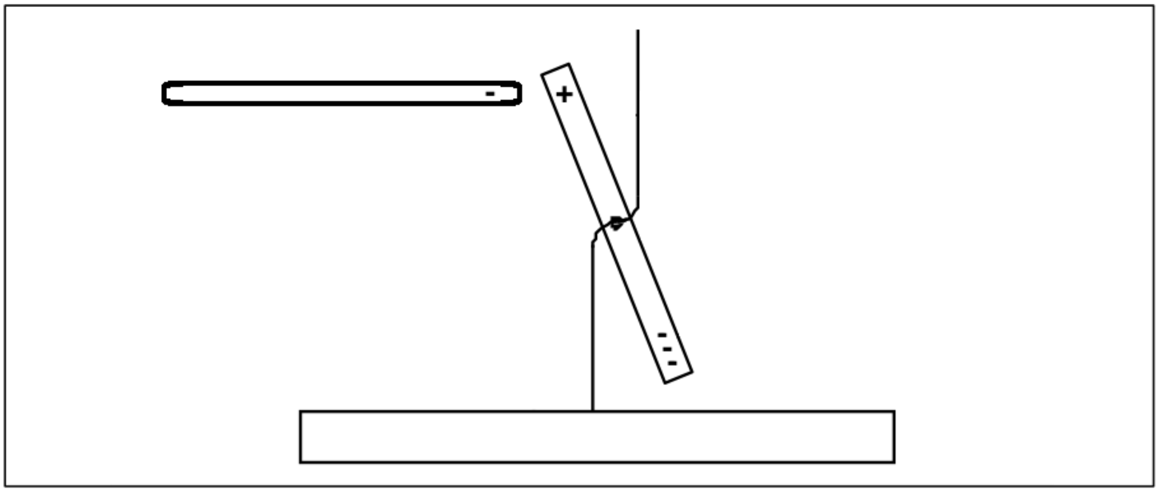

Fig. 4.6 A negatively charged rod is brought near a neutral electroscope. Some of the electrons from the top of the electroscope tube are repelled to the opposite end of the tube.

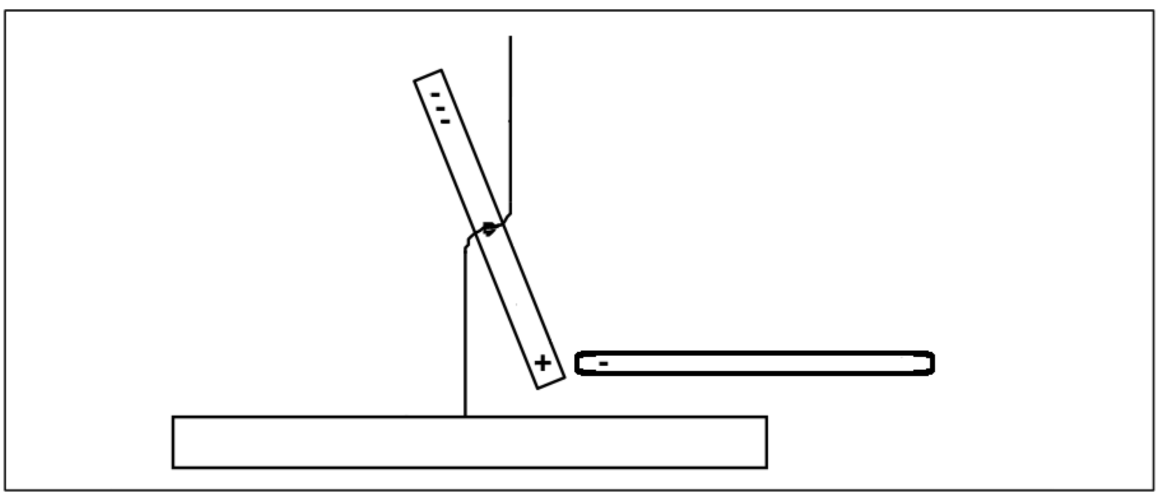

Fig. 4.7 Similar to in Figure 4.6, a negative rod is brought near to an initially neutral electroscope. Some of the electroscope's electrons are repelled to the opposite side of the tube.

Name ______________________________ Date __________________________

SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Objective: Show that the spatial distribution of charges in a conductor can change easily.

Materials:

- Electroscope
- Teflon Rod
- Silk

Prediction:

1. Predict the behavior of the electroscope when the charged Teflon rod is brought near to the top of the similarly charged electroscope tube. Explain your prediction.

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Procedure:

1. Rub the Teflon rod on silk. Rub the Teflon rod across the lip of the electroscope to charge it up.

2. Rub the Teflon rod on silk again. Starting from 10 cm away, slowly move the Teflon rod close to the top of the electroscope *tube*. Describe the behavior of the tube in the entire process.

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3. Pull the rod away. If the electroscope is still charged, move on to Step 4. If the electroscope seems to have lost its charge, recharge it as in Step 1 before moving on to Step 4.

4. Recharge the Teflon rod and slowly move it close to the bottom of the tube, also starting from 10 cm away. Describe the behavior of the tube in the entire process.

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Name ______________________________ Date __________________________

Explain

1. Were your observations in Step 2 in agreement with your prediction? Why or why not?

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2. Were your observations in Step 4 similar to your observations in Step 2? Why or why not?

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3. How can the tube be repelled and then attracted, while having the same amount of net charge on it? Explain the mystery by drawing reference to the movement of charges in a conductor.

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Name ________________________________ Date ___________________________

Lab 5
Charging by Induction

Relevant SOLs: PS.6b, PS.6c, PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 4.3d, 6.1c

Overview

An object can become charged through contact with another charged object. This is a phenomenon known as *charging by conduction*. When objects are charged without coming into contact with a charge source, the process is known as *charging by induction*. This process primarily works with conductors. One method of charging involves moving a charged object to the vicinity of two uncharged conductors in contact with each other. See **Fig. 5.0.1**, **Fig. 5.0.2**, **Fig. 5.0.3**, **and Fig. 5.0.4**.

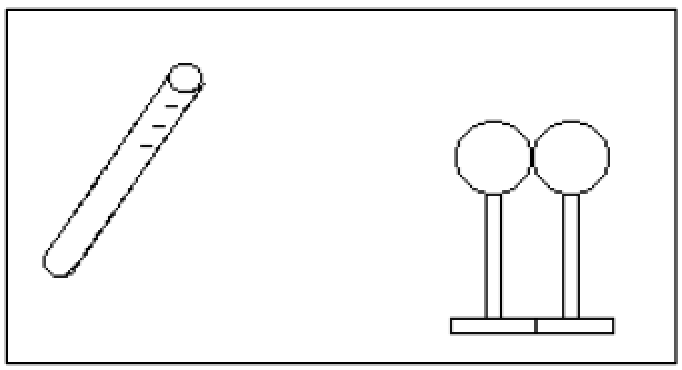

Fig. 5.0.1 Negative charge accumulates on a plastic rod after it is rubbed against silk. Far away from the rod, two metal spheres in contact with each other are placed on insulating stands. They are electrically neutral in the beginning.

Name ________________________________ Date ___________________________

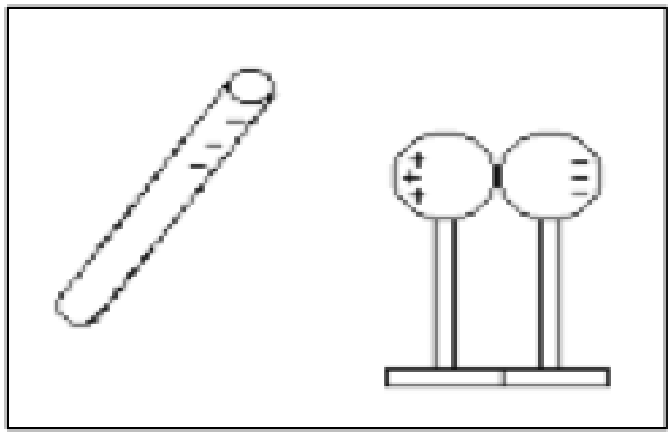

Fig. 5.0.2 The negatively charged plastic rod is brought close to the metal spheres. Negative charge moves to the sphere farther from the rod, leaving the closer sphere positively charged. The two spheres as a whole remain electrically neutral, because they are insulated from the surroundings.

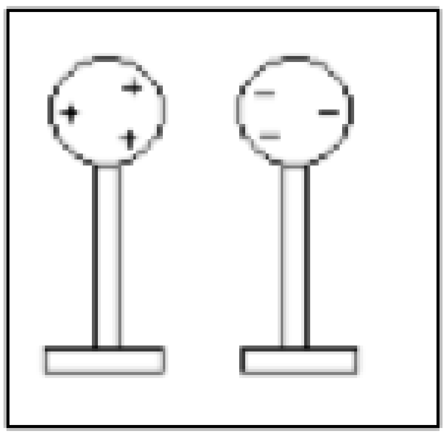

Fig. 5.0.3 The metal spheres are then separated. Each sphere retains its excess charge.

Name ________________________________ Date ___________________________

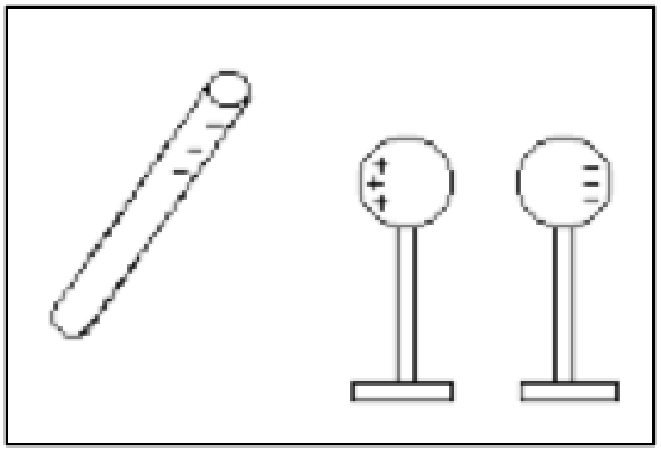

Fig. 5.0.4 The negatively charged plastic rod is now removed, leaving the metal spheres individually charged. They carry equal and opposite amounts of electric charge because the two spheres as a whole have to remain electrically neutral.

***In this experiment, we are assuming that all parts of the brass support and aluminized tube are conductive. In reality, the aluminized tube has an insulating coating. This can be ignored for the purposes of these activities.

Name ______________________________ Date __________________________

Activity 5 - 1: Charging the Electroscope by Induction

Objective: Charge the electroscope by induction.

SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 6.1c

Materials:

- Teflon Rod
- Silk
- Electroscope
- Protractor (optional)

Prediction

3. Predict the behavior of the electroscope when the charged Teflon rod is brought near to the brass support of an uncharged electroscope.

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4. Predict the behavior of the electroscope when the charged Teflon rod is brought near to the brass support of an uncharged electroscope **and** your finger is in contact with the opposite end of the brass support.

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Observation and Procedure

7. Rub the Teflon rod on silk. Hold the Teflon rod in your right hand.

8. Move the Teflon rod horizontally towards the lower part of the brass support. The tube will start to deflect. Be very careful not to let the tube deflect more than 45 degrees.

9. When the Teflon rod is about 5 mm away from the brass support, stop the horizontal movement. Move the Teflon rod upward. The tube will deflect more and more until the middle portion of the tube comes into contact with the Teflon rod. Stop when contact is made.

Name ________________________________ Date ___________________________

10. Pull out the Teflon rod from under the tube. Pull along the length of the rod so that it slides out smoothly without touching the brass support.

11. With the rod removed, the tube will oscillate back and forth around its new equilibrium position. Wait for it to settle down. Estimate the angle of tube deflection.

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12. Neutralize the electroscope and the Teflon rod by rubbing them with your hand.

13. Repeat Steps 1-3 but then, instead of removing the Teflon rod right away, touch the top lip of the brass support with your finger while maintaining contact between the rod and tube. See **Fig. 5.1.1**. Then take your finger off the brass support while maintaining contact between the rod and the electroscope. Describe the behavior of the electroscope.

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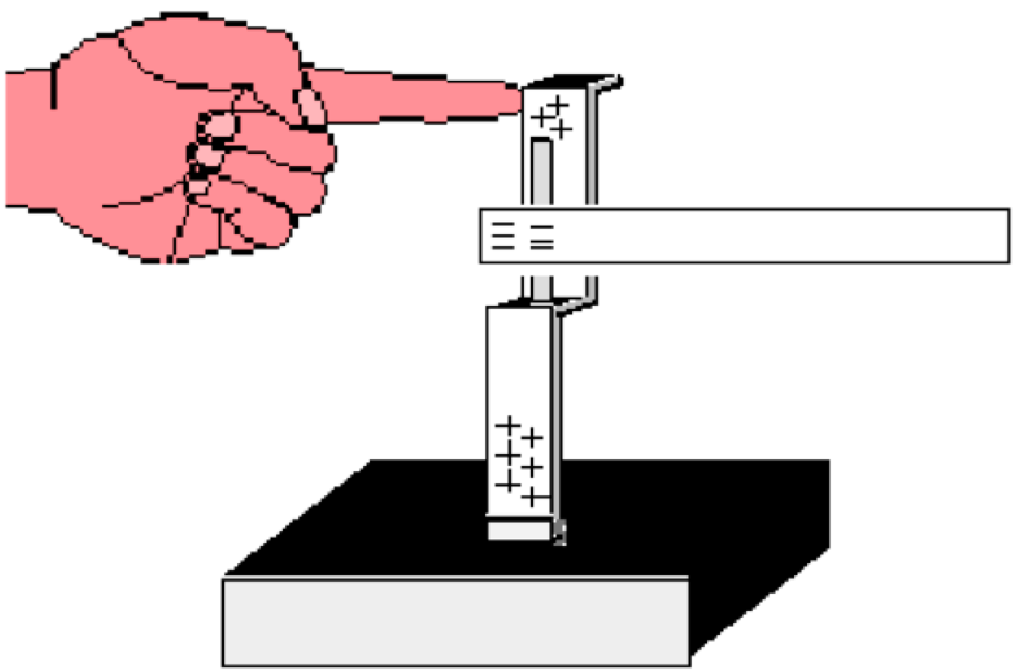

Fig. 5.1.1

Name ______________________________ Date __________________________

14. This time, repeat Step 7, but after removing your finger, you will go ahead and pull out the Teflon rod from under the tube. Be sure to pull along the length of the rod so that it slides out smoothly without touching the brass support. Wait for the tube to settle down in its new equilibrium position. Describe the behavior of the electroscope.

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15. Estimate the angle of tube deflection.

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Explain

1. The procedure above describes 2 experiments – the first one is a control experiment to contrast the effect made by touching the electroscope with your finger. Draw a 3x2 (3 rows x 2 columns) table in the space below. In the first column, list the key difference in the procedure. In the second column, list the key difference in the results. Remember to label the columns in the top row.

Name ______________________________ Date __________________________

2. Previously, your finger was used to neutralize the electroscope. It seems counterintuitive that the electroscope doesn't get neutralized in the second part of the activity. Explain the paradox – how does charge get onto the tube when you touch the brass support? What is the polarity of the charge on the tube?

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Name ______________________________ Date _________________________

Activity 5 - 2: Induction Applications

Objective: Observe applications of charge induction.

SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 4.3d

Materials:

- Teflon Rod
- Silk
- Soda Bottle (optional, from home)
- Tack Pin (optional, from home)
- Coffee Mug x2 (optional, from home)
- Water faucet and sink (soda bottle, pin, and mug are not needed if you have access to a water faucet and a sink in the classroom.)
- Handheld VDG
- Large Pie Tin (from home)

Prediction:

In this activity, you will be holding your charged rods near neutral samples of water. Predict whether each of the rods described below will attract the water, repel the water, or have no effect on the water.

1. A positively charged rod. __________________

2. A negatively charged rod. __________________

3. A neutral rod. __________________

Observation and Procedure:

1. If you have a water faucet and a sink available, you can skip steps 2-5 and 8.

2. Use the tack pin to drill a hole 0.5mm in diameter on the side of the soda bottle. The hole has to be lower than ¼ of the height of the bottle.

3. Go to a kitchen or bathroom in your building. Plug the hole with your finger and fill the soda bottle with water up to 3/4 of its height. Release your finger to test whether the hole is big enough for water to come out as a stream. If the hole is too small, use the tack pin to widen it.

Name ______________________________ Date __________________________

4. Put the lid back on. Flip the bottle upside down so that water doesn't come out through the hole. Go back to the classroom with the bottle.

5. Put the bottle on the edge of a table. Flip the bottle right side up. Remove the lid and water will start streaming out of the hole. Set the first coffee mug on the floor to receive the stream.

6. Neutralize the Teflon rod by rubbing it across your hand. Approach the stream with the rod. Describe the behavior of the stream.

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7. Rub the Teflon rod on silk. Approach the stream with the rod from different directions. Describe the behavior of the stream.

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8. Set the second coffee mug next to the first one. Use the charged rod to bend the stream of water into the second mug.

9. The procedure above describes 2 experiments – the first one is a control experiment and the second one is to see whether the stream can be bent. Enter your results in **Table 5.2.1**.

Charge on Teflon Rod	Effect on the stream of water

Table 5.2.1

10. Repeat Steps 6 and 7 with the acrylic rod. Describe the behavior of the water stream.

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Name ________________________________ Date ___________________________

11. Obtain "The Firefly." The firefly consists of an old discarded plastic film canister that is partially transparent. A Christmas tree light bulb is placed on the inside with one end connected to aluminum foil and glued across the top. On the bottom you have the same thing. See **Fig. 5.2.1** for details. The firefly in the class kit comes pre-assembled.

Fig. 5.2.1

12. Dim the lights in the room.

13. Charge up the Teflon rod by rubbing it on silk. Then hold the Firefly capsule by grabbing the bottom. Maintain contact with the tin foil on the bottom with your hand.

14. Rub the charged Teflon rod on the top foil of the firefly. What do you see in the firefly capsule when the discharge occurs?

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Name ________________________________ Date ___________________________

Explanation:

1. Why does the water stream bend when the charged Teflon rod is nearby? (Hint: water is a conductor too). Describe the redistribution of charge in the water stream under the influence of the charged Teflon rod.

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2. Explain how it is possible for the Teflon rod and the acrylic rod to have the same effect on the water when their charges are opposite.

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3. If you could make a stream of another liquid, such as ethanol or gasoline, would the charged rod bend the stream? Explain your reasoning.

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4. Describe what you think is happening when The Firefly lights up.

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Name ________________________________ Date ___________________________

Activity 5 - 3: The Electrophorus

Introduction:

An electrophorus is a device that can generate static electricity repeatedly by induction. The device consists of a charged insulating plate, and a metal plate with an insulator handle. The metal plate can be charged as often as desired without draining the charge on the insulating plate. See **Fig. 5.7 to Fig. 5.10.**

Objective: Build and test a homemade electrophorus.

SOLs: PS.6b, PS.6c, PS.11a, 4.1b, 4.3a, 4.3c, 4.3d

Materials:

- Class Kit plastic Box
- Silk
- Electroscope
- Letter-size Paper (from home)
- Large Pie Tin (from home)
- Styrofoam Cup (from home)
- Scotch Tape (from home)

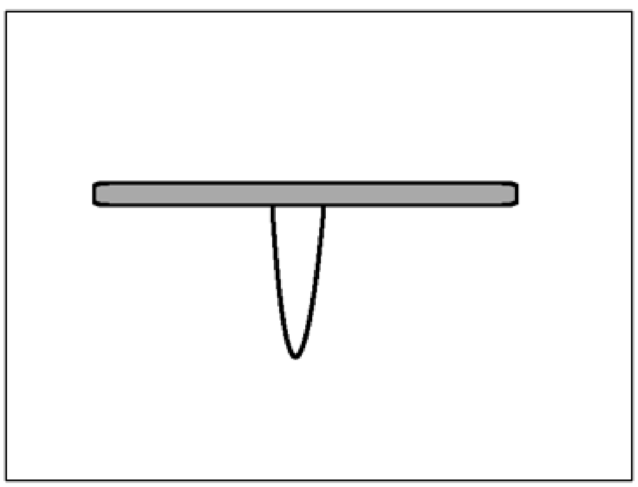

Fig. 5.3.1 The metal plate is neutral in the beginning. It has an insulator handle.

Name ________________________________ Date ___________________________

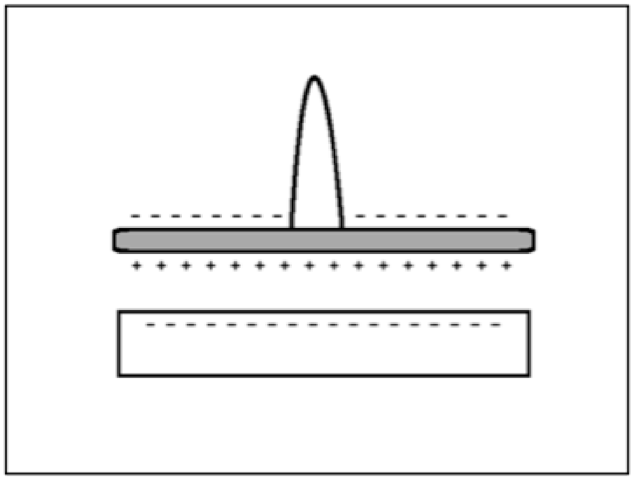

Fig. 5.3.2 A Teflon insulating plate is charged. Then the metal plate is suspended above the charged plate. Negative charge moves to the top surface of the metal plate, leaving the bottom positively charged. In our activity, a piece of paper will keep the two plates from touching.

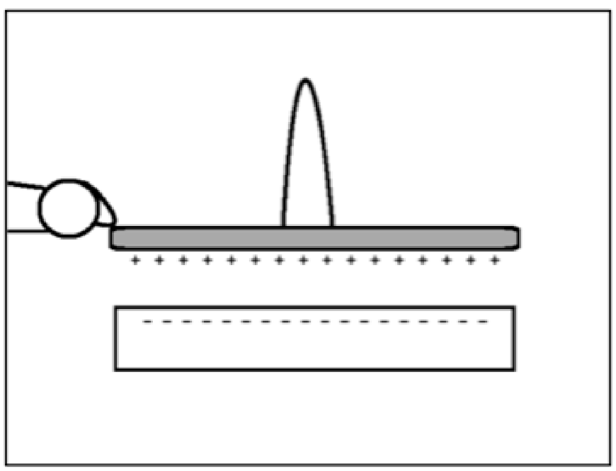

Fig. 5.3.3 The top surface is touched for a brief moment. Negative charge escapes through the finger.

Name ________________________________ Date ___________________________

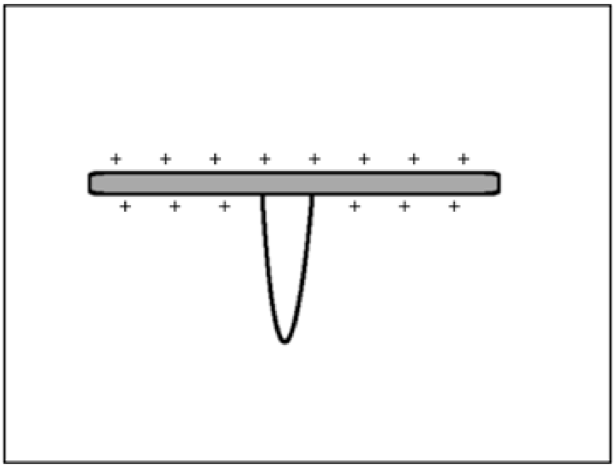

Fig. 5.3.4 The metal plate is now positively charged. It can be moved away from the acrylic plate without losing its charge.

Prediction:

The introduction states: "*the metal plate can be charged as often as desired without draining the charge on the insulating plate.*" This is of course theoretical. In practice, how many times do you believe the metal plate can be charged without draining the charge on the insulating plate? 10? 100? 1000?

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Observation and Procedure

1. Tape the Styrofoam cup to the inside bottom of the pie tin. The tape should be strong enough to hold the weight of the pie tin when you use the cup as a handle to pick up the pie tin as shown in **Fig. 5.3.5**.

Name ________________________________ Date ___________________________

Fig. 5.3.5

2. Cut out a round shape from paper about the same size as the pie tin bottom. Tape it to the outside bottom of the pie tin in **Fig. 5.3.6.** The paper acts as an insulator and will prevent charge from flowing on to the bottom of the plate.

Fig. 5.3.6

3. Flip the E&M kit box upside-down. Rub silk against the plastic box. The flat surface of the box will become negatively charged. See **Fig. 5.3.7**.

Name ________________________________ Date ___________________________

Fig. 5.3.7

4. Set the pie tin on the charged surface of the box using the Styrofoam cup as a handle. Do not touch the tin plate. Only touch the handle. Then pick it back up using your left hand and touch the rim of the plate again with a finger on your right hand. Instead of your finger you may use the firefly to see if a discharge occurs. If it does, the firefly will light up. See **Fig. 5.3.8.** Is there a discharge from the plate? Record your observations here.

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Fig. 5.3.8

Name ________________________________ Date ___________________________

5. Set the pie tin on the charged surface again using the cup as a handle. This time, touch the rim of the plate while it's sitting on the charged surface. See **Fig. 5.3.9**. Record your observations.

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Fig. 5.3.9

6. Now pick up the pie tin with the handle using your left hand and touch the rim of the plate again with your right hand finger. Instead of your finger you may use the firefly to see if a discharge occurs. If it does, the firefly will light up. See **Fig. 5.3.10** and **Fig. 5.3.11**. Is there a discharge from the plate? Record your observations here.

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Name ________________________________ Date ___________________________

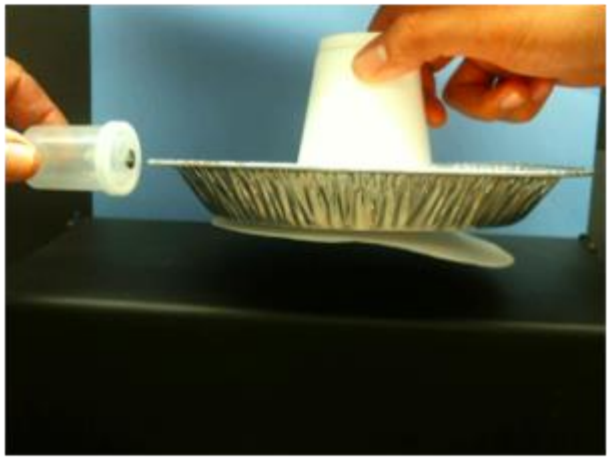

Fig. 5.3.10

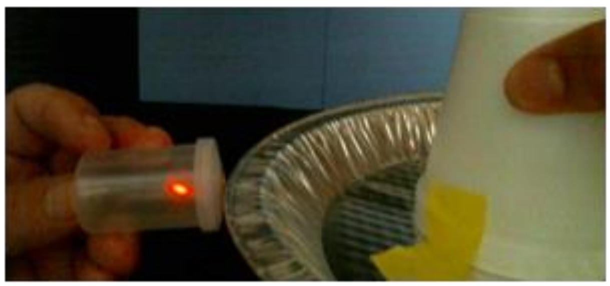

Fig. 5.3.11

7. Repeat steps 5 and 6. Does the charge on the box become exhausted?

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Explain

1. In Step 4, if there is a discharge, is the charge positive or negative that leaves the plate? What type of charge stays on the plate?

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2. In Step 5, what happens to the negative charge on the plate when you touch it with your finger? Does it remain on the plate or does it flow through your finger?

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Name ______________________________ Date __________________________

3. In Step 6, if there is a discharge, what type of charge leaves the plate? What type of charge stays on the plate?

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4. Each time a discharge happens, electric energy is dissipated as light and sound. It seems paradoxical that we can create discharge events perpetually using this method. Does it violate the conservation of energy? Where does the electric energy come from?

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Name ________________________________ Date ___________________________

Name ________________________________ Date ___________________________

Lab 6
Magnetism and Electromagnetism

Relevant SOLs: PS.1h, PS.1j, PS.1k, PS.11a, PS.11b, 3.1a, 3.1j, 4.1a, 4.1f, 4.1h, 4.3e, 4.3f, 5.1e, 5.1f, 6.1g, 6.1i

Overview

People are fascinated with magnets, largely because magnets act at a distance. You can put your hand between a magnet and a steel paper clip and move the paper clip. A neurosurgeon can guide a pellet through brain tissue to an inoperable tumor, or implant electrodes while doing little harm to brain tissue.

The term *magnetism* comes from the name Magnesia, a coastal district of ancient Thessaly, Greece, where the Greeks found unusual stones more than 2000 years ago. These stones, called lodestones, had the property of attracting iron.

The Chinese were the first to use magnets that were fashioned into compasses and use them in navigation. [1]In the 16^{th} century, William Gilbert, Queen Elizabeth's physician, made artificial magnets by rubbing pieces of iron against lodestone, and he suggested that a compass always points north and south because Earth has magnetic properties.

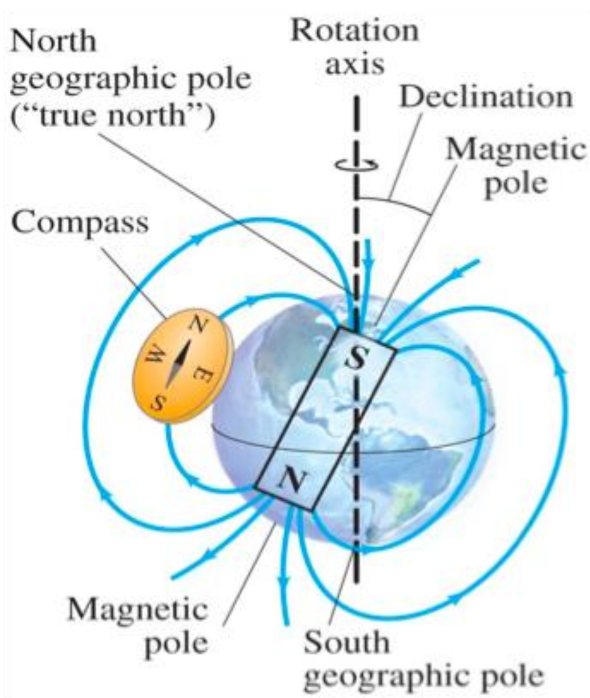

Fig 6.0.1 The magnetic field of the Earth resembles that of a bar magnet with the South magnetic pole in the Northern hemisphere and the North magnetic pole in the Southern hemisphere. A compass aligned as is shown has its North pole arrow pointing towards the South magnetic pole which is what we normally call North.

Name ________________________________ Date ___________________________

In 1750 John Michell, an English physicist and astronomer, found that magnetic poles obey the inverse-square law, and his results were confirmed by Charles Coulomb. The subjects of magnetism and electricity developed almost independently of each other until 1820, when a Danish physicist named Hans Christian Oersted discovered, in a classroom demonstration, that an electric current affects a magnetic compass. He saw confirming evidence that magnetism was related to electricity. Shortly thereafter, the French physicist André Marie Ampere proposed that electric currents are sources of all magnetic phenomena.

A permanent magnet is a magnet that does not lose its magnetic field. However, what makes a magnet permanent? In order to understand this we need to know how magnets work. Magnetism is an aspect of the phenomenon known as the electromagnetic force a fundamental force of the physical universe. Magnetism, like its other aspect electricity, manifests itself as a field. What makes a magnet is when certain substances and elements are induced with a strong magnetic field. In the case of permanent magnets this field remains over time without weakening.

A permanent magnet is a magnet because of the orientation of its domains. Domains are the small magnetic field inherent in the crystalline structure of ferromagnetic materials. It is believed that the magnetism comes from the spinning electrons in the atom. Since electrons are charged this corresponds to a current flowing in a wire which we know produces a magnetic field. Ferromagnetic materials are the only substances capable of being made into magnets; they are normally iron, nickel, cobalt, or alloys that are made of rare-earth metals. A magnet is created when certain conditions cause separate domains in a ferromagnetic item to be all aligned in the same direction. However the method used in most cases can make only weak magnets. The normal method is by either direct contact with a naturally magnetic material or by running an electric current through it.

One of the earliest pioneers in electrical and magnetic theory was Hans Christian Oersted, a Danish physicist and chemist. In 1820 he observed that a wire carrying an electrical current deflected a compass needle. Others had made similar observations, but Oersted systematically showed that the magnetic field circled the wire in a direction that depended on the direction of the electrical current in the wire. This magnetic field was an example of the **Right Hand Rule**, as shown in **Fig 6.0.2.**

Name ________________________________ Date ___________________________

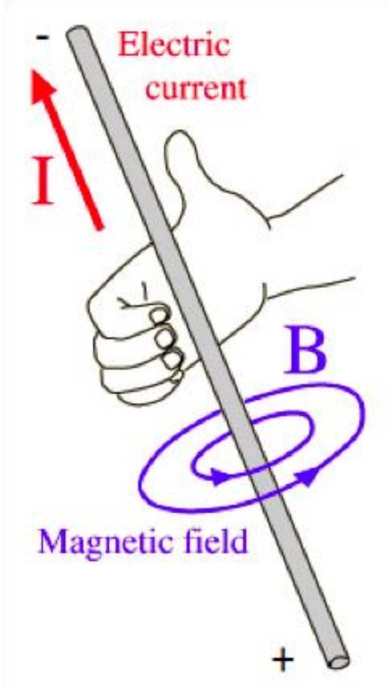

Fig. 6.0.2 (Diagram from http://hyperphysics.phy-astr.gsu.edu)

The nominal current flows from the positive terminal to the negative terminal through the circuit. If you place the thumb of your right hand on the wire pointed in the direction of the nominal current, then your fingers curl around the wire in the direction of the magnetic (B) field.

Name ______________________________ Date __________________________

Activity 6 - 1: Properties of Magnetism and Magnetic Fields

Objectives: The student will learn some of the characteristics of magnetism.

SOLs: PS.11b, 3.1a, 3.1j, 4.1a, 4.3e

Materials:

- 4-1 inch, 3 inch, 6 inch iron bar magnets
- Compass
- Plastic battery holders
- Aluminum foil – minimum size is 4” x 6” (from home)
- Steel paper clip (from home)
- Plastic ruler (from home)
- Wood block – minimum size is 4” x 6” x ¾”
- Steel sewing needle or a steel straight pin (from home)
- Plastic cups (from home)
- Scotch tape (from home)
- Sheet of paper (from home)

Prediction

1. In this activity, you will be testing how magnets interact with common materials. For each object, predict if a magnet will attract, repel, or neither and explain why you made that prediction.
   a. plastic battery holder
   b. block of wood
   c. aluminum foil
   d. south pole of a bar magnet
   e. north pole of a bar magnet
   f. steel paper clip

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2. You will also be using a compass to map the magnetic field around a bar magnet. Sketch directly onto **Fig 6.1.1** to predict where each compass will point.

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Name ______________________________ Date _________________________

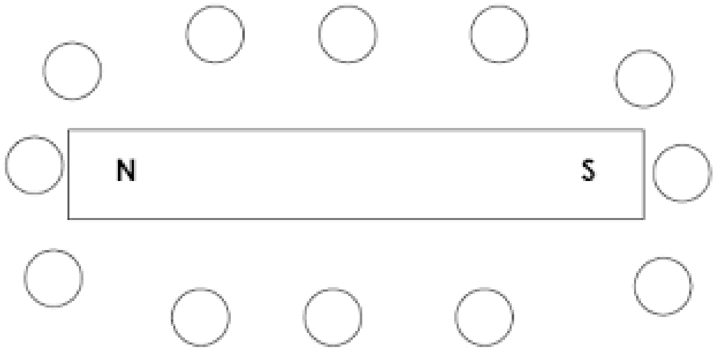

Fig 6.1.1 Sketch the direction that the arrow on a compass placed at each circle will point. Image from St. Marys High School[1].

3. You will also attempt to float a bar magnet on water. If you are successful, your bar magnet will respond to the Earth's magnetic field. Predict the orientation of the bar magnet after it comes to rest.

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Observation and Procedure

1. Take one of your bar magnets and observe what happens when you touch a variety of objects with the North Pole of the bar magnet. Record your observations in **Table 6.1.1.**

Material	Attraction/repulsion/no effect
Plastic battery holders	
Block of wood	
Aluminum foil	
South pole of bar magnet	
North pole of bar magnet	
Steel paper clip	

Table 6.1.1

2. This is a simple and clean way to make a compass and get a feeling for the sensitivity of magnetic forces. The magnetic field due to the earth in this room is about 0.5 Gauss. The magnetic field due to your bar magnets is about 100 to 1000 Gauss. The largest magnetic field recorded in the Laboratory without destroying the equipment is about 1 Million Gauss. Now take your 1-inch smallest bar magnet and place it lengthwise so it lies along the bottom of your small plastic cup. Place the cup with the magnet in a bowl of water with enough depth so the cup floats in the water. Watch the cup slowly rotate until it stops. In

Name ________________________________ Date ___________________________

what direction does the North-South poles of the bar magnet align when it comes to rest?

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3. Place your sheet of paper on a table in which there is no magnetic material around or under the desk.

4. Using your compass determine geographic north. Keep your compass away from your bar magnet while doing this. Next place the bar magnet as shown in **Fig 6.1.2** on the sheet of paper. Orient your sheet of paper so that the earths magnetic field is along the bar magnet.

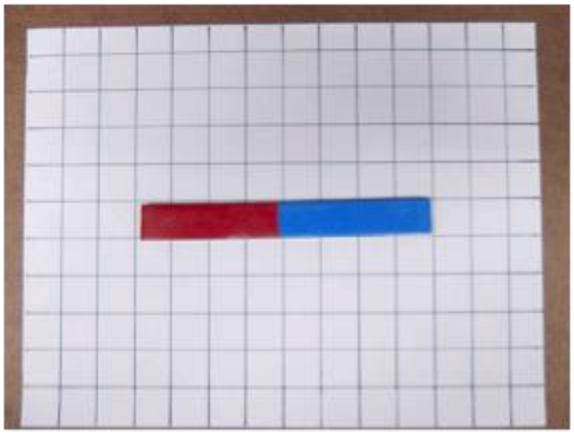

Fig 6.1.2 Your paper does not need the grid lines.

5. Draw an outline of the magnet. **Be sure the magnet is in this location at all times.** You may wish to use a little scotch tape to securely fasten the magnet down in this location. Use a pencil to mark the location of the magnet in case it moves.

6. Place your compass at each location indicated in **Fig 6.0.2** and draw a short line with a pencil under the compass pointing from S to N with an arrow at N.

7. On the paper, mark the north pole of the magnet. Mark the location of the south pole of the magnet.

8. Include a copy of your diagram here.

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Explanation:

1. Based on your results, why are some materials attracted or repelled while others are unaffected? Summarize the results you observed.

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2. Explain why the bar magnet came to rest where it did in Step 2.

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3. In step 7, explain how you knew the South from the North Pole.

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4. Explain how your diagram indicates that the magnet is strongest at its ends.

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5. Is the magnetic field the same above the magnet as below? Explain.

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Activity 6 – 2: Oersted's Experiment

Objective: Observe the behavior of a magnetic compass in the presence of an electrical current.

SOLs: PS1k, PS.11a, PS.11b, 3.1a, 3.1j, 4.1a, 4.3e, 4.3f

Materials:

- Compass
- Alligator Wires
- 1.5 Volt battery (from home)
- Wooden shims x2 (Popsicle sticks or very thin dowel rods or coffee stirrers, from home)
- Duct Tape or scotch tape (from home)

Prediction:

Before everyone owned cell phones with built-in GPS apps, compasses were used to help navigate. This is possible because the ends of the compass points towards the Earth's magnetic poles. Do you think that the magnetic field generated by a battery will affect a compass in the same way as the earth's magnetic field?

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Observation and Procedure

1. Place the compass flat on a surface with no nearby sources of electricity or magnetism. Place the 1.5V cell in a battery holder.

2. Place the electrical wire across the top of the compass so that the wire crosses the center of the compass and the taped section makes a 45° angle clockwise from the north end of the compass. It may be necessary to use some duct tape to secure the wire across the face of the compass. See **Fig 6.2.1.** Describe the movement (or lack) of the compass needle in the presence of the wire.

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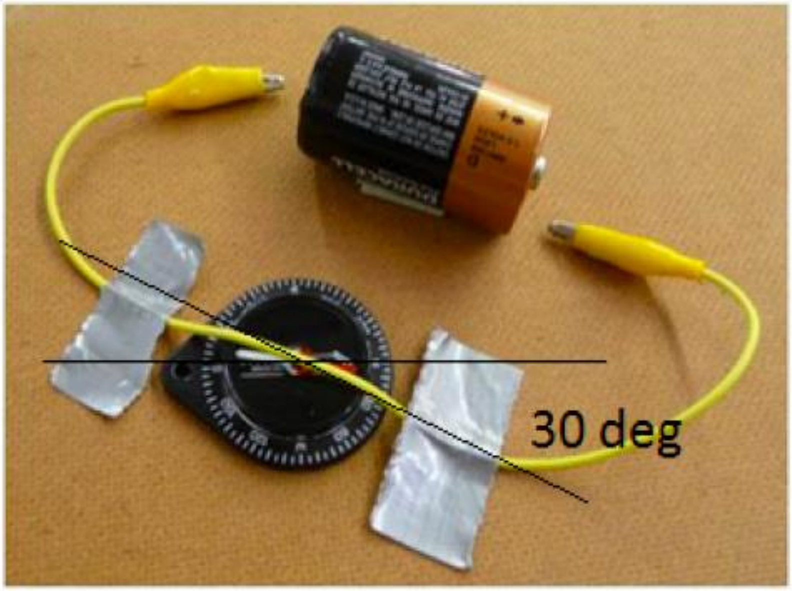

Fig. 6.2.1

3. Connect the end of the wire closer to the south end of the compass to the negative terminal of the 1.5-Volt cell. Briefly (!) connect the other end of the wire to the positive terminal of the 1.5-Volt cell. Describe the direction that the compass needle deflects in the space provided. Compare the direction with the direction of the magnetic field predicted by the Right Hand Rule. **(!) Warning: The wire will get hot very fast because the cell is essentially shorted, which means there will be a large current through the wire. This will also drain the cell rapidly. Do not keep the wire connected to the cell for too long. It will only take less than 3 seconds to see the deflection.**

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4. Switch the direction of the current: connect the end of the wire closer to the south end of the compass to the positive terminal of the 1.5-Volt cell. Briefly (!) connect the other end of the wire to the negative terminal of the 1.5-Volt cell. Describe the direction that the compass needle deflects and comment on the relationship between the direction of the current in the wire and deflection. Compare the direction with the direction of the magnetic field predicted by the Right Hand Rule.

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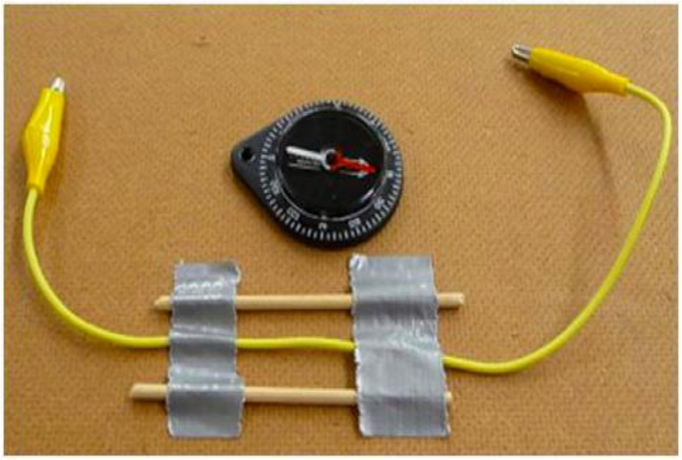

Fig 6.2.2

5. Maintain the direction of the taped section of wire. Remove the compass from underneath the wire. Place one shim on each side of the wire, and put the compass on top of the two shims. The taped section of wire should make a 45° angle clockwise from the north end of the compass. Connect the end of the wire near the south end of the compass to the negative terminal of the 1.5-Volt cell. Briefly (!) connect the other end of the wire to the positive terminal of the 1.5-Volt cell. Describe the direction that the compass needle deflects in the space provided. Compare it to the direction that the compass needle deflected in #3. Compare the direction with the direction of the magnetic field predicted by the Right Hand Rule.

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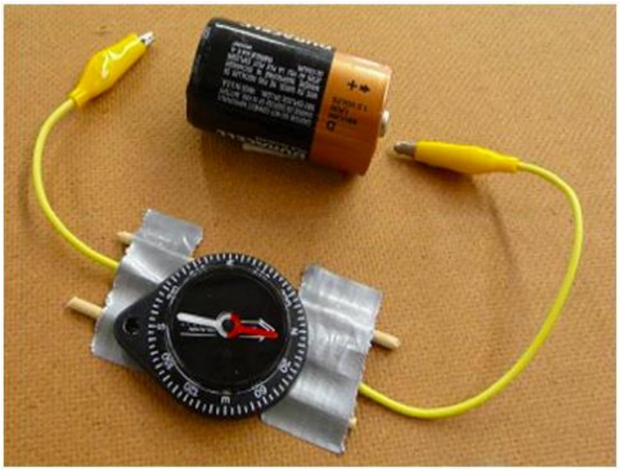

Fig 6.2.3

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6. Switch the direction of the current: connect the end of the wire closer to the south end of the compass to the positive terminal of the 1.5-Volt cell. Briefly (!) connect the other end of the wire to the negative terminal of the 1.5-Volt cell. Describe the direction that the compass needle deflects in the space provided. Comment on the relationship between the direction of the current in the wire and deflection. Compare the direction with the direction of the magnetic field predicted by the Right Hand Rule. Compare this result to result #4.

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7. Wrap the wire around the compass tightly to form a loop that starts at the center on the backside of the compass, loops around through the center on the front side, and loops back through the center on the backside again. Then rotate the compass until the loop forms a 45° angle clockwise from the north end of the compass needle. Tape the wire on the table and use one hand to hold down the wire against the compass, as well as making sure the compass stays level. Use the other hand to clamp the end of the wire closer to the south end of the compass to the negative terminal of the battery holder. Briefly (!) touch the positive terminal with the other end of the wire. Describe the direction that the compass needle deflects in the space provided.

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Fig 6.2.4

Explanation

Name ________________________________ Date ___________________________

1. Comment on the relationship between the direction of the current in the wire and the deflection of the compass.

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2. Since a wire that runs across the top of the compass deflects the compass one way and a wire that runs under the bottom of the compass deflects the compass the other way, shouldn't the two fields cancel out? Provide a brief explanation in support of your answer.

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Activity 6 – 3: Semi-quantitative Paperclip Pickup I

Introduction:

In this activity, you will be constructing a solenoid by coiling wire around an iron rod. The coils in the solenoid all produce magnetic fields that add to one another and create a strong electromagnet. You will be studying solenoids more in Investigation 5.

Objectives: Investigate the effect of changing the voltage (current) on the strength of an electromagnet.

SOLs: PS.1h, PS.1j, PS.1k, PS.11a, PS.11b, 3.1a, 3.1j, 4.1a, 4.1f, 4.1h, 4.3e, 5.1e, 5.1f, 6.1g, 6.1i

Materials:

- Alligator Wires
- Iron rod (7.5 cm long and 0.95 cm in diameter)
- Enameled Wire 3.0 m (26 gauge enamel-covered copper wire)
- 1.5-Volt cells x3 (from home)
- Steel wool or a blade to scrape the ends of the enameled wire (from home)
- Transparent adhesive tape (from home)
- Small paper plates or bowls x2 (to hold paperclips, from home)
- About 100 Paper clips (from home)

Prediction

In this activity, you will be powering an electromagnet with standard 1.5 Volt batteries and measuring the strength of the electromagnet by how many paper clips it can pick up. In the first trial, a single battery will power your electromagnet. Predict the effect of using two and three batteries on the number of paperclips. Explain.

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Observation and Procedure

1. Wrap the wire around the iron rod, counting how many coils you create. Record the number of coils.

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2. Secure the coiled wire with transparent tape. Leave at least 10 cm of wire free for connection to the cell(s). Scrape the end of the wire so that the copper is exposed with steel wool. See **Fig 6.3.1**.

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Fig 6.3.1

3. Place ~100 paper clips on a paper plate. Connect one alligator clamp lead to each end of the electromagnet wire. You may try connecting the ends of the electromagnet directly to the cells but the connection may be erratic and intermittent depending on how well the ends were cleaned of enamel.

4. Place the end of the electromagnet directly over and touching the pile of paper clips. Connect the leads, picking up a number of paper clips. Transfer the magnetically attracted paper clips to the other plate and disconnect the leads. Count the number of paper clips transferred. Enter your data in **Table 6.3.1**. Do this for a total of 4 trials.

# of cells	Trial 1	Trial 2	Trial 3	Trial 4	Average
One					
Two					
Three					

Table 6.3.1

5. Add a second 1.5 V cell in series with the first cell. Since the resistance of the electromagnet will not significantly change, the current through the electromagnet should be twice the current through the electromagnet with just one cell, assuming that the cells have the same voltage. Repeat the experiment of transferring paper clips for 3 more trials. Enter your data in **Table 6.3.1**.

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6. Add a third 1.5 V cell in series with the first and second cell. Since the resistance of the electromagnet will not significantly change, the current through the electromagnet should be three times the current through the electromagnet with just one cell, assuming that the cells have the same voltage. Repeat the experiment of transferring paper clips for 3 more trials. Enter your data in **Table 6.3.1**.

7. Use Excel to plot the average number of paper clips picked up vs. the number of cells used. Include your graph here.

8. Save the electromagnet. You will be using it again in Investigation 5, Activity 2.

Explanation

1. On your graph, can you draw a best-fit line that goes through all three data points? If not, explain.

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2. Do you think that if you continued adding more batteries, the trend observed in your graph would continue? Why or why not?

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Name ________________________________ Date ___________________________

Lab 7
Electromagnetism Applications

Relevant SOLs: PS.1a, PS.1h, PS.1j, PS.1k, PS.8c, PS.8d, PS.11a, PS.11b, PS.11c, 3.1a, 3.1g, 3.1j, 4.1a, 4.1f, 4.1h, 4.3b, 4.3e, 5.1e, 5.1f, 5.2c, 6.1c, 6.1i

Overview

Electromagnets are used widely in many applications that we use every day. A small sample of applications includes motors, generators, headphones, and ear-buds, microphones, and doorbells. In this investigation, you will continue to study the properties of electromagnets and you will build your own speaker.

Fig 7.0.1 Headphones are one of many applications of electromagnets.

Name ________________________________ Date ___________________________

Activity 7 - 1: Solenoid

Objectives: Observe the behavior of a magnetic compass in the presence of an electrical current in a coil of wire.

SOLs: PS.1a, PS.1k, PS.11a, PS.11b, 3.1a, 3.1j, 4.1a, 4.3b, 4.3e, 5.1e, 5.1f, 6.1c

Materials:

- Compass
- Enameled Wire 1.0 m (26 gauge enamel-covered copper wire)
- Iron rod
- 1.5-Volt cell (from home)
- Pencil (from home)
- Duct tape (from home)

Prediction:

In this activity, you will be testing the magnetic field around a solenoid. See **Fig 7.1.1**.

Fig 7.1.1 The wire is fashioned into a solenoid. Note that since the positive terminal of the battery is not connected to the solenoid, there should be no current in the wire.

1. In **Fig 7.1.1**, which direction is the compass pointing; North, South, East, or West. Explain your answer.

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Name ________________________________ Date ___________________________

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2. If the top of the solenoid is connected to the battery so that current goes through the wire, what direction will the compass point? Explain your answer.

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Observation and Procedure

1. Place the compass flat on a surface with no nearby sources of electricity or magnetism. Turn the compass until the red end of the pointer is pointed 0°. Describe the direction that the compass needle points in the space provided.

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2. Remove the enamel from the ends of the 1.0 m of magnet wire by scraping with a flat blade like a knife or box-cutter. (Alternatively, you can scour the enamel off with steel wool). Wrap the magnet wire tightly around the iron rod approximately thirty times to produce a coil or solenoid. Take the iron rod out of the coil. Place the coil so that one end is at the 90° heading on the compass (as in **Fig 7.1.1**). Connect one end of the coil to the positive terminal of the 1.5-Volt cell. Briefly (!) connect the other end of the coil to the negative terminal of the 1.5-Volt cell. **(!) Warning: The wire will get hot very fast because the cell is essentially shorted, which means there will be a large current through the wire. This will also drain the cell rapidly. Do not keep the wire connected to the cell for too long. It will only take less than 3 seconds to see the deflection.** Describe the direction that the compass needle points.

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3. Without moving the coil, turn the 1.5-volt cell around and connect the other end of the coil to the positive terminal of the 1.5-Volt cell. Briefly (!) connect the first end of the coil to the negative terminal of the 1.5-Volt cell. Describe the direction that the compass needle points in the space provided.

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4. Place the iron rod in the middle of the coil. Repeat steps #2 and #3. Note that in **Fig 7.1.2**, an iron nail is used instead of an iron rod, but that shouldn't matter. Describe the direction that the compass needle points in the space provided.

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Fig 7.1.2 A nail is now inserted into the solenoid.

Explanation

1. Use your observations from Steps 2 and 3 to conclude how you can tell the direction of the magnetic field generated by the current in a solenoid. T

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2. State whether the magnetic field produced by the current was stronger or weaker with the nail inserted. Explain how you made your determination.

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Name ________________________________ Date ___________________________

Activity 7 – 2: Semi Quantitative Paperclip Pickup II

Objectives: Investigate the effect of changing the number of coils on the strength of an electromagnet.

Materials:

- Alligator Wires
- Iron rod (7.5 cm long and 0.95 cm in diameter)
- Enameled Wire 3.0 m (26 gauge enamel-covered copper wire)
- 1.5-Volt cells x3 (from home)
- Steel wool or a blade to scrape the ends of the magnet wire (from home)
- Transparent adhesive tape (from home)
- Small paper plates or bowls x2 (to hold paperclips, from home)
- About 100 Paper clips (from home)

SOLs: PS.1h, PS.1j, PS.1k, PS.11a, PS.11b, 3.1a, 3.1g, 3.1j, 4.1a, 4.1f, 4.1h, 4.3b, 4.3e, 5.1e, 5.1f, 6.1c, 6.1i

Prediction:

During Investigation 4, Activity 3, you built an electromagnet that was able to pick up a large number of paperclips. In this activity, you will keep the current going through the wire constant but you will vary the number of coils of your electromagnet. How do you think the number of coils of wire in your electromagnet will affect the number of paperclips that your magnet can pick up? Explain.

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Observation and Procedure

1. Use the electromagnet that was prepared in Lab 6, Activity 3. Record the number of coils present in the electromagnet. Start with 10 coils, then 20 coils, 30 coils. 40 coils and 50 coils.

2. Place ~100 paper clips on a paper plate. Connect one alligator clamp lead to each end of the electromagnet wire. You may try connecting the ends of the electromagnet directly to the 3 cells but the connection may be erratic and intermittent depending on how well the ends were cleaned of enamel.

3. Place the end of the electromagnet directly over and touching the pile of paper clips. Connect the leads, picking up a number of paper clips. Transfer the magnetically attracted paper clips to the other plate and disconnect the leads. Count the number of paper clips transferred and enter your data in **Table 7.2.1**. Do this for a total of 4 trials.

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# of turns	Trial 1	Trial 2	Trial 3	Trial 4	Average

Table 7.2.1

4. Divide the total number of coils by 6 and round down to the nearest coil. State the result here.

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5. Remove the number of turns of wire that you calculated in Step 4 from the electromagnet by unraveling the wire from the iron rod. The unwrapped wire will just hang loose from the rod. Repeat Steps 2 and 3 above capturing paper clips and counting them. After four trials, unwind again by the number of coils calculated in Step 4. Continue until **Table 7.2.1** is completely filled in. Since the length of the wire has not changed, the current through the wire should remain the same.

6. Use Excel to plot the average number of paper clips picked up vs. the number of turns in the electromagnet coil. Include your graph here.

Explain

1. What happens to the strength of the electromagnet as you decrease the number of coils of wire? How can you tell?

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2. Describe the relationship shown on the graph. Why do you think this relationship exists?

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3. Do you think this relationship would be valid all of the way down to 0 coils of wire? Explain.

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Activity 7 – 3: Loudspeaker

Objectives: Build a simple loudspeaker from magnets and a coil of wire.

SOLs: PS.8c, PS.8d, PS.11a, PS.11b, PS.11c, 3.1a, 4.1a, 4.3b, 4.3e, 5.2c

Introduction

A simple loudspeaker consists of a magnetic, a coil of wire, and a membrane that can vibrate back and forth to produce sound. See **Fig 7.3.1**. A solenoid (coil) will produce a magnetic field that will attract another magnet when the current flows one way and will repel the same magnet when the current flows the other way. If a flexible membrane is attached to the coil then the membrane will move back and forth with the changes in the current. If the current changes are rapid enough, the membrane will produce sounds audible to the human ear.

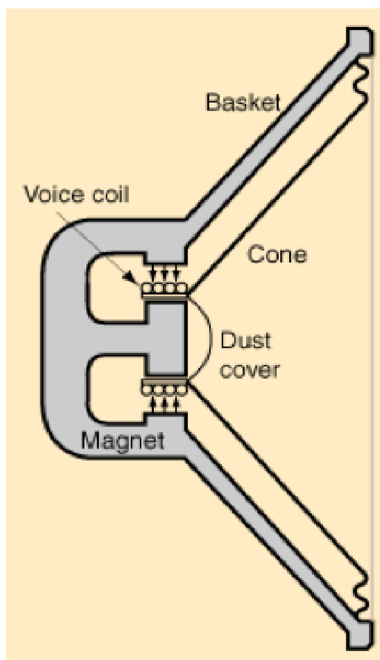

Fig 7.3.1 A speaker

Materials:

- Enameled Wire 1.0 m (26 gauge enamel-covered copper wire)
- Neodymium Magnet
- 3.5 mm Audio Jack Plug
- Disposable Clear Cups x2 (from home)
- Needle or pin (from home)
- Steel wool or a blade to scrape the ends of the magnet wire (from home)
- Cell phone, computer or mp3 player (from home)

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Prediction

In this activity, you will be building a speaker out of two plastic cups, a magnet, and a coil of wire. You will play music or some other audio file from a phone, Ipad, computer or mp3 player. Predict what you think you will hear when you play the file. Will you be able to tell what song it is? How loud will it be?

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Observation and Procedure

1. Wrap the wire between your two fingers to make a coil of about 3 cm in diameter. It should be just slightly larger than the neodymium magnet. Secure the coil by winding the ends around the coil on opposite sides of the coil. Leave at least 10 cm of wire free for connection to the cell(s). Scrape the end of the wire so that the copper core is exposed.

2. Flip a clear cup upside-down. Place the coil at the center of the bottom of the cup. Draw a line on the bottom of the cup to mark the diameter of the coil. Then use a needle or a pin to poke a small hole through the cup on each end of the line. See **Fig 7.3.2.**

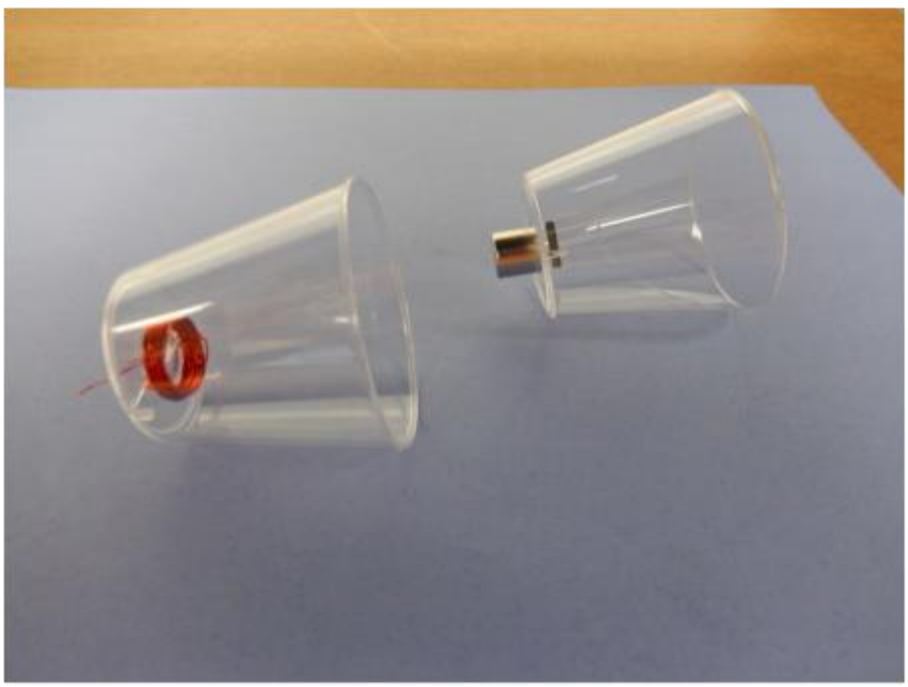

Fig 7.3.2

3. Pick up the cup. Put the coil inside. Thread the two ends of the coil through the two holes. On the outside of the cup, tie a knot with the wire ends that stick out

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of the holes on the cup. Pull on the two ends until the knot is tight and the coil is secured against the inside bottom of the cup.

4. Tape the neodymium magnet at the center of the bottom of the other cup. Push the second cup into the first cup. Tape the rim of the second cup to the rim of the first cup in order to make sure they fit snuggly to each other. See **Fig 7.3.3.**

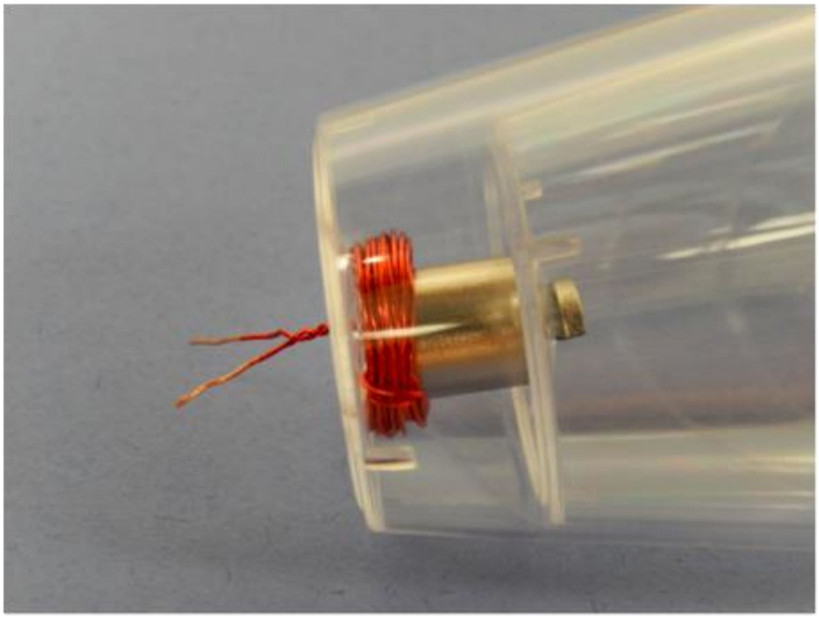

Fig 7.3.3

5. See **Fig 7.3.4** for an illustration of the 3.5 mm audio jack plug. Hook one end of the wire to Terminal C. Hook the other end of the wire to Terminal A. Make sure the copper core of the wire is exposed to the terminals.

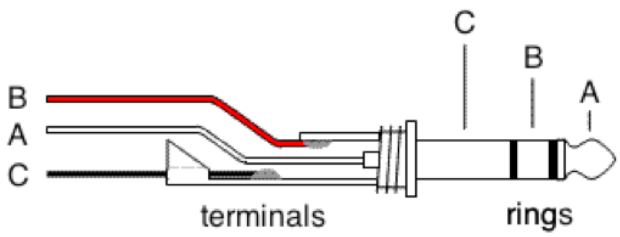

Fig 7.3.4

6. Connect the plug to an audio jack from your phone, iPad, computer or an mp3 player. Turn up the volume to the maximum. Describe what you hear from the clear cups?

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Explain

1. Compare the sound you heard to your prediction.

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2. Why isn't your sound system as good as the one in **Fig 7.3.5**?

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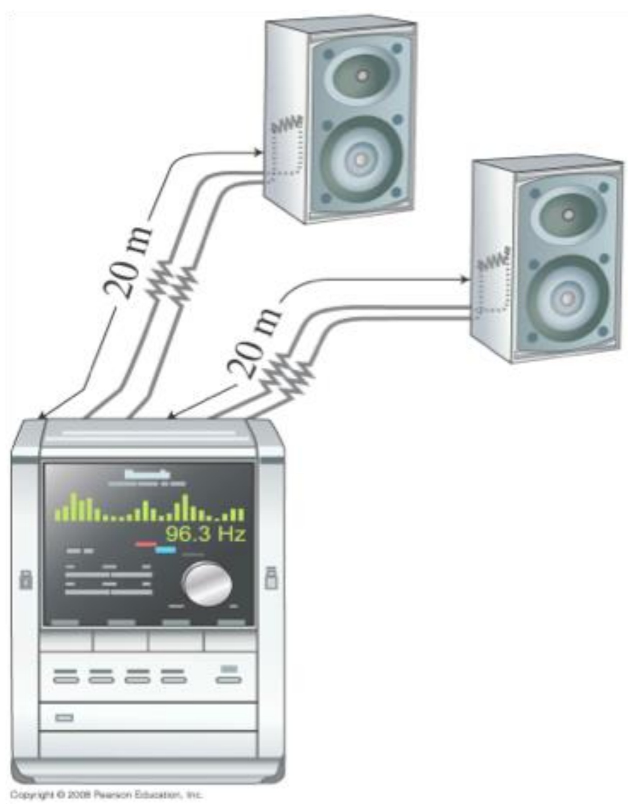

Fig 7.3.5

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Lab 8
Measuring Instruments

Relevant SOLs: PS.1a, PS.1k, PS.6b, PS.11a, 3.1j, 4.3a, 4.3b, 6.1c

Overview

There are three primary quantities that are used to describe the properties of electrical circuits: voltage, resistance, and current. In this activity, you will learn how to measure these properties.

In actuality, the real name for voltage is electric potential difference. This quantity refers to a difference in energy per charge between two locations on a circuit or device. The job of a battery is to provide a potential difference so that as charges move through a device, they lose energy and the energy lost can be converted into a usable form by the device. Since the unit for electric potential difference is the Volt, it is often called voltage.

Resistance is a quantity related to how easily charges can move through a material. An insulator has a high resistance as charges have a difficult time moving through the material whereas a conductor has a low resistance as charges can move through the material quite easily. Resistance is measured in ohms.

Current is a measure of how much charge is moving through a material. Current is measured in amperes.

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Activity 8 - 1: Measuring Voltage

Introduction:

The investigation of electrical effects involves the measurement of several different quantities: voltage, current and resistance. The DT9205A Multi-meter provided in the class kit can measure all of these quantities within limits. Different quantities require that the multi-meter be hooked up differently. For example, a multi-meter used to measure voltages should have a high resistance, approximately 20 million ohms, while a multi-meter used to measure current should have a low resistance, on the order of 1 ohm or even less.

Objective: Measure the potential difference of a D battery.

SOLs: PS.1a, PS.1k, PS.6b, PS.11a, 3.1j, 4.3a, 4.3b, 6.1c

Materials:

- DT9205A Multimeter
- Multimeter leads
- Breadboard
- 1.5 Volt D cell
- Battery holder

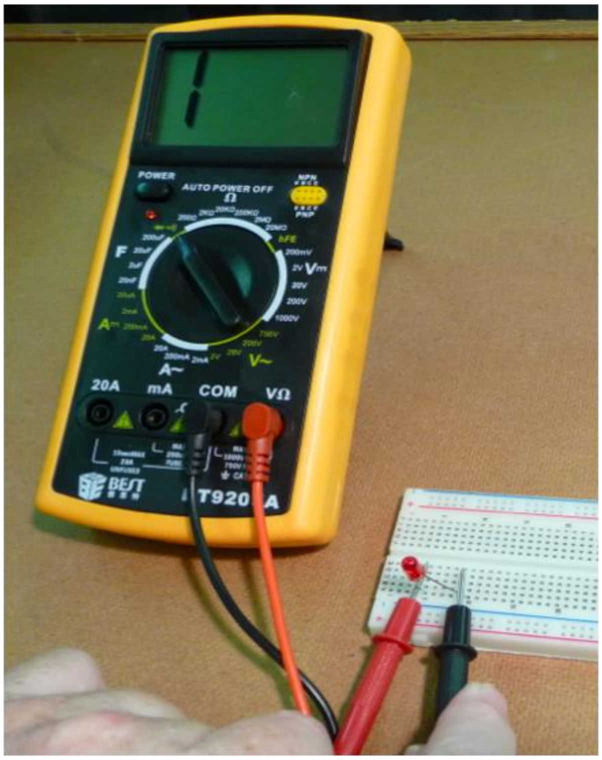

Fig. 8.1.1 The "1" displayed by the meter shows that a bad setting was used which could result in the meter being damaged.

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One brief warning: The multimeter will valiantly attempt to measure quantities that will blow the fuse on the meter. **Whenever the meter shows 1 with no following digits, the meter is overloaded.** See **Fig. 8.1.1.** Depending on what is being measured, this condition could damage the meter (typically by blowing the fuse). **If this happens, please stop, disconnect the power source and check your circuit.**

The most common fix is to increase the range of what is being measured. For example, attempting to measure 3.0 V when the meter is set to 2V will result in the overload 1 showing. Simply increasing the range by turning the dial to 20V will fix this.

Procedure:

1. Place a fresh D battery in the battery holder. Turn the multimeter on by pushing the POWER button. Turn the dial so that it points to 2 V DC. The symbol for DC is a straight line over three dots while the symbol for AC is a wavy line like a Spanish tilde. The dial will be pointed to just above 3 o'clock as seen in **Fig. 8.2** below.

Fig. 8.1.2 The multimeter is measuring the voltage of a single D battery.

2. Insert the multi-meter leads into the two rightmost openings at the bottom of the meter. Standard practice is to put the red lead into the rightmost (VΩ) opening and the black lead into the COM opening next to VΩ, as shown in **Fig. 8.1.2.** The schematic is shown in **Fig. 8.1.3.**

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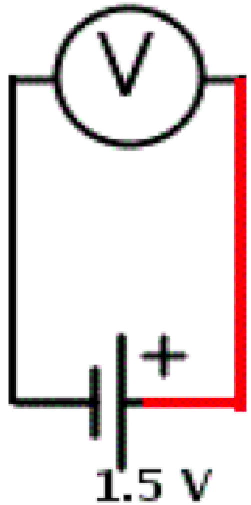

Fig 8.1.3

3. Touch the two leads to the metal outlets of the battery holder. The red probe lead (+) should touch the metal lead of the top of the battery. The black probe lead should touch the metal lead of the bottom of the battery.

4. Reverse the two probes. Touch the red probe to the bottom of the battery and the black probe to the top of the battery. Record the potential difference (voltage) of the battery including appropriate units.

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____

5. Compare the measured voltage with the nominal 1.5 V of the battery.

____
____
____

6. Does changing the probes change the sign?

____
____
____

7. Does changing the probes change the magnitude of the voltage?

____
____
____

Name _________________________________ Date ____________________________

Activity 8 – 2: Measuring Resistance

Objective: Measure the resistance of a resistor.

SOLs: PS.1a, PS.1k, PS.6b, PS.11a, 3.1j, 4.3a, 4.3b, 6.1c

Materials:

- DT9205A Multimeter
- Multimeter leads
- Breadboard
- 100 ohm resistor

Procedure:

1. Place a 100 ohm resistor into the breadboard as shown in **Fig. 8.2.1** below

2. Turn the multimeter on by pushing the POWER button. Turn the dial so that it points to 200 Ω. The dial will point to 11 o'clock as seen in **Fig. 8.2.1** below.

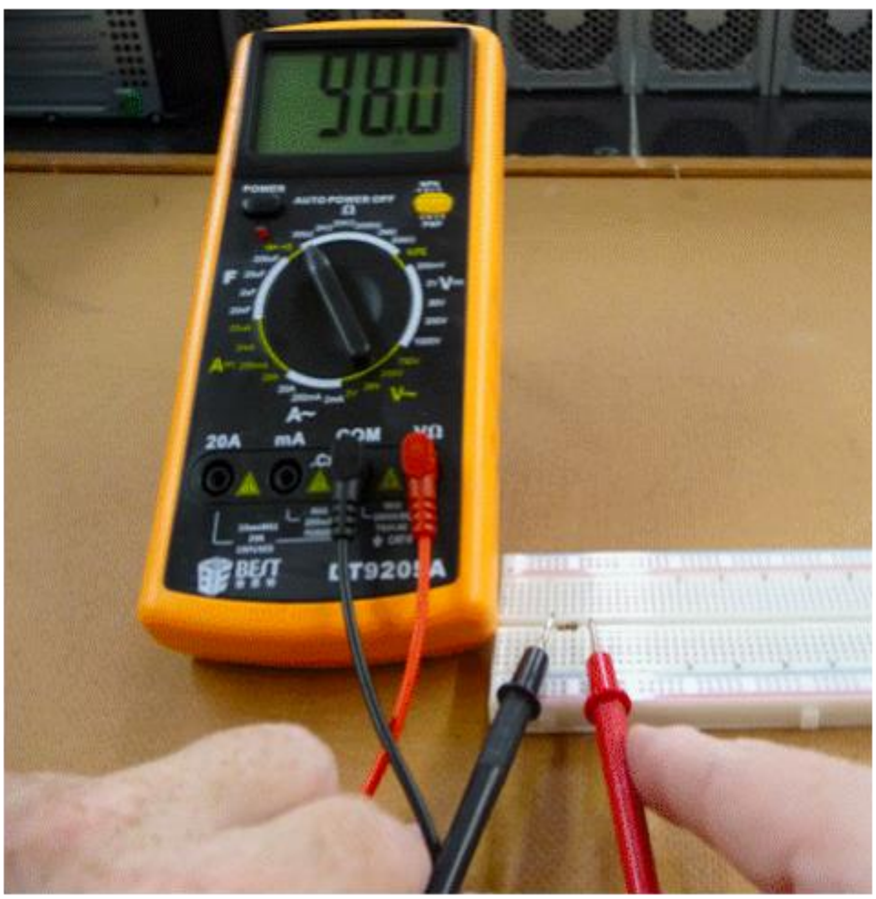

Fig. 8.2.1

Name ______________________________ Date __________________________

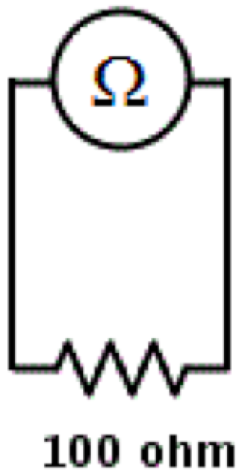

Fig. 8.2.2

3. Insert the multi-meter leads into the two rightmost openings at the bottom of the meter. Standard practice is to put the red lead into the rightmost (VΩ) opening and the black lead into the COM opening next to VΩ, as shown in **Fig. 8.2.1.** The schematic is shown in **Fig. 8.2.2.**

4. Touch the two probes to either leg of the resistor. The red probe lead (+) should touch the right lead of the resistor. The black probe lead should touch the left lead of the resistor. **You may use your wires with alligator clips so that you do not have to hold the probe to the resistor. The wire will add negligible resistance to the probe but allow you to switch the meter scale with one hand while you do not have to hold the probe. Just clip one end of the wire to the probe and the other end to the resistor.**

5. Record the resistance of the resistor including appropriate units here and compare the recorded value to the nominal 100 Ω of the resistor.

____
____
____

6. Reverse the two probes. Touch the red probe to the left leg of the resistor and the black probe to the right leg of the resistor. Record the resistance of the resistor including appropriate units. Compare the recorded value to the nominal 100 Ω of

Name ______________________________ Date ______________________________

the resistor. Does changing the probes change the sign? Does changing the probes change the magnitude of the resistance?

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____
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Name ________________________________ Date ___________________________

Activity 8 – 3: Measuring Current

Materials:

- DT9205A Multimeter
- Multimeter leads
- Breadboard
- 100 ohm resistor
- 1.5 Volt D battery
- Battery holder
- Electrical lead with alligator clips

Objective: Measure the current in a circuit.

SOLs: PS.1a, PS.1k, PS.6b, PS.11a, 3.1j, 4.3a, 4.3b, 6.1c

Procedure

1. Place a 100-ohm resistor into the breadboard as shown in **Fig. 8.3.1** below. The schematic is shown in **Fig. 8.3.2.**

2. Place a fresh D battery in the battery holder in the correct orientation. Turn the multi-meter on by pushing the POWER button. Turn the dial so that it points to 200 mA.

3. Insert the multi-meter leads into the two middle openings at the bottom of the meter. Standard practice is to put the red lead into the left middle (mA) opening and the black lead into the COM opening next to (mA).

4. Connect an electrical lead from the bottom of the D battery to the right leg of the resistor. Touch the two probes to the circuit as shown below in **Fig. 8.3.1.** The red probe lead (+) should touch the top of the D battery. The black probe lead should touch the left leg of the resistor.

Name ________________________________ Date ___________________________

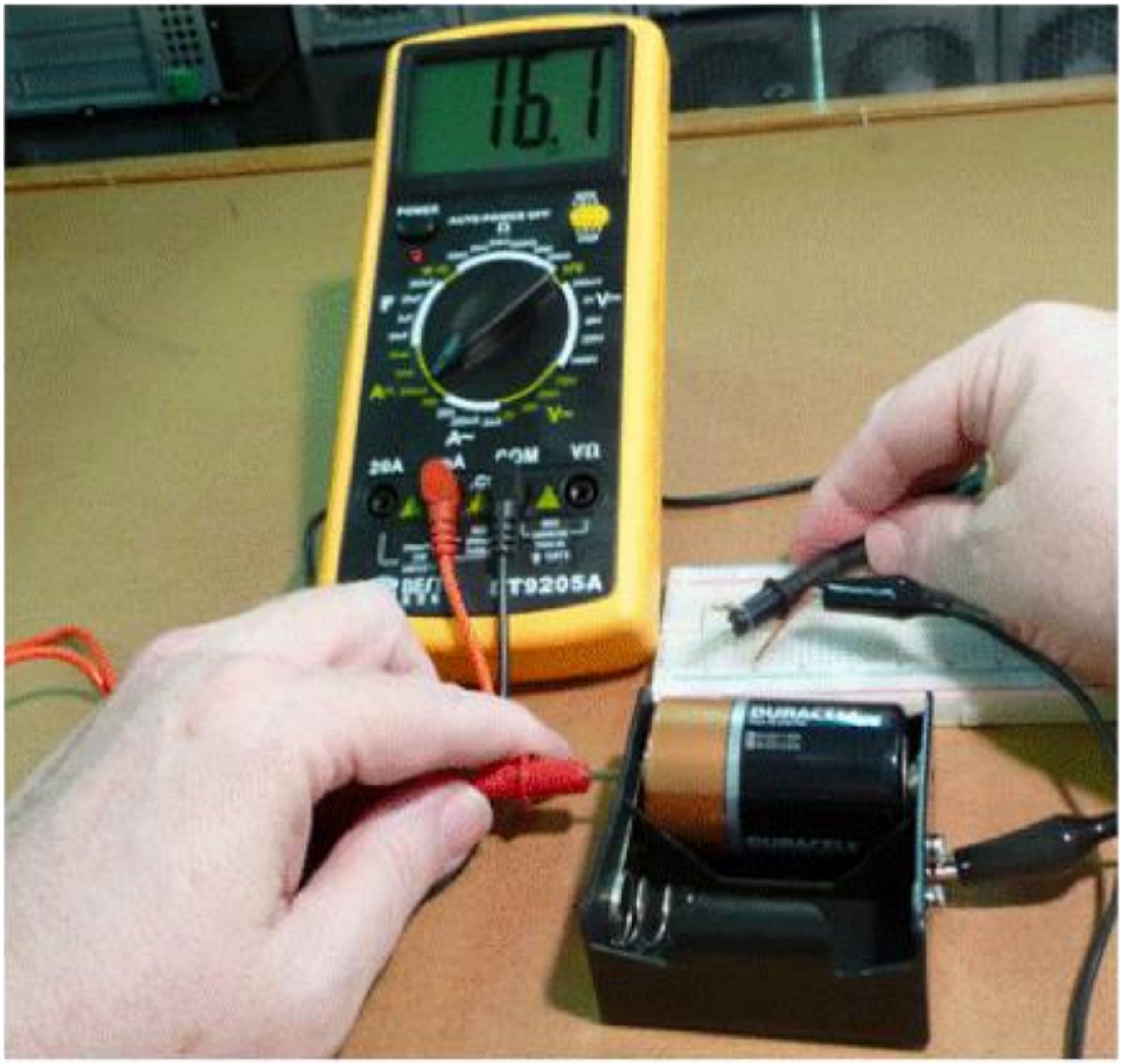

Fig. 8.3.1

Name ________________________________ Date ___________________________

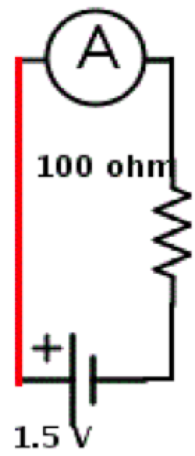

Fig. 8.3.2

5. Record the current of the circuit including appropriate units.

____

____

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6. Reverse the two probes. Touch the red probe to the left leg of the resistor and the black probe to the top of the D cell. Record the current of the circuit including appropriate units. Does changing the probes change the sign? Does changing the probes change the magnitude of the current?

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Name ________________________________ Date ___________________________

Lab 9
Simple Circuits

Relevant SOLs: PS.1k, PS.6b, PS.6c, PS.11a, 3.1a, 3.1j, 4.1a, 4.3a, 4.3b, 4.3d, 6.2e

Overview

In this series of investigations you will learn how to construct a circuit and analyze some of the different ways that circuit elements can be connected to each other.

You will be using wires to connect your circuit elements, but in many devices, conductive material is painted onto a circuit board to connect devices as in **Fig. 9.0.1**.

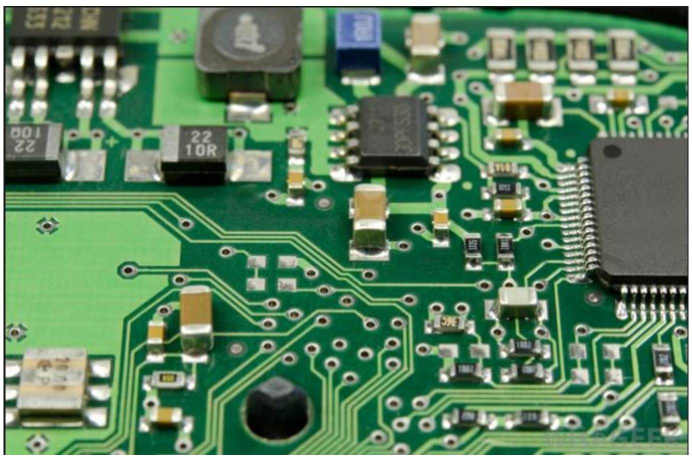

Fig. 9.0.1 The light colored lines are conductive and serve as the wires on this circuit board. (Image from wisegeek.org)

Name ________________________________ Date ___________________________

Activity 9 - 1: Lighting a Bulb

Objective: Build a complete circuit that will light a bulb.

SOLs: PS.1k, PS.6b, PS.6c, PS.11a, 3.1a, 3.1j, 4.1a, 4.3a, 4.3b, 4.3d, 6.2e

Materials:

- Light bulb
- 1.5 V D Cell Battery
- Wire with alligator clip ends

Prediction:
In this Activity, you will be using a single wire to light a bulb. Do you think that the bulb in **Fig. 9.1.1** will light up? Why or why not? ___________________________

Fig. 9.1.1

Observation and Procedure

1. Connect your battery, wire, and bulb as in **Fig. 9.1.1**. Does the bulb light up? __

2. Hold the light bulb and touch the end of the bulb against the free end of the battery as in **Fig. 9.1.2.** Does the bulb light up? Explain__________________

Name ______________________________ Date __________________________

Fig. 9.1.2

3. If your bulb did not light up in either step it is possible that it is damaged. If this might be the case, consult with your teacher or try a different bulb.

4. Try other ways of hooking up the battery, bulb, and wire. Sketch one additional way that allows the bulb to light up. (Hint, try switching where the wire is connected to the bulb or battery).

Explanation

1. Explain what happened in Step 1 and provide an explanation. _____________

2. Explain what happened in Step 2 and provide an explanation. ______________

3. When the bulb lit up, there are electric charges moving around the circuit. Make a general statement about the properties of a circuit that are necessary to make charges flow. ____

Name ________________________________ Date ___________________________

Activity 9 - 2: Building a Circuit

Objective: Construct a simple circuit to test continuity of the current flow.

SOLs: PS.1k, PS.6b, PS.6c, PS.11a, 3.1j, 4.3b, 4.3d, 6.2e

Materials:

- Battery holder with leads
- Light bulb
- Alligator wires
- Light bulb holder
- 1.5 V battery

Procedure

1. Place the battery in the battery holder, and connect the red wire with alligator clips to the positive end of the battery and the other end of the red wire to the light bulb. Connect the black wire to the negative end of the battery and the other end of the black wire to the other side of the light bulb. See **Fig. 9.2.1** and **Fig. 9.2.2**. Describe your observations. ____________________________________

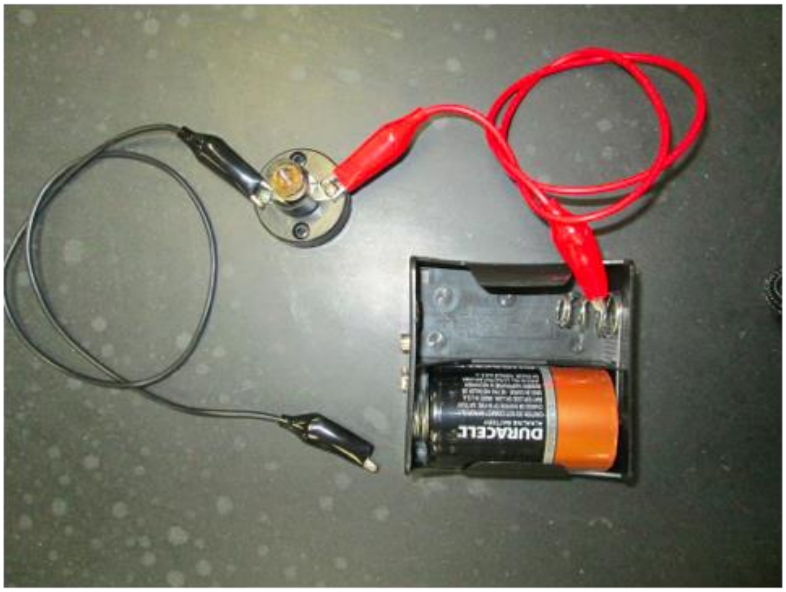

Fig. 9.2.1

Name ________________________________ Date ___________________________

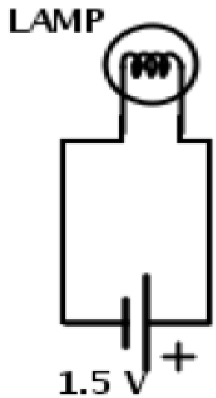

Fig. 9.2.2

2. What is moving or said to be flowing in the wires in the circuit?______________

3. Reverse the polarity of the wire leads by connecting the red wire to the negative end of the battery, and the black wire to the positive end of the battery. Describe your observations?

____
____
____

4. Does reversing the positive and negative terminals of the battery affect the brightness of the bulb?

____
____
____

5. Based upon your observations what can you conclude about the orientation of the battery with regard to the terminals and its effect on our simple circuit?

____
____
____
____
____
____

6. Disconnect somewhere in the circuit. Does the bulb light up? When I disconnect any part of the circuit the light bulb does not light up.

Name ________________________________ Date ___________________________

7. Now connect three batteries in series with the help of another battery holder. See **Fig. 9.2.3**. Note the brightness of the bulb. Explain why the brightness of the bulbs changes again as you added more batteries.

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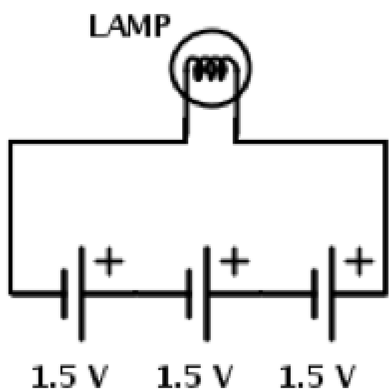

Fig 9.2.3 Each battery has a voltage of 1.5 V. When connected in series, the voltages add together.

8. What can be inferred about the relationship between voltage and current assuming brightness as an indication of current?

____
____
____

9. Now connect three bulbs in series as shown in **Fig. 9.2.4** and **Fig. 9.2.5**. Note that the black alligator clip is not yet connected in the picture because we want to use it as a switch to turn the bulbs on and off. Compare the brightness of each bulb with that of one bulb connected to one battery as in step 1. Record your observations here. Do you see any similarity between the two cases? Why do you think that happens?

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Name ________________________________ Date ___________________________

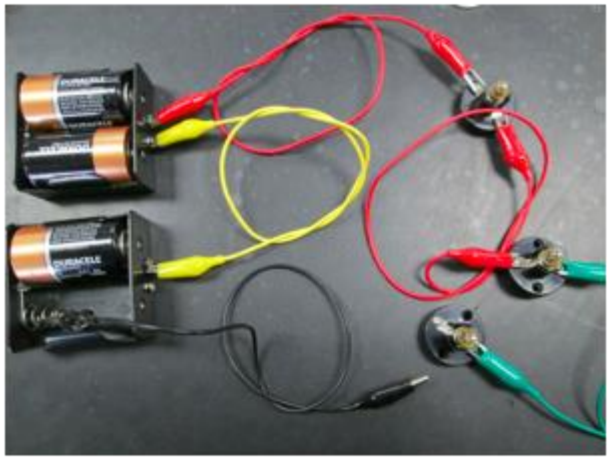

Fig. 9.2.4

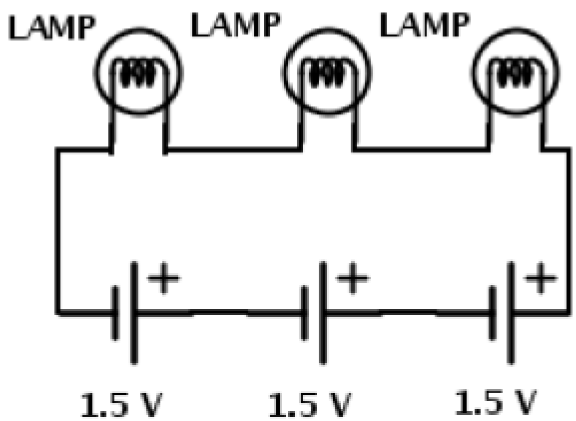

Fig. 9.2.5

10. Assume each bulb has the same amount of resistance against electricity. When more bulbs are added in series, how does the resistance change?

11. How does the current change in response to that?

____

____

____

12. Now connect three bulbs in parallel as shown in **Fig. 9.2.6** and **Fig. 9.2.7** Note that the white alligator clip in the picture is not yet connected to the bulbs because we want to use it as a switch to turn the bulbs on and off.

Name ________________________________ Date ___________________________

Fig. 9.2.6

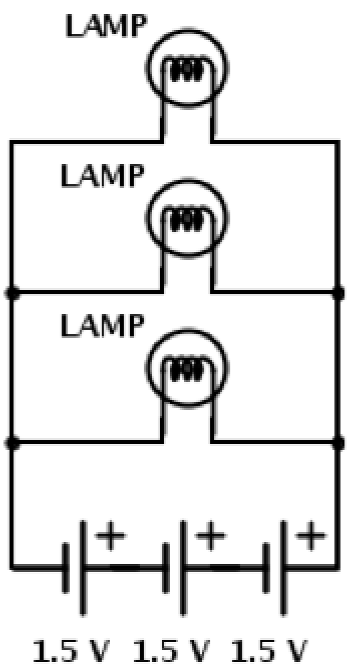

Fig. 9.2.7

13. How does the brightness of each bulb compare to the earlier case in Step 7 when one bulb was connected to three batteries? Explain why.

___

___

___

Name ________________________________ Date ___________________________

14. How does the voltage across each bulb change as more bulbs are added in parallel?

____

____

____

15. As bulbs are added in parallel, does the total current in the circuit increase or decrease? Explain why.

____

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____

____

____

Name ______________________________ Date ___________________________

Activity 9 – 3: Ohm's Law V = IR

Objective: Explore Ohm's Law

Materials:

- Breadboard
- Multimeter
- 100 Ω resistors
- Battery holder
- Alligator Wires
- Jumper wires
- 3 D size batteries

Procedure:

1. Locate the three 100 Ω resistors in the bag of electronics. Use your volt/ohm meter (VOM) to determine the exact value. Record the values of the three resistors here. ____.

2. Use appropriate jump wires to make a simple circuit with your battery holder, one D cell battery, one of the 100 Ω resistors you just measured and the breadboard. See the schematic in **Fig. 9.3.1** and the photo of the actual circuit in **Fig. 9.3.2.**

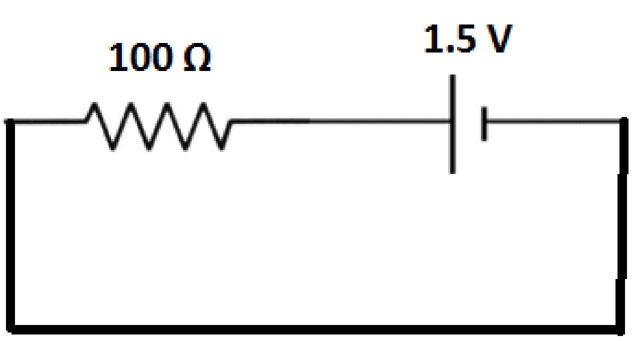

Fig 9.3.1

Name ________________________________ Date ___________________________

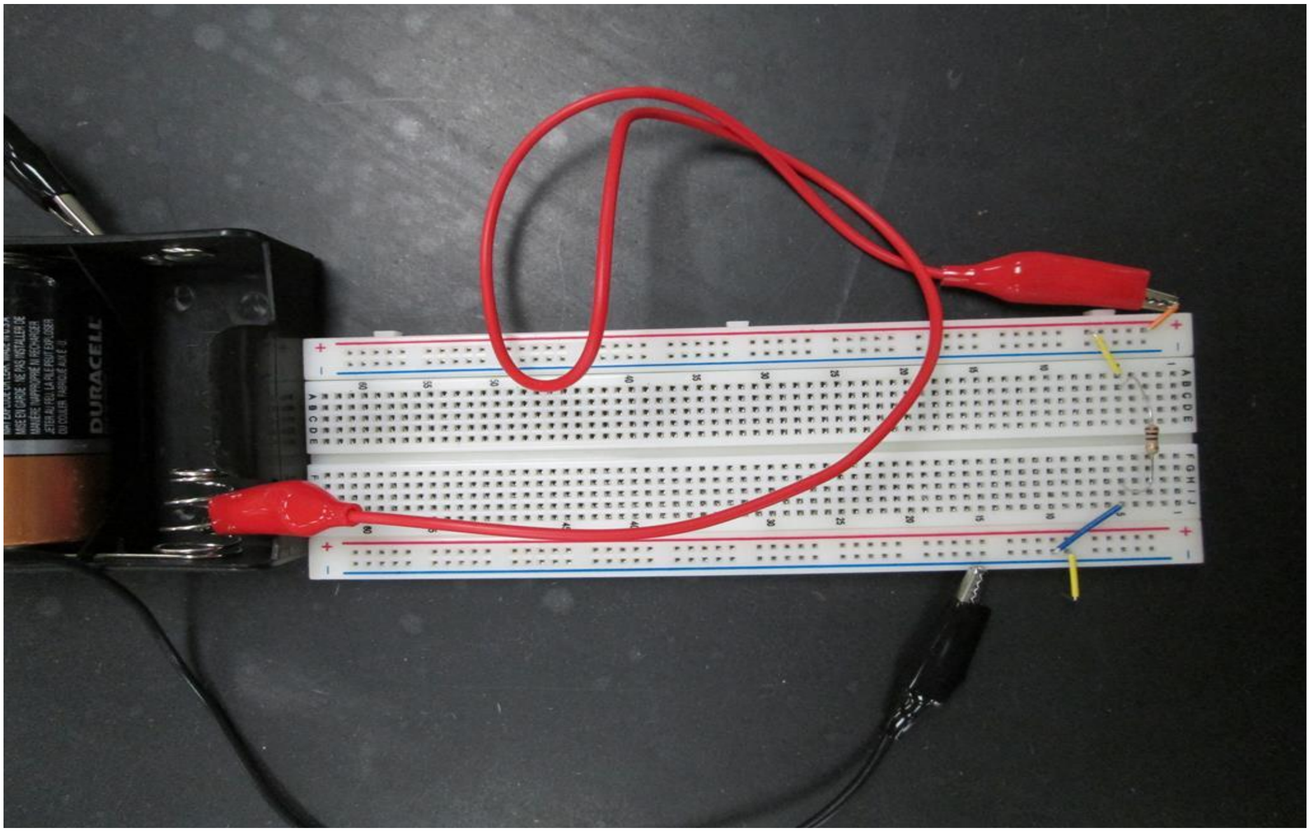

Fig. 9.3.2

3. We will now hook the volt/ohm meter (VOM) in the circuit. To measure voltage across the resistor, the VOM must be hooked in parallel with the resistance as shown in **Fig. 9.3.3** and the photo in **Fig. 9.3.4**.

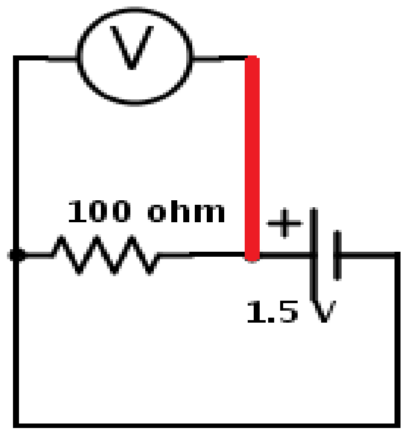

Fig. 9.3.3

Name ______________________________ Date _________________________

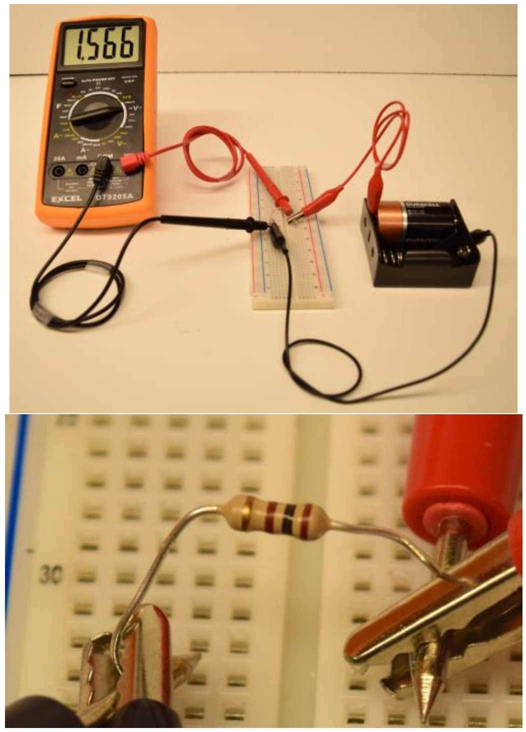

Fig. 9.3.4

4. We will now determine the voltage and the current in the circuit. Remember to start your VOM on the HIGHEST voltage/current scale when making measurements. Failure to do so may damage your VOM. Measure the voltage across the resistor and tabulate it in Table 9.3.1 in the row and column for 1 battery.

5. To measure current through the resistor, the VOM must be hooked in series with the resistor. See Fig. 9.3.5 and Fig 9.3.6 as an example of how to connect up VOM as ammeter (A) in series to measure current. Record your values in volts and amps in **Table 9.3.1**. Make sure the units are correct. Ask your instructor for confirmation here.

Name ______________________________ Date _________________________

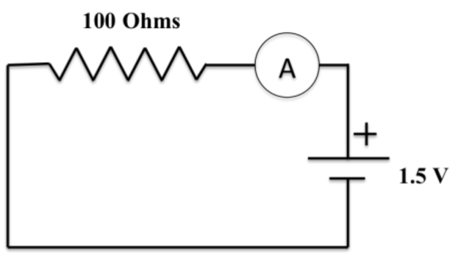

Fig. 9.3.5

Fig. 9.3.6

6. Now place two batteries in your circuit. We will hook another battery holder in series with the first battery holder. Record the voltage and the current in the circuit in Table 9.3.1. Then repeat with 3 batteries. Record the values in **Table 9.3.1**.

Number of Batteries in series	**Measured Voltage (V)**	**Measured Current (A)**	**Measured Resistance (Ω)**	**Calculated Voltage using Ohms Law V=I*R**
1				
2				
3				

Table 9.3.1

7. In the final column of Table 9.3.1, calculate the voltage by multiplying the measured Current (I) times your measured Resistance (R).

8. How does the calculated voltage from Ohms Law compare with the measured voltage? ____

9. Explain why you expect see a difference between Ohms law and the measured value.____

_

Name ________________________________ Date ___________________________

Lab 10
Energy Transfer using Motors and Generators

Relevant SOLs: PS.1a, PS.1k, PS.5a, PS.10c, PS.11a, PS.11b, PS.11c, 3.1a, 3.1j, 3.11b, 4.1e, 4.1g, 4.3a, 4.3b, 4.3d, 4.3e, 6.1c, 6.1h, 6.2d, 6.2e

Overview

Electricity can do work, most noticeably by producing light or motion, such as in a light bulb or in a motor. The general formula for electric power is $P = V * I$ where V is the voltage across an electrical component, I is the current through the component, and P is the power consumed. If the current goes in the opposite direction as voltage, the power consumption will turn out to be negative, which means the component actually outputs power, such as a battery does.

An electric motor works by running a current through a coil that is placed in a magnetic field. The current produces a pair of forces acting on the coil in opposite directions. See **Fig. 10.1**

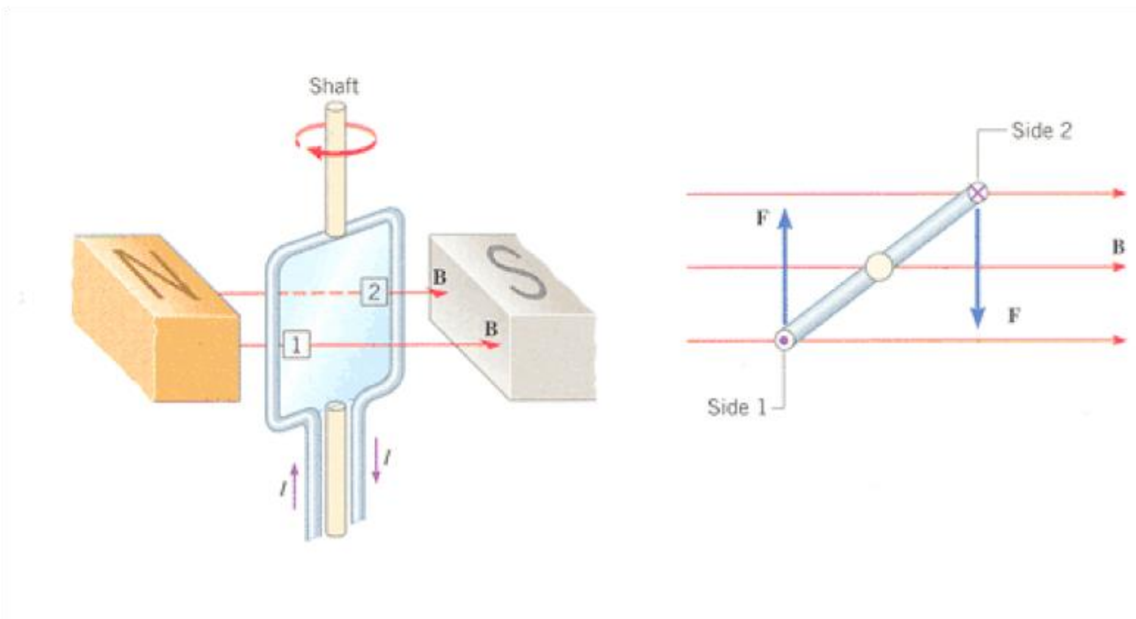

Figure 10.0.1

Name ________________________________ Date ___________________________

If the current reverses direction every time the coil turns 180 degrees, the torque will remain in the same direction, thus spinning the coil continuously. Torque is an angular force. Just like a net force causes acceleration, a net torque causes an angular acceleration, meaning that the rate of spinning will change. This is achieved by means of a commutator that is essential to every DC motor. **See Fig. 10.0.2**

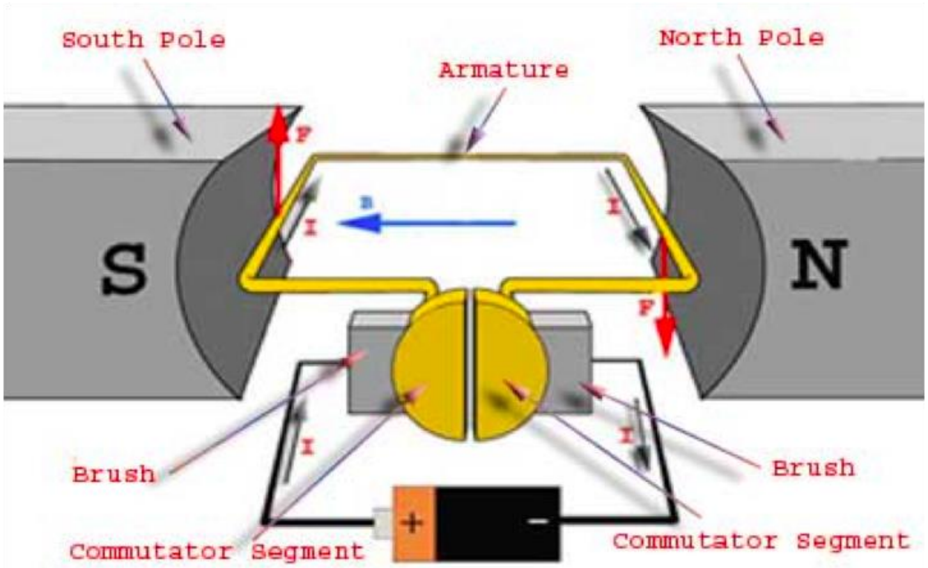

Fig. 10.0.2

Name ________________________________ Date ___________________________

Activity 10 - 1: Simple Motor

Objective: Build a simple motor.

Materials:

- Bare copper wire x2 (16 gauge ~15 cm long)
- Enameled Wire 1.0 m
- Rectangular magnet (~2.5 cm x 1.5 cm)
- Wooden Block with Groove
- Wide rubber band
- Scalpel or knife or steel wool (to remove enamel from wire, from home)
- 1.5-Volt battery

SOLs: PS.5a, PS.6b, PS.11a, PS.11b, PS.11c, 4.3a, 4.3b, 4.3d, 4.3e, 6.2e

Procedure:

1. Using a pencil as a jig, make one and a half loop around the pencil with the 16-gauge wire to form a hoop with two long parallel legs of roughly equal length. Repeat with the other piece. The legs should be even and about 1 cm apart. See **Fig. 10.1.1**

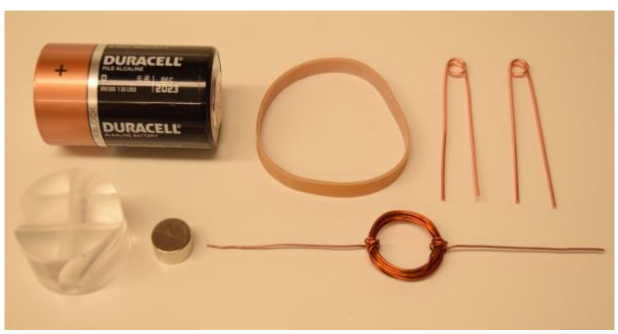

Fig 10.1.1 Component of simple motor

2. Wrap the rubber band around the 1.5 Volt D battery. You may have to double-loop the rubber band to make sure it's taut. Then insert the two 16-gauge copper hoops under the rubber band against the battery terminals. Place the battery in the groove on the acrylic block, and put the magnet on the battery. See **Fig. 10.1.2**

Name ________________________________ Date ___________________________

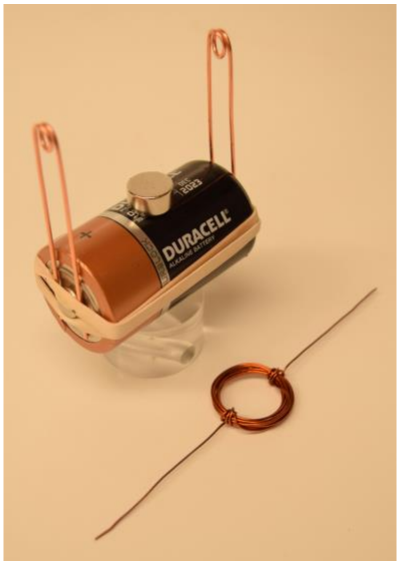

Fig 10.1.2 Assembled motor

3. Wrap the 26-gauge wire in a coil with a diameter or 2 to 3 cm leaving about 5 cm free at each end. The best way to make the coil is to loop the wire around your index and middle fingers. You will get an elliptical loop. Then round it by pulling along the short axis of the ellipse. It will have about 12 turns. Use the free ends to secure the coil by wrapping them around the coil (in and out) several times.

4. Strip the enamel around the wire for about 3 cm from one end. Strip the enamel only on one side of the wire for about 3 cm from the other end. This is going to act as the commutator. See **Fig. 10.1.3**. The stripped copper wire has a bright copper color as opposed to the orange red enamel.

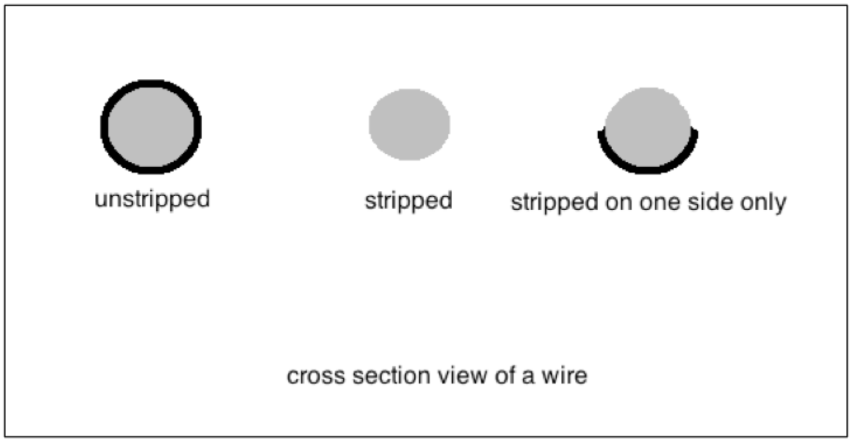

Figure 10.1.3

5. Place the thin wire coil between the two thick wire hoops so that the coil is directly over the magnet. See **Fig. 10.1.4**. Try to align the two ends (axles) of the

coil so that they are on a straight line. The coil should start spinning now. (It may be necessary to nudge the coil to get the motor started.) **WARNING: the coil gets hot with prolonged use.**

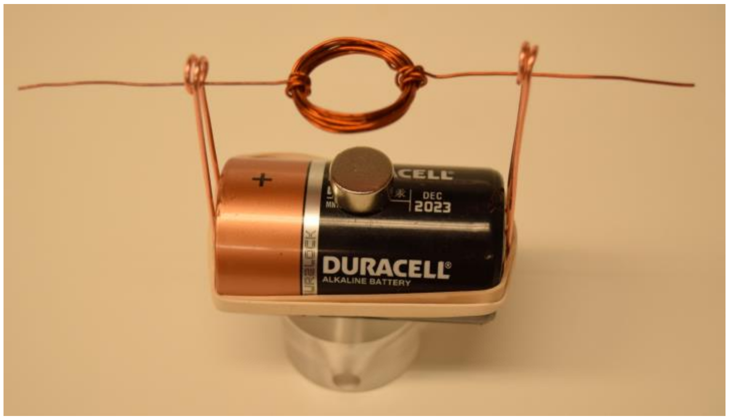

Fig. 10.1.4

6. If the coil is not turning, take it off the rack before it gets too hot. Then check the following:
   a. The two free ends of the coil should be in a straight line with each other and there should be no sag in the coil.
   b. The insulation may not be sufficiently stripped from one end or the other.
   c. The 16 g copper loops may not be in contact with the terminals of the D battery.

7. Raise the height of the hoops. Then add the second magnet on top of the first magnet. Describe what happens to the speed of rotation of the coil. Provide an explanation for the change. The speed does not seem to change by much, however, the coil bounces more and moves laterally with the second magnet in place. I believe this implies that there is more energy in the coil with the second magnet in place. This makes sense since the magnetic field is stronger and the change in magnetic field strength should also be larger as the coil rotates.

8. Identify each component of the motor in **Fig. 10.0.2** with the proper part of the motor in **Fig. 10.1.4**

9. Take the coil off and store it separately so that the cell will not discharge by itself. Note that as a classroom activity, the components (except for the 1.5-volt D battery) cost less than a $1 per setup and can be purchased at the local electrical store or at an electronics store such as Radio Shack.

Name ________________________________ Date ___________________________

Activity 10– 2: Motor

Objective: To study how electrical energy is converted into mechanical energy using a motor

Materials:

- Motor
- Jumper Wires
- Alligator Wires
- Two 1.5V D-Cell Batteries

Procedure:

1. Take a good look at the motor. Can you visualize how this is similar to the simple motor encapsulated in a metal housing. There are two pairs of slots on the motor for jumper wires. It doesn't matter which pair you use. Two on the top and two on the sides. Insert a short jumper wire in each slot on the top and secure with scotch tape as shown in **Fig. 10.2.1**. Then do the same on the other slot.

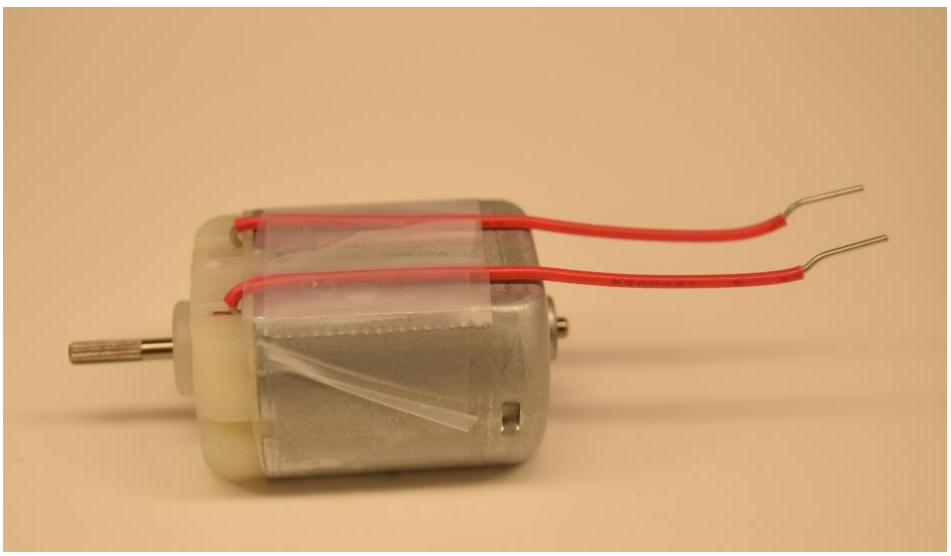

Fig. 10.2.1 Motor with two short wires connected to motor terminals and secured with scotch tape

2. Connect the jumper wires to the wires with alligator clips, and then connect one end of the wire to the + terminal of the 1.5 V D cell battery. Before you connect the other end to the - terminal of the battery, ask your instructor to check out your wiring first. After the instructor approves it, connect the wire to the negative terminal of the battery. See **Fig. 10.2.2**. What do you observe happens to the shaft of the motor?

Name ________________________________ Date ___________________________

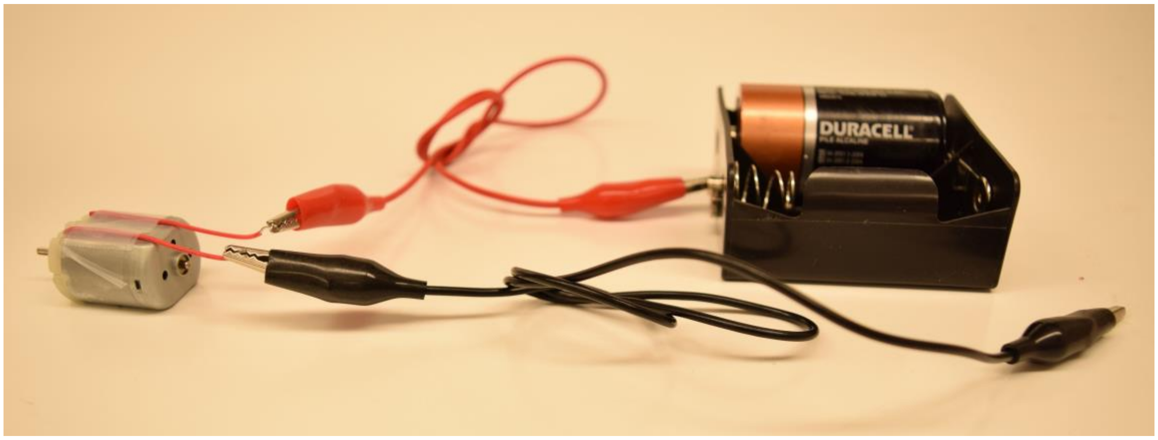

Fig. 10.2.2 Motor with two short wires connected to D cell battery in holder. The Black wire is not yet connected to the - terminal of the D cell.

3. Connect two batteries in series and connect them to the motor. What change do you observe to the shaft of the motor?

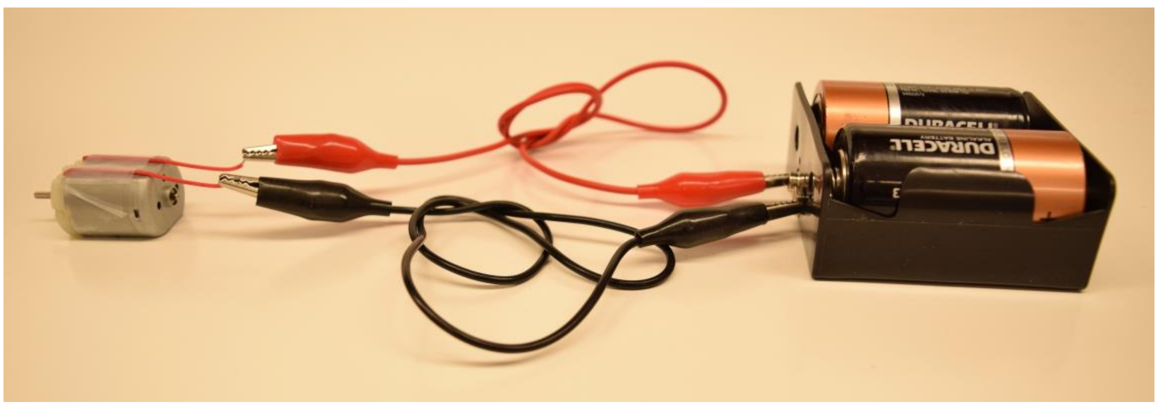

Fig. 10.2.3 Motor with two short wires connected to two D cell batteries in holder.

4. What can you conclude about the motor as you increase the voltage to the motor?

5. What do you call the kind of energy that went into the motor and what kind of energy came out of the motor?

6. What other kind of energy is involved inside the motor?

Name ________________________________ Date ___________________________

Activity 10– 3: Generator

Objective: To study how mechanical energy is converted into electrical energy and then into energy in the form of visible light using a motor run in reverse.

Materials:

- Motor
- Jumper Wires
- Alligator Wires
- Red and Green LED
- Fingers
- Multi-meter

Procedure:

1. Connect the jumper wires to the wires on each side of the motor to the two wires with alligator clips, and then to the bare wires on the red LED from your kit as shown in **Fig. 10.3.1**. LED stands for **L**ight **E**mitting Diode.

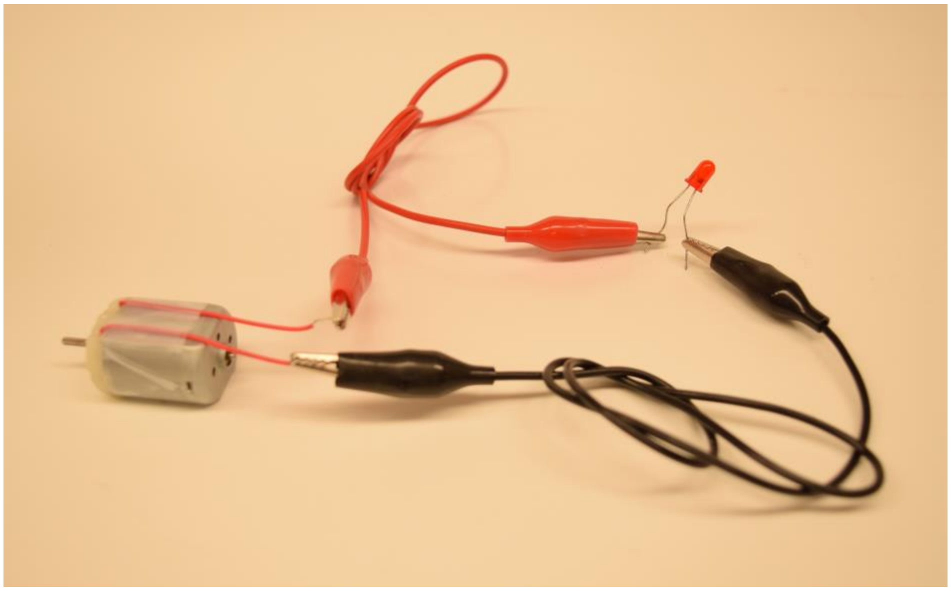

Fig. 10.3.1 Output terminals of motor connected to the bare wires on the red LED

2. Identify the terminal on the motor that is connected to the negative end of the LED. The negative end of the LED has a shorter wire coming out of it and a flat part on the perimeter of the plastic cap as shown in **Fig. 10.3.2.** In **Fig. 10.3.1** and **Fig. 10.3.2** the black wire is connected to the negative side of the LED.

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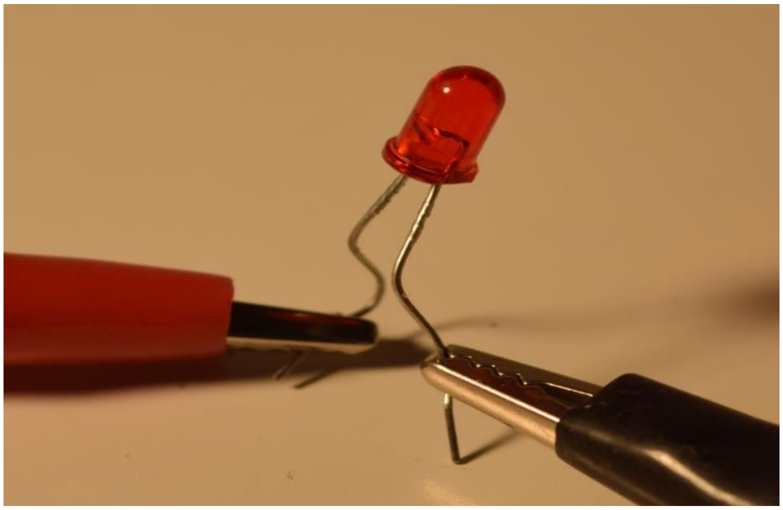

Fig. 10.3.2 Close-up of LED showing black wire connected to the shorter bare wire on the flat side of the LED

3. Turn the motor shaft clockwise with a rapid twist of your fingers. (clockwise as you look down the motor shaft into the housing) Does the LED light up? Now twist the shaft counterclockwise? Does it light up?

4. The LED will only light up when the polarity of the voltage is negative on the black wire. What do you conclude about the polarity of the voltage on the terminal of the motor that is connected to the black wire when the LED lights up?

5. In what direction does the current flow through the wires in **Fig. 10.3.1** when the LED lights up - clockwise or counterclockwise? Explain

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6. Connect up the multi-meter as a voltmeter to measure the voltage across the terminals of the generator when you twist it, as shown in **Fig. 10.3.3.** Set the voltage scale to 2 V on the voltmeter. The scale reading will be the voltage you generated by twisting the shaft. What is the maximum reading on the voltmeter when you try twisting it as hard as you can? Record the value here including the sign. Which direction is the current flowing in the circuit - counterclockwise or clockwise? How do you know? Check your result for confirmation with your instructor. You should conclude from this activity that a generator is like a motor operating in the reverse direction. Mechanical energy in and electrical energy out where as the motor was electrical energy in and mechanical energy out.

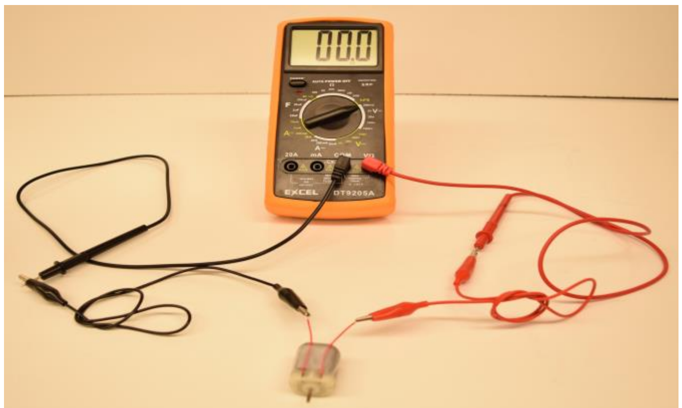

Fig. 10.3.3 Voltmeter connected to read voltage produced by generator when you twist the shaft

Name ________________________________ Date ___________________________

Activity 10 - 4: Windmill/Wind Turbine

SOLs: PS.1a, PS.1k, PS.5a, PS.6b, PS.6c, PS.10c, PS.11a, PS.11b, PS.11c, 3.1a, 3.1j, 3.11b, 4.1e, 4.1g, 4.3a, 4.3b, 4.3d, 4.3e, 6.1c, 6.1h, 6.2d, 6.2e

Overview

A wind turbine consists of a series of blades attached to a rotor. The rotor can cause a generator inside the turbine to spin. A generator is the opposite of a motor; when the generator spins, an electric current is generated. See **Figure 10.4**. Wind turbine blades come in lots of different shapes and sizes. In this activity you will construct your own wind turbine.

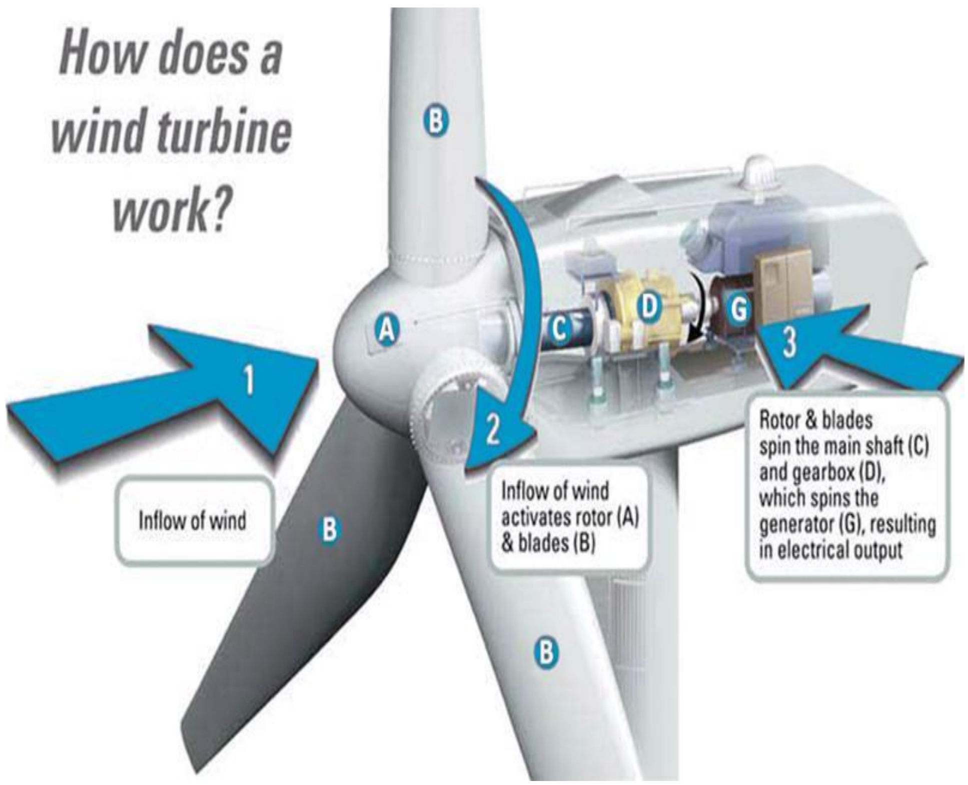

Fig. 10.4.1 A wind turbine consisting of a cowl or rotor (A), 3 blades (B), shaft (C), Gearbox (D), generator (G) to give the electrical output. There is no D.

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Objective: To use the wind from a fan or other source, a propeller and a motor to generate electricity and measure the amount of electricity or voltage it generates.

Materials:

- Propeller and Threaded Cowl (Rotor)
- Motor
- Jumper Wires
- Wires with Alligator Clips
- Multi-meter

Procedure:

1. In this activity, set up the colorful propeller and motor and connect them to the voltmeter. Locate the colorful multi-blade propeller, the motor and threaded cowl in the kit. These materials are shown **Fig. 10.4.2**

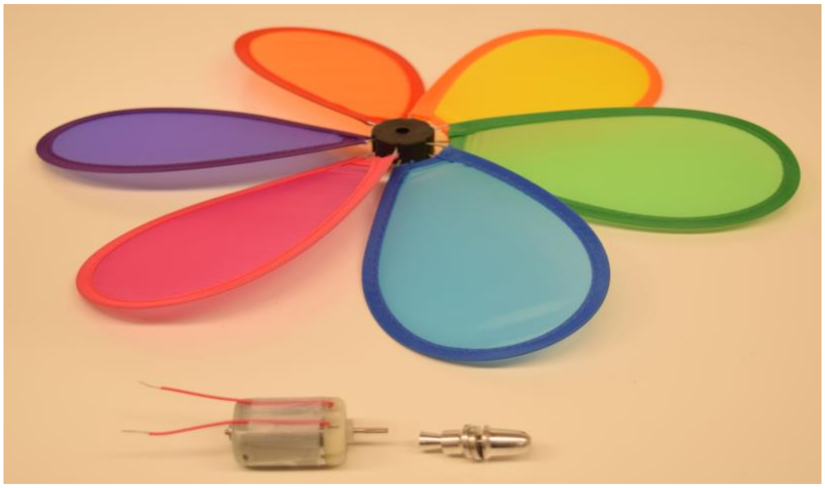

Fig. 10.4.2 Colorful multi-blade propeller, the motor and threaded cowl

2. Connect the propeller to the motor using the threaded cowl as shown in **Fig. 10.4.3.** Ask your instructor to help you with this.

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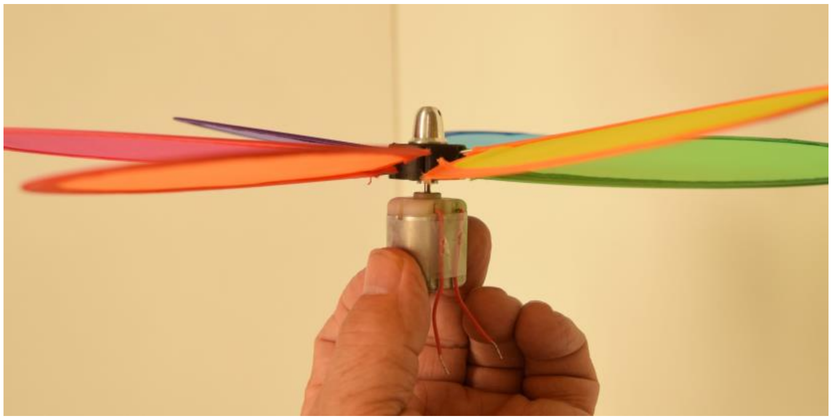

Fig. 10.4.3. Assembled propeller, cowl, and motor

3. Keep the two short jump wires in the two slots in the motor. Connect the ends of the short wires to two wires with alligator clips on each end. Wrap the motor tightly with sufficient paper towels with the wires protruding through the towels and stuff the assembly into the tubing of the support structure as shown in **Fig. 10.4.4.** The support structure was made from PVC tubing bought at LOWES and glued together with Elmer's glue. Connect other end of the two wires with the alligator clips to the voltmeter. Place the blades about 25 cm in front of a source of wind such as a cooling fan with the blade free to rotate without obstruction. **See Fig. 10.4.4. Safety Concern and Warning: When the propeller rotates at high speed, which is the third position on the fooling fan, sometimes one of the blades flew off the rotor. We have glued each blade to the rotor and this no longer happens. Just to be safe wear safety-goggles and keep your eyes at least 2 meters away from the blade when watching**.

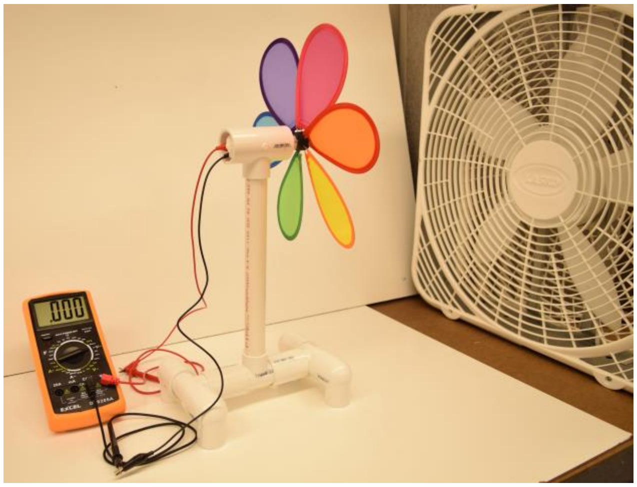

Fig. 10.4.4 Propeller, motor, wires, support, voltmeter, and fan ready to be switched on.

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4. Set up your multi-meter to measure DC voltage. See **Figure 10.4.5**. Start with the multi-meter on the 2 V setting and if the reading is less than 2 V, you can change it to the 2 mV setting. There are two types of voltage scales on the multi-meter. One is for DC voltage such as batteries and the other is for AC voltage where the meter measures a kind of average voltage. For your measurement chose the DC scale. Check with your instructor about which scale to use.

5. Before turning on the fan make sure the rotating propeller doesn't fly off and hit you or somebody else. Make sure the screws are tight on the propeller collar and the motor is secured to the support structure and the blades are free to rotate. Safety goggles are recommended. Turn on the fan on its lowest setting and you should see the voltage on the digital voltmeter rise. Record your voltage here.

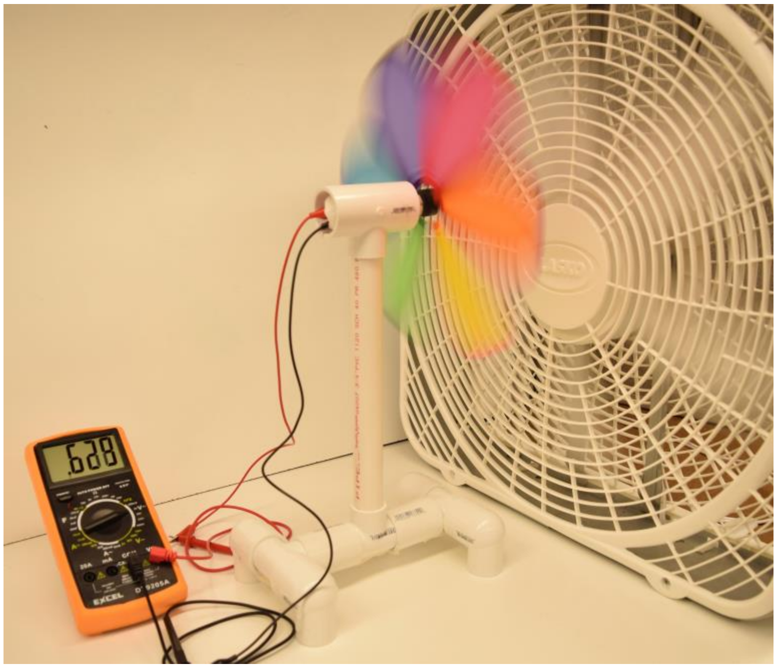

Fig. 10.4.5 Typical voltage reading 0.628 volts from fan running at low speed.

6. Increase the fan speed to the next higher level and note the change in Voltage. Record the voltage here

7. If there is a third higher speed on the fan, record the corresponding voltage here. **Again stay clear of the blades in case it flies off.**

8. What conclusion can you draw about the change in voltage with increase in fan speed?

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9. Explain why the readings fluctuate or why they do not fluctuate. If the propeller spins at a constant rate, the readings should be steady. More likely than not, the propeller won't spin at a constant rate and the readings will fluctuate by 10-20 percent.

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(Extra Credit)

10. If you replaced the voltmeter with a red LED as shown earlier when you twisted the shaft with your fingers, do you think the LED would light up using your wind turbine. Try it. Does it light up?___________________.

11. If the LED does not light, the polarity may be wrong and you should switch the wires that are connected to the LED. If the LED still doesn't light up, what could you conclude about the voltage required to light up the LED________________?

12. What changes could you make to the fan speed to get the LED to light up or make it light more brightly______________________________________?

13. What conclusion can you draw about using wind power to generate electricity? Is it possible____?

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Activity 10 - 5: Bobble head / Solar Dancing

SOLs: PS.1a, PS.1k, PS.5a, PS.6b, PS.6c, PS.10c, PS.11a, PS.11b, PS.11c, 3.1a, 3.1j, 3.11b, 4.1e, 4.1g, 4.3a, 4.3b, 4.3d, 4.3e, 6.1c, 6.1h, 6.2d, 6.2e

Overview: How do the Solar powered dancing toys work? When light from the sun or from another light source such as an incandescent lamp or compact fluorescent bulb strikes the photo voltaic cell on the dancing toy, it randomly wobbles back and forth. Here is a video on youtube with the sides of the dancing flower cutaway exposing the motion. You can easily see the random and chaotic motion of the swaying pendulum attached to the stem of the leaves and flower. Go to this link: https://www.youtube.com/watch?v=kBouHRd3yEU



Fig. 10.4.1 Examples of solar powered dancing toys. In each case there is a solar photaic cell attached to each toy (black looking rectangle).

Objective: To study how a solar powered toy works.

Materials:

- Solar dancing toy
- Sunlight
- Incandescent Lamp
- CFL (Compact Fluorescent lamp)
- Small screwdriver

Prediction:

Your solar powered dancing monkey toy is designed to "dance" when light strikes its solar photovoltaic panel. Predict whether your dancing toy will dance in the following conditions:

1. Outside on a bright sunny day. ________________________________

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2. Outside on a gloomy sunless day. _______________
3. Inside a room with a bright 100 Watt incandescent lamp 1 m from the photovoltaic cell. _________________________
4. Inside a room with a bright 100 Watt equivalent CFL lamp 1 m from the photovoltaic cell. __________________
5. Inside a room with a bright 60 Watt incandescent lamp 1 m from the photovoltaic cell. ____
6. Inside a completely dark room. ________________________________

Procedure

1. Take your solar powered dancing toy out of your kit and place it on your desktop. What do you observe? Describe the brightness of the room and how much dancing the monkey is doing. ___________________________________

2. Does the toy dance outside on a bright sunny day? Explain_________________

3. Does the toy dance outside on a gloomy sunless day. Explain_______________

4. Does your toy dance inside a room with a bright 100 Watt incandescent lamp 1 m from the photovoltaic cell. Explain____________________________________

5. Does your toy dance inside a room with a bright CFL equivalent 100 Watt incandescent lamp 1 m from the photovoltaic cell. Explain__________________

6. Does your toy dance inside a room with a bright 60 Watt incandescent lamp 1 m from the photovoltaic cell. Explain____________________________________

7. Inside a completely dark room. (Cover up the photovoltaic cell with your finger)____.

8. Find the minimum light need to make it dance. Explain___________________

9. Remove the base of the toy with a screw driver and identify the pieces in **Fig. 10.4.2** below with those in your toy.

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Fig. 10.4.2 View of 4 basic components of the dancing toy.

Explain

1. Find the photo voltaic cell in **Fig. 10.4.2** and explain the function of the solar voltaic cell.

2. Find the amplifier in **Fig. 10.4.2** and explain the function of the amplifier.

3. Find the coil of wire in **Fig. 10.4.2** and explain the function of the coil.

4. Find the permanent magnet in **Fig. 10.4.2** and explain the function of the magnet.

5. Explain the changes in the form of energy in going from sunlight to the dancing head.