Topic 4.2
What are charges and how do they behave?

Overview

In this topic, students will explore the properties of static electricity. In Investigation 4B, they will conduct experiments to test different materials for their ability to become charged. Using the Law of Electric Charge, students will explain how charged objects behave with one another, and apply their understanding of the law to make and test predictions in Activity 4.6, Rubbing and Static Electricity. Students will also investigate the difference between conductors and insulators using a conductivity meter.

Common Misconceptions

- **Since insulators do not allow electrons to flow easily through them, some students may conclude that insulators do not become charged no matter how much you rub them.** This idea is not true. Have students charge a rubber balloon and a foil balloon separately, then hold them against the wall and let go. The charged rubber balloon will stick to the wall much more easily than the charged foil balloon. Being an insulator means it is harder for the charge to move elsewhere. (In actuality, it is better to use an insulator than a conductor to demonstrate static buildup and other properties of static electricity.)
- **Some students may think that positively charged objects contain only protons and negatively charged objects contain only electrons.** This is not true. Have students review their understanding of the structure of an atom. Every atom contains protons (and neutrons) in the nucleus with electrons orbitting around it. When objects rub against each other some, but not all, of the electrons will move from one atom to another.
- **Some students believe that neutral objects do not respond in the presence of a charged object.** Demonstrate the attractive forces between these objects by using a plastic comb, a piece of wool, and small pieces of paper. Charge the comb and wool by rubbing them together. They will become oppositely charged by friction. When each is held over the neutral pieces of paper, the paper will "jump up" to stick to both types of charged objects.

Background Knowledge

Static electricity refers to the buildup of electric charges on an object. One effect of static electricity is static cling, which occurs when different materials stick together. For example, static cling occurs when drying clothes in a dryer. In the rotating drum of a dryer, static charges build up on the different materials as they rub against one another in the warm, dry air, causing oppositely charged clothing items to attract and stick together.

When two objects made of different materials are rubbed together, electrons transfer from one object to another, producing two objects with opposite charges. This process is called charging by friction. Whether an object becomes charged positively or negatively depends on what type of materials are involved. For example, a rubber balloon becomes negatively charged when rubbed with a piece of wool, but positively charged when rubbed with a piece of foam.

The Law of Electric Charge states that opposite charges attract each other, and charges that are alike, or the same, repel each other. This law can be used to explain why charged objects attract neutral objects.

Specific Expectations

- **E2.1** use appropriate terminology related to static and current electricity, including, but not limited to: *ammeter, ampere, battery, conductivity, current, energy consumption, fuse, kilowatt hours, load, ohm, potential difference, resistance, switch, voltmeter, and volts*
- **E2.2** use an inquiry process to determine and compare the conductivity of various materials
- **E3.1** compare conductors and insulators, and explain how materials allow static charges to build up or be discharged

Skills

- formulate scientific questions and hypotheses
- gather, organize, and record data using appropriate formats
- draw and justify conclusions

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see page TR-48 for a summary of the materials required in this topic.

Materials can be classified according to their electrical conductivity. Materials in which electrons can move easily between atoms are called *conductors*. Materials that do not allow electrons to flow through them easily are called *insulators*. Because different materials have different degrees of conductivity, there is a range between strong insulators and strong conductors. Typically, metals are good conductors and non-metals are good insulators. However, there are some non-metals, such as silicon, that conduct fairly well. These non-metals are called semiconductors.

Literacy Strategies

Before Reading

- Review what students learned about the particles that make up atoms in Unit 2. Use a diagram of an atom to relate the meaning of the first three Key Terms to protons, electrons, and the entire atom. Have students use the meanings of words they know to predict the meanings of conductor, conductivity, and insulator.
- Have students preview the text features in this topic. Use each heading as a topic title for discussion. Ask students to scan the margins for key terms and examine the diagrams to make predictions about what each section will be about. Use the discussion to gauge students' prior understanding of the concepts in this topic.

During Reading

- ELL The diagrams in this topic convey a lot of information. If English language learners have trouble understanding the text, encourage them to check the diagrams and their captions for help. Consider previewing the diagrams with them before they read each chunk.
- Note taking is an important skill for all students, including English language learners. Have students discuss and record the main ideas and supporting details. Students can use the titles of each spread as the main ideas and take ten minutes to record supporting details for the text and visuals on the spread. Ask the groups to share orally while you clarify the main ideas and missed details. Record a summary on an overhead, and allow English language learners to copy the summary in their notes.

After Reading

- Ask students to review their notes, and use a graphic organizer to compare conductors and insulators and include two examples for each.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Learning Check questions, page 255	Students explain the relationship between positive and negative charges and protons and electrons.	• Work with students to model atoms using simple sketches of Bohr-Rutherford diagrams (or **BLM 4-9 Remembering Atoms**) and red and black counters.
Learning Check questions, page 257 Activity 4.4, page 256 Topic 4.2 Review question 5, page 261	Student describes and explains in words or diagrams the law of electric charges.	• Have students complete **BLM 4-10 The Law of Electric Charges**, a scaffolded version of the law.
Learning Check questions, page 258	Students identify negative charges as able to move and test conductivity to classify materials as conductors or insulators.	• Demonstrate the procedure for students who need support following written instructions. • Create two boxes for students to place tested materials in: one for conductors and one for insulators. Allow students to explain their classification orally.

Topic 4.2 (Student textbook pages 252–263)

Using the Topic Opener (Student textbook pages 252–253)

- Have students work in pairs to carry out the Starting Point Activity, which will provide students with concrete examples of static charge. English language learners especially will benefit from observing or experiencing a concept before they read about it.
- Before reading the text, have students look at the two pictures on the opening spread. Ask students how the images show the presence of static charge. (Answer: The picture on page 252 shows hair sticking to a sweater as it is being pulled off because of static charge. The picture on page 253 shows socks sticking to the shirts, and the boy's hair and cat's fur standing on end because of static charge.)
- Read the paragraph on page 252 aloud. Ask students if they have experienced static cling. Under what conditions did they feel the effects of static electricity? (e.g., dry air) Encourage students to share their stories.

Starting Point Activity

Pedagogical Purpose

Students will become curious about phenomena related to static electricity and will develop a hypothesis about these phenomena using simple atomic theory.

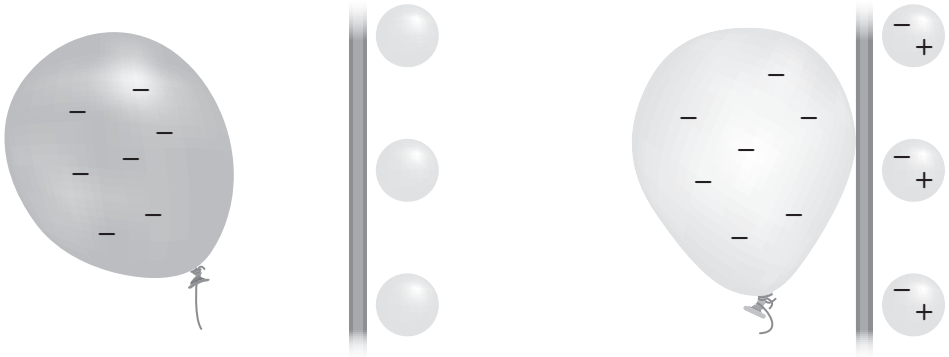
Planning	
Materials	latex balloons about 20–30 cm diameter (one per student or pair of students)
Time	10 min in class
Safety	ALERGY ALERT – Students allergic to latex should not touch the balloons.

Skills Focus

- work cooperatively
- connect experimental results to the real world

Background Knowledge

A charged object will attract a neutral object. If you charge a balloon by rubbing it on your hair, it picks up extra electrons and gains a negative charge. Holding it near a neutral object will cause the charges in that object to move. If it is a conductor, like a metal, many electrons move easily to the other side, as far from the balloon as possible. If it is an insulator, the electrons in the atoms and molecules can only move very slightly to one side, away from the balloon. In either case, there are more positive charges closer to the negative balloon. The Law of Electric Charge states that opposite charges attract and the balloon sticks temporarily, until the surplus electrons on the balloon slowly leak off.



Source: http://www.sciencemadesimple.com/static.html

Activity Notes and Troubleshooting

- This activity works very well on dry winter days and poorly on humid warm days, so plan accordingly.
- Medium length hair works better than very long or very short hair. This activity also works better when the hair contains no conditioner.

Additional Support

- Focus on the key point that a negative charge can move and positive charge cannot. If that concept is clear, then all static phenomena can be explained by a surplus of electrons.
- DI Bodily-kinesthetic learners may benefit from acting this out. Give two students each two red balls and two black balls. Tell them that they represent negative and positive charges. Then give one of the students two additional red balls, to indicate that they are negatively charged. As they move toward the other student, elicit from the rest of the class how the other student's charges would move.

Answers

1. Answers may vary. For example: In picture A, I would expect my hair to follow the balloon and try to stick on as I pull it away and bring it back. In picture B, I would expect the balloon to stick to the wall.

Instructional Strategies for Topic 4.2

- ELL Many items mentioned in the student textbook, such as anti-static sheets, different fabrics (nylon, silk, wool, cotton), and so on, will be new to English language learners. To build background knowledge that may be missing, bring either the items themselves or photographs of them to class.
- Have students who are comfortable doing so read aloud the information in this topic. Stop often to examine the diagrams that help students to visualize the concepts described in the text. As an alternative to reading aloud, provide English language learners, and others who require this accommodation, with the text in a recorded format.
- After reading each chunk, for example, the section about the behaviour of positive and negative charges, check for understanding by asking students to quickly sketch the different concepts such as a positively charged object or the transfer of electrons. as students sketch, walk about the class, providing feedback.
- DI Bodily-kinesthetic learners may benefit from modelling each charging situation using small paper plates (for each object), pennies (for protons), and paperclips (for electrons), moving paperclips from one plate to another to model what is happening before they draw diagrams.
- Have students copy into their notes the Law of Electric Charge on page 256, including the simplified diagrams with the plus and minus signs.
- ELL To ensure English language learners fully understand, and are successful with, the activities, explain and model the learning processes. Show them what is expected, let them participate with an English-speaking peer, and then have them try out activities on their own. For example, use Activity 4.6 to ensure that students understand the words *predict*, *observe*, and *record*. It may be helpful to complete the activity with students, using the key terms and these process words, and model what they would record. Explain that they will be using these process skills in Investigation 4B.
- Demonstrate how to use a conductivity meter and assign Activity 4.5, Conductors or Insulators? This hands-on activity will provide students with the opportunity to rank materials according to how well they conduct charges, and help them realize that there are varying degrees of conductivity.

Activity 4.3 Remembering Atoms (Student textbook page 254)

Pedagogical Purpose

Students will review the structure of atoms including the characteristics of neutrons, protons, and electrons, including charge and location.

Planning	
Materials	**BLM 4-9 Remembering Atoms** (optional)
Time	10–15 min in class

Skills Focus

- use appropriate symbolic and graphic modes of representation

Background Knowledge

The Bohr-Rutherford model of atoms includes a dense, central nucleus made up of relatively heavy protons and neutrons surrounded by electrons in orbits or shells. The protons remain relatively fixed in matter and carry a positive electric charge. Electrons are relatively mobile and carry a negative charge.

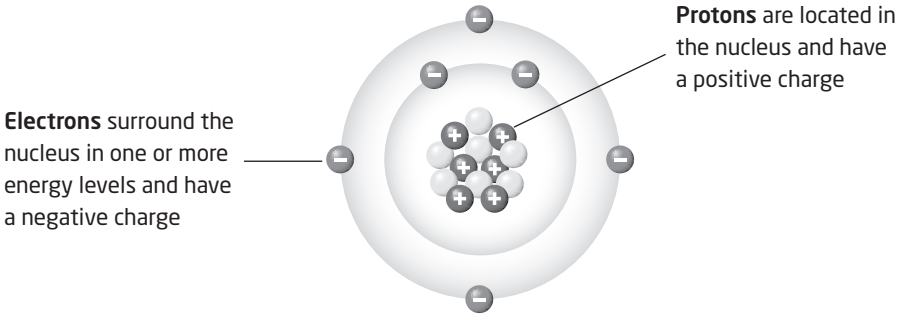
Activity Notes and Troubleshooting

- Encourage students to use pencils to draw a diagram like the one in the answers section.
- If you began this topic by sketching an atom, students may not find the drawing part of this activity difficult. Emphasize the importance of complete and accurate labels.

Additional Support

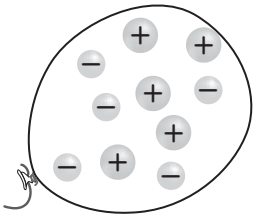
- Preview page 254 of the textbook with students to make sure that your expectations about explaining the properties are clear.
- ELL English language learners could use **BLM 4.9 Remembering Atoms** to record their results for this activity.
- For students having difficulty identifying relevant properties, focus on these distinctions: electrons are light, negative, and mobile, while protons are relatively, heavy, positively charged and fixed in position.

Answers



Learning Check Answers (Student textbook page 255)

1. Negative charges are the electrons in an atom and postive charges are the protons in an atom. Both are found in all atoms.
2. When two different materials are rubbed together, some of the negative charges, or electrons, will go from one material to the other. The number of positive charges on each material do not change. As a result, the material that loses electrons becomes positively charged and the material that gains electrons becomes negatively charged.
3. a)



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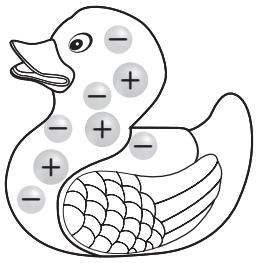

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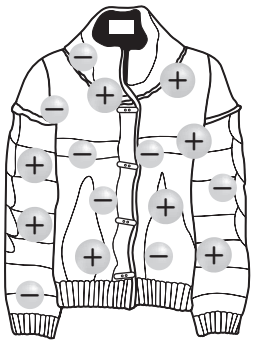

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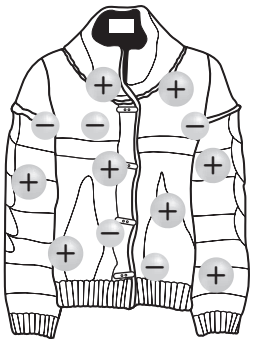


Activity 4.4 Like Charges Repel (Student textbook page 256)

Pedagogical Purpose

Students will use an inquiry process to investigate the law of electric charges.

Planning	
Materials	latex balloons about 20–30 cm diameter (two per student or pair of students) string (about 2 m per student or group of students cut into 1 m lengths)
Time	10 min in class
Safety	ALERGY ALERT – Students allergic to latex should not touch the balloons.

Skills Focus

- conduct an inquiry adapting their technique as required
- organize and record relevant data
- work cooperatively
- connect experiment results to the real world

Background Knowledge

The Law of Electric Charges was first discovered by Charles Augustin de Coulomb. It explains that all magnetic objects have the tendency to repel or attract one another. Like charges repel one another and unlike charges attract one another. Most objects are neutral until they gain or lose electrons to become charged.

Activity Notes and Troubleshooting

- This activity works very well on dry winter days and poorly on humid warm days, so plan accordingly.
- Medium length hair works better than very long or very short hair. This activity also works better when the hair contains no conditioner.
- Light string works best; nylon or cotton thread is fully adequate for this purpose

Additional Support

- ELL Pre-teach key terms: *like* and *unlike*.
- ELL Match English language learners with students who have strong communication skills.
- Focus on the movement of electrons from hair to the balloons so the balloons both gain negative charge.
- Encourage students to repeat the activity several times to ensure that results are consistent.

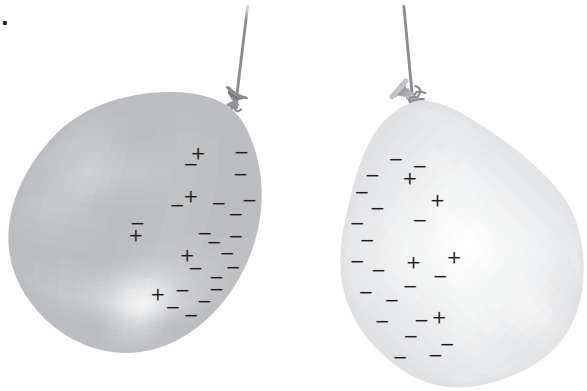
Answers

4. When I try to get the balloons close together, they repel each other so I can never get the balloons to touch.

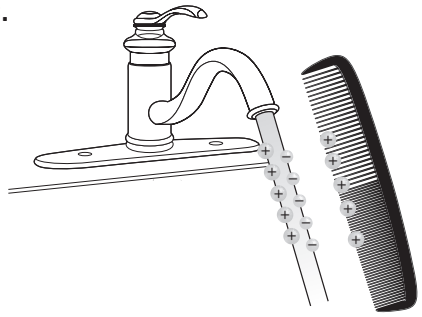
Learning Check Answers (Student textbook page 257)

1. The law of electric charge states that opposite charges attract each other, and like charges (charges that are alike, or the same) repel each other.

2.



3.



Learning Check Answers (Student textbook page 258)

1. Only negative charges can move through a solid.

2.

Conductor	Insulator
• a material in which electrical charges move easily • examples are most metals such as copper, iron, gold, and silver	• a material in which electrical charges do not move easily • examples are most non-metals, such as wood, plastic, glass, and Styrofoam™.

3. Electrical wires are covered by an insulator to prevent to prevent the charges from moving to other objects outside of the wire.

Activity 4.5 Conductors or Insulators (Student textbook page 259)

Pedagogical Purpose

Students will use an inquiry process to determine and compare the conductivity of various materials.

Planning	
Materials	conductivity meter (one for each group) a variety of materials such as paper, glass, plastic, metal, water, salt solution, and sugar solution (for each group)
Time	30–40 min in class 10 min preparing solutions (To make the salt solution, add 5 g of salt to 500 mL of water. To make the sugar solution, add 5 g of sugar to 500 mL of water.)
Safety	Although the photograph in the student text shows a technician wearing gloves, they are not necessary for the solutions described here.

Skills Focus

- use materials and equipment safely, accurately, and effectively
- analyze and interpret qualitative data
- use appropriate modes of representation to communicate findings

Background Knowledge

An electrical conductor is a substance that contains movable electric charges. In metals, the movable electric charge consists of mobile electrons. In solutions, the movable electric charges are ions (charged particles). Electrical insulators are materials that resist the movement of electrons or ions.

Activity Notes and Troubleshooting

- Advise students in advance not to contaminate solutions. Ensure that they rinse and dry the electrodes thoroughly, as described in the student text, before using a new solution.
- False negative readings could result from weak batteries. Be sure to check all conductivity meters in advance of the lab. As an alternative, you may wish to provide an incomplete circuit with a light that the students can assemble after you model how to do so.
- False positive readings are usually a result of contamination of the sugar solution with other ions, e.g., salt or other ionic contaminant.

Additional Support

- ELL Pre-teach key vocabulary, e.g., probe, solution.
- ELL Match English language learners with students who have strong communication skills to support reading and understanding the instructions.
- Focus students' attention on the movable electric charges that are electrons in metals and ions in solutions.
- Students may wish to create a physical T-chart as they work by placing materials on one side of the desk or the other to indicate whether they are conductors or insulators.

Answers

1. Answers may vary depending on materials chosen. For example: The conductivity meter had numbers greater than zero for metal and the salt solution, so they are conductors. The conductivity meter had numbers less than zero, or close to zero, for paper, glass, plastic, pure water, and the sugar solution, so they are insulators.
2. Answers may vary. For example, the metal had the greatest conductivity and the plastic, glass, and paper had the least conductivity.
3. Answers may vary. For example: When we make electrical appliances, it is important to use wires that allow electrical charges to move. So, we want to make these wires out of the most conductive materials. We normally coat wires with plastic because we do not want to get electrocuted when we touch them, so we want a very poor conductor for this task.

Activity 4.6 Rubbing and Static Electricity (Student textbook page 260)

Pedagogical Purpose

Students will use an inquiry process to investigate the law of electric charges.

Planning	
Materials	ebonite rod, fur, small pieces of paper (for each group) **BLM 4-11 Rubbing and Static Electricity** (optional)
Time	20–30 min in class

Skills Focus

- use an inquiry approach to investigate phenomena related to charge and static electricity
- gather, record, and organize data
- draw conclusions based on inquiry results
- communicate results using appropriate language and format

Background Knowledge

Ebonite is a very hard rubber first obtained by Charles Goodyear by vulcanizing rubber for prolonged periods. It is about 30 percent to 40 percent sulphur. Its name comes from its intended use as an artificial substitute for ebony wood. Ebonite is a brand name—it is also known as vulcanite or hard rubber.

When rubbed together, ebonite becomes negatively charged, while fur takes on a positive charge. The two materials only need to come into contact and then separate for electrons to be exchanged. After coming into contact, a chemical bond is formed between some parts of the two surfaces, called *adhesion,* and charges move from one material to the other to equalize their electrochemical potential. This is what creates the net charge imbalance between fur and ebonite.

Activity Notes and Troubleshooting

- As with some of the other activities involving static electricity, this activity works better on dry winter days than on humid warm days, so plan accordingly.
- The exchange of electrons is dependent on other factors, such as contaminants in the fur and paper, as well as humidity, as previously stated, so results can vary from day to day.
- Remind students not to rub the ebonite with fur gently rather than too vigorously.

Additional Support

- ELL Pre-teach key vocabulary such as ebonite and fur.
- ELL Match English language learners with students who have strong communication skills to help with reading the instructions.
- If possible, arrange to have senior chemistry students available to help with lab skills and crowd control during the activity.
- Focus students' attention on the movable electric charges, which are electrons.
- Students who require support recording and organizing data can use **BLM 4-10 Rubbing and Static Electricity.**

Answers

2. Answers may vary. For example, the charged objects would attract each other.

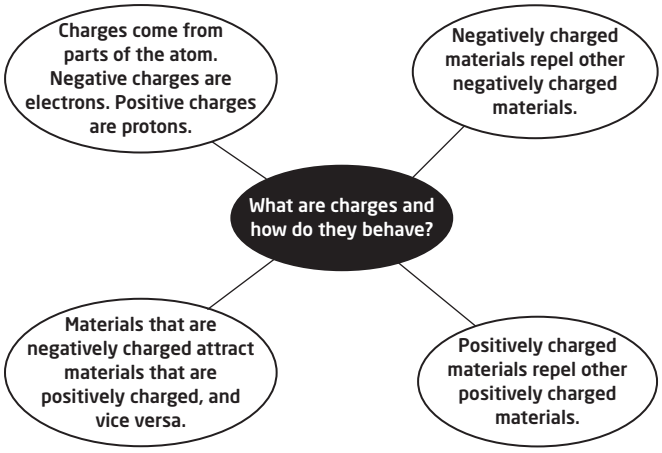
3. Answers may vary. For example, the charged object will charge the uncharged object.

Topic 4.2 Review (Student textbook page 261)

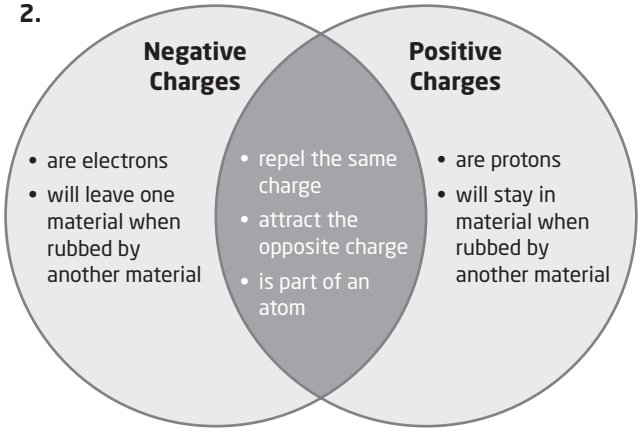
Please also see **BLM 4-11 Topic 4.2 Review (Alternative Format)**.

Answers

1. Answers may vary.

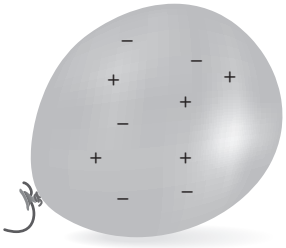


2.



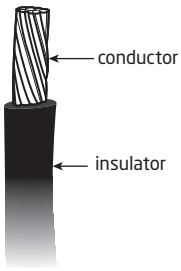
3. An insulator is a material that will not conduct electrical charges easily. Examples are plastic, wood, and diamonds. A conductor is a material that will conduct charges easily. Examples are metals such as copper.

4.



This balloon has the same number of protons and electrons, so it is neither positively charged nor negatively charged. It is electrically neutral.

5.

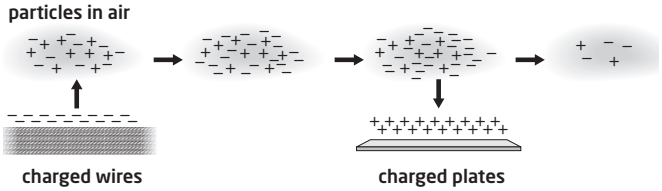


6. When two different materials are rubbed together, the negative electric charges travel from one material to the other. The positive electric charges remain where they are.

7. a) **Column 1:** The two objects repel each other.
Column 2: The two objects attract each other.
Column 3: The two objects repel each other.

b) **Column 1:** Objects with like charges repel each other.
Column 2: Objects with opposite charges attract each other.
Coumn 3: Objects with like charges repel each other.

8. For example:



Step 1. The particles in the air pass over the negatively charged wires and draw the negative charges from the wires.

Step 2. The particles become negatively charged.

Step 3. The particles pass over the positively charged plates. Since objects with opposite charges attract each other, the particles are drawn from the air on to the plates.

Step 4. The air is now free of the particles and is easier to breathe.

Investigation 4B Charging Materials (Student textbook page 262)

Pedagogical Purpose

Students will use an inquiry process involving conduction and induction to investigate the law of electric charges.

Planning		
Materials (for class of 24)	12 support stands 12 iron ring 12 rolls invisible tape 12 plastic comb 12 acetate strip 12 glass rod	12 ebonite rod 12 pieces of polyethylene (about 15 cm by 15 cm) 12 pieces fur 12 pieces of wool (about 15 cm by 15 cm) **BLM G-22 Data Tables** (optional)
Time	30–40 min in class 5–10 preparation time	
Safety	Remind students to handle the glass rod carefully, and advise them not to use a chipped or broken glass rod.	

Skills Focus

- use an inquiry approach to investigate phenomena related to charge and static electricity
- gather, record, and organize data
- draw conclusions
- communicate results using appropriate language and format

Background Knowledge

When rubbed together, one material becomes negatively charged, while the other takes on a positive charge. The two materials only need to come into contact and then separate for electrons to be exchanged. After coming into contact, a chemical bond is formed between some parts of the two surfaces, called adhesion, and charges move from one material to the other to equalize their electrochemical potential. This is what creates the net charge imbalance between the materials used in this activity and located on the so-called *triboelectric* (from "tribology", the study of friction) series as follows:

Become Most Positively Charged
human skin
rabbit fur
glass
wool
paper (small positive charge)
acetate (small negative charge)
plastic
polyethylene
ebonite
Become Most Negatively Charged

Activity Notes and Troubleshooting

- To reduce the amount of materials you need, set up stations to which the students can rotate in groups.
- As with some of the other activities involving static electricity, this activity works better on dry winter days than on humid warm days, so plan accordingly.
- The exchange of electrons is dependent on other factors, such as contaminants in the two materials, as well as humidity, as previously stated, so results can vary.
- Remind students to rub the materials gently.

Additional Support

- ELL Pre-teach key vocabulary, e.g., fur, glass, wool, acetate, plastic comb, polyethylene, ebonite.
- ELL Match English language learners with students who have strong English communication skills.
- Focus students' attention on the movable electric charges, which are electrons.

Answers

1. The first time when the pieces of tape were near each other, they were both pulling electrons from the table and becoming negatively charged, so they repelled each other. The second time when one piece was on top of the other piece, the top piece of tape pulled electrons from the bottom piece of the tape, so the bottom piece of tape was positively charged and the top piece of tape was negatively charged.

2. a) The glass rod attracted the negative piece of tape and repelled the positive piece of tape, so the glass rod must have acquired a positive charge from the polyethylene.

b) The ebonite rod attracted the positive piece of tape and repelled the negative piece of tape so the ebonite rod must have acquired a negative charge from the fur.

c) The plastic comb attracted the positive piece of tape and repelled the negative piece of tape so the plastic comb must have acquired a negative charge from the wool.

d) My finger attracted both pieces of tape.

3. My finger attracted both pieces of tape because my finger is electrically neutral so it had the potential to attract both. The charges on the tape could repel any of the same charge on the surface of my finger temporarily creating an opposite charge to the piece of tape, which would cause the attraction.

4. No pieces repelled both pieces of tape because only opposite charges repel. We have seen that a charged object will attract a neutral object, so for an object to repel both pieces of tape, we would need an object both positively and negatively charged. This is impossible so this will not happen.