Topic 4.3
How can objects become charged and discharged?

Specific Expectations

- **E2.3** conduct inquiries involving conduction and induction to investigate the law of electric charges
- **E3.2** explain the law of electric charges with reference to common electrostatic phenomena (e.g., charging by contact or by induction)

Skills

- select appropriate instruments and materials for particular inquiries
- conduct inquiries
- 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.

Overview

In this topic, students will learn how objects can become charged by contact and by induction, and how they can be discharged by sparking or by grounding. Using pith balls and electroscopes, students will conduct investigations to detect the presence of electric charges. They will draw diagrams to show the movement of electrons during charging, and make predictions about the overall charge of an object in different situations.

Common Misconceptions

- **Some students may confuse *charging by friction* with *charging by contact,* since both methods involve two objects touching each other.** Have students use diagrams to represent both methods visually, showing the movement of electrons in each situation and the end products. Charging by friction involves rubbing two different and neutral materials together to produce oppositely charged objects, while charging by contact involves touching a charged object to a neutral object, resulting in both objects having the same type of charge. You can also refer students to Figure 4.4 in Topic 4.2 to compare with Figure 4.9 in Topic 4.3, and have them look carefully at the charges on each object before and after the two materials touch.

Background Knowledge

Charging by contact involves touching a neutral object with a charged object. Suppose you touch a neutral object with a negatively charged object. Some of the excess electrons in the charged object are repelling each other, so they will try to spread apart by moving onto the neutral object. Now, the charged object will not be as negative as before. The neutral object always acquires the same type of charge as the charged object.

Charging by friction involves rubbing two different neutral objects together, which dislodges some electrons. Electrons in one of the objects will be dislodged and move to the other object, resulting in two oppositely charged objects.

Charging by induction involves bringing a charged object near a neutral object, but not touching it. No negative charges actually transfer between the objects. Instead, the negative charges in the neutral object respond to the charged object by either moving toward or away from the charged object. With the electroscope, the metal sphere always acquires a charge opposite to that of the charged object.

An electroscope is an instrument used to detect the presence of an electric charge. The first electroscope was invented around 1600. It consisted of a metal needle that could pivot freely on a pedestal, like a compass needle. The pith ball electroscope, invented in 1754, includes a ball made of lightweight material suspended on a thread. The neutral ball swings toward any charged object brought close to it. Some models involve two pith balls hanging side-by-side, similar to the parallel strips of metal leaves in a metal-leaf electroscope, which was developed in 1787. When an object with an electric charge is brought near, the pair of pith balls (or leaves) will separate in response to the presence of a charge. Electrons in the electroscope will either move into or out of the leaves, depending on the type of charge on the charged object. If they move in, the leaves will both become negative and repel from each other. If the electrons move out, the leaves will both become positive and repel each other.

Charged objects can be discharged by sparking or by grounding. The accumulated charge is eliminated by adding or taking away electrons from the charged object to make it neutral.

Literacy Strategies

Before Reading

- Help students make connections with prior knowledge. Have them recall their observations from Activity 4.6 in Topic 4.2, or do a quick demonstration by rubbing a plastic comb and using it to pick up small pieces of paper. Ask students to apply what they learned about the behaviour of charges to explain why the pieces of paper "jump" up to the comb. Ask them how this process is different from charging by friction.

During Reading:

- Have students divide one piece of paper or page in their notebooks into four sections, each with a heading: Charging by Contact, Charging by Induction, Discharging by Sparking, and Discharging by Grounding. Have students summarize the key ideas in each section as they read, and include diagrams where appropriate (e.g., an electroscope).
- English language learners will need support. Give them a purpose for reading each section. Model skimming the text by posing a question and then skimming the text to find the answer to this question. For example, select the heading Charging by Contact, ask, "What happens to an electroscope when it is charged by contact?" and skim to find the sentence that begins, "When you touch a charged object to the metal ball …". Explain why and how this sentence was selected. (Answer: Because it includes the phrase "touch a charged object to the metal ball".) To practise this skill, have students work with a partner to locate information in the student textbook to answer four or five questions you pose.

After Reading:

- Have students compare and contrast charging by friction, by contact, and by induction using a Venn diagram. They can use **BLM G-38 Venn Diagram** to compare two types of charging at a time, or create a three-part Venn diagram. Working with a classmate or in a group of three to create a large Venn diagram on chart paper would support the development of language skills.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check question 1, page 267 Activity 4.8, page 270 Topic 4.3 Review question 2, page 273	Students describe the process of charging by contact and charging by induction.	• Demonstrate the activity. Stop after every stage of charging and ask students to describe where the electrons are. • Have two students act out the charging process by holding red and black balls and transferring them to correspond to the behaviour of electrons. • Distribute **BLM 4-14 Charging by Contact and Charging by Induction**.
Learning Check questions 1 and 2, page 269 Activity 4.9, page 271 Topic 4.3 Review questions 3 and 5, page 273	Students desribe discharge by sparking and by grounding.	• Have students work with magnets to experience a situation analogous to sparking, where energy jumps across a gap. • Encourage the use of diagrams, showing positive and negative charges, to help students explain what happens during each process. • Consider extending the dramatic representation described above using students and balls to represent charged objects that discharge by sparking (tossing one ball) or grounding (dropping excess balls of one colour).

Topic 4.3 (Student textbook pages 264–273)

Using the Topic Opener (Student textbook pages 264–265)

- Use the opening paragraph and picture on page 264 to elicit responses from students about electric charges, shocks, sparks, and lightning. Ask questions to determine their prior knowledge of these concepts. For example, "What can you do to eliminate or reduce the risk of an electric shock?" and "What happens to objects that are struck by lightning?"
  - ELL To support English language learners, print key words on the chalkboard accompanied by icons to represent the meanings of the words, or create a word map.
- As an alternative, use a local news story about electrical storms, or lightning strikes, to get students thinking about occurrences of charging and discharging of electric charges in our daily lives. For English language learners, ensure that these types of materials are supported by clear illustrations.
- Carry out the Starting Point Activity as a demonstration. Emphasize when the charged rod is near the pith ball and when it is touching it. Have students draw sketches to show the response of the pith ball after each test.

Starting Point Activity

Pedagogical Purpose

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

Planning	
Materials	pith ball clamp retort stand ebonite rod fur glass rod
Time	10–20 min in class 15 min preparation
Safety	• Handle the glass rod carefully. • Do not use a chipped or broken glass rod.

Activity Notes and Troubleshooting

- As with some of the other activities involving static electricity, this activity works very well on dry winter days and poorly on humid warm days, so plan accordingly.
- The exchange of electrons is dependent on other factors, for example, contaminants in the two materials, as well as humidity, as previously stated, so results can vary from day to day.
- Pith balls move easily so it is important to minimize air movement when attempting this activity.

Additional Support

- ELL Pre-teach key vocabulary by showing students, and letting them handle, fur, glass, silk, ebonite, and a pith ball.
- ELL Have English language learners work with students who have strong communication skills, to ensure understanding of the instructions.
- For this and other activities in this unit, if possible, arrange to have senior chemistry or physics students available to help with lab skills and crowd control during the activity.
- Focus students' attention on the movable electric charges, which are electrons.
- Enrichment—Ask students to repeat the activity several times using glass and silk first and fur and ebonite second to see if similar results are obtained.

Answers

6. The ebonite rod became negatively charged when rubbed with fur. The pith ball is initially uncharged. The ebonite rod repels the negative charges on the surface of the pith ball giving the surface a temporary positive charge. This causes the attraction of the ebonite rod to the pith ball. Once the ebonite rod and pith ball touch, the negative charge on the rod goes onto the pith ball giving the pith ball a negative charge. When the glass rod is rubbed with silk, it gains a positive charge. The glass rod is now attracted to the pith ball which causes the pith ball to move towards the glass rod. Once the glass rod touches the pith ball, the rod obtains the negative charge making both the pith ball and glass rod neutral. So they no longer move when close to each other.

Instructional Strategies for Topic 4.3

- As students read and complete the activities, have them compare and contrast the different methods to charge an object by using a graphic organizer such as a Venn diagram or a double bubble organizer. They can use **BLM G-38 Venn Diagram** or **BLM G-39 Double Bubble Organizer**.
- Use Figures 4.9 and 4.10 to supplement the information in the text about the behaviour of an electroscope when it is charged by contact and by induction. Be sure to dispel the misconception that positively charged objects contain only positive charges and negatively charged objects contain only negative charges. Emphasize that the diagrams only show the excess charge on the objects, but in fact, there are many more positive and negative charges in each object.
- Assign Activities 4.8 and 4.9. Students with difficulty drawing the electroscope diagrams should prepare for the activities by making tracings of the electroscope in Figure 4.9A, with the metal leaves missing. Then students will complete the drawings with the position of the leaves observed. Alternatively, students can record on **BLM 4-15 Charging and Grounding an Electroscope**.
- After reading the section about grounding and lightning rods, have students complete Investigation 4C, Materials for Lightning Rods. Ask them to explain how the apparatus resembles the conductivity tester they used in Topic 4.2.

Activity 4.7 Predict the Result (Student textbook page 267)

Pedagogical Purpose

Students will conduct an inquiry involving conduction to investigate the law of electric charge.

Planning	
Materials	electroscope ebonite rod fur
Time	10–15 min in class 5 min to prepare materials
Safety	Remind students to handle all equipment and materials carefully.

Skills Focus

- make a prediction based on acquired knowledge
- use an inquiry approach to investigate phenomena
- draw conclusions based on inquiry results

Background Knowledge

When the metal terminal of an electroscope is touched with a charged object, the metal leaves at its base spread apart in an inverted 'V'. This is because some of the charge on the object is conducted through the terminal and metal rod to the leaves. Since each leaf receives the same sign charge, they repel each other and thus diverge. If additional charge of the same sign is again brought to the electroscope, the leaves will diverge farther.

Activity Notes and Troubleshooting

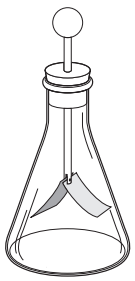
- As with some of the other activities involving static electricity, this activity works very well on dry winter days and poorly on humid warm days, so plan accordingly.
- The exchange of electrons is dependent on other factors, e.g., contaminants in the two materials, as well as humidity, as previously stated, so results can vary from day to day.
- The focus of this activity is on predicting. Students could use think-pair-share to develop predictions and sketches. Discuss their predictions as a class. Encourage all reasonable predictions that students can support with reasons. Sketch, or have a student sketch, them on the chalkboard. Then demonstrate the results for the class, or have groups conduct the activity, and have students talk about how the results related to their predictions.

Additional Support

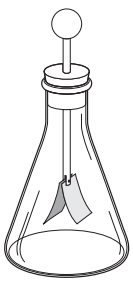
- As you discuss predictions and results, focus students' attention on the movable electric charges, which are electrons.
- Enrichment—Ask students to predict whether similar results would be obtained if they used glass and silk. They could set up the experiment to test their prediction

Answers

1.

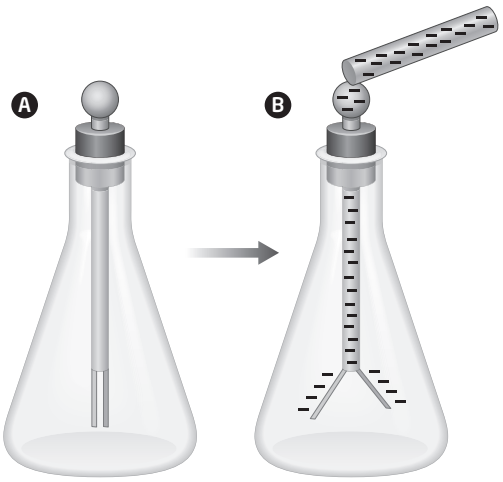


2.



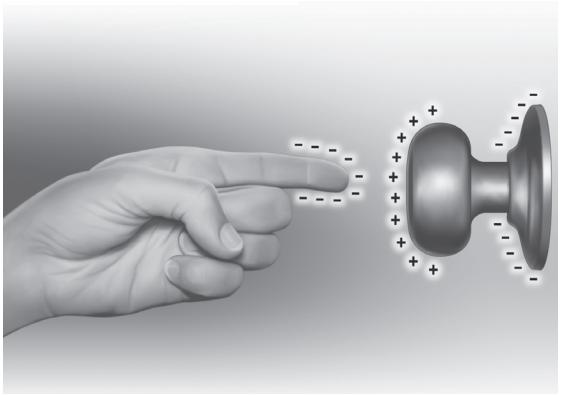
Learning Check Answers (Student textbook page 267)

1. **a)** A neutral object can be charged by contact by touching it with a charged object.
   b) A neutral object can be charged by induction by bringing a charged object near to, but not touching, the object.
2. An electroscope can be used to determine whether an object is charged. If you touch the ball of the electroscope with an uncharged object, the leaves will not move. If you touch a charged object to the metal ball, the leaves will move apart.
   Students' diagrams should be similar to those in Figure 4.9.



Learning Check Answers (Student textbook page 269)

1. When a spark occurs, charges jump across the gap between oppositely charged objects. For example, there could be a spark here, as the person reaches to touch the door knob.



2. An object can become discharged by sparking or by grounding.
   Discharge by sparking: A charged object induces an opposite charge on an object near it. If the attraction between the charges are great enough, the excess charges will jump across the gap between the two objects.
   Discharge by grounding: A conductor is used to connect the charged object to Earth's surface so the excess charges can flow safely to the ground.
3. Grounding a metal object prevents sparks from occurring because the excess charges are allowed to flow through the metal conductor into the ground instead of jumping across the air between two objects.

Activity 4.8 Charging an Electroscope (Student textbook page 270)

Pedagogical Purpose

Students will conduct an inquiry involving conduction to investigate the law of electric charge.

Planning	
Materials	electroscope ebonite rod fur glass rod silk (optional) **BLM 4-15 Charging and Grounding an Electroscope** (optional)
Time	10–15 min in class 5 min to prepare materials
Safety	Handle the glass rod carefully. Do not use a chipped or broken glass rod.

Skills Focus

- make a prediction based on acquired knowledge
- use an inquiry approach to investigate phenomena
- draw conclusions based on inquiry results

Background Knowledge

When the metal terminal of an electroscope is touched with a charged object, the metal leaves at its base spread apart in an inverted 'V'. This is because some of the charge on the object is conducted through the terminal and metal rod to the leaves. Since each leaf receives the same sign charge, they repel each other and thus diverge. If additional charge of the same sign is again brought to the electroscope, the leaves will diverge farther.

Activity Notes and Troubleshooting

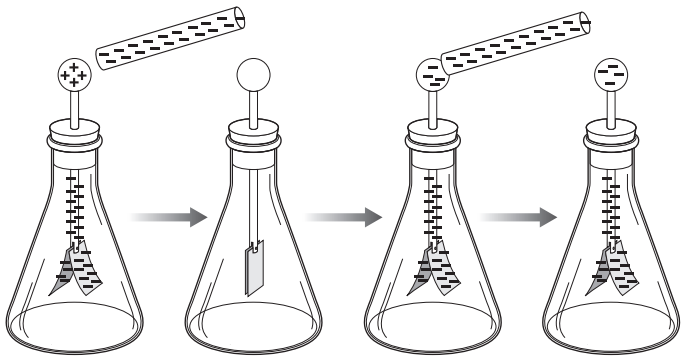
- As with some of the other activities involving static electricity, this activity works very well on dry winter days and poorly on humid warm days, so plan accordingly.
- The exchange of electrons is dependent on other factors, e.g., contaminants in the two materials, as well as humidity, as previously stated, so results can vary from day to day.
- Typically, students have difficulty in isolating charge because they tend to allow the rod to brush against the electroscope or other objects. Have them practise bringing the rod close to, but not touching, the electroscope before they begin the activity.

Additional Support

- ELL Match English language learners with students who have strong communication skills to ensure instructions are understood.
- DI This activity includes opportunities for visual and bodily-kinesthetic learning. Ensure students have opportunities to take on roles in their group that will support their learning.
- Focus students' attention on the movable electric charges, which are electrons.
- Enrichment—Ask students to repeat the activity several times using glass and silk to determine if similar results are obtained.

Answers

1. In step 2, the leaves moved apart because the ebonite rod moved all of the negative charges in the ball into the leaves. In step 3, the leaves returned to their original positions because once the rod was removed, nothing was pushing the negative charges away from the ball, so the negative charges moved back into the pith ball leaving the entire electroscope uncharged. When the rod actually touches the ball of the electroscope, the leaves move apart due to the negative charge applied and stay apart because excess charge transferred from the rod to the electroscope making the entire electroscope negative.

2. 

Activity 4.9 Grounding An Electroscope (Student textbook page 271)

Pedagogical Purpose

Students will conduct an inquiry involving conduction and induction to investigate the law of electric charge.

Planning	
Materials	electroscope ebonite rod fur glass rod silk (optional) **BLM 4-15 Charging and Grounding an Electroscope** (optional)
Time	10–15 min in class 5 min to prepare materials
Safety	Remind students to handle all equipment and materials carefully.

Skills Focus

- make a prediction based on acquired knowledge
- use an inquiry approach to investigate phenomena
- draw conclusions based on inquiry results

Background Knowledge

When a charged object is brought near the metal terminal of an electroscope, the metal leaves at its base spread apart in an inverted 'V'. This is because the charge on the object is conducted through the terminal and metal rod to the leaves. Since each leaf receives the same sign charge, they repel each other and thus diverge. If the charged object is moved away, the induced charge will cease.

However, if the electroscope is grounded while the inducing charge is present, electrons will be conducted away from the electroscope. As a result, the metal leaves will drop to the rest position. If the ground is removed and then the charged object is removed, the electroscope will be left with an overall deficit of electrons. The electrons will redistribute throughout the entire electroscope leaving the metal leaves slightly positively charged. Since each leaf is left with a slight positive charge, they repel each other and thus diverge.

Activity Notes and Troubleshooting

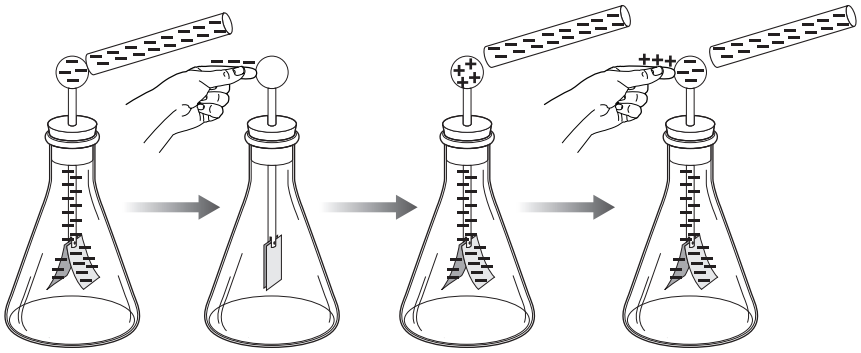
- As with some of the other activities involving static electricity, this activity works very well on dry winter days and poorly on humid warm days, so plan accordingly.
- The exchange of electrons is dependent on other factors, e.g., contaminants in the two materials, as well as humidity, as previously stated, so results can vary from day to day.

Additional Support

- ELL Pre-teach key vocabulary, for example, induced charge and induction.
- ELL Match English language learners with students who have strong communication skills to ensure instructions are understood.
- DI This activity includes opportunities for visual and bodily-kinesthetic learning. Ensure students have opportunities to take on roles in their group that will support their learning.
- Focus students' attention on the movable electric charges which are electrons.
- Enrichment—Ask students to repeat the activity several times using glass and silk to determine if similar results are obtained.

Answers

1.



2. Since our bodies are good conductors, by touching the charged electroscope, the excess charges will move onto our fingers making the electroscope neutral.

3. The leaves are separated. This is due by a temporary charge caused by induction. The rod will force all the negative charges into the leaves temporarily making the ball positively charged and the leaves negatively charged.

Investigation 4C Materials for Lightning Rods

(Student textbook page 272)

Pedagogical Purpose

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

Planning	
Materials	Styrofoam® cup two 5 cm aluminum foil strips invisible tape 2 cm × 10 cm test materials, including metal, plastic, cardboard, wood ebonite rod fur **BLM 4-16 Investigation 4C** (optional)
Time	30–40 min in class 10–15 min preparation time
Safety	Remind students to handle all equipment and materials carefully.

Skills Focus

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

Background

An electrical conductor is a material that contains movable charge. In metallic conductors, such as copper or aluminum, the movable charged particles are electrons. Non-conducting materials lack mobile charges, and so resist the flow of electric current. A lightning rod is a single component in a lightning protection system. In addition to rods placed at regular intervals on the highest portions of a structure, a lightning protection system typically includes a rooftop network of wires which provide multiple conductive paths from the roof to the ground. The actual rooftop lightning rod is a metal strip or rod, usually of copper or aluminum.

Activity Notes and Troubleshooting

- As with some of the other activities involving static electricity, this activity works very well on dry winter days and poorly on humid warm days, so plan accordingly.
- The exchange of electrons is dependent on other factors, e.g., contaminants in the two materials, as well as humidity, as previously stated, so results can vary from day to day.
- Students must be patient to see movement in the strips of aluminum. Since the charges involved are small, the movement will be difficult to see.

Additional Support

- ELL Pre-teach key vocabulary by showing, and allowing students to handle a Styrofoam® cup, metal, plastic, carbon, cardboard, and wood. Introduce the terms insulator and conductor and help students to make connections with English words they already know. Have them list common objects made of these materials in a T-chart under conductor or insulator.
- DI Bodily-kinesthetic learners will be helpful in this activity. As much as possible, ensure that there is at least one in each group.
- ELL The diagrams in the margin will help English language learners and visual learners understand what to do in steps 2–4. Consider assembling the materials yourself, and demonstrating, while describing the procedures aloud in a simple and slower-paced manner, what to do in each of steps 5–8 before students begin.
- Focus students' attention on the movable electric charges, which are electrons.
- Enrichment—Ask students to try other substances of their own choosing to determine if they would make good lightning rods.

Answers

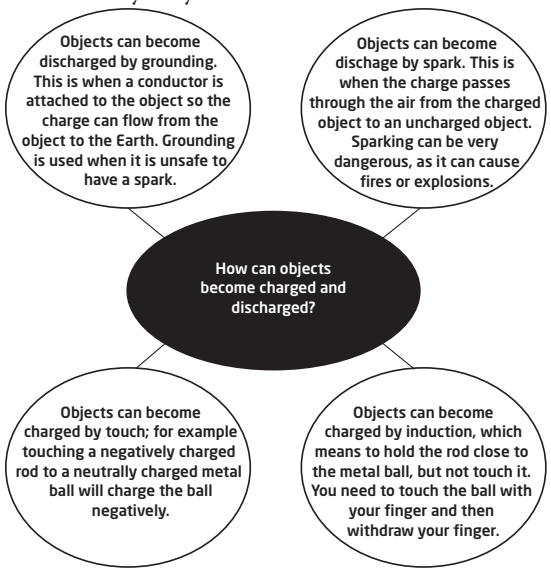
1. Metal is the best conductor, then carbon, then air. The rest of the materials do not conduct any electricity.
2. Metal would make the best lightning rod because we want a material of high conductivity to get struck and safely ground the electricity. If we chose a material that was an insulator, it would most likely not be hit by the lightning and in turn, we might be hit by the lightning instead.

Topic 4.3 Review (Student textbook page 273)

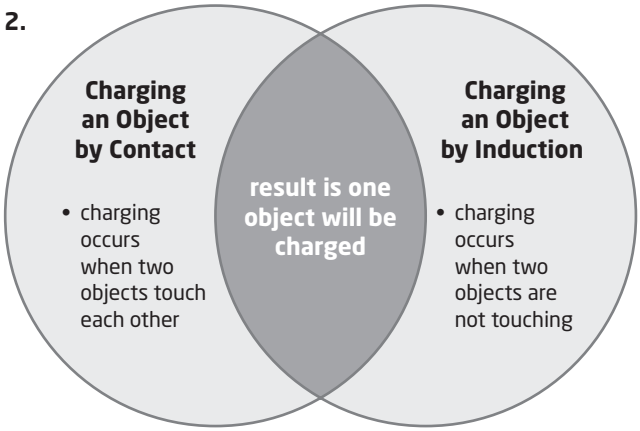
Please also see **BLM 4-17 Topic 4.3 Review (Alternative Format)**.

Answers

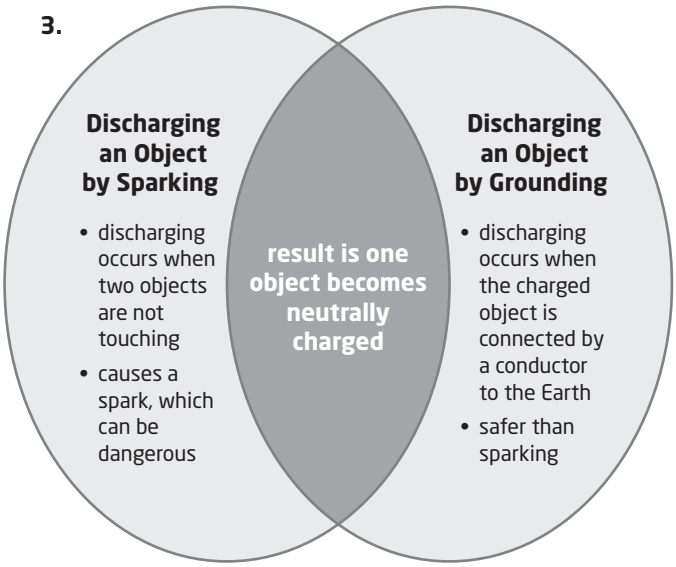
1. Answers may vary.



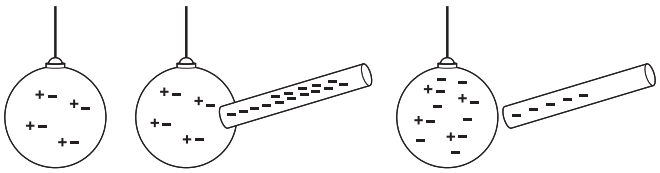
2.



3.



4. For example: The pith ball has an equal number of positive and negative charges, so it is neutrally charged. A negatively charged rod touches the pith ball, and the negative charges flow to the rod.



5. When clothes are tumbled in a clothes dryer, they rub against each other. Negative charges flow from one material to another. Some of the clothes then have opposite charges, so they are attracted to one another. Sparking can occur when the clothes are close, but not touching, because there is a build up of negative charges.

6. It a good idea to place the gas can a safe distance from the truck. If it is too close, a spark might go from the truck to the can, which would cause the gas to ignite and explode.

7. Lightning is like a giant spark that occurs when negative charges on the bottom of clouds travel to the nearest positive charges on the ground. Since the roof of a house might be closest to the bottom of the cloud, there is a chance the house could get struck by lightning and burn. A metal lightning rod is designed to prevent this from happening. The rod is higher than any other part of the house so it is the item that receives the lightning. The rod is grounded, so all the energy from the lightning goes safely into the ground instead of into the house.

8. a) The hair and the comb are both neutrally charged because they have an even number of negative charges and positive charges.

b) When the comb is negatively charged, it will have more negative charges.

c) When the comb is negatively charged, the hair will be positively charged.