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# Activity 1: Gel-Heating Pad

**Introduction:**
The gel-heating pad used in this investigation is shown in Fig. 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. 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 gel pads work?


**Fig 1a,1b, and 1c Hot gel and warm mate pads, flexible disk trigger, and spring-type trigger.**

The "hot gel" and "warm mate" heat pads are shown in **Fig 1a**. The flexible disc is shown in **Fig.** 1b and the spring-type trigger in **Fig. 1c.** The flexible disk trigger is 19 mm in diameter and is the type in your gel pad. Before discussing the gel pad, here is a simple analogy with supercooled water and the formation of ice. What is happening with the gel pad appears strange, but the process can be understood if you think about water freezing. Water freezes at 32 degrees Fahrenheit (0 degrees C). If you were to stick a thermometer in a cup of water and put the cup in the freezer, you would find that the temperature of the water falls to 32 degrees F and then hangs there until all the water is completely frozen. Then the temperature of the solid water falls to the temperature of the freezer. What happens if you **supercool** the water? Suppose you could get the water's temperature to 10 degrees below the freezing point without it crystallizing into a solid (ice). You can do this if you fill a very clean glass with distilled water and place it in your freezer. Because the water is distilled, there are no points for the water to begin crystallizing. However, if you tap the glass the temperature of the water will jump up to 32 degrees F (0 degrees C), and the water will solidify quickly. The pad works in a similar manner.

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Your gel pad contains **sodium acetate** and water. Sodium acetate is very good at supercooling. It "freezes" at 130 degrees F (54 degrees C), but it is happy to exist as a liquid at a much lower temperature and is extremely stable. Clicking the disk by squeezing the pad with your hands. This forces a few molecules to flip to the solid state, and the rest of the liquid then rushes to solidify as well. The temperature of the solidifying liquid jumps up to 130 degrees F in the process. When the liquid 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 130 degrees F °C. which is high enough to keep your hands warm. 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. It won't look the same as it did when new.

**More details on crystallization**

The super-cooled liquid is metastable because of a nucleation barrier that prevents the growth of macroscopic particles of crystalline material. A spontaneous transition to the solid phase will not occur. The heating pad contains a trigger device that can be manipulated by the user to initiate the crystallization of the super-cooled liquid. The flexing of the 19 mm disk shown in **Fig. 1**b causes "a single molecule to crystallize and subsequently nucleation occurs throughout the super-cooled liquid. One proposed mechanism is friction between metal layers of the disk as it is snapped. This friction produces molecular vibrations throughout the liquid causing nucleation to occur throughout the crystal. The crystals grow quickly, approximately 5 mm/s, and the solid phase has a polycrystalline structure shown in **Fig. 2.**

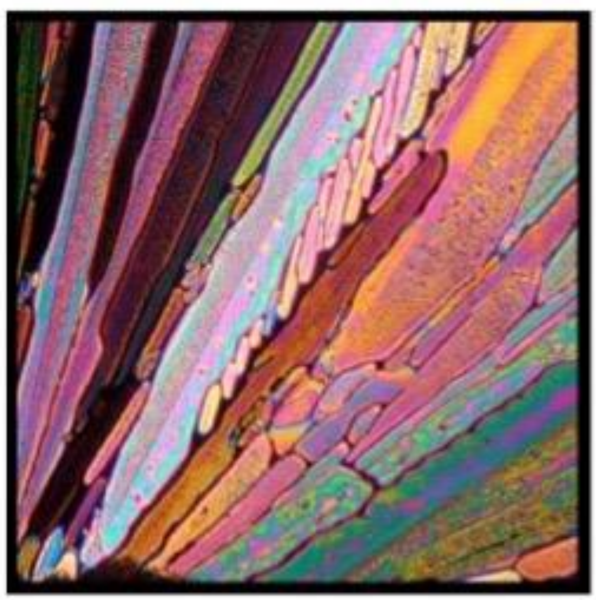

**Fig. 2** The art of sodium acetate trihydrate crystals. A drop of the solution was placed between two microscope slides, and crystallization of the supercooled liquid was seeded from one edge. The images show the polycrystalline structure observed between crossed polarizers in a microscope using a 5X objective.

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**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.

**Virginia 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

**Suitable for students in grades 6-12**

**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**, 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.).

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**Table 1**

| Time (minutes) | Temperature Degrees °C | Observations |
|---|---|---|
| 0 | | |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |
| 17 | | |
| 18 | | |
| 19 | | |

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| | | |
|---|---|---|
| 20 | | |

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 have take place 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

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# Activity 2: Piezo-Electric Popper

**Introduction:**
In this Activity 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.

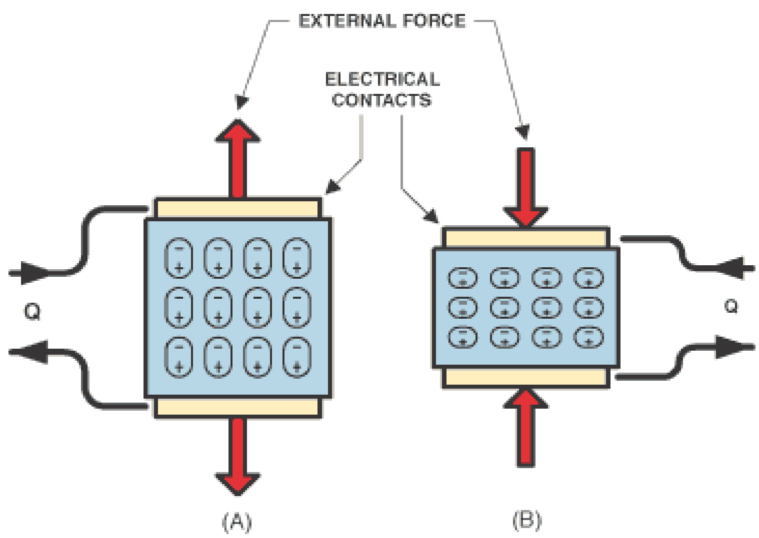


**Fig. 1** Some crystal structures have a charge separation when the crystal undergoes tension (A) or compression (B). This charge separation can generate electrons to flow and convert mechanical energy into electric energy. In a gas lighter, when you depress the switch, a piezoelectric crystal is squeezed, generating a high enough voltage to generate a spark. This spark will ignite a combustible fluid and produce a flame.
(Image from http://archives.sensorsmag.com/articles/0203/33/main.shtml)

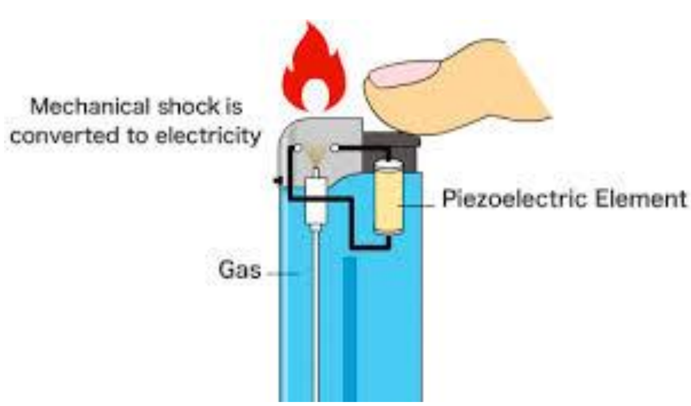


**Fig. 2** A gas lighter uses piezoelectricity to produce a spark. (Image from global.kyocera.com)

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# Activity 2-1: Firing the Popper

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

**Virginia 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
**Suitable for students in grades 6-12**

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

**Introduction**
The "piezo-popper" works similarly 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. 3** The piezo popper uses piezoelectricity. (Image from teachersource.com)
A closer view of the spark gap is shown in **Fig. 4**

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**Fig. 4** Closer view of end of wire in canister

**Types of air-fuel mixtures**

While perfume (which is mostly alcohol) works 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). To create 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.

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

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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 it 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 resultant 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.

**Predictions**

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 to launch the popper into the air. Predict how high the popper will rise.

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**Observations**

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.

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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 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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**Explanations**

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 is 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 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 dichloro-methane, also known as methylene chloride ($CH_2Cl_2$). It is bluish in Fig.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** Dippy Duck poised to dunk into a cup of water

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

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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

**Virginia 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**

**Suitable for students in grades 6-12**

**Prediction:**

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

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**Procedure:**

1. Fill a glass cup with water to almost the top as shown in Fig.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. 2. Before you hold it, predict the behavior here.

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

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**Fig. 2** Instructor using fingers to warm the fluid inside the bulb

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

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5. Slide the metal band shown in **Fig. 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.

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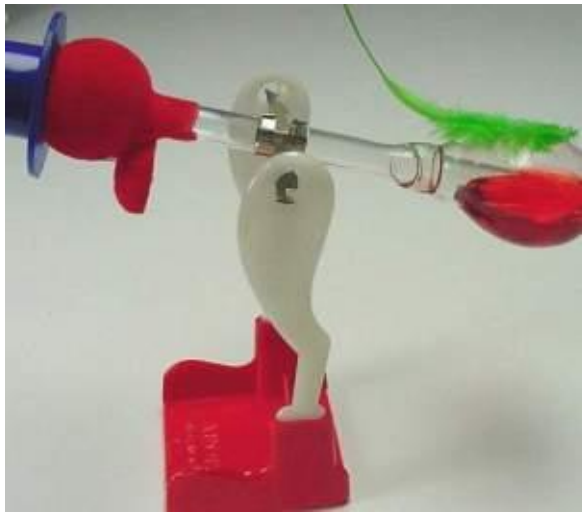

Fig. 3 Close up emphasizing the metal band near the cm of Dippy Duck's head, bulb with fluid, and glass tube.

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.

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

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8. Explain your observations here.

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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.

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

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11. Explain your observations here.

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# Activity 4: Rookie Solar Racer

**Introduction**

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 to increase the temperature of the water. See **Fig. 1**. Homes in sunny regions sometimes have special solar collectors that help to heat the house's water supply.

**Fig. 1** 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/.

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** shows a typical residential solar photovoltaic panel.

**Fig. 2** A typical rooftop arrangement of solar photovoltaic panels. Image from Advanced Energy Industries, http:// www.vaadvancedenergy.org/.

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**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 but each uses a different amount of electrical energy. **Table 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 inefficient 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 1** (data from http://www.designrecycleinc.com/led%20comp%20chart.html)

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.

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

**Virginia 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**

**Suitable for students in grades 6-12**

**Materials:**

- Screwdriver
- Lamp
- Long Nose Pliers
- Rookie Solar Racer Material List (See Fig. 3)

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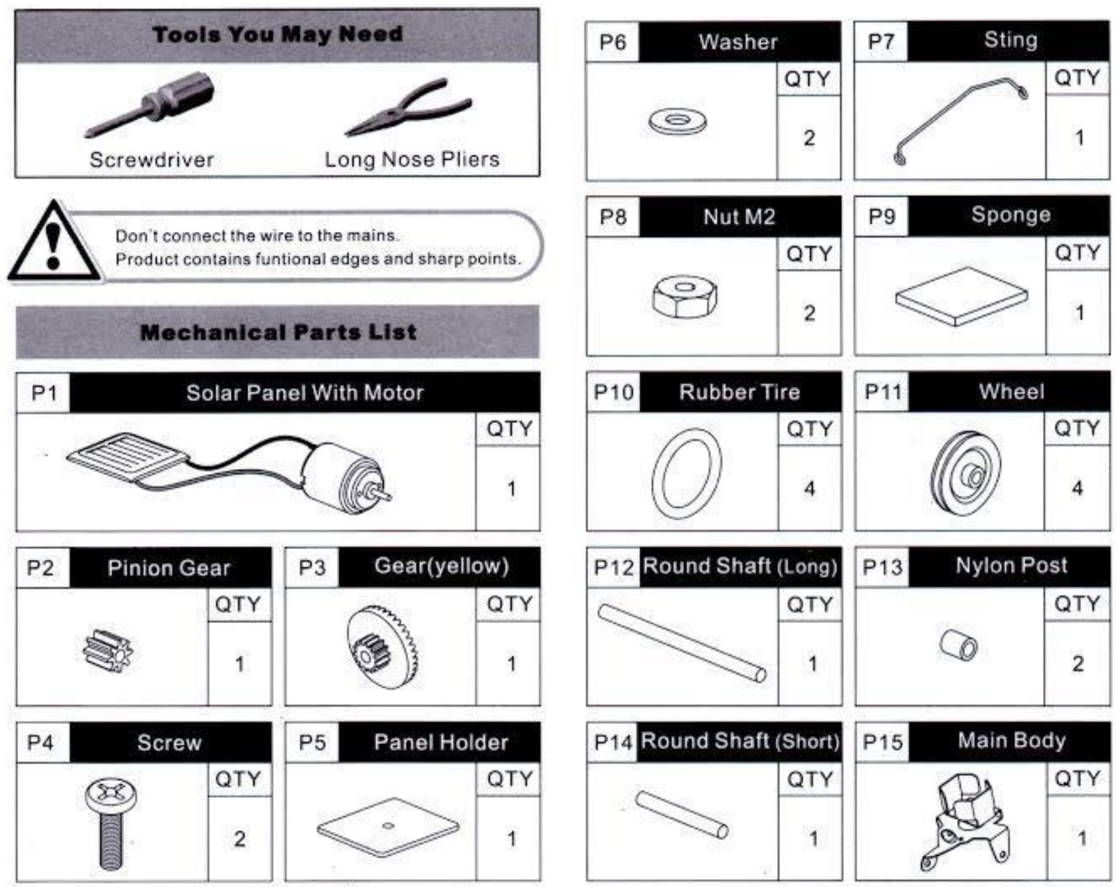


**Fig. 3** Material list for the Rookie Solar Racer Kit

**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 lights?

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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. 4**

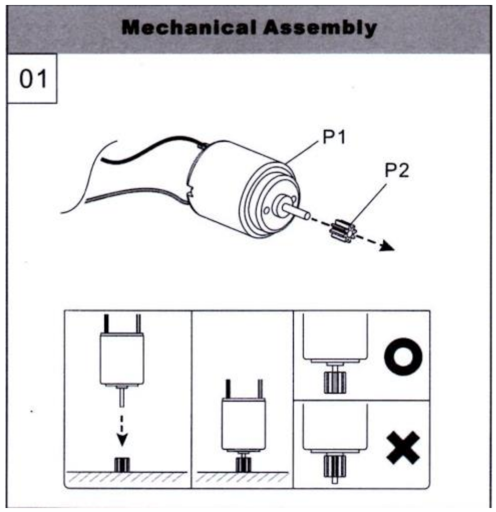


**Fig. 4**

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. 5**

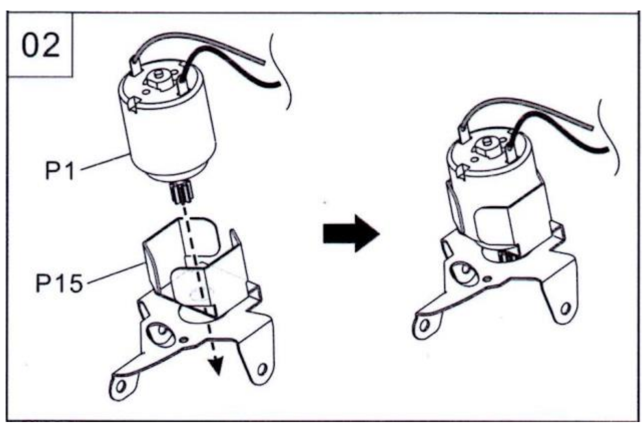


**Fig. 5**

3. Arrange the screw, panel holder, washer, sting, and bolt as shown in **Fig. 6** 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.

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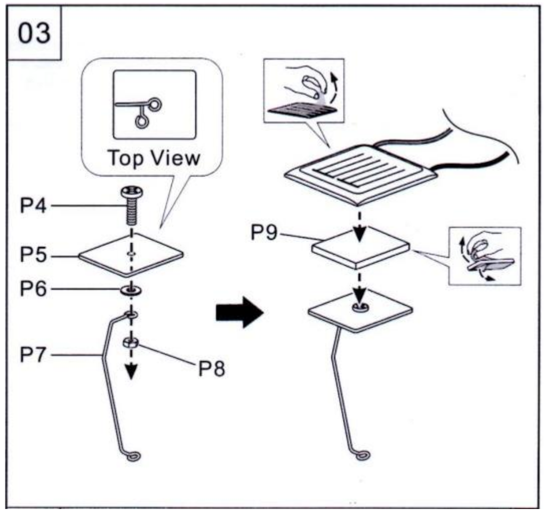


**Fig. 6**

4. Now, attach the sting to the base using a screw, washer, and nut. See **Fig. 7**

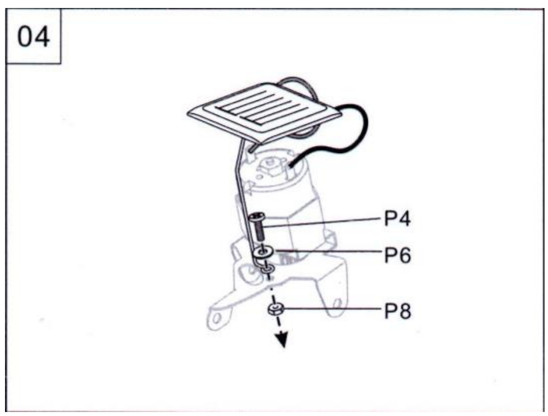


**Fig. 7**

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. 8.** What would happen if the wheels were attached too tightly?

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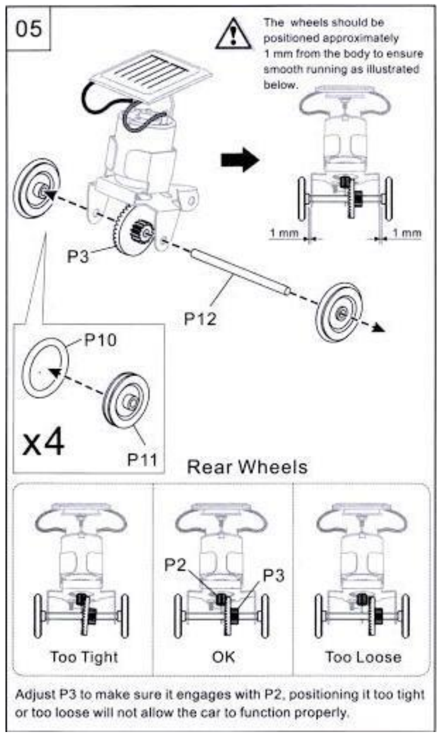


**Fig. 8**

6. Attach the two front wheels, again leaving a 1mm clearance between the wheels and the mount. See **Fig. 9**

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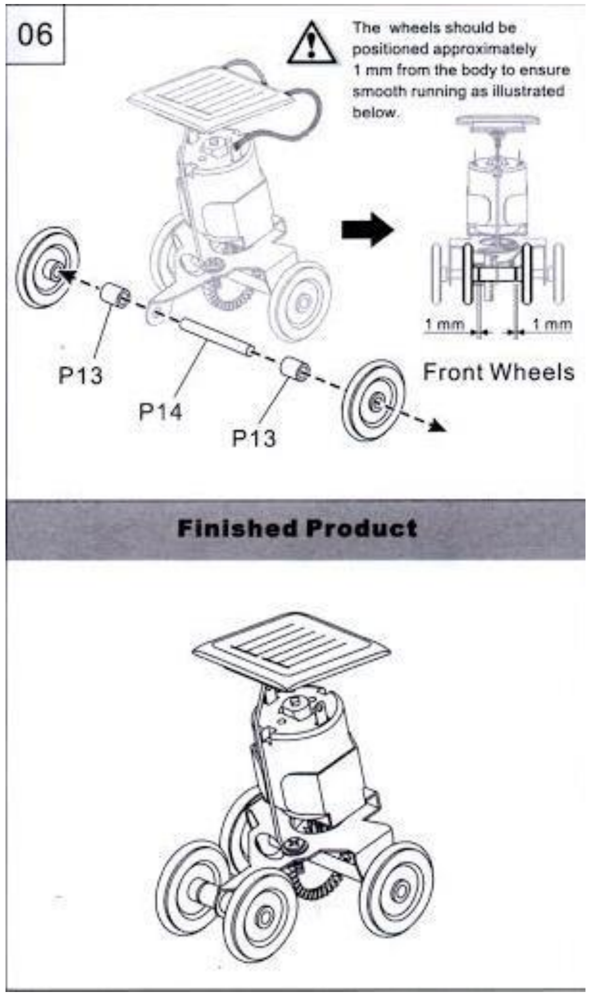


**Fig. 9** The finished solar racer

**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?

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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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# Activity 5: Charging Objects by Rubbing

## Overview

Static electricity is the result of an imbalance of charge in materials. All materials are made up of atoms. Atoms are extremely small and are made of even smaller components called electrons, protons, and neutrons. (Figure 1) 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.

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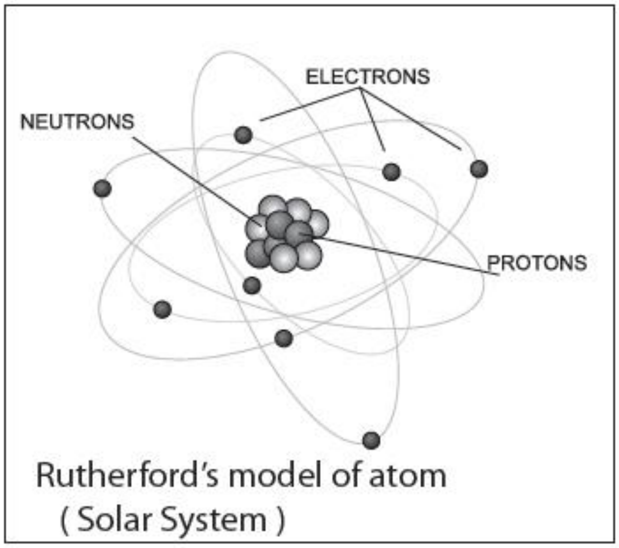


**Fig. 1** Solar System Model (a.k.a Rutherford's Model of Atom) is the most common way to picture an atom. The model describes electrons orbiting around the nucleus in a fashion similar to planets orbiting the Sun. Just like planets have their orbits and are located at different distances from the Sun, 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.

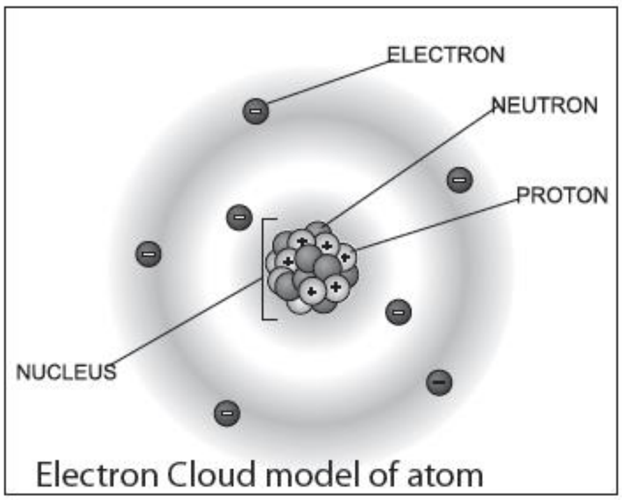


**Fig. 2** The Electron Cloud Model claims that there are no orbitals. Instead, the electrons are located around the nucleus within certain boundaries or shells.

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.

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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 rubbing. 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**) 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.

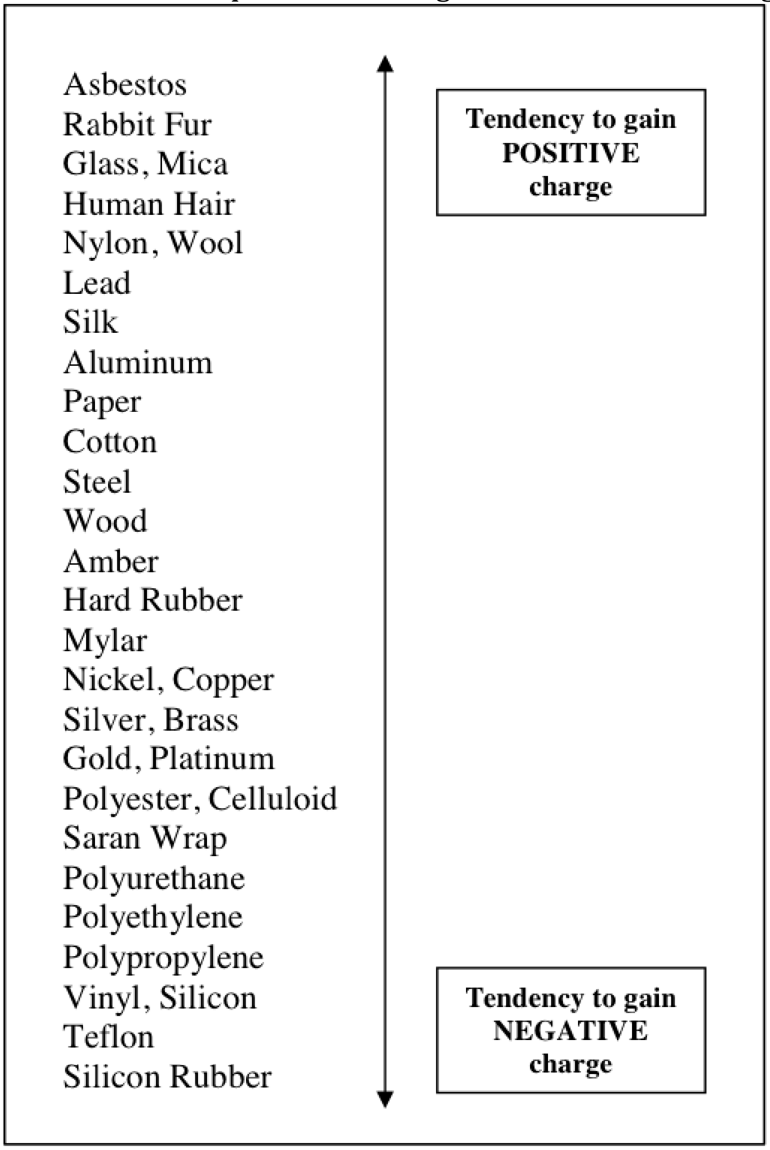


**Fig. 3** The triboelectric series shows the relative tendencies of objects to gain positive (lose electrons) or negative charges (gain electrons) when rubbed against one another.

## Neutral and Polarized Objects

An object is said to be neutral if it contains the same number of positive and negative charges. In **Fig. 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

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charge is on the other. Each atom is arranged randomly so that the orientation of the charges is different throughout the material.

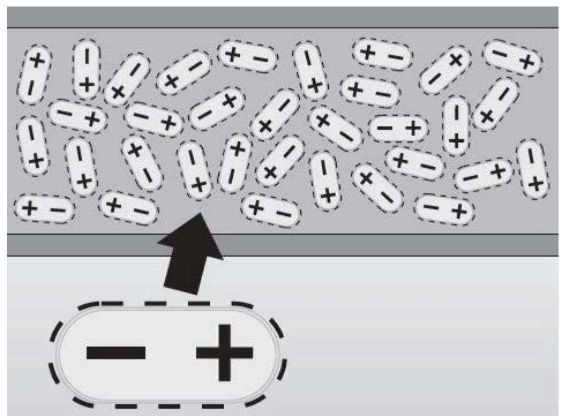

**Fig. 4** Each oval represents an atom. Each neutral atom has an equal amount of negative charge (electrons) and positive charge (protons)

A neutral object can, however, produce some of the same phenomena as a charged object due to 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 5)** As a result, the neutral object will appear to react to an electric force as though it were charged.

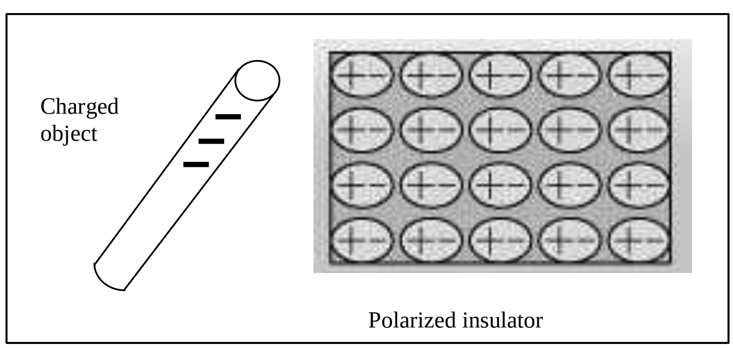


**Fig. 5** A charged object is shown polarizing a neutral piece of material. Note how the positive and negative charges are alternate in the material.

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 6** below, a plastic comb (negatively charged) attracts pieces of paper (neutral) after combing through hair.
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**Fig. 6** A charged comb causes polarization of charge within neutral pieces of paper

**Different methods to charging materials**

Materials can acquire charge through different methods. For example, they can acquire charge by rubbing two materials together (rubbing), conduction (touching two conducting materials), and induction as shown in Fig.7.

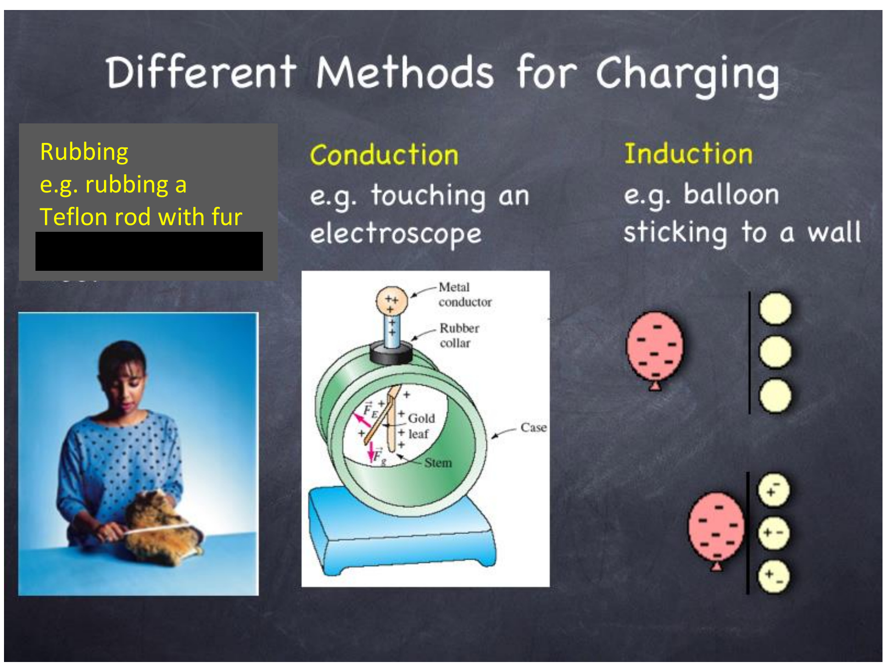


**Fig. 7** The three primary ways to electrically charge an object

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# Activity 5-1: Charging Objects by Rubbing

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

**Materials:**

- Two 8 in long Teflon rods – also known as poly(tetrafluoroethylene)
- Two 8 in long Acrylic rods – also known as poly(methyl methacrylate)*
- Silk cloth
- Scrap paper (confetti) - from home

* 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. 8**

**Virginia 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. **Suitable for students in grades 9-12**

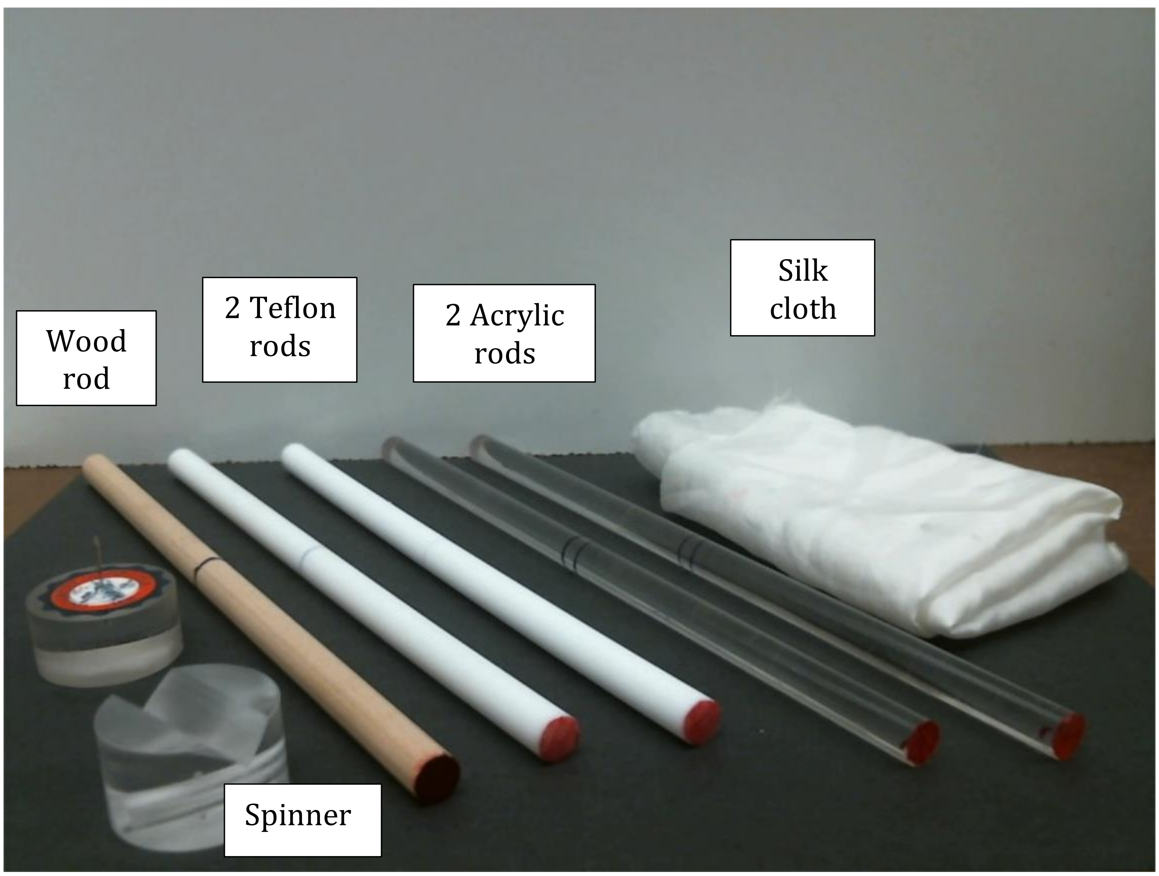


**Fig. 8**

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**Prediction**

1. When you rub Teflon with silk, use the triboelectric series in Fig. 3 to predict that Teflon acquires a net ________ charge and silk acquires a net ________ charge.
2. When you rub Acrylic with silk, use the triboelectric series in Fig. 3 to predict that the Acrylic acquires a net ________ charge and the silk acquires a net ________ charge.
3. Predict how neutral pieces of paper will behave when a positively charged rod is brought near them. Explain your answer. Re-read the overview on Neutral and Polarized Objects.

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

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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. Neutralize the Acrylic 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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5. Rub the Acrylic rod with silk. Move the rod towards the paper squares. Describe the behavior of the squares.

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**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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## Activity 5-2: Electrical Forces between Charged Objects

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

**Materials:**

- Two 8 in long Teflon rods – also known as poly(tetrafluoroethylene)
- Two 8 in long Acrylic rods – also known as poly(methyl methacrylate)*
- 8 in Wood rod
- Silk cloth
- Spinner* (also called swivel)

* 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 also made from acrylic that is designed to rotate (and swivel) freely on the metal support pin with minimum friction. See **Fig. 9** and **Fig. 10**

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

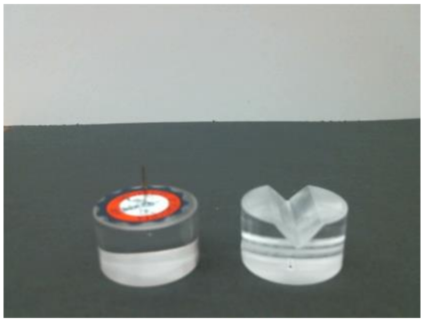

**Fig. 9**

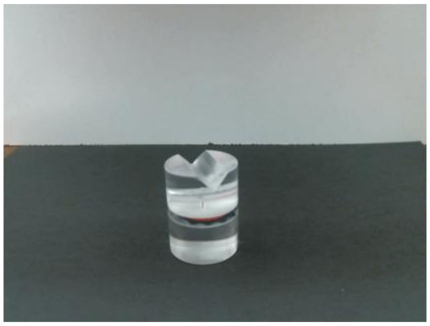

**Fig. 10**

**Prediction:**

1. If two Teflon rods are each charged by rubbing with the silk cloth, predict what will happen you hold one Teflon rod in your hand parallel to the Teflon rod on the spinner as shown in **Fig. 11** and **Fig. 12**.

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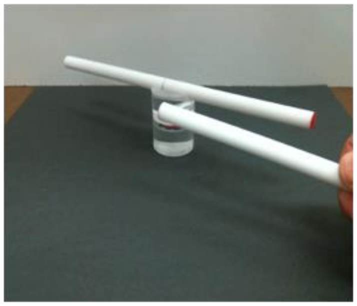

**Fig. 11.**

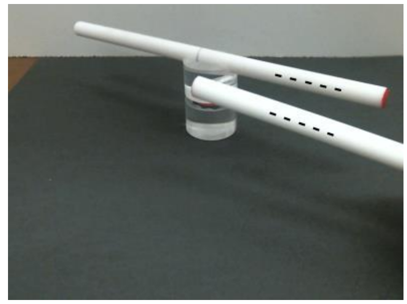

**Fig. 12**

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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 place the charged acrylic rod on the spinner and you hold one charged Teflon rod parallel to the one on the spinner. Explain your answer.

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

**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. One end of the rod is marked red. Always charge the length of the rod closest to the end marked red. Hold the other end in your hand otherwise your hand will dissipate the charge.

2. Hold the second charged rod next to the first one with lengths parallel to ensure the greatest possible interaction between the two rods. Record the direction of the force (attract or repel) in **Table 1**.

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

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

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| **Table 1** | **Direction of Electrical Forces Between Charged Objects** | |
|---|---|---|
| | Teflon (-) | Acrylic (+) |
| Teflon (-) | | |
| Acrylic (+) | | |

5. Place the uncharged 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 Fig. 13 to ensure the greatest possible interaction. Record the direction of the force in **Table 2. Do the rods attract or repel?**

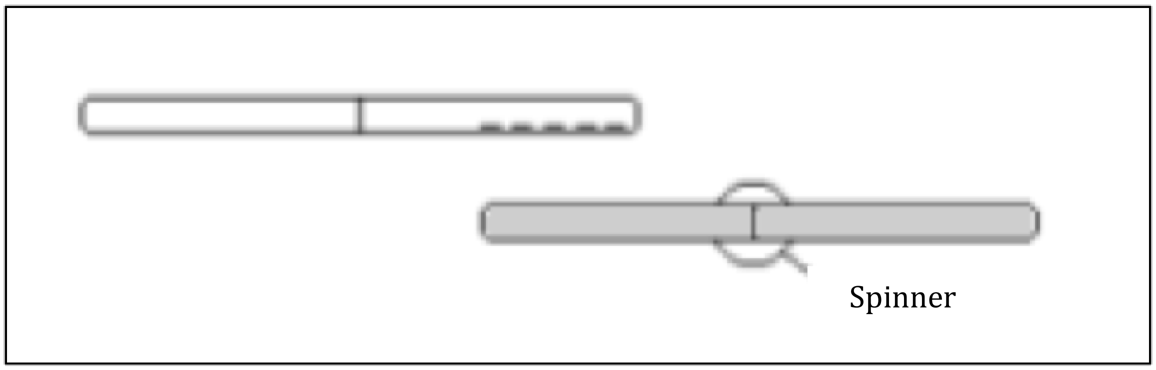


**Fig. 13** An uncharged wooden rod is placed on the spinner. A Teflon rod is then charged and used to rotate the wooden rod without touching it. Note the direction of the electric force between the two.

7. Hold the charged acrylic rod in your hand parallel to the wooden rod on the spinner as shown in **Fig. 12** to ensure the greatest possible interaction. Record the direction of the force in **Table 2**. **Do the rods attract or repel?**

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 2**.

| Table 2 Direction of Electrical Forces between a Charged and an Uncharged Object | | |
|---|---|---|
| | Teflon (-) | Acrylic (+) |
| Wood (0) | | |

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| | | |
|---|---|---|
| Paper (0) | | |

**Explain**

1. Based on your data in **Table 1**, draw 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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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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# Activity 6 : Detection of Charge Using the UVa Electroscope

**State of Virginia 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 has some net charge, its two conductive components will acquire like charge and deflect from each other due to a repulsive force. See **Fig. 1** and **Fig. 2** for an illustration of the standard metal leaf electroscope and the UVa electroscope. In the UVa electroscope the electrical torque about the axis of rotation is balanced by the gravitational torque due to the offset of the pivot point from the center of mass of the tube.

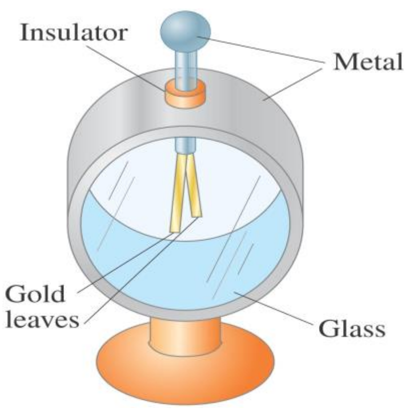


**Fig. 1** Standard metal leaf electroscope

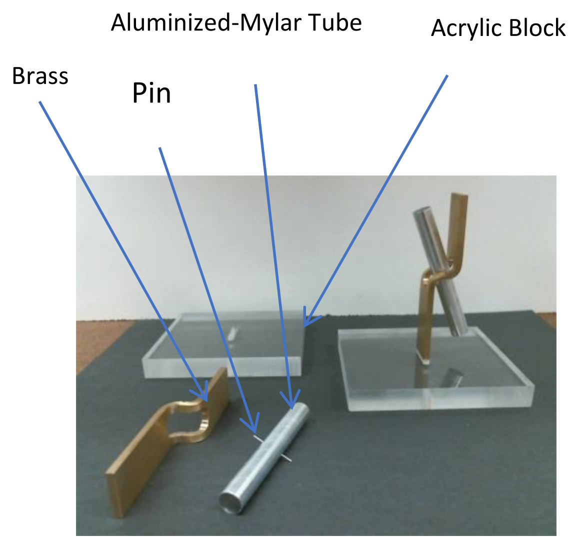


**Fig. 2** UVa electroscope components

**How the UVa Electroscope Works**

The base of the UVa electroscope in **Fig. 2** is constructed out of acrylic block, an insulator, to eliminate charge leakage to the table. The acrylic block holds the brass conducting support on which charge is placed by rubbing a charged object across it. A rotating conducting tube acts as the "needle" that measures the total charge on the electroscope.

If you rub the top of the brass support with a charged object such as the white Teflon rod that has been previously rubbed with silk as shown in **Fig. 3,** the excess electrons will move from the Teflon rod to the conducting tube and brass support. The repulsive force between the electrons will force them to move along all the conducting elements until they are uniformly separated along the tube and brass rod. This also produces a repulsive force between the tube and the support. This electric force pushes the conducting tube away from the brass support producing a torque to rotate the tube counter clockwise. The rotation axis of the tube is provided by a steel pin through the tube about 0.075 inches above the center of mass of the tube. Because the axis of rotation is offset from the center of mass, the larger mass below the pivot point produces a gravitational torque in the opposite direction. The tube will rotate until the opposing gravitational torque is balance by the electrical torque. As the deflection angle increases towards 90 degrees, eventually the repulsive torque from the bottom of the brass support will start pushing back on the tube and it will go no further. The maximum angle seems to be around 50 degrees.

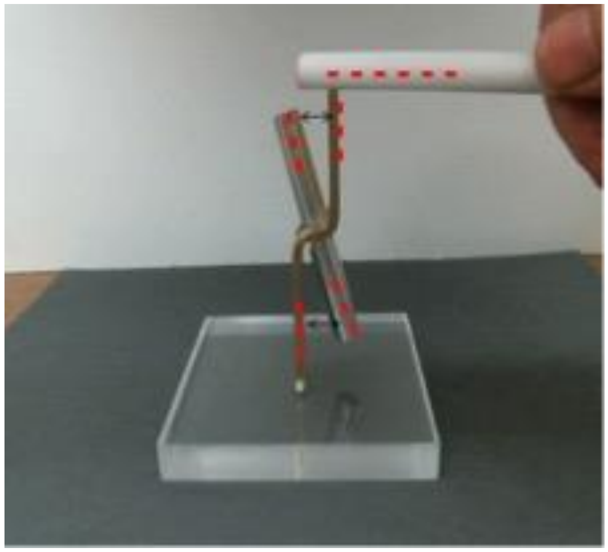

**Fig. 3 A negatively charged Teflon rod charges up the electroscope by rubbing it across the end of the brass support.**

A crucial piece of the apparatus is the rotating conducting tube shown in **Fig. 4** below. The distance between the pin hole and the center of mass can be changed to produce different amounts of sensitivity between the deflection angle and the amount of charge. By increasing the distance d more charge on the tube will be needed to offset the gravitational torque.

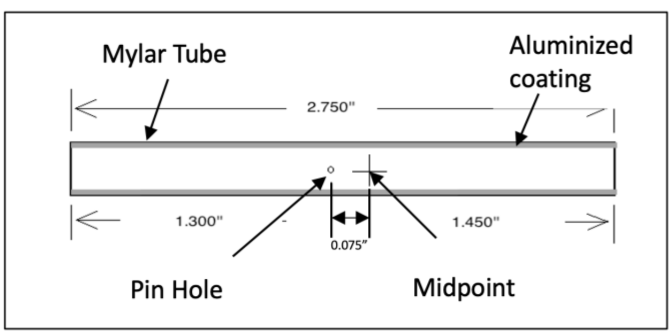


**Fig. 4** The rotation axis of the tube is .075 inches (1.9 mm) offset from the midpoint of the 2.750 inches (7.0 cm) long mylar tube. The diameter of the tube is 0.375 inches (0.95 cm). The aluminized coating makes the tube conducting.

# Activity 6-1: Using electroscope to detect the presence of charge

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

**Materials:**

- Electroscope
- 1 Acrylic Rod
- 1 Teflon Rod
- Silk

**Virginia State of Virginia SOLs:** PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c
**Suitable for students 9-12**

**Prediction:**

1. Assemble the electroscope according to **Fig. 2.** Predict the behavior of the electroscope when you touch a charged Teflon rod to the top of the brass support on the electroscope.

2. In what ways will a negatively charged rod touching the electroscope look different or the same from a positively charged rod touching the electroscope?

**Procedure:**

1. 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 with a silk cloth.

3. Rub the charged Teflon rod along the top of the brass support on the electroscope a shown in **Fig. 3**. Describe the behavior of the electroscope. If you do not get a good response, use a tissue with alcohol to wipe along the length of the Teflon rod at the end painted red. This will clean off any oils or dust. What is the sign of the charge on the electroscope. Explain.

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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. You may also have to clean the acrylic rod with alcohol dry with tissue. What is the sign of the charge on 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.

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. Explain why now the angle of the tube gets smaller. If you keep rubbing charge on it from the acrylic rod, the angle goes to 0 and starts increasing again. Explain.

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**Explanation**

1. Explain why the tube of the electroscope rotates around the pivot 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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_____________________________________________________________________

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

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# Activity 6-2: 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
- Wooden Rod
- Acrylic Rod
- 100% Metal Object such as metal utensil or piece of rolled up aluminum foil
- 100% Plastic Object such as a plastic utensil

**State of Virginia SOLs:** PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

**Prediction:**

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

**Table 1 Conductor/Insulator Predictions and Reasoning**

| Material | Predictions and Reasoning |
|---|---|
| Your Finger | |
| Wood | |
| Acrylic | |
| Teflon | |
| Metal object | |
| Plastic object | |

1. Which of the 6 predictions above are you confident about and why?

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2. Which of the 6 predictions above are you are not confident about and why?
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**Procedure**

1. Charge up the electroscope again using the Teflon rod by rubbing it with silk. Charge it up until a large angle appears. Now touch the top lip of the electroscope with your finger as shown in **Fig. 5.** Describe the behavior of the tube and whether your finger is a conductor or insulator. If the tube returns to the vertical position, then your finger is a conductor because the electrons have been conducted away from the electroscope. Record your results in **Table 2**.

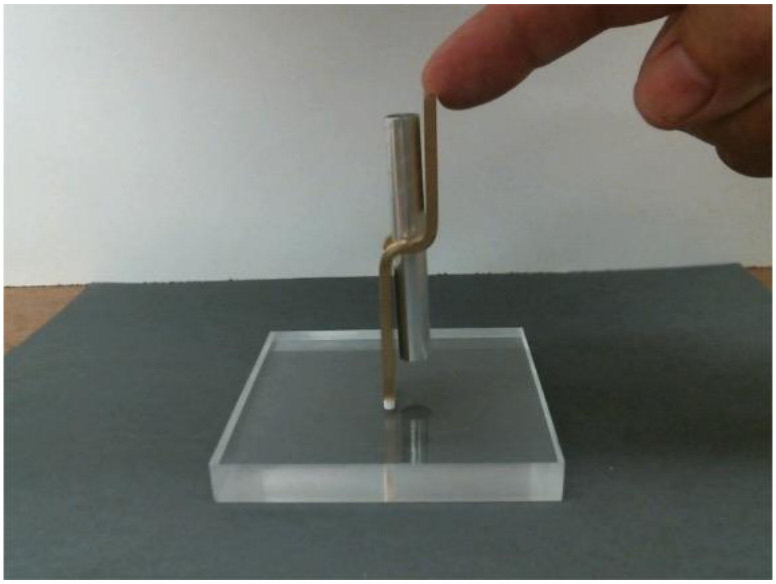

**Fig. 5 Charged electroscope being shorted to ground through your body**

2. Determine if the wooden rod is a conductor. Now you know from step 1 your hand is a conductor and will discharge the electroscope. This was also shown in Activity 6-1. Hold one end of the wooden rod in your hand. Touch the top lip of the charged electroscope with the other end of the wooden rod, as shown in **Fig. 6**. If the wooden rod is a conductor, it will discharge the electroscope through your hand. If it doesn't discharge

it, it will be an insulator. Describe the behavior of the tube and whether the wood is a conductor or insulator. Record your results in **Table 2**.

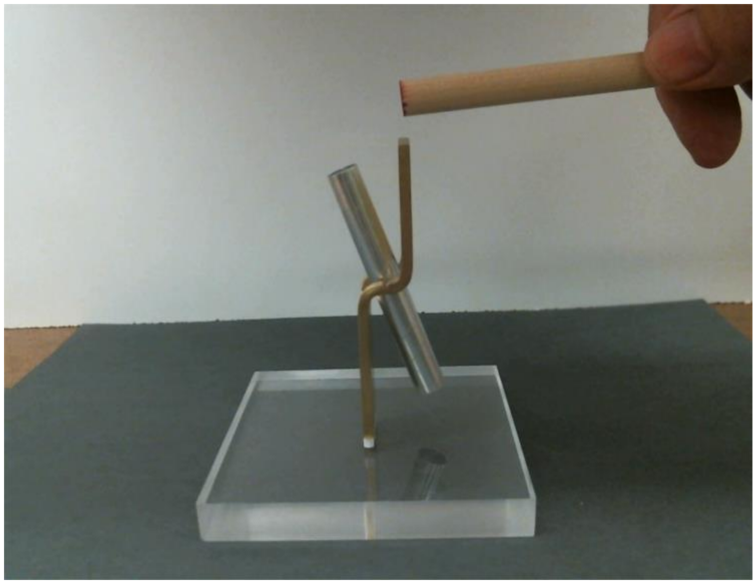

**Fig. 6 Charged electroscope about to be touched with wooden rod**

3. Substitute the acrylic rod for the wooden rod. Do not forget to neutralize the acrylic rod before it touches the electroscope. Repeat step 2. Describe the behavior of the electroscope and record results in **Table 2**.

4. Substitute a Teflon rod for the acrylic rod. Charge the electroscope up with the Teflon rod. Now neutralize the Teflon rod thoroughly by rubbing your finger up and down it. Repeat step 2. Describe the behavior of the electroscope tube and record in Table 1.

5. Substitute a metal object for the Teflon rod. You may also use a piece of aluminum foil. Repeat step 2. Describe the behavior of the electroscope in **Table 2**.

6. Substitute a plastic object for the metal object. Repeat step 2. Describe the behavior of the electroscope and in **Table 2**.

7. How do you decide whether a material is a conductor or insulator based on the behavior of the tube in the experiments above? State your line of reasoning.
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6. Sometimes wood is a conductor and sometimes an insulator. Explain why?
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9. Fill in **Table 2** with your conclusions.

**Table 2 Conclusions and Observations**

| **Material** | **Conductor or Insulator and Observations** |
|---|---|
| Your Finger | |
| Wood | |
| Acrylic | |
| Teflon | |
| Metal object | |
| Plastic object | |

# Activity 6-3: Adding positive charge to negative charge

**Objective:** Use the electroscope to determine the effect of adding positive charge to negative charge**.**

**Materials:**

- Electroscope
- 1 Acrylic Rod
- 1 Teflon Rod
- Silk

**State of Virginia SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c**

**Procedure:**

1. Set the tube in the vertical position by touching the top of the brass support with your finger as in **Fig. 5.** Your finger is a conductor and therefore it will drain all the electric charge off the electroscope so it becomes neutral after you touch it.

2. 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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3. 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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4. 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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5. 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.

6. 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 away from the vertical position 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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5. What happens when an equal amount of positive charge meets an equal amount of negative charge?

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# Activity 6 – 4: 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. That is electrons are free to move through the conductor. 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. 6 and Fig. 7**

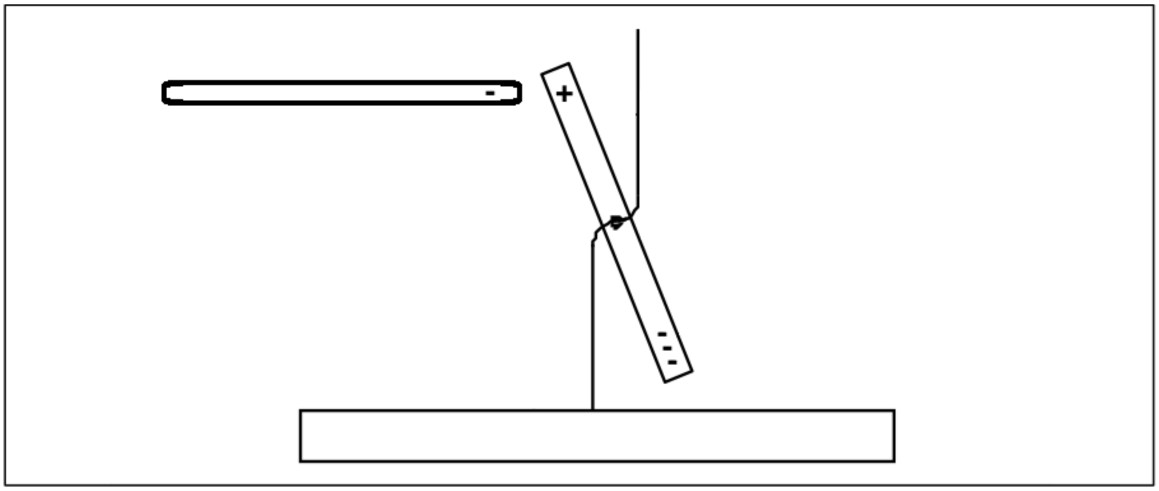


**Fig. 6** A negatively charged rod is brought near a neutral electroscope. Some of the electrons from the top of the electroscope tube are repelled to the opposite end of the tube leaving a net positive charge behind.

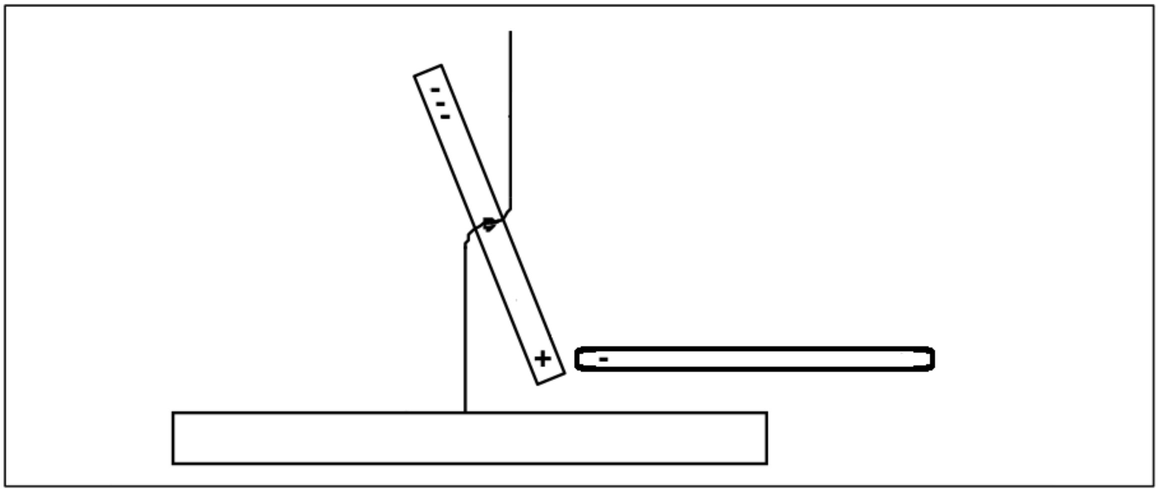


**Fig. 7** A negative rod is brought near to an initially neutral electroscope. Some of the electroscope's electrons are repelled to the opposite side of the tube leaving a net positive charge behind. This is similar to the situation **Fig 6**.

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

**Materials:**
- Electroscope
- Teflon Rod
- Silk

**State of Virginia 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 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.

1. 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 those you observed 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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# Activity 7: Hand Held Van de Graaff 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 conveyer belt made of rubber going around a Teflon roller at the bottom and a metal roller at the top. A schematic model of a typical VDG generator is shown in **Fig. 1**.

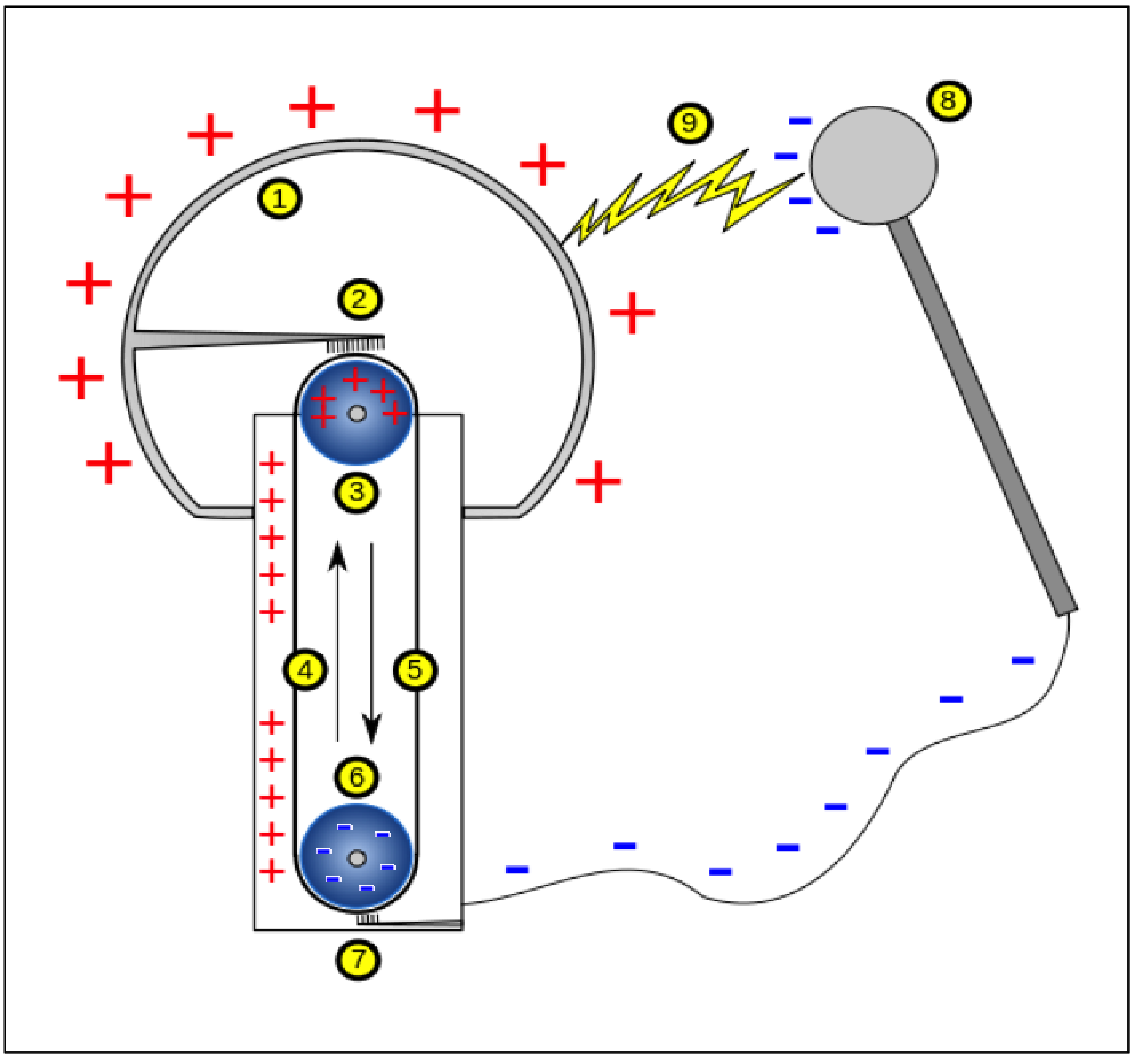


**Fig. 1** A traditional Van de Graaff Generator with components 1) Metal dome, 2 &7 ) Metal brush, 3)Metal roller, 4&5) Rubber belt, 6)Teflon roller, 8)metal sphere, and 9) spark from electric discharge

According to the triboelectric series, rubber loses some of its electrons to Teflon when they come into contact. As the belt revolves, positive charge accumulates on the metal

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roller and negative charge accumulates on the Teflon roller. When there's so much charge on the roller it can exceed the breakdown potential of air, the insulation, the charge on the roller can leap onto the metal brush nearby. The sharp tips on the metal brush facilitate the leap. The metal dome and the metal sphere act as reservoirs of electric charges. They allow for charges to build up. There is often hundreds of thousands of volts between them. Discharge between the dome and the sphere creates a long and bright spark that can be seen and heard. 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. **Fig. 2** is a picture of the handheld VDG.

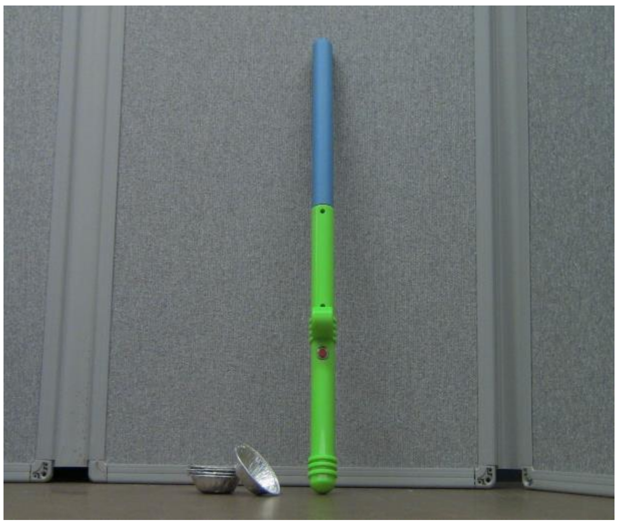

**Fig. 2** A photo of the handheld Van de Graaff generator that is safe to use in the classroom.

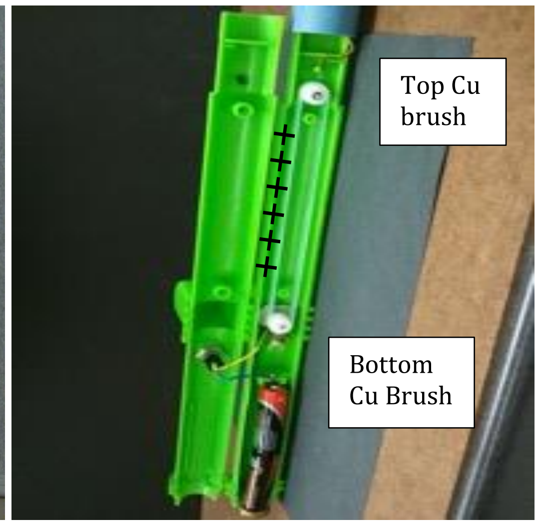


**Fig. 3** A cutaway look inside the hand held VDG showing two AA batteries.

Look at the inner workings of your handheld VDG shown in **Fig. 3**. There are two Teflon rollers – one on the bottom and one on the top. A rubber belt runs over the rollers. See **Fig. 4**. Electrical charges are separated at the point where the rubber belt and the bottom Teflon roller separate. The top roller is made of Teflon instead of metal, presumably to reduce cost. It does not participate in charge generation. As we learned from the triboelectric series, the Teflon roller at the bottom holds on to the electrons from the belt and becomes negatively charged, while the belt becomes positively charged as shown in **Fig. 4** and **Fig. 5.**

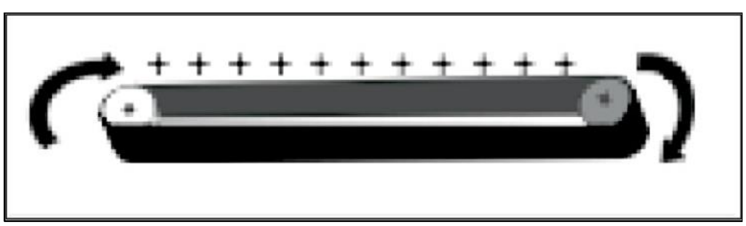

**Fig. 4** The rubber belt acquires + charge as it rubs over the Teflon roller

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There are two copper brushes, one on top and one on the bottom. They come as close as possible to contact with the belt, but never touch the belt directly. The bottom brush is shown in **Fig. 5**.

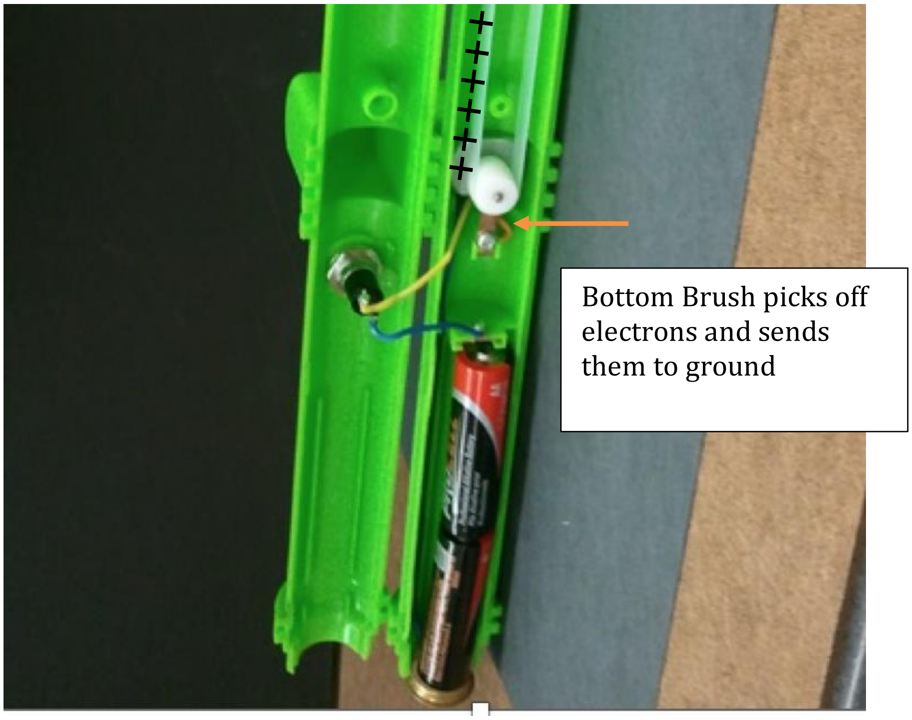


**Fig 5.** A cutaway view of the VDG showing the two double AA batteries.
The bottom brush collects the negative charge and is wired to the motor casing, which is then wired to the button you push. All the negative charge goes into your body. The top brush collects the positive charge and passes that to the cardboard tube.

The cardboard tube is in direct contact with the upper brush. It serves as a reservoir for positive charge and is analogous to the spherical metal dome on the traditional Van de Graaff generator. A frequently repaired part on the handheld VDG is the top brush. Since the tip close to the rubber belt is constantly exposed to electric discharge, it will become oxidized over time and no longer conduct electricity. **If your handheld VDG stops producing charge, it is likely due to oxidation of the brush. You can take off the top brush and sand its tip to restore its conductivity.** (Bonus question: the bottom brush is usually immune from oxidation; can you guess the reason?)

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# Activity 7-1 Determine the charge polarity on the VDG

**Objective:** Determine whether positive or negative charge is generated on the cardboard-tube by the handheld VDG described above in **Fig. 2**.

**Materials:**

- Handheld VDG
- The Spinner (You may use the electroscope instead of the spinner)
- Teflon Rod
- Acrylic Rod
- Silk

**Virginia SOLs:** PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 4.3d
**Suitable for students in grades 9-12**

**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.

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**Procedure**

1. Set up the spinner as shown earlier. 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 **Fig. 6.** What is the polarity of charge on the acrylic rod when rubbed with silk? Where does acrylic lie with respect to Teflon in the triboelectric series?

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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 **Fig. 6**. How does the acrylic rod react? What does this movement say about the polarity of the charge on the VDG?

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**Fig. 6 Spinner with charged acrylic rod**

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. Where does Teflon lie with respect to silk in the triboelectric series?

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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?
What does this movement say about the polarity of the VDG. Are you results consistent?

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# Activity 7-2 Electric Firefly

**Overview:**
The firefly consists of a mini salt and pepper partially transparent canister from Dollar Tree that. A mini electronic neon glow light bulb is placed on the inside with two wires coming out of the shaker holes on the top as shown in **Fig. 7.** One wire is connected to the anode and the other is connected to the closely spaced cathode inside the bulb. The glass also contains a low-pressure neon gas mixed with another gas that when ionized it gives off an orange light when high voltage and sufficient current is applied. It is used as an indicator light in the electronics industry or even a check engine light in your car**.** The wires are glued so that they hold the firefly suspended inside the cannister. The firefly in the class kit comes pre-assembled.

**Fig. 7** A mini salt/pepper cannister with a neon gas filled bulb with wires from its anode and cathodes protruding from the holes in the top

**Objective:** (1) Show that that the indicator light can made to glow with the voltage from the VDG stick. (2) Show it can be made to glow with charged Teflon Rod.

**Materials:**

- Handheld Van de Graaff
- Teflon rod with silk cloth
- Cannister with neon bulb

**Procedure (1) VDG stick:**

1. Dim the lights in the room.

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2. Turn on the VDG and hold it as close as possible to the capsule. What do you see? It should see an orange glow that comes on and then turns off. After the VDG discharges and the spark stops, the glow stops until the VDG voltage increases again until it discharges the neon bulb and the process repeats itself. If you touch one wire with your finger, it might stay on almost continuously since it requires less voltage if you provide a path for the current to flow.

**Procedure (2) Teflon rod with silk cloth:**

1.The charged Teflon rod does not produce as much voltage as the VDG. It requires a little more care to get a glow. Here is a reliable method to get the neon bulb to glow..
You need to get closer to the bulb itself. Unscrew the cap and remove the top and set it upside down on your table with the bulb facing upwards.

2. Now dim the lights again – maybe even more than before.

3. Rub the Teflon rod with silk to get it charged up as best as you can. Bring the rod as close as possible to the bulb. First the bulb will be attracted to the rod and then when it touches the rod the spark will occur. What do you see in the firefly capsule when the discharge occurs? The glow will occur

4. If the glow does not occur, try charging the rod up again. If the relative humidity is higher than 50%, you may not get enough charge on the Teflon rod. You may also try touching one of the protruding wires while bring the rod close to the bulb. Usually steps 1-3 work.

**Questions:**

1. Why does the glass bulb get attracted to the rod when you bring the rod close to the bulb?_________________________________________________________________________
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2. Why don't you have to take the glass bulb out of the container to get it to glow using the VDG? ________________________________________________________________
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3. When the spark occurs and ionizes the gas, how is the light generated? Use ideas from the atomic model of the atom_____________________________________________
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# Activity 7-3: Electric Levitation

**Objective:** Levitate thin conductive strips by means of electric repulsion.

**Materials:**

- Thin conductive strips or pieces of thin foils provided. You may use any of the provided shapes in the booklet
- Handheld VDG

**Procedure:**

1. Unfold the band-shaped conductive strip and hold it in one hand. Use the handheld VDG to generate charge. Release the strip and touch it with the handheld VDG. **Fig. 8** is an illustration of a successfully charged strip. What shape does the strip turn into? What does this have to do with static electricity?

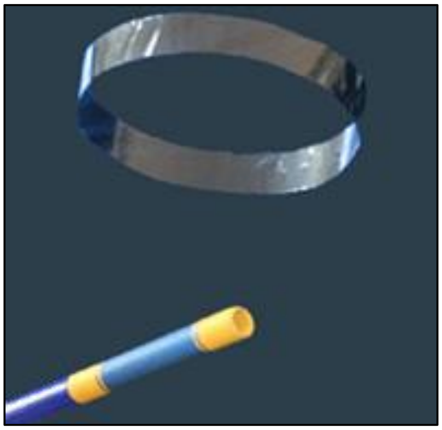

**Fig. 8 Levitating circular charged conducting strip**

2. Keep the handheld VDG underneath the strip to levitate the strip. Some people might claim the handheld VDG produces a shield against gravity. Is that true? What keeps the strip from falling to the ground?

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3. Reach your palm towards the strip but don't get too close. How does the strip respond to your "beckoning hand"? Why?

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4. Now touch the strip with your hand. What shape does the strip turn into? Why?

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# Activity 7-4: Faraday Cage

**Introduction:**
A metal wire mesh screen that is connected to ground can be used to prevent an electric field from permeating through the space behind it. If the screen surrounds some space entirely, then anything inside feels no electric field from the outside, even if the screen is not grounded any more. The Faraday Cage consists of such a screen that closes upon itself to provide shielding from any electric field outside the cage. A common example of a Faraday Cage is an elevator. Cell phone signals are blocked inside the elevator unless a relay antenna is installed. A metal car could also be a Faraday cage if it weren't for the windows. A wire mesh screen also acts as a Faraday cage even though it it has small holes in it. A microwave has such a screen and is used to block the microwaves from coming through the glass window.

**Objective:** Demonstrate the shielding effect of a wire mesh screen.

**Materials:**
- Handheld Van de Graaff
- Wire Mesh Screen
- Electroscope (you may use the spinner and a charged Teflon rod instead of the electroscope)

**Procedure:**
1. Neutralize the electroscope by touching the brass support with your finger. The tube should be at a negligible angle against the brass support.

2.Turn on the handheld VDG and move its front end to about 5-10 cm away from the electroscope. See **Fig. 9** for the geometry. How does the tube behave when the charged VDG approaches it?

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**Fig. 9** Charged VDG is held near the electroscope tube but not touching.

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3. Turn off the handheld VDG and neutralize the electroscope again. Now, hold up the wire mesh screen about 5 cm in front of the electroscope. Make sure your fingers are in contact with the metal part of the screen. Then repeat step 2. See **Fig. 4**. How does the tube behave this time? What makes the difference and why? (Hint: Recall the activities on “charge by induction/polarization at the beginning of Activity 6”)

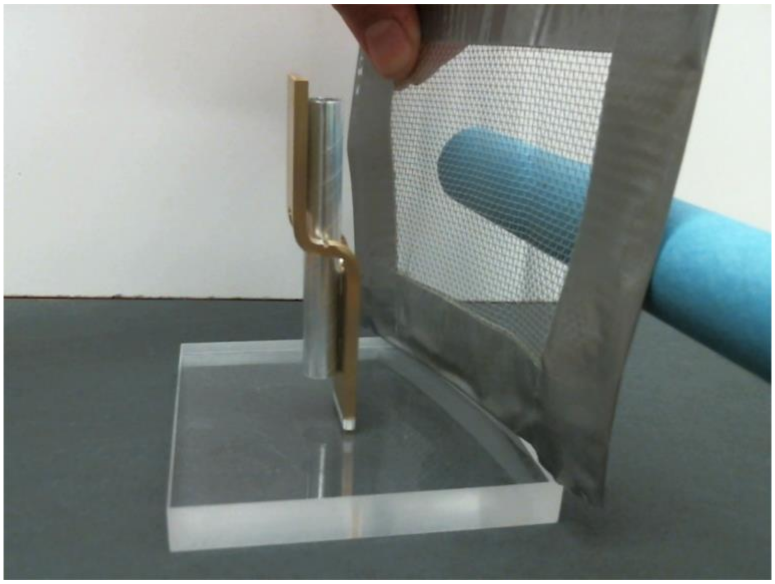

**Fig. 10**

4. If the mesh screen were made from an insulating material, would it still act as a Faraday cage?
Explain.______________________________________________________________

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# Activity 7-5: Flying Saucer

**Objective:** Observe the strength of static electricity compared to gravity.

**Materials:**

- Handheld VDG
- Small Pie Tins x 5 (from home or Dollar Tree)

**Procedure:**

1. Get 5 small pie tins that are used to make mini tarts. Hold the handheld VDG pointing straight up. Stack the pie tins upside-down on the tip of the handheld VDG

2. Press the button on the handheld VDG to start the charge generation process. Describe the reaction of the pie tins.

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3. What causes the pie tins to fly off as in **Fig. 11**? Describe the role of static electricity in the takeoff process

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**Fig. 11 The handheld VDG is shown blowing the pie tins upward**

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