Lab 5
Charging by Induction

Relevant SOLs: PS.6b, PS.6c, PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 4.3d, 6.1c

Overview

An object can become charged through contact with another charged object. This is a phenomenon known as charging by conduction. When objects are charged without coming into contact with a charge source, the process is known as charging by induction. This process primarily works with conductors. One method of charging involves moving a charged object to the vicinity of two uncharged conductors in contact with each other. See Fig. 5.0.1, Fig. 5.0.2, Fig. 5.0.3, and Fig. 5.0.4.

Fig. 5.0.1 Negative charge accumulates on a plastic rod after it is rubbed against silk. Far away from the rod, two metal spheres in contact with each other are placed on insulating stands. They are electrically neutral in the beginning.
Fig. 5.0.2 The negatively charged plastic rod is brought close to the metal spheres. Negative charge moves to the sphere farther from the rod, leaving the closer sphere positively charged. The two spheres as a whole remain electrically neutral, because they are insulated from the surroundings.

Fig. 5.0.3 The metal spheres are then separated. Each sphere retains its excess charge.
Fig. 5.0.4 The negatively charged plastic rod is now removed, leaving the metal spheres individually charged. They carry equal and opposite amounts of electric charge because the two spheres as a whole have to remain electrically neutral.

***In this experiment, we are assuming that all parts of the brass support and aluminized tube are conductive. In reality, the aluminized tube has an insulating coating. This can be ignored for the purposes of these activities.
Activity 5 - 1: Charging the Electroscope by Induction

Objective: Charge the electroscope by induction.

SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 6.1c

Materials:
• Teflon Rod
• Silk
• Electroscope
• Protractor (optional)

Prediction
1. Predict the behavior of the electroscope when the charged Teflon rod is brought near to the brass support of an uncharged electroscope.

2. Predict the behavior of the electroscope when the charged Teflon rod is brought near to the brass support of an uncharged electroscope and your finger is in contact with the opposite end of the brass support.

Observation and Procedure
1. Rub the Teflon rod on silk. Hold the Teflon rod in your right hand.

2. Move the Teflon rod horizontally towards the lower part of the brass support. The tube will start to deflect. Be very careful not to let the tube deflect more than 45 degrees.

3. When the Teflon rod is about 5 mm away from the brass support, stop the horizontal movement. Move the Teflon rod upward. The tube will deflect more and more until the middle portion of the tube comes into contact with the Teflon rod. Stop when contact is made.
4. Pull out the Teflon rod from under the tube. Pull along the length of the rod so that it slides out smoothly without touching the brass support.

5. With the rod removed, the tube will oscillate back and forth around its new equilibrium position. Wait for it to settle down. Estimate the angle of tube deflection.

6. Neutralize the electroscope and the Teflon rod by rubbing them with your hand.

7. Repeat Steps 1-3 but then, instead of removing the Teflon rod right away, touch the top lip of the brass support with your finger while maintaining contact between the rod and tube. See Fig. 5.1.1. Then take your finger off the brass support while maintaining contact between the rod and the electroscope. Describe the behavior of the electroscope.

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Fig. 5.1.1
8. This time, repeat Step 7, but after removing your finger, you will go ahead and pull out the Teflon rod from under the tube. Be sure to pull along the length of the rod so that it slides out smoothly without touching the brass support. Wait for the tube to settle down in its new equilibrium position. Describe the behavior of the electroscope.

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9. Estimate the angle of tube deflection.

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Explain

1. The procedure above describes 2 experiments – the first one is a control experiment to contrast the effect made by touching the electroscope with your finger. Use the effect produced by the two spheres touching and then separated to isolate the net charge on each sphere as discussed in the overview to explain the difference in results when your finger touches the brass.
2. Previously, your finger was used to neutralize the electroscope. It seems counterintuitive that the electroscope doesn’t get neutralized in the second part of the activity. Explain the paradox – how does charge get onto the tube when you touch the brass support? What is the polarity of the charge on the tube?

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Objective: Observe applications of charge induction.

SOLs: PS.11a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c, 4.3d

Materials:
- Teflon Rod
- Silk
- Soda Bottle (optional, from home)
- Tack Pin (optional, from home)
- Coffee Mug x2 (optional, from home)
- Water faucet and sink (soda bottle, pin, and mug are not needed if you have access to a water faucet and a sink in the classroom.)
- Handheld VDG
- Large Pie Tin (from home)

Prediction:
In this activity, you will be holding your charged rods near neutral samples of water. Predict whether each of the rods described below will attract the water, repel the water, or have no effect on the water.

1. A positively charged rod. _____________________

2. A negatively charged rod. _____________________

3. A neutral rod. _____________________

Observation and Procedure:
1. If you have a water faucet and a sink available, you can skip steps 2-5 and 8.

2. Use the tack pin to drill a hole 0.5mm in diameter on the side of the soda bottle. The hole has to be lower than ¼ of the height of the bottle.

3. Go to a kitchen or bathroom in your building. Plug the hole with your finger and fill the soda bottle with water up to 3/4 of its height. Release your finger to test whether the hole is big enough for water to come out as a stream. If the hole is too small, use the tack pin to widen it.
4. Put the lid back on. Flip the bottle upside down so that water doesn’t come out through the hole. Go back to the classroom with the bottle.

5. Put the bottle on the edge of a table. Flip the bottle right side up. Remove the lid and water will start streaming out of the hole. Set the first coffee mug on the floor to receive the stream.

6. Neutralize the Teflon rod by rubbing it across your hand. Approach the stream with the rod. Describe the behavior of the stream.

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7. Rub the Teflon rod on silk. Approach the stream with the rod from different directions. Describe the behavior of the stream.

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8. Set the second coffee mug next to the first one. Use the charged rod to bend the stream of water into the second mug.

9. The procedure above describes 2 experiments – the first one is a control experiment and the second one is to see whether the stream can be bent. Enter your results in Table 5.2.1.

<table>
<thead>
<tr>
<th>Charge on Teflon Rod</th>
<th>Effect on the stream of water</th>
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Table 5.2.1

10. Repeat Steps 6 and 7 with the acrylic rod. Describe the behavior of the water stream.

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University of Virginia Physics Department
11. Obtain “The Firefly.” The firefly consists of an old discarded plastic film canister that is partially transparent. A Christmas tree light bulb is placed on the inside with one end connected to aluminum foil and glued across the top. On the bottom you have the same thing. See Fig. 5.2.1 for details. The firefly in the class kit comes pre-assembled.

12. Dim the lights in the room.

13. Charge up the Teflon rod by rubbing it on silk. Then hold the Firefly capsule by grabbing the bottom. Maintain contact with the tin foil on the bottom with your hand.

14. Rub the charged Teflon rod on the top foil of the firefly. What do you see in the firefly capsule when the discharge occurs?
1. Why does the water stream bend when the charged Teflon rod is nearby? (Hint: water is a conductor too). Describe the redistribution of charge in the water stream under the influence of the charged Teflon rod.

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2. Explain how it is possible for the Teflon rod and the acrylic rod to have the same effect on the water when their charges are opposite.

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3. If you could make a stream of another liquid, such as ethanol or gasoline, would the charged rod bend the stream? Explain your reasoning.

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4. Describe what you think is happening when The Firefly lights up.

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Activity 5 - 3: The Electrophorus

Introduction:
An electrophorus is a device that can generate static electricity repeatedly by induction. The device consists of a charged insulating plate, and a metal plate with an insulator handle. The metal plate can be charged as often as desired without draining the charge on the insulating plate. See Fig. 5.7 to Fig. 5.10.

Objective: Build and test a homemade electrophorus.

SOLs: PS.6b, PS.6c, PS.11a, 4.1b, 4.3a, 4.3c, 4.3d

Materials:
- Class Kit plastic Box
- Silk
- Electroscope
- Letter-size Paper (from home)
- Large Pie Tin (from home)
- Styrofoam Cup (from home)
- Scotch Tape (from home)

Fig. 5.3.1 The metal plate is neutral in the beginning. It has an insulator handle.
Fig. 5.3.2 A Teflon insulating plate is charged. Then the metal plate is suspended above the charged plate. Negative charge moves to the top surface of the metal plate, leaving the bottom positively charged. In our activity, a piece of paper will keep the two plates from touching.

Fig. 5.3.3 The top surface is touched for a brief moment. Negative charge escapes through the finger.
Fig. 5.3.4 The metal plate is now positively charged. It can be moved away from the acrylic plate without losing its charge.

**Prediction:**

The introduction states: “the metal plate can be charged as often as desired without draining the charge on the insulating plate.” This is of course theoretical. In practice, how many times do you believe the metal plate can be charged without draining the charge on the insulating plate? 10? 100? 1000?

**Observation and Procedure**

1. Tape the Styrofoam cup to the inside bottom of the pie tin. The tape should be strong enough to hold the weight of the pie tin when you use the cup as a handle to pick up the pie tin as shown in Fig. 5.3.5.
2. Cut out a round shape from paper about the same size as the pie tin bottom. Tape it to the outside bottom of the pie tin in Fig. 5.3.6. The paper acts as an insulator and will prevent charge from flowing on to the bottom of the plate.

3. Flip the E&M kit box upside-down. Rub silk against the plastic box. The flat surface of the box will become negatively charged. See Fig. 5.3.7.
4. Set the pie tin on the charged surface of the box using the Styrofoam cup as a handle. Do not touch the tin plate. Only touch the handle. Then pick it back up using your left hand and touch the rim of the plate again with a finger on your right hand. Instead of your finger you may use the firefly to see if a discharge occurs. If it does, the firefly will light up. See Fig. 5.3.8. Is there a discharge from the plate? Record your observations here.

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Fig. 5.3.8
5. Set the pie tin on the charged surface again using the cup as a handle. This time, touch the rim of the plate while it’s sitting on the charged surface. See **Fig. 5.3.9**. Record your observations.

6. Now pick up the pie tin with the handle using your left hand and touch the rim of the plate again with your right hand finger. Instead of your finger you may use the firefly to see if a discharge occurs. If it does, the firefly will light up. See **Fig. 5.3.10** and **Fig. 5.3.11**. Is there a discharge from the plate? Record your observations here.
Repeat steps 5 and 6. **Does the charge on the box become exhausted?**

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**Explain**

1. **In Step 4, if there is a discharge, is the charge positive or negative that leaves the plate? What type of charge stays on the plate?**

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2. **In Step 5, what happens to the negative charge on the plate when you touch it with your finger? Does it remain on the plate or does it flow through your finger?**

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3. In Step 6, if there is a discharge, what type of charge leaves the plate? What type of charge stays on the plate?

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4. Each time a discharge happens, electric energy is dissipated as light and sound. It seems paradoxical that we can create discharge events perpetually using this method. Does it violate the conservation of energy? Where does the electric energy come from?

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