Electrostatics:

Laboratory for Secondary Level Students

Teacher Manual

WOMEN SUPPORTING
WOMEN IN THE SCIENCES

Mission Statement

This laboratory will teach electrical energy concepts to a target audience of middle and high school/secondary-aged students (ages ~12-18) through experiments related to static electricity.

Contents

1. Introduction to WS2 Laboratories

1.1. Information about WS2

Women Supporting Women in the Sciences (WS2), an international organization unifying and supporting graduate and professional-level women and allies in science, technology, engineering, and mathematics (STEM), was awarded an American Physical Society (APS) Innovation Fund in 2020 to form international teams to design and distribute low-cost physics and materials science lab kits to 5000 primary and secondary school students, predominantly in eastern Africa. The lab kits are intended to utilize local resources and include topics that are especially relevant to young girls in order to spur their interest in STEM subjects. The international teams, which designed the content found in these laboratory manuals, worked with WS2 Partners in eastern Africa in order to successfully deliver and teach the science lab kits to their local communities through 2022. WS2 gratefully acknowledges the hard work of the teams in the creation of this lab kit content. For more information about WS2, please visit our website at ws2global.org.

WS2 is sponsored by the APS Innovation Fund, Northwestern University Materials Research Science and Engineering Center, and Northwestern University Multicultural Student Affairs. WS2 Partners receiving lab kits are representatives from Makerere University (Uganda), Masinde Muliro University of Science and Technology (Kenya), Mbeya University of Science and Technology (Tanzania), Mkwawa University College of Education (Tanzania), Nelson Mandela African Institution for Science and Technology (Tanzania), University of Dar es Salaam (Tanzania), University of Dodoma (Tanzania), and University of Rwanda (Rwanda). The APS, Materials World Modules, SciBridge, and Projekt Inspire have provided valuable input on WS2 lab kit design. WS2 especially thanks WS2 Partner representatives (John Bakayana, Pendo Bigambo, Daudi Mazengo, Lawrence Robert Msalilwa, Celine Omondi, Marcellin Rutegwa), Tom Coon and students of Haile-Manas Academy (Debre Birhan, Ethiopia), and Carla Johnston and students of Frank Bergman Elementary School (Manhattan, KS, USA) for piloting the lab kits with small focus groups in late 2021. WS2 also tremendously thanks the virtual lab kit design team that created the content for this lab manual.

1.2. Using this Guide

This manual is to be used by the teacher of the laboratory, and it is similar in content to the student manual but contains additional material, namely: Overview, Fundamental Physics and Materials Science Concepts Covered, Practical Skills, Background on Main Topics, Summary of Experiments, Results, Teacher Pre-Lab, Troubleshooting. These additional sections are intended to provide the teacher with the background and foundation critical for successfully implementing this laboratory kit in the classroom. It is recommended that the teachers of this laboratory go through the guide from beginning to end to familiarize themselves with the laboratory content prior to teaching the laboratory to students. Questions about the laboratory content can be directed at any time to ws2global.org@gmail.com, using the subject line "Question about Lab Kit Content".

<u>IMPORTANT NOTES:</u>

- This laboratory is intended for use with secondary-level students (ages ~12-18), but depending on the specific students' educational background, the content may need to be modified by the teacher to be made simpler or more complex. The teacher is encouraged to also cover the laboratory content at the pace that works best for the students; some younger students may need more time and attention from the teacher and/or facilitator to go through the questions and experiments, while older students may be more independent and require less attention from the teacher and/or facilitator. Thus, the content covered, depth of coverage, and pacing are left to the teacher's and/or facilitator's discretion.
- The content in this lab manual may not fit into the specific curriculum of the school in which it is being taught. It is up to the facilitator(s) and teacher(s) whether they would like to introduce new content or skip certain sections that are not applicable to their classrooms.
- In certain areas, modifications to the supply list may need to be made depending on the availability of the supplies in the specific area in which the lab is being taught. We have attempted to list some alternatives in the supply list, but we understand this list of alternatives is not exhaustive.
- In the experiments, the students are split into groups of three to four. If supplies allow, students may instead be split into groups of two.

1.3. Key Vocabulary

- Electric charge: One of the basic properties of elementary particles of matter giving rise to electric and magnetic forces and interactions; the two types of charges are positive (+) and negative (-), and the negative charge is also known as an electron
- Static electricity: A stationary electric charge, typically produced by friction, which causes sparks, crackling, or the attraction of dust or hair
- Lightning: The occurrence of a natural electrical discharge between a cloud and the ground or within a cloud
- Lightning rod/ lightning conductor: A metal rod used to protect someone or something from being damaged by lightning

1.4. Key Questions

- How does lightning occur?
    - Answer: The build-up of negative charges at the bottom of the cloud in a thunderstorm causes an attraction of positive charges nearby. Eventually the charges between the two locations connect and a large and fast discharge occurs, resulting in the characteristic flash of lightning! This discharge can happen within the cloud itself, but sometimes the charges travel between the cloud and ground beneath it.
- What are the two types of charges?
    - Answer: Positive (+) and negative (-), and the negative charge is also known as an electron
- What are some general rules about static electricity?
    - Answer: Objects can become charged by rubbing them against other objects, like plastic on hair. Same sign charged objects repel each other, while opposite sign charged objects attract each other. A charged object can attract a neutral object by inducing an oppositely charged area in the neutral object close to the charged object. Static charges dissipate over time, and attraction and repelling by static dissipates over distance.
- How can we design a device to protect a building from lightning?

- Answer: We can use a lightning rod made of metal on the exterior near the top of the building that grounds the discharge from lightning (i.e., routes the discharge from the lightning to the ground safely).

1.5. Purpose

The purpose of this laboratory is to learn about electrostatics concepts, culminating in the learning about lightning rods or lightning conductors and how they work. Lightning rods or lightning conductors protect buildings and other structures against lightning strikes.

1.6. Overview

Through this laboratory, middle and high school/secondary-aged students (ages ~12-18) are going to be taught electrostatics concepts through experiments related to static charging, grounding, and lightning rods.

1.7. Fundamental Physics and Materials Science Concepts Covered

This laboratory introduces the topics of electrical charges and statically charged objects, relevant to numerous fields including Physics, Chemistry, and Biology, to middle and high school/secondary-level students. Specifically, the labs encourage students to think about how charged objects attract or repel each other, general rules of static electricity, and the phenomenon of lightning. Students will build a conceptual model that includes the following: (1) objects can be positively charged (+), negatively charged (-), or uncharged (neutral), (2) objects with the same charge repel each other; oppositely charged objects attract each other, and (3) charged and uncharged objects attract each other regardless of whether the charged object has a positive or negative charge.

1.8. Practical Skills

- Students will understand static charging and how this can lead to objects being repelled or attracted to each other.
- Students will understand how lightning occurs and how to protect themselves and/or structures from lightning.
- Students will connect electrostatics concepts to everyday experiences at school and home (e.g., getting shocked by static electricity).

2. Background on Main Topics

2.1. Lightning

Have you ever witnessed a thunderstorm? If so, likely, this means that you have seen brilliant flashes of lightning and heard loud claps of thunder. Lightning has long interested humankind, and some of the earliest written reports described lightning as fire in the sky. Scientific understanding did not come until much later with some basic understanding of electricity. Lightning is the occurrence of a natural electrical discharge between a cloud and the ground or within a cloud. This discharge involves a large flow of electrical charges, and this flow of moving charges is known as current. Electrical charges can either be positively or negatively charged, and the negative charges are called electrons.

So how does lightning occur? In hot weather, water evaporates from the ground and is carried upwards into the atmosphere. At high altitudes, the air becomes cooler, which causes the water vapor in the air to condense, forming clouds that contain water droplets and ice crystals. The water droplets and ice crystals each contain electrical charges. As these water droplets and ice crystals move past each other, they rub into each other, and charges are exchanged between the two. Positive charges accumulate on the ice crystals which are generally located at the top of the cloud, and electrons accumulate on the water droplets which are generally located at the bottom of the cloud. If you could see the charges in the cloud, you would see that the top portion of the cloud is overall positively charged, while the bottom of the cloud is overall negatively charged. This built-up imbalance of charges in the cloud is a distinct feature of static electricity. This static electricity can be built up until there is a route for the discharge or release of the charges.

Opposite-sign charges (positive and negative) are attracted to each other, while the same-sign charges are repelled by each other. The build-up of negative charges at the bottom of the cloud in a thunderstorm cause an attraction of positive charges nearby. Eventually the charges between the two locations connect and a large and fast discharge occurs, resulting in the characteristic flash of lightning (see Figure 1)! This discharge can happen within the cloud itself, but sometimes the charges travel between

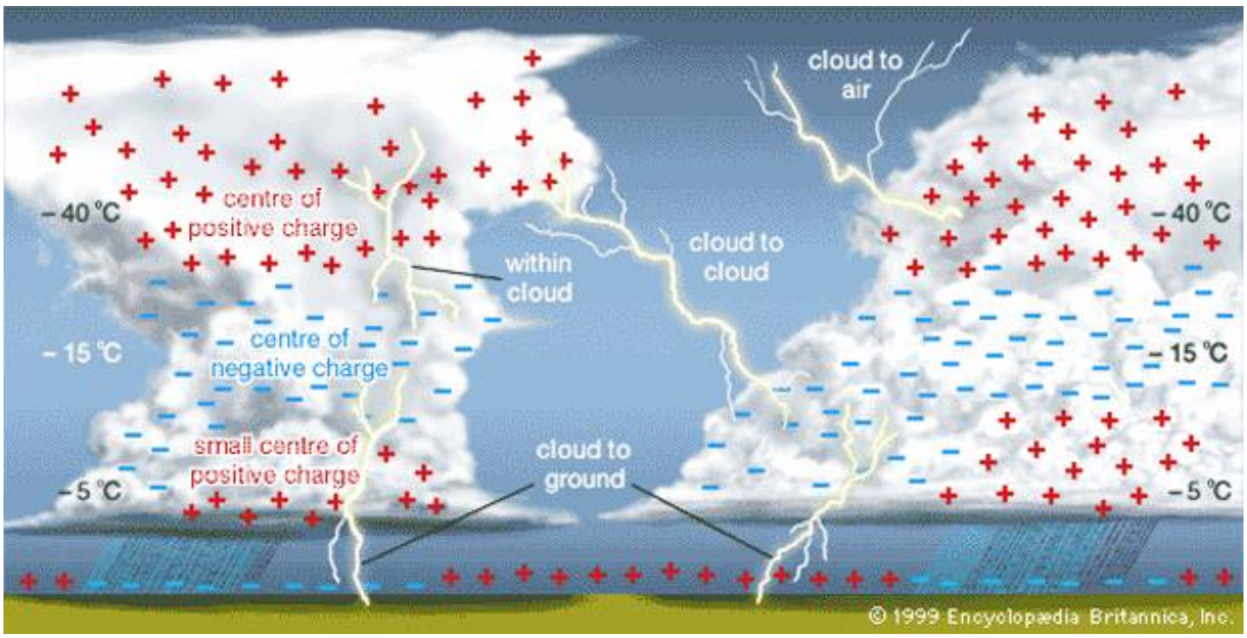


Figure 1. A schematic of the build-up of static charges in a thunderstorm. Cloud-to-cloud lightning and cloud-to-ground lightning are both shown, as well as typical temperatures in the cloud. This Photo by Encyclopedia Britannica is licensed under CC BY-SA-NC.

the cloud and ground beneath it. This is how cloud-to-ground lightning strikes happen on earth, like those shown in the photograph below (see Figure 2). Lightning strikes on the earth every moment, often accompanied by heat during the discharge. In fact, lightning is approximately six times hotter than the surface of the Sun! This heat associated with lightning, along with the large static discharge, can cause destruction of property and life, so we have to be careful when we think that lightning may strike. As the earth's climate changes over time, extreme weather events, like lightning storms, may become more common in tropical regions of the world, such as in parts of East Africa. There are strategies to try to control where lightning strikes to prevent injury or destruction. One prominent strategy is the use of a lightning rod, which is a metal wire or object placed on the exposed part of a building or on a tall structure that can divert the lightning discharge safely into the ground, which protects people and objects.

Figure 2. Examples of cloud-to-ground lightning. Francois Loubser/Alamy via New York Times.

Notes for teacher for the following experiments:

- The source of electric charge is from negatively charged electrons and positively charged protons, which are within the atoms that make up all substances. However, this level of detail is not specifically needed for this investigation. If your students are unfamiliar with electrons, you can refer to them as negatively charged particles that move between objects.
- Objects almost never have an equal amount of positive and negative charge. They may have areas that are positively charged and others that are negatively charged. However, to begin with, we will assume that objects are homogeneously charged, or neutral. We will also ignore the dimension and shape of the objects, and instead think of them as point-like objects.

2.2. Sources

SEVERE WEATHER 101, NOAA National Severe Storms Laboratory, https://www.nssl.noaa.gov/education/svrwx101/lightning/.

Severe Weather Safety Guide Lightning, National Weather Service, https://www.weather.gov/media/pah/WeatherEducation/lightningsafety.pdf.

3. Summary of Experiments

This lab consists of three experiments and one design challenge to understand the concepts of electrostatics. This investigation starts with an introduction to the driving question for the unit: "Why do some things appear to 'stick' together and some things don't?" Throughout the investigation, students will begin to develop a conceptual model of electrostatic interactions by exploring how various charged objects (Scotch tape, balloons, rods of various materials) interact with one another. By the end of the investigation, the model will include positive and negative charges as well as patterns that can be used to explain and predict how charged objects interact with each other (i.e., opposite charges attract; objects of the same charge repel) and how neutral and charged objects (regardless of charge) attract each other. The goals of the experiments and design challenge are the following:

Part I: To demonstrate the existence of charges using different objects

Part II: To show the existence of opposite charges using different objects

Part III: To observe the effects of grounding

Design Challenge: To design a device to protect objects or people from lightning

3.1. Supplies List

- Plastic (e.g., plastic pen, comb, straw, anything handheld and made of plastic)
- Paper
- Hair (e.g., on your student's head), wool, or fur
- Balloon
- Aluminum can (empty) or other metal object that can roll across the floor
- Sticky tape
- Metal (e.g., fork, spoon, metal pen, keys, anything handheld and made of metal)
- Pen or pencil
- Scissors (optional)

3.2. Safety Information

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Students should be aware that they may get shocked while doing these electrostatics experiments. The experiments should not pose any harm to them, but it is advised to not complete these experiments around anything especially flammable (e.g., gasoline fumes).
- Students can cut paper using scissors for experiments, or teachers can cut the paper for students beforehand. Scissors should always be handled with care. As an alternative, students can rip paper by hand since the exact size of paper is not important to lab.

3.3. Teacher Pre-Lab

Teachers can organize the supplies for the experiments ahead of time. For each student or each group of 2-4 students, the materials needed are: 2 pieces of plastic (various possibilities are listed above), 1 piece of paper, 1 piece of metal (various possibilities are listed above), 1 balloon, 1 empty aluminum can, and a pen or pencil. There should be various "surfaces" of hair, wool, fur, or glass and sticky tape that the classroom can share.

4. Experiments

4.1. Pre-Lab Questions

<u>Notes for teachers:</u>

- Discussion and demonstrations of electrostatic interactions will be used to engage students driving them to answer the following questions. Have a discussion with the students in small groups or as a class to share ideas before the lab experiments begin.

1. What are some examples of things that appear to "stick" together (without being sticky themselves)?

    a. Answer: Wool (or other clothes) and hair, dust and glass, pollen on most surfaces, etc.
2. What are some reasons that objects can "stick" together?
    a. Answer: Discuss with students, and answers may vary. Some reasons could be sticky material used (tape, honey, sap), textured surfaces that make materials 'grip' each other (dirt or dust and walls or plants, some glues), electrostatic charges (wool or balloon and hair, dust and glass). Encourage students to be creative to think of various ideas in their everyday life.
3. What are some examples of things that don't "stick" together no matter what you do?
    a. Answer: Liquids, things that are slippery, two metals, etc.
4. Have you ever created a "shock" when you picked up a piece of metal or touched a wall? Why do you think this happened?
    a. Answer: In dry climates, static charges build up on our skin as we move about the world. Then, when we touch a surface that can conduct the charges, the charge that has built up on our skin leaves all at once, creating a "shock". If the air is humid, the water conducts charges for us and makes electric "shocks" less likely.

4.2. Part Ia. Static attraction!

4.2.1. *Summary*

In this experiment, we are going to test how a piece of plastic (a pen or a comb, for example) can become charged on its surface.

4.2.2. *Materials*

- Plastic (e.g., pen, comb, plastic straw)
- Piece(s) of paper
- Hair (or fur, wool, glass, or skin)
- Scissors (optional)

4.2.3. *Procedure (work in groups of 2-4)*

1. Lay several pieces of paper on a table (these should be small pieces of paper, about 1x1 or 2x2 cm).
2. Rub a plastic instrument through (or against) your hair, skin, wool/fur, or piece of glass.
3. Bring the plastic near the pieces of paper, but without touching them, and observe what happens.
4. Hold the plastic for 15 seconds near the paper and observe what happens.
5. Repeat steps 1-4 (you can use the same pieces of paper) by rubbing the piece of plastic against another recommended surface (air, skin, wool/fur, or piece of glass), and observe what happens.
6. Record your results in the table below, trying to rank the materials' ability to generate an attraction based on your observations (rank in order with 1 being the best, 2 being the second best, and so on).

4.2.4. *Results*

Material 1	Material 2	Observation	Rank
Paper (neutrally charged)			

4.2.5. *Post-Experiment Questions*

1. What happened when you brought the plastic (after rubbing it) near the pieces of paper?
    a. Answer: The plastic attracted the paper and lifted the paper slightly off of the table.
    b. Extension question: What happened as you continued to hold the plastic near the paper? Were there any changes over time?
        i. Answer: Over time, the attraction between the paper and the plastic should decrease. This is because the charges on the plastic surface are temporary.
2. What happened when you tried rubbing the plastic against different surfaces and bringing the plastic near the paper? Did different surfaces work better than others? What else can you do to improve the effect of attracting the paper?
    a. Answer: Hair and skin should attract the paper the strongest, then glass, then fur, then wool. This will depend on how long the students rub the plastic on the surface (the longer you rub, the more charges will build up and create a stronger attraction). If students get different results, discuss why this may be (e.g., time, different plastics, different products used, oil in your hair, lotion on your skin). Moisture will lessen the effect of static charges.
3. Circle whether the following materials are charged or neutral:

Plastic at start of experiment	Charged	Neutral
Plastic after rubbing	Charged	Neutral
Other surface (hair, wool) after rubbing	Charged	Neutral
Paper at start of experiment	Charged	Neutral

4. Why do you think the attraction between the paper and plastic happens? What needs to happen to the surface of these materials to attract each other? Try answering this question using the words “electric charge”, “positive” and

"negative". <u>One hint:</u> the plastic surface can pick up negatively charged particles from the hair during rubbing.

   a. <u>Answer:</u> When we rub the plastic on our hair (or other surface recommended), we create a positive charge on the surface of our hair and a negative charge on the surface of the plastic generated by electrons moving from your hair to the plastic. Then, when we bring the negatively charged plastic close to the neutral piece of paper, the negatively charged plastic repels negatively charged particles in the regions of the paper closest to it, which causes these parts of the paper to become slightly positively charged. The negatively charged plastic and the positively charged regions of the paper are attracted to each other. In summary, charges on the surface of one material can induce the opposite charge in the other material surface, thus causing them to be attracted to each other. Remember: opposites attract!

4.3. Part Ib. Racing cans!

4.3.1. *Summary*

In this experiment, we are going to show how static attraction can induce movement in a nearby object.

4.3.2. *Materials*

- Balloon
- Aluminum can (empty) or other metal object that can roll across the floor

4.3.3. *Procedure (work in groups of 2-4)*

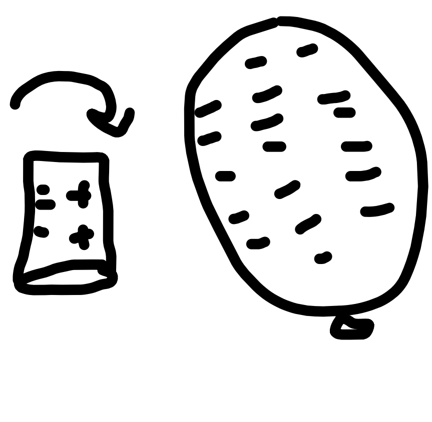
1. Blow up the balloon and tie a knot so that it stays inflated.
2. Rub the balloon on a volunteer student's hair several times.
3. Place the empty aluminum can on its side on a flat surface and have one student hold the can to prevent it from rolling.
4. Bring the balloon close to the side of the can (~2-3 cm).

5. Let go of the can gently. As the can rolls, keep moving the balloon to "guide" the can.
6. Move the balloon to the other side of the can and repeat steps 4-5. You may need to "recharge" the balloon by rubbing it on a volunteer student's hair several times.

   Extra challenge:
7. With the other groups in your class, try racing to see which group can move their can the fastest over a set distance without touching it and using only their balloon.

4.3.4. *Post-Experiment Questions*

1. What happened to the balloon after rubbing it on the hair? Try answering this question by explaining how charges move. Hint: the process is similar to Part Ia.
   a. Answer: The balloon picks up extra negatively charged particles (electrons) from the hair. After the rubbing, the balloon is negatively charged.
2. How was the balloon able to attract the can and cause it to move without touching it? Again, try answering this question by explaining how charged objects attract other objects. Hint: the process is similar to Part Ia.
   a. Answer: The rubbed balloon is negatively charged to begin with, and the can is neutral. When the negatively charged balloon comes close to the can, the negative charges in the can are repelled by the balloon, which makes the part of the can closest to the balloon positively charged. Because opposites attract, the balloon can "pull" the can toward it, which is why the can rolls when the charged balloon is close to it.
3. Draw roughly how the charges are distributed on the balloon and can as the rubbed balloon is brought close to the can.



4. How can you make the can roll faster?
    a. Answer: Rubbing the balloon more to make it more charged can help make the can roll faster. Bringing the balloon as close to the can as possible without touching it will also make the can roll faster.
    b. Extension question: How can you make the can roll slower?
        i. Answer: Possible answers include rubbing the balloon less so that it is less charged, waiting longer after the balloon is rubbed so that the charging dissipates, moving the balloon farther away from the can, trying to roll the can uphill.

4.4. Part II. Static repulsion!

4.4.1. *Summary*

In this experiment, we will be observing what happens when the same material develops the same (and opposite) types of charge.

4.4.2. *Materials*

- Sticky tape
- Pen or pencil

4.4.3. *Procedure (work in groups of 2-4)*

1. Tear 4 pieces of tape, each about 10 cm long, or as long as your pen/pencil.
2. Fold ~1 cm (the top of your finger length) of each piece of tape onto itself so that you can easily hold it.
3. Stick two pieces of tape to a table with the folded over edge overhanging the table. The smooth part of the tape should be

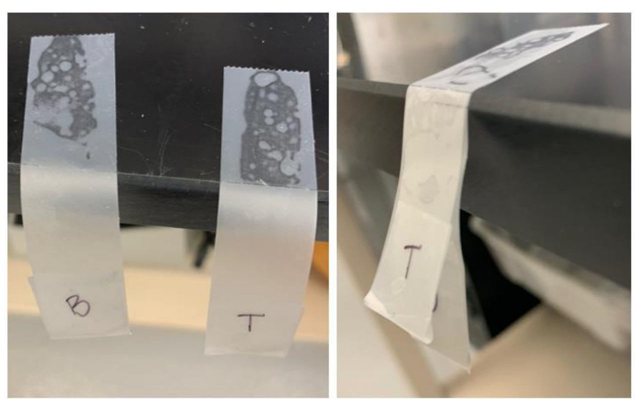


Figure 3. Experimental set-up for Part II before sticking tape together (left) and after (right).

facing up toward you and the sticky part should be facing toward the table.

4. Label these pieces of tape with a “B” because they are on the bottom.
5. Stick the remaining two pieces of tape on top of the “B” pieces. The sticky parts of the top pieces of tape should be in contact with the smooth parts of the bottom pieces. Label the pieces on top “T”.
6. For both sets of tape, pull the “T” and “B” strips off the table while they are stuck together. You should have two sets of tape with a sticky side exposed of “B” and the smooth side exposed of “T”.
7. Using your fingers, rub each side of the tape so that the tape is no longer attracted to your hand (~5 times).
8. Then, pull apart the “T” and “B” strips quickly so you have two, single pieces of tape again. After doing this to both sets of tape, you should have four pieces of tape, two “T” and two “B”.
9. Using different combinations of “T” and “B”, bring two strips of tape close together (but not touching). Record your observations in the table below.

Figure 3 shows the set-up of this experiment.

4.4.4. *Results*

Tape Combination	Observations
T + B	
B + B	
T + T	

4.4.5. *Post-Experiment Questions*

1. How are the "T" and "B" strips different? What combinations of tape repel each other? Attract each other?
    a. Answer: When "T" tape is pulled from the "B" tape, charges move from one tape to the other. One ends up with an excess of positive charges, and the other with an excess of negative charges. The "T" + "T" and "B" + "B" pieces of tape should repel each other since they were treated in the same way, creating the same charge. "T" + "B" should attract each other since they were treated in opposite ways.
    b. Extension question: How do your observations with the tape combinations change over time?
        i. Answer: The charging effect may decrease over time.
2. Using the charged plastic or charged balloon from Part I, how might you figure out which piece of tape (top or bottom) is positively charged and which is negatively charged? (Advice for students: hold the charged plastic/balloon a few ~centimeters from the tape to see the effects)
    a. Answer: The negatively charged plastic/balloon should repel the negatively charged piece of tape and attract the positively charged piece of tape, because same charges repel and opposites attract!

4.5. Part III. Grounding effects

4.5.1. *Summary*

In this experiment, we will observe the effects of grounding. The process of electrons moving out of a charged object and into the ground (or earth or other material) is called grounding. After an object is grounded, the charged object returns to neutral so that it has no effect on (i.e., does not attract nor repel) the objects around it through electrostatic interactions. As you learned in the Background section, grounding is critical for success of lightning conductors or lightning rods, as the lightning's discharge can be routed harmlessly into the ground and prevent injury and destruction.

4.5.2. *Pre-Experiment Questions*

1. Why might grounding be helpful in everyday life?
    a. Answer: Grounding is used in electronics to prevent dangerous currents from occurring which can start fires or present other safety concerns. It is also used with electrical grid lines and radio antennas.
2. What are some examples of materials that conduct electricity easily? These materials are called conductors.
    a. Answer: There are several possible answers, like metals (e.g., copper, gold, silver, platinum, aluminum).
3. What are some examples of materials that do not conduct electricity easily? These materials are called insulators.
    a. Answer: There are several possible answers: glass, wood, plastic, rubber, concrete, etc.

4.5.3. *Materials*

- 2 pieces of plastic (e.g., pen, comb, plastic straw)
- Piece(s) of paper
- Hair (or fur, wool, glass, or skin)
- Piece of metal (e.g., fork, spoon, metal pen, key)

4.5.4. *Procedure (work in groups of 2-4)*

1. Lay several pieces of paper on a table (these should be small pieces of paper, about 1x1 or 2x2 cm).
2. Rub a plastic instrument through (or against) your hair, skin, wool/fur, or piece of glass.
3. Attempt to ground the charged plastic with a piece of metal by touching the metal to the charged plastic.
4. Bring the plastic near the pieces of paper, but without touching them, and observe what happens.
5. Repeat steps 1-4 (you can use the same pieces of paper), but instead use another piece of plastic, instead of metal, to try to ground the charged plastic and observe what happens.

4.5.5. *Post-Experiment Questions*

1. What did you observe when you used the metal to ground the charged plastic? What about when you used the second piece of plastic to ground the charged plastic? Try answering this question using the words "conductor" and "insulator".
   a. Answer: When metal is used to ground the charged plastic, the plastic cannot attract the paper pieces as well because the plastic is not as charged as in Part Ia. Metal works well to ground the plastic because it is a conductor, which means that charges readily flow through it. When plastic is used to ground the charged plastic, the charged plastic still attracts the paper. Plastic does not work as well to ground the plastic because it is an insulator, which means that charges do not readily flow through it.
2. Which object works well to ground the charged plastic? Why do you think this is?
   a. Answer: Grounding can occur through materials that conduct electrons (or electricity) very easily so that the object returns to a neutral charge. This means that the metal will work well as a grounding tool.

5. Design Challenge

The Challenge: Save yourself from lightning! Now that you have learned how to create static charges on the surface of objects and what happens when similarly charged or oppositely charged objects are brought close to each other, you have proven for yourself part of why lightning strikes! Since we know that opposite charges attract, the electrons in the negatively charged bottom of the cloud want to flow towards the positively charged earth. We also know that lighting tends to strike areas that are closest to the clouds, since that is the closest area of positive charges on the earth which means that the electrons don't have to travel as far. Since you've learned that grounding is an important technique to return charged objects to neutral, we are going to put everything together to design a "lightning-safe space".

5.1 Design Questions

1. If you were going to design a safe space to stay during a lightning storm, what materials would you use?

   a. Consider:
      i. How will the materials allow charges from the lightning bolt to flow away from you?
      ii. How will the materials react to the extreme heat of lightning?
2. How will the outside of your space be different from the inside of your space?
3. Will your structure be high off the ground or low to the ground?

Possible answers to the questions above (encourage discussion of class):

Ideally, the lightning-safe structure should have metal on the outside (or some type of conductor of electricity) and plastic, wood, or rubber on the inside (or some type of insulator). This will allow the lightning bolt's negative particles (electrons) to flow through the metal and into the ground (grounding the lightning) without lighting on fire while the insulation inside of the metal will prevent the bolt from hitting your body and injuring you. You also would want the structure to be low to the ground making it less likely to be hit by lightning.

5.2 Design Sketch

Try out your design by sketching it on paper. You can also color it in with markers, pens, pencils, and crayons. Be creative!

My lightning safe space:

6. Sources

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