Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

This lesson consists of three activities: The Levitating Ring, Balloons and Cans, and Predicting Charge and Movement. Each requires one 50-minute class period. In the first activity, students engage with static electric charges and forces, ask questions, and share what they notice. In the next two activities, students work with various objects to generate static charges, then analyze how charges can sometimes make objects move. The activities should be conducted after Magnets, 4.P.1.1.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Objects can transfer and accumulate charge.
- Objects with similar charges repel each other.
- Objects with different charges attract each other.
- The attractive and repulsive forces between charged objects can be strong enough to move objects.

Students demonstrate this knowledge and understanding by predicting how charged objects will react when placed next to each other.

Correlations to NC Science Standards

4.P.1.2 *Explain how electrically charged objects push or pull on other electrically charged objects and produce motion.*

Brief Science Background

Sometimes, when two objects are rubbed together, electrons move between them so that one object gives up electrons and the other takes on those electrons. This gives the objects static charges. We usually think of "static" as meaning unmoving or unchanging, but these charges do move and change. Static electricity refers to accumulated electrical charges as opposed to electric current flowing in a circuit.

Objects that take on extra electrons are negatively charged. Objects that lose electrons are positively charged. Different materials give up or accept charges differently. For example, when a balloon is rubbed on someone's hair, it picks up electrons from the hair and becomes negatively charged. It can then be made to stick to a nearby wall. This is because the wall doesn't have a negative charge, and objects that have different charges are attracted to one another. However, two balloons that are both negatively charged resist being pushed together, that is, they repel each other.

Part 1 — The Levitating Ring – 50 minutes

Materials

Materials for the whole class

- 5-6 thin plastic grocery bags (to be supplied by the teacher)
- A plastic ring and rod to demonstrate the levitating ring

Materials for groups of 2 students

- 1 plastic rod
- 1 plastic ring made from a grocery bag (see diagram 1 black line masters)
- 1 wool fabric sample

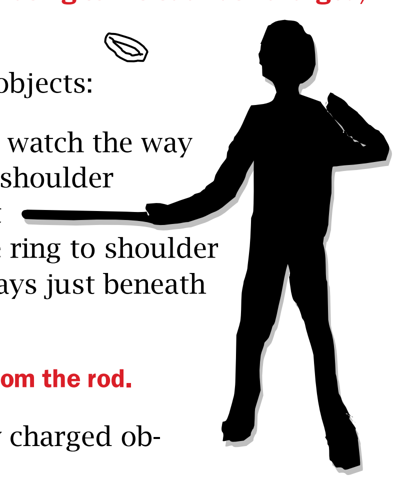
Preparation

This activity works when humidity is low, but not in moist air. Before trying this with your students, charge a rod and ring and practice moving the ring through the air. If the air is dry enough, you will easily levitate the ring after a few tries. If you have difficulty levitating the ring, the air is too moist. In that case, skip this activity and begin with Part 2: Balloons and Cans on the next page. If it is dry enough to levitate the ring, use the template on BLM 1 in the Blackline Masters to precut grocery bags into loops for students.

Procedure

Activity—50 minutes

NOTE: This lesson (Part 1) is intended for students to engage with materials and concepts, ask questions, and share what they notice. Avoid teaching content at this time, even during discussions. In this initial exploration, avoid using terms such as “charged,” “uncharged,” or other references to static electricity.



1. Demonstrate “normal” behavior of uncharged objects:

   Show students the plastic ring and ask them to watch the way to it falls to the floor when you release it from shoulder height. Then show them the plastic rod. Hold it in one hand and the ring in the other. Raise the ring to shoulder height and release it. Move the rod so that it stays just beneath the falling ring. Do not let it touch the ring.

   The ring should drift to the floor without any affect from the rod.

2. Demonstrate the unusual behavior of statically charged objects:

   Let students watch as you charge the plastic rod by rubbing it with the wool fabric for about 10 seconds. Charge the plastic ring by holding one edge down on a non-metallic table and swiping it with the wool in the same direction about a dozen times. Then repeat the step above in which you release the ring and move the rod just beneath the falling ring without touching it. The ring will stop falling, and with a little juggling, you can keep the ring floating above the rod.

Part 1 (cont.)

3. Ask students to describe what they saw. Students should say that the rod kept the ring from falling, or the rod appeared to lift the ring.

   Ask students to think of an explanation for what they just saw: why did the ring stay in the air after the ring and the rod were rubbed with wool? **Accept all answers at this time, and then let them know that they will be able to provide an answer for this soon, after they conduct some experiments for themselves**.

4. Ask students, working in pairs, to experiment with the plastic rods, rings, and wool and see if they notice any factors that might influence the behavior of the rod and the ring. **Students might notice that if the rod is too far from the ring, the ring will begin to sink. It will also appear to be pushed down if the rod is held above the ring.**

Part 2 — Balloons and Cans - 50 minutes

Materials

Materials for the whole class

- 1 balloon pump
- balloons
- 15 32-oz deli containers with lids (to make charge detectors)
- 15 12-inch lengths of bare copper wire (to make charge detectors)
- 15 hollow plastic coffee stirrers (to make charge detectors)
- aluminum foil sheet (to make charge detectors)

Materials for groups of 2 students

- 1 charge detector
- 1 plastic rod
- 1 wooden rod
- 1 metal rod
- 1 inflated balloon with string
- 1 empty soda can (supplied by the class)
- 1 wool fabric square
- 1 cotton fabric square
- 1 fleece fabric square

Part 2 (cont.)

Preparation

1. Assemble the charge detectors (1 per group of 2); see BLM 1 Plastic Bag Levitation Ring Template and BLM 2 Charge Detector Assembly in black line masters at the end of this section.
2. Use the balloon pump to inflate and tie off the balloons. Attach strings to the inflated balloons.
3. Have one uncharged balloon with no string and a detector ready for steps 2 and 3.
4. Collect 15 empty aluminum soda cans.

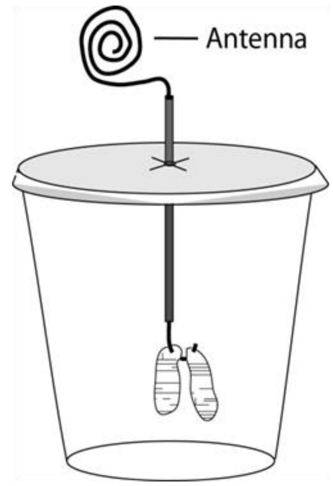


Diagram 2: Charge Detector

Procedure

Activity

1. If you did the levitating ring activity, explain that after the rod and plastic ring were rubbed with wool, they showed one way that objects can behave when charged with static electricity. If you did not do the levitating ring, say that the class will work with static electricity, and you have an instrument, called a charge detector, that shows when something is charged with static electricity. Every pair of students will get their own charge detector.
2. Demonstrate the charge detector to prepare students to try it for themselves. Circulate with an uncharged balloon and charge detector so students see the balloon and detector close-up. Do not touch the antenna with the balloon or your hand. Carefully move the balloon closer to and farther away from the antenna and ask students to look carefully at the "leaves" inside the detector. Moving the uncharged balloon toward and away from the antenna should have no effect.
3. Demonstrate charging a balloon by rubbing it vigorously with cotton or on your shirt. Again, do not touch the antenna with the balloon or your hand. Move the charged balloon toward the detector's antenna then back, so that the leaves clearly move. Circulate for students to see this. Ask them what they notice. **They should notice foil leaves moving.**
4. Give out balloons and charge detectors and ask students to do likewise with their team's balloon and charge detector. See if they can get the foil leaves to move *without touching the antenna*.

NOTE: If a charged object touches the antenna, electrons transfer to the foil leaves so that the leaves will continue to repel each other until the system is discharged. The leaves in the charge detector still move, but they do not come together unless discharged or unless something with opposite charge approaches the antenna. In every case, the charge detector responds with leaves *moving,* regardless of how they move.

Part 2 (cont.)

5. Explain that when a charge is near the detector, the foil leaves move. If the leaves move in any way, either apart or together, a charged object is near the antenna.

6. Charge a plastic rod with cotton and move it near a balloon that you hold up by a string. Show students that the charged rod moves the balloon. To show that the rod was charged, hold it near the charge detector to make the leaves move. Ask students to describe what they saw. **If they haven't used these terms already, remind students of "attract" and "repel", terms that they used in their studies of magnets.**

7. Challenge students to use the different cloths and rods to come up with their own demonstrations of movement between rods and balloons. Each time after they try to move the balloons, ask them to check for charge of both rods and balloons with their detectors.

   Notebook prompt: *Record which cloth-and-rod combinations make a balloon move the most. Also record whether the rods and balloons were charged.*

8. Discuss students' answers to the notebook prompt as a class.

9. Charge a plastic rod with a piece of cotton. Use the detector to confirm that an empty soda can is not charged. Move the charged rod close to the uncharged can lying on its side. Make sure students see the can move without the rod actually touching it. Ask students to try to do the same with their rod, cloth, and can. After they try to move the can (whether it moves or not) ask them to use the detector to confirm that the rod is charged.

10. Challenge students to use the different cloths and rods to come up with their own demonstrations of movement between rods and the empty soda can. After each trial, ask students to use the detector to confirm that the rod is charged.

    Notebook prompt: *Record which cloth-and-rod combinations made the can move the most. Also record whether the rod was charged on each trial.*

11. Discuss students' examples of charged objects (rods, balloons and soda cans) and the various movements they caused. Ask students to describe the different kinds of movement they saw between charged objects.

    Descriptions should include the words attraction and repulsion. Remind students that the foil leaves moving apart in the charge detector are responding to repulsion.

Part 2 (cont.)

Wrap Up

Notebook Prompt: *Write some general rules about charged and uncharged objects and making things move.*

1. Ask students to share their ideas about charged and uncharged objects and their abilities to cause movement.

   Students might say that charged objects can make other charged objects move without touching, and charged objects can also make uncharged objects (the soda cans) move without touching. However, two uncharged objects don't make each other move without touching. (If a student says that magnets make things move without touching, even though magnet and the thing are not charged, accept this. It will be discussed next.)

2. Ask the class to compare charged objects and magnets. How was the movement of the empty soda can in this activity like what happened with the magnets?

   Charged objects can either repel or attract other objects. Often the charged objects attracted other charged objects. This is similar to the way two magnets attract each other if their opposite poles are held near each other. Magnets also attract things made of iron, similar to the way the charged rods attracted the uncharged soda can. Students may have seen the foil leaves in the charge detector move away from each other. This is like two magnets repelling when their like poles are brought together.

3. Movement involving charged objects and movement involving magnets are similar, but the causes of the movements are different. Tell students that the effects of static electricity they saw today are produced by a static electric charge, which happens when one object gives electrons to another. Electrons are parts of the small atoms that make up everything. If the charges on two objects are the same, the objects repel each other. If two objects have different charges, they attract each other. This is like the magnet activity in which students found that opposite poles attract and similar poles repel. Project BLM 3 and leave it up for the following activity:

Part 3 — Predicting Charge and Movement (50 minutes)

Materials

Materials for the whole class

- balloon pump and balloons to pre-inflate
- a meter stick for demonstration (supplied by the teacher)
- string to pre-tie the balloons
- BLM 3 visible to all students:
  Same Charge – Repels, Different Charges – Attract

Materials for pairs of students (if you intend for students to experiment)

- 2 balloons on strings
- a meter stick (supplied by the teacher)
- charging rods and cloths

Preparation

1. Inflate a pair of balloons and attach strings for demonstration.

2. Loosely tie the free ends of the strings to a meter stick. Leave open loops to allow you to freely move the strings and balloons along the meter stick.

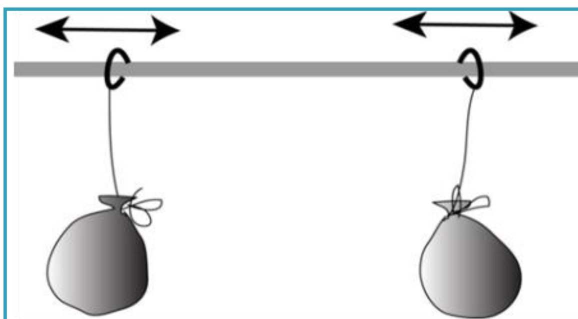
3. If you expect students to experiment with the system, inflate additional balloons for student groups (2 balloons/group), tie 12" string to each, and provide meter sticks.

Procedure

Activity

If you *can* do this activity, it is important to do it. However, moist air can produce confusing results, so try every part of this activity before doing it with your class. Skip the activity if the balloons do not attract or if the two charged balloons behave the same way with the charged rod (both attract or both repel).

1. Project BLM 3: Rules of Charge Attraction and Repulsion and show the class two balloons hanging from a horizontal stick. **You might need a student to help hold the meter stick.** Bring the balloons close enough to one another to rub them vigorously together for 30 seconds, then move them as far apart as you can. Finally, ask the class to watch what happens while you bring the balloons close to each other. **The balloons will be attracted to each other.**



Movable Balloons on a Stick

2. Ask students what they think the behavior of the two balloons placed close to one another tells us. How did they move, and what does this mean about their charges? **They are attracted, so they must have different charges. Students only need to know that the balloons now have different charges. This activity provides no information to determine the charge on each balloon. When the balloons rub together, electrons from one transfer to the other. The balloon that gives up electrons**

Part 3 (cont.)

becomes positively charged and the one that takes on extra electrons becomes negatively charged, but we can't tell which is which.

3. Use the strings to separate the balloons (avoid touching them). Move the balloons to opposite ends of the stick so that they no longer attract each other but remain charged. Charge a plastic rod with wool and place it near one of the balloons. Keep the rod well away from the other balloon. The rod will either attract or repel the balloon that you chose.

4. Ask the class what they think about the charges of the balloon and the rod. **If the rod repelled the balloon, both objects must have the same charge, because like charges repel one another. If the rod attracted the balloon, the balloon and rod must have different charges, because different charges attract one another**.

5. At this point, having tested only one balloon, ask the students to predict what the charged plastic rod will do to the other balloon. Ask for their reasoning. **Give students time to work through their logic about this. They need to remember that the balloons were attracted to each other after being rubbed together. This means that the balloons have different charges. However, the plastic rod is charged in just one way, either positively or negatively, but they don't know which. (It doesn't matter if it is positive or negative.) since the balloons both have different charges, whatever the rod did to the first balloon (attract or repel it), it will have to do the opposite thing to the second one.** Perform the demonstration. Discuss what happened to check for understanding.

6. Ask a student to hold a stick up and out at arm's length. Rub a balloon-on-a string with wool to charge it and hang the charged balloon on the end of the stick. Charge a second balloon-on-a-string with wool and hang it on the opposite end of the stick from the other charged balloon. Ask the class what they think the two balloons might do moved closer together. Bring the two balloons near each other and ask what this tells us about the charges of the balloons. **The balloons will repel because they have the same charge.**

7. Separate the charged balloons. Charge the plastic rod with wool and ask students what they think will happen when the rod is placed near one of the balloons. **They don't know the charge of the rod, and can only predict that the balloon will move, either repelled or attracted. Once they see how one balloon moves, they should be able to predict what will happen with the other one. The two balloons repel each other, so they both have the same charge. Students should be able to reason that the second balloon will do the same thing as the first one.** Conduct these demonstrations and check for understanding.

8. If time allows, let students experiment with this setup.

Notebook Prompt: *Explain how the plastic ring was able to stay in the air when the plastic rod was held underneath it.*

Part 3 (cont.)

Rubbing both objects with wool made them both have the same charge. Like charges repel, so when the rod was underneath the ring, it pushed the ring upward and kept it from floating down.

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following “test items” to the class. Ask them to write responses in notebooks. You can project the following from BLM 4.

1. A student said that if you charge two of the same kind of object by rubbing them with the same kind of cloth, the two objects will have the same charges and attract each other. What do you think about this statement? Support your answer with an example from class.

2. A student rubbed a cotton cloth on a plastic rod and an empty aluminum can. The can rolled toward the plastic rod when they were placed close together on a flat surface. You can conclude:

   A. The plastic rod and can have the same charges.

   B. The plastic rod and can have different charges.

   C. There are no static charges on either object.

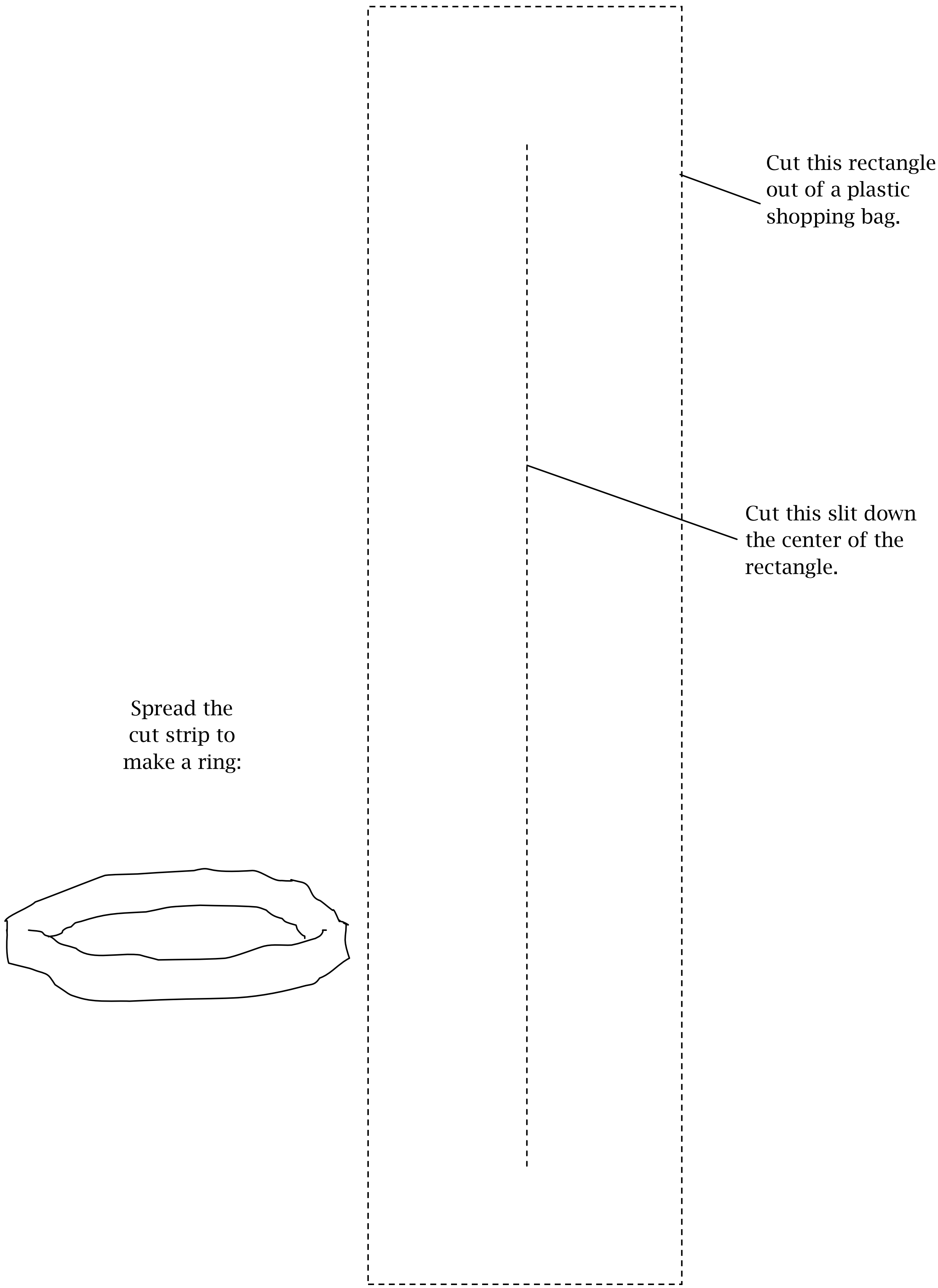
   D. The aluminum is non-magnetic.

Answer Key

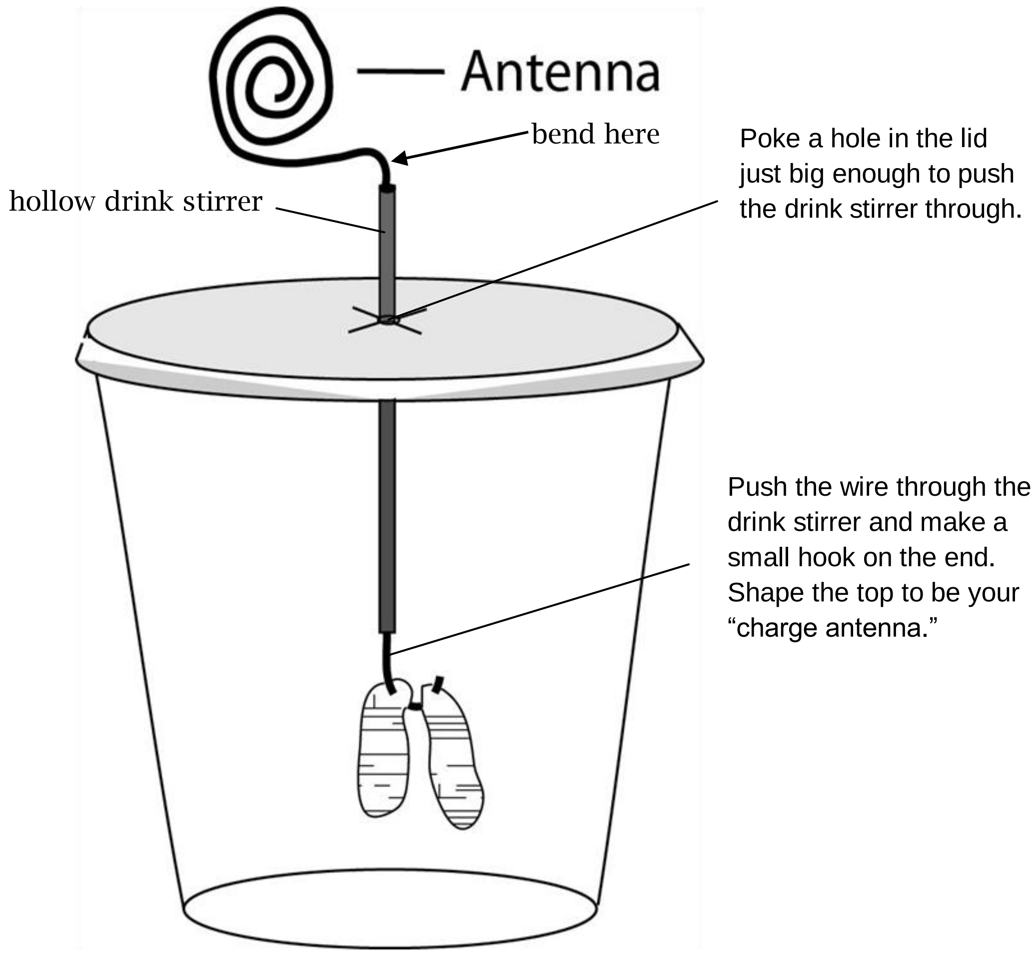
1. The student is correct about the charges of the objects, because if you charge two of the same kind of object by rubbing them with the same kind of cloth, the objects will have the same charges. But the student is not correct that the objects will be attracted to each other. To be attracted, two objects must have different charges. Instead, the two objects will repel each other. An example from class was when two balloons charged with the same kind of cloth repelled each other. (Students may have other examples depending on what experiments they tried with cloths, rods, and balloons on their own.)

2. B is correct. The plastic rod and the can have different charges. The correct answer cannot be choice A because if the rod and the can had the same charge, they would repel each other. It can’t be C because if there were no static charges, the can would not roll toward the rod. It can’t be D because neither the rod nor the can is magnetic, as students discovered in their previous study of magnets. Therefore, the can and the rod can only be attracted

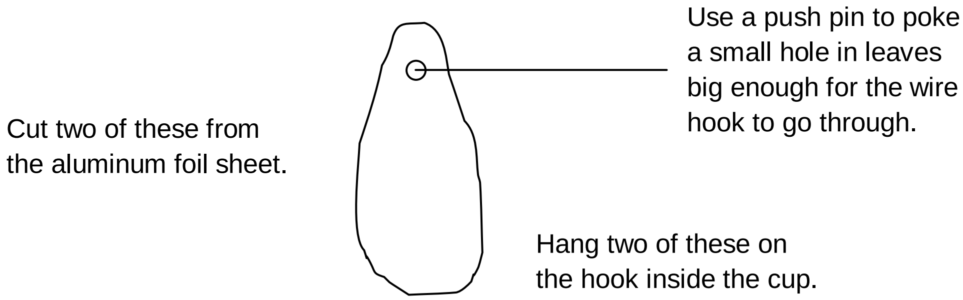
BLM 1: Plastic Bag Levitation Ring Template



BLM 2 - Charge Detector Assembly



Aluminum Foil Leaves



BLM 3: Rules of charge Attraction and Repulsion

Same Charge – Repels

Different Charges – Attract

BLM 4: Guided Practice

1. A student said that if you charge two of the same kind of object by rubbing them with the same kind of cloth, the two objects will have the same charges and attract each other. What do you think about this statement? Support your answer with an example from class.

2. A student rubbed a cotton cloth on a plastic rod and an empty aluminum can. The can rolled toward the plastic rod when they were placed close together on a flat surface. You can conclude:

    A. The plastic rod and can have the same charges.
    B. The plastic rod and can have different charges.
    C. There are no static charges on either object.
    D. The aluminum is non-magnetic.

Appendix

Common Student Preconceptions About This Topic

Children's most common association with static electricity involves feeling a shock from walking across a rug, or seeing hair stand on end when someone removes a sweater. The idea of electrons is a pure abstraction for children of this age, so explanations involving atoms and electrons are not likely to be retained or be involved in sense-making. As with magnetism, they tend to lump attractive forces together with gravity. Although lightning is a powerful example of static electric discharge, children tend to see it as a force of nature and a part of weather rather than an example of static electricity. However, giving children an opportunity to concretely experience and produce these forces can give them a clearer sense that attraction and repulsion can result from doing something to charged objects. Most fourth graders simply take the teacher's word that there are two different kinds of charge, and that different arrangements of those charges can cause attraction and repulsion.

Detailed Background Information

An atom is the smallest bit of an element that can exist and still have the chemical characteristics of a larger piece of that same element. All atoms consist of a central nucleus with one or more electrons circling it in three dimensions. A hydrogen atom has only one electron, but an atom of silver has forty-seven, which orbit around the nucleus in several layers. Regardless of the number of electrons an atom has, all electrons are negatively charged.

An atom's nucleus also contains protons, which are positively charged. Atoms usually have the same number of protons and electrons. The protons' positive charges balance the electrons' negative charges, so atoms usually have no net electrical charge. However, sometimes when two different materials rub together, electrons transfer from one to the other so that one object loses electrons and the other gains them. The transfer of electrons between objects creates static electricity.

Objects that lose electrons have more protons than electrons, and they become positively charged. Objects that gain extra electrons have more electrons than protons, and they become negatively charged.

Charged objects behave much like magnets and magnetic objects. When the same poles of two magnets are brought close together, the magnets repel each other. Similarly, when two objects bearing the same charge are brought close together, they repel each other. For example, if a balloon is rubbed on someone's hair, the individual hairs "donate" electrons to the balloon. Since the individual hairs are now all positively charged, they repel each other and stand up away from the scalp and away from one another. Rubbing a balloon in hair provides a truly "hair-raising" experience.

Appendix (cont)

A balloon rubbed on hair becomes negatively charged because it gains excess electrons on its surface. If the balloon is held near the hair, the hair is attracted to the balloon. This can be seen by passing a charged balloon over and around the head of the person who charged it. As the balloon moves past, the hairs bend toward it.

A balloon that has been charged by rubbing it on hair will also stick to a wall (or most any other vertical surface). The wall is ordinarily neutral, or uncharged, but when the negatively charged balloon is brought near, electrons on the surface of the wall are repelled and move as far from the balloon as they can. With the electrons moved aside, excess protons are left near the balloon. Since opposites attract, the balloon sticks to the wall. Students will observe this in the activity involving a statically charged rod and an uncharged empty soda can. The balloon will not stick to the wall indefinitely. Eventually, electrons on its surface “leak off” and redistribute among available protons on the balloon and in the air.

Some materials are more likely to give up electrons when in contact with another material, and some are more likely to take on electrons. For example, glass, hair, and nylon are good electron donors, and tend to become positively charged. Plastics are often good at accepting electrons and becoming negatively charged. Some combinations of materials will transfer very few electrons. For example, rubbing paper with cotton will not produce much static charge.

Weather conditions also affect buildup of static electricity. For example, people experience more static shocks in the winter when walking across a carpet and touching a doorknob. Humid summer air reduces static charging, but dry winter air promotes the buildup of charges in hair, clothes, and blankets.

A bolt of lightning is a spectacular large-scale discharge of static electricity. It occurs during storms when charges in the clouds and opposite charges on the ground are strongly attracted to each other. Immediately before the charges meet as a bolt of lightning, the ground charges first flow upward on trees or other tall structures, which is why lightning usually strikes tall structures beneath the charged clouds.