

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.

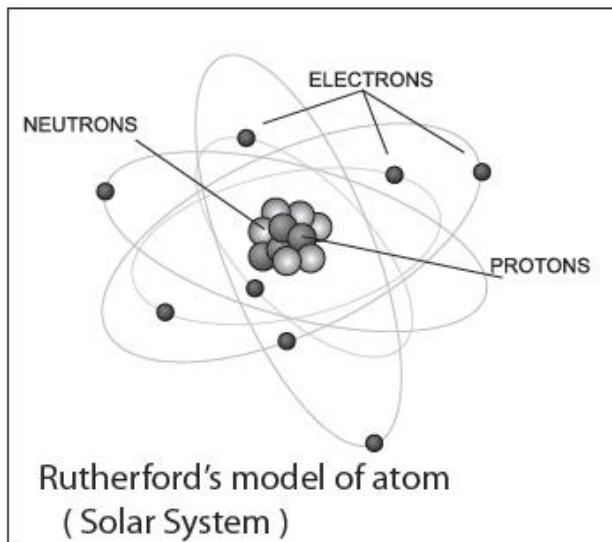


Fig. 1 Solar System Model (a.k.a Rutherford's Model of Atom) is the most common way to picture an atom. The model describes electrons orbiting around the nucleus in a fashion similar to planets orbiting the Sun. Just like planets have their orbits and are located at different distances from the Sun,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

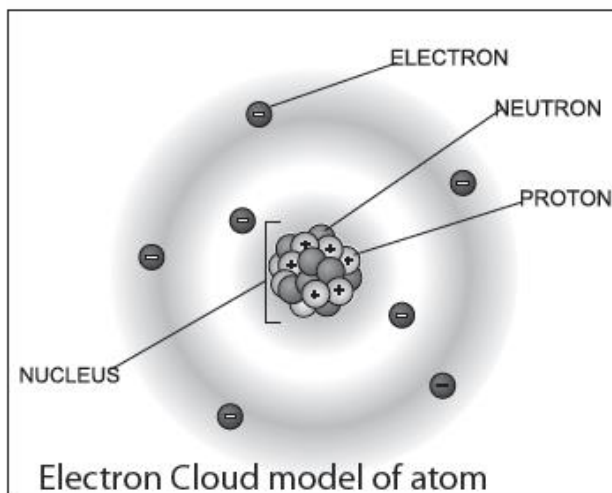


Fig. 2 The Electron Cloud Model claims that there are no orbitals. Instead, the electrons are located around the nucleus within certain boundaries or shells.

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.

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 its 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.

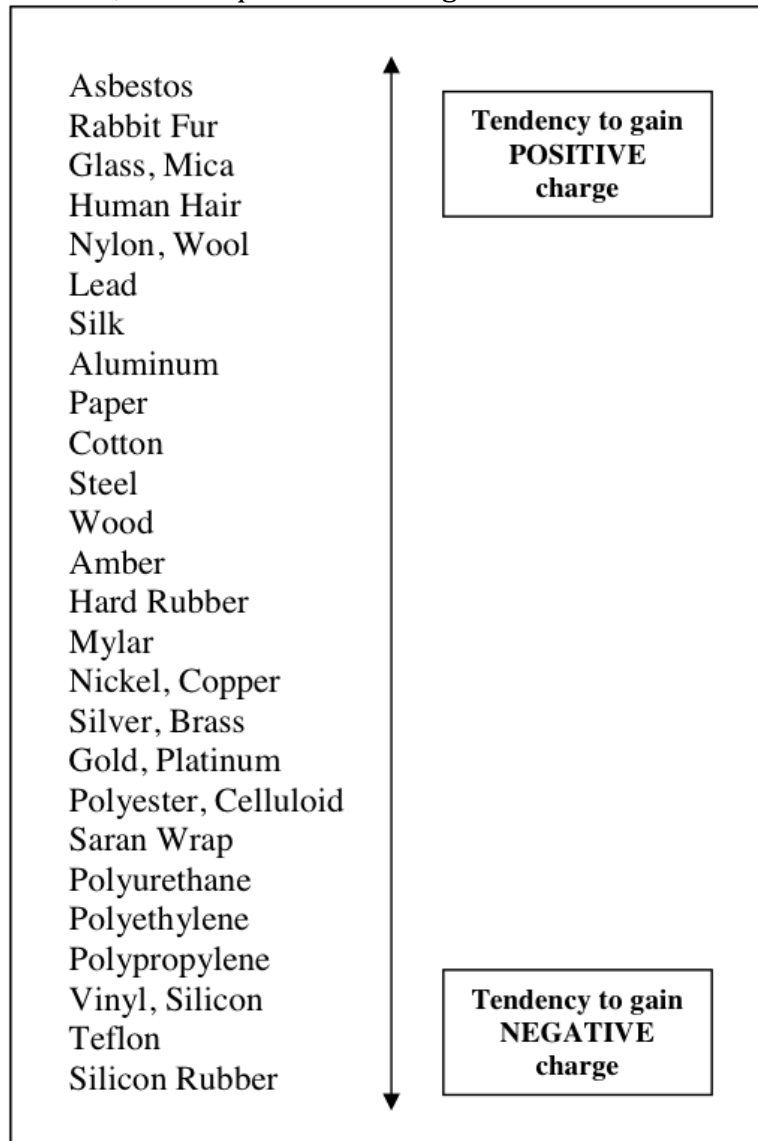


Fig. 3 The triboelectric series shows the relative tendencies of objects to gain positive (lose electrons) or negative charges (gain electrons) when rubbed against one another.

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

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

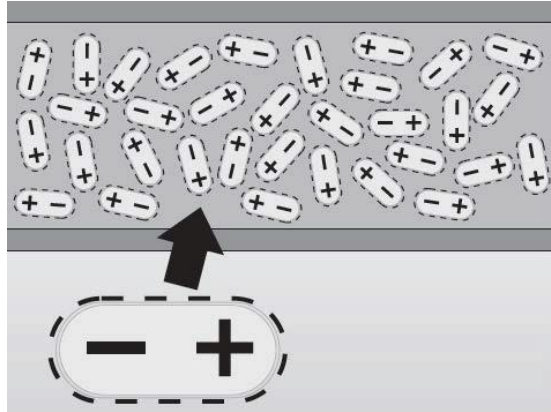


Fig. 4 Each oval represents an atom. Each neutral atom has an equal amount of negative charge (electrons) and positive charge (protons)

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.

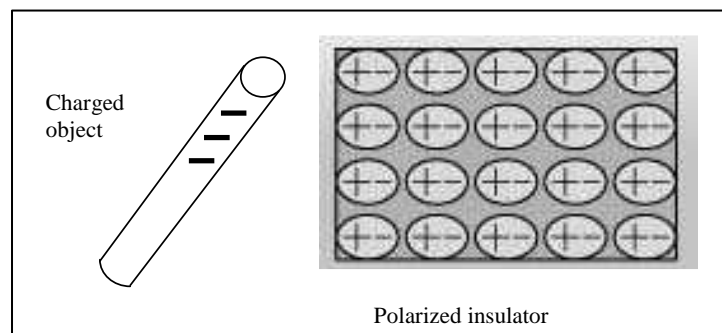


Fig. 5 A charged object is shown polarizing a neutral piece of material. Note how the positive and negative charges are alternate in the material.

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. Supported by the University of Virginia Physics Department and Curry School of Education through the SCHEV Math-Science partnership



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.

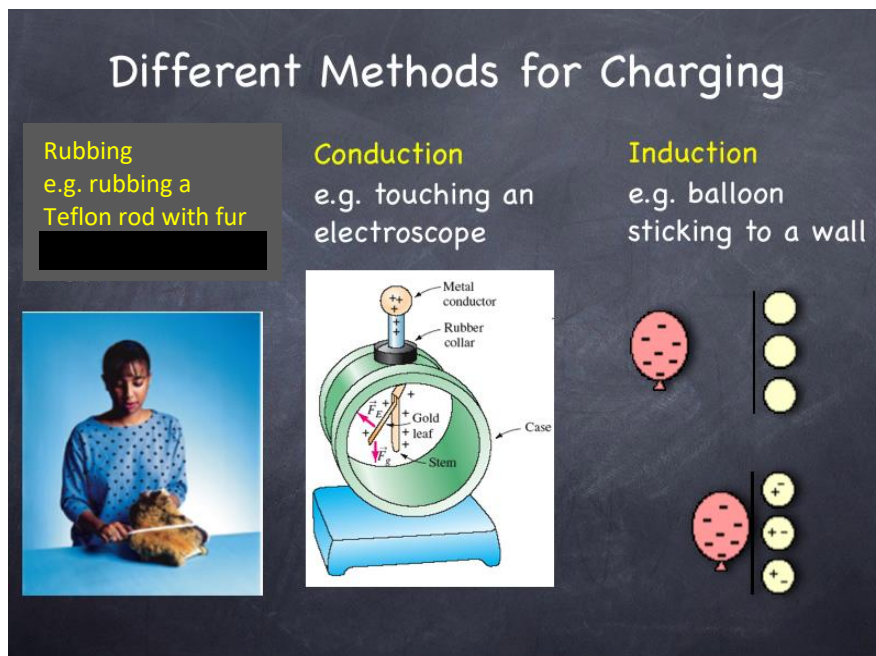


Fig. 7 The three primary ways to electrically charge an object

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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**

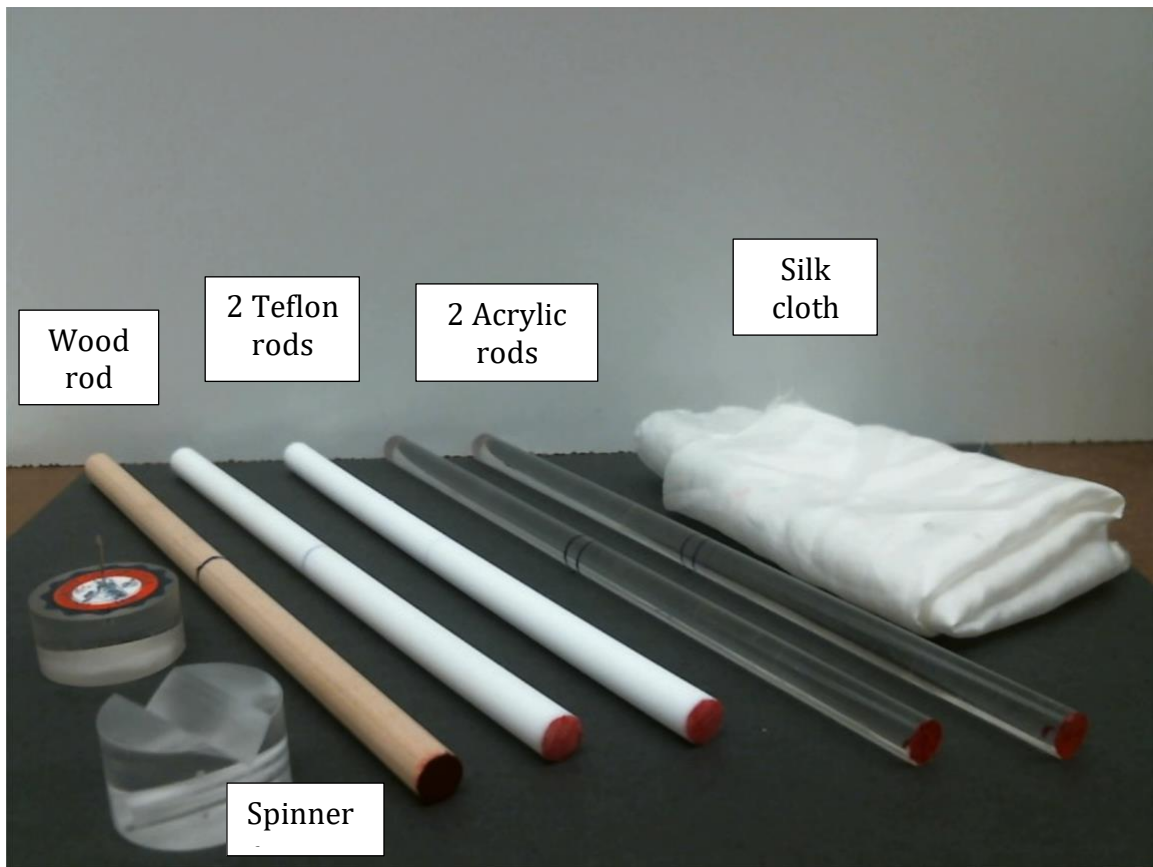


Fig. 8

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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.

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

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

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

Explain

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

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

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

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

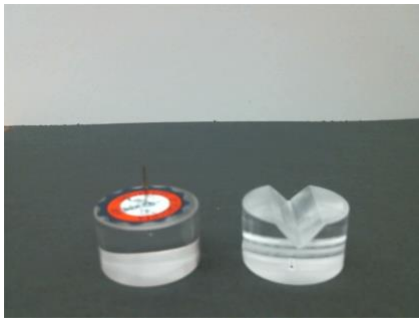


Fig. 9



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**.



Fig. 11.



Fig. 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.

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?**

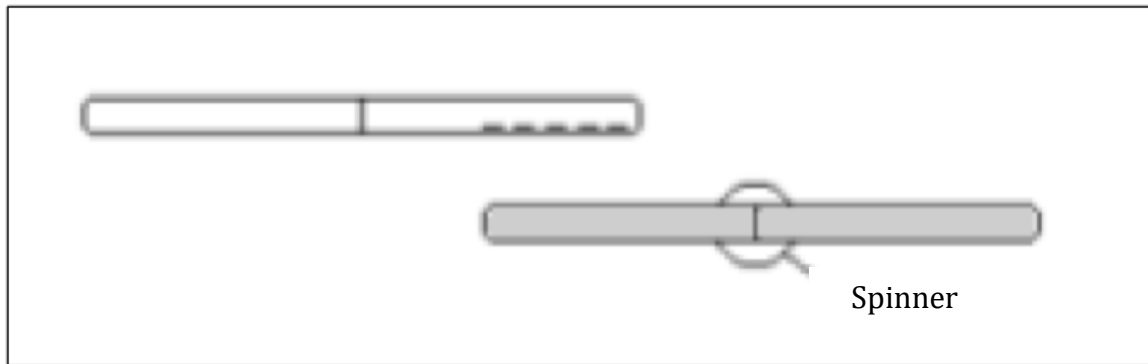


Fig. 13 An uncharged wooden rod is placed on the spinner. A Teflon rod is then charged and used to rotate the wooden rod without touching it. Note the direction of the electric force between the two.

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)		

Paper (0)		
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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.

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)

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