Activity 6 : Detection of Charge Using the UVa Electroscope

State of Virginia Relevant SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Overview

An electroscope is an instrument that detects the presence of charge on an object, either through actual contact (conduction) or through induction. When the electroscope itself has some net charge, its two conductive components will acquire like charge and deflect from each other due to a repulsive force. See **Fig. 1** and **Fig. 2** for an illustration of the standard metal leaf electroscope and the UVa electroscope. In the UVa electroscope the electrical torque about the axis of rotation is balanced by the gravitational torque due to the offset of the pivot point from the center of mass of the tube.

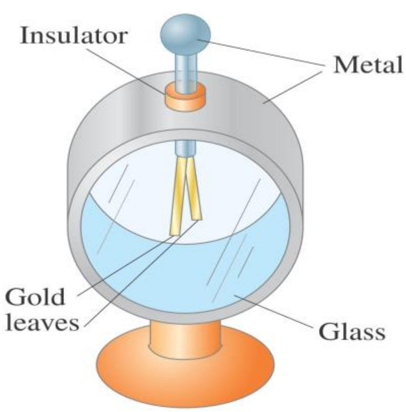

Fig. 1 Standard metal leaf electroscope

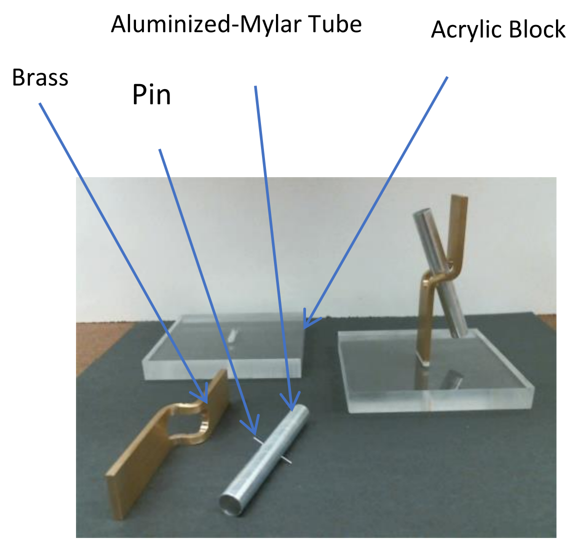

Fig. 2 UVa electroscope components

How the UVa Electroscope Works

The base of the UVa electroscope in **Fig. 2** is constructed out of acrylic block, an insulator, to eliminate charge leakage to the table. The acrylic block holds the brass conducting support on which charge is placed by rubbing a charged object across it. A rotating conducting tube acts as the “needle” that measures the total charge on the electroscope.

If you rub the top of the brass support with a charged object such as the white Teflon rod that has been previously rubbed with silk as shown in **Fig. 3,** the excess electrons will move from the Teflon rod to the conducting tube and brass support. The repulsive force between the electrons will force them to move along all the conducting elements until they are uniformly separated along the tube and brass rod. This also produces a repulsive force between the tube and the support. This electric force pushes the conducting tube away from the brass support producing a torque to rotate the tube counter clockwise. The rotation axis of the tube is provided by a steel pin through the tube about 0.075 inches above the center of mass of the tube. Because the axis of rotation is offset from the center of mass, the larger mass below the pivot point produces a gravitational torque in the opposite direction. The tube will rotate until the opposing gravitational torque is balance by the electrical torque. As the deflection angle increases towards 90 degrees, eventually the repulsive torque from the bottom of the brass support will start pushing back on the tube and it will go no further. The maximum angle seems to be around 50 degrees.

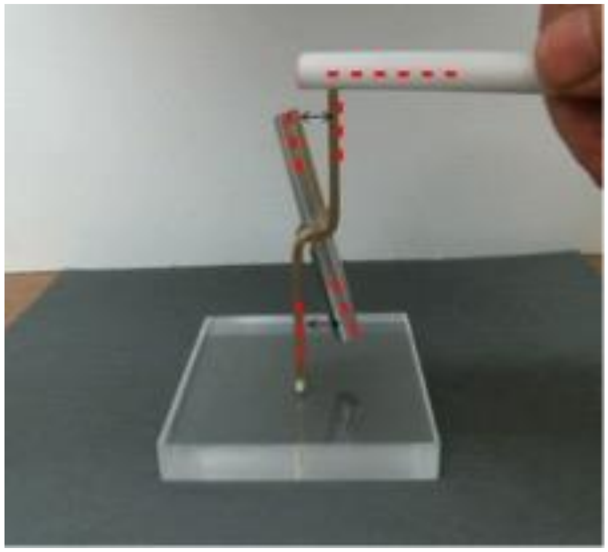

Fig. 3 A negatively charged Teflon rod charges up the electroscope by rubbing it across the end of the brass support.

A crucial piece of the apparatus is the rotating conducting tube shown in **Fig. 4** below. The distance between the pin hole and the center of mass can be changed to produce different amounts of sensitivity between the deflection angle and the amount of charge. By increasing the distance d more charge on the tube will be needed to offset the gravitational torque.

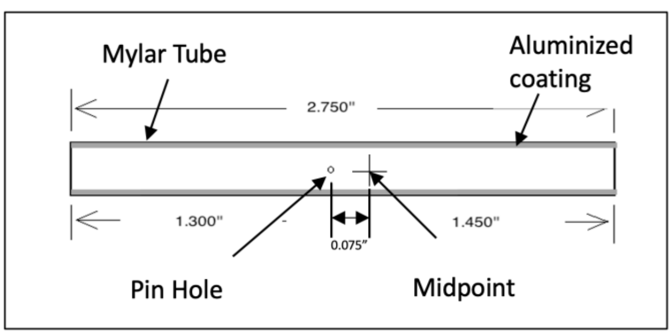

Fig. 4 The rotation axis of the tube is .075 inches (1.9 mm) offset from the midpoint of the 2.750 inches (7.0 cm) long mylar tube. The diameter of the tube is 0.375 inches (0.95 cm). The aluminized coating makes the tube conducting.

Activity 6-1: Using electroscope to detect the presence of charge

Objective: Use the electroscope to detect the presence of charge.

Materials:
- Electroscope
- 1 Acrylic Rod
- 1 Teflon Rod
- Silk

Virginia State of Virginia SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c
Suitable for students 9-12

Prediction:

1. Assemble the electroscope according to **Fig. 2.** Predict the behavior of the electroscope when you touch a charged Teflon rod to the top of the brass support on the electroscope.

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2. In what ways will a negatively charged rod touching the electroscope look different or the same from a positively charged rod touching the electroscope?

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Procedure:

1. Set the tube in the vertical position by touching the top of the brass support with your finger. Your finger is a conductor and, therefore, will drain any electric charge on the electroscope so it becomes neutral after you touch it.

2. Rub the Teflon rod with a silk cloth.

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3. Rub the charged Teflon rod along the top of the brass support on the electroscope a shown in **Fig. 3**. Describe the behavior of the electroscope. If you do not get a good response, use a tissue with alcohol to wipe along the length of the Teflon rod at the end painted red. This will clean off any oils or dust. What is the sign of the charge on the electroscope. Explain.

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4. Repeat the process of charging the Teflon rod and touching the electroscope several times to accumulate more charge. Describe how the angle of the tube changes as you add charge. Is there a maximum angle?

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5. Touch the top of the brass support with your finger to make it become neutral. Now rub the acrylic rod with silk and repeat step 3 and 4. You may have to repeat the process a few times for the effect to be evident. Describe the behavior of the electroscope. You may also have to clean the acrylic rod with alcohol dry with tissue. What is the sign of the charge on the electroscope?

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6. Touch the upper lip of the brass support to make it neutral. Then, using the Teflon rod, charge up the electroscope until the tube goes out as far as it can.

7. Rub the acrylic rod on silk. Then slowly slide the rod on the upper lip of the brass support while watching the movement of the tube very closely. Describe the behavior of the tube as more charge gets rubbed off the acrylic tube. Explain why now the angle of the tube gets smaller. If you keep rubbing charge on it from the acrylic rod, the angle goes to 0 and starts increasing again. Explain.

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Explanation

1. Explain why the tube of the electroscope rotates around the pivot when a charged rod touches the top of the brass support.

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2. In Step 4, explain why there is a maximum angle that the tube of the electroscope will rotate through.

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3. Compare the behavior of the electroscope after being charged by a Teflon rod and an acrylic rod. Explain the reasons for the similarities and differences.

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4. When the polarity of the charge on the electroscope was negative what real particle was being transferred to or from the electroscope? When the polarity of the charge on the electroscope is positive what real particle was being transferred to or from the electroscope?

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5.What happens when an equal amount of positive charge meets an equal amount of negative charge?

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Activity 6-2: Conductor or Insulator?

Introduction:
The main difference between a conductor and an insulator is that a conductor allows charge to move through it while an insulator doesn't. While the atoms in an object are stationary, the electrons can sometimes escape the grasp of the atomic nuclei and drift through the material. A material whose electrons can easily move through is said to conduct electricity. Conversely, a material whose atomic nuclei are strongly attached to all the electrons is an insulator since they are not allowed to move.

Objective: Determine whether an object is a conductor or insulator.

Materials:
- Teflon Rod
- Silk
- Electroscope
- Wooden Rod
- Acrylic Rod
- 100% Metal Object such as metal utensil or piece of rolled up aluminum foil
- 100% Plastic Object such as a plastic utensil

State of Virginia SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Prediction:

1. Use **Table 1** to record your predictions as to whether certain materials are electrical conductors or insulators.

Table 1 Conductor/Insulator Predictions and Reasoning

Material	Predictions and Reasoning
Your Finger	
Wood	
Acrylic	
Teflon	
Metal object	
Plastic object	

1. Which of the 6 predictions above are you confident about and why?

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2. Which of the 6 predictions above are you are not confident about and why?
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Procedure

1. Charge up the electroscope again using the Teflon rod by rubbing it with silk. Charge it up until a large angle appears. Now touch the top lip of the electroscope with your finger as shown in **Fig. 5.** Describe the behavior of the tube and whether your finger is a conductor or insulator. If the tube returns to the vertical position, then your finger is a conductor because the electrons have been conducted away from the electroscope. Record your results in **Table 2**.

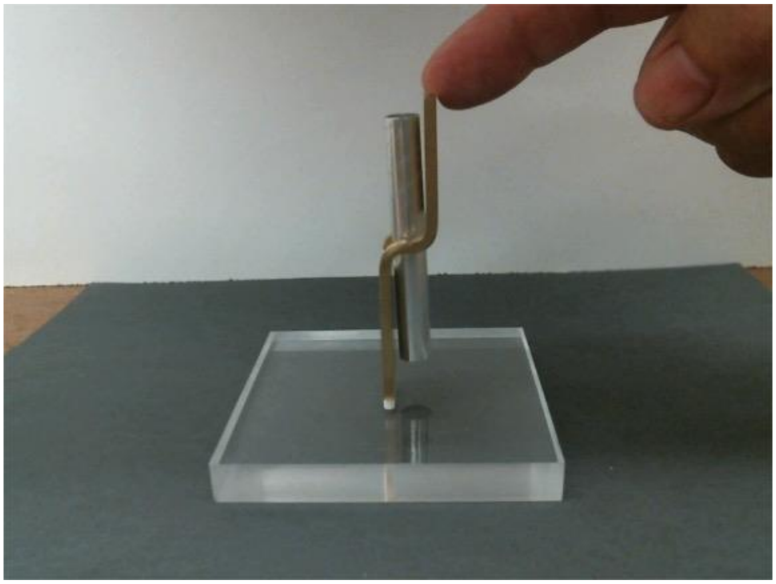

Fig. 5 Charged electroscope being shorted to ground through your body

2. Determine if the wooden rod is a conductor. Now you know from step 1 your hand is a conductor and will discharge the electroscope. This was also shown in Activity 6-1. Hold one end of the wooden rod in your hand. Touch the top lip of the charged electroscope with the other end of the wooden rod, as shown in **Fig. 6**. If the wooden rod is a conductor, it will discharge the electroscope through your hand. If it doesn't discharge

it, it will be an insulator. Describe the behavior of the tube and whether the wood is a conductor or insulator. Record your results in **Table 2**.

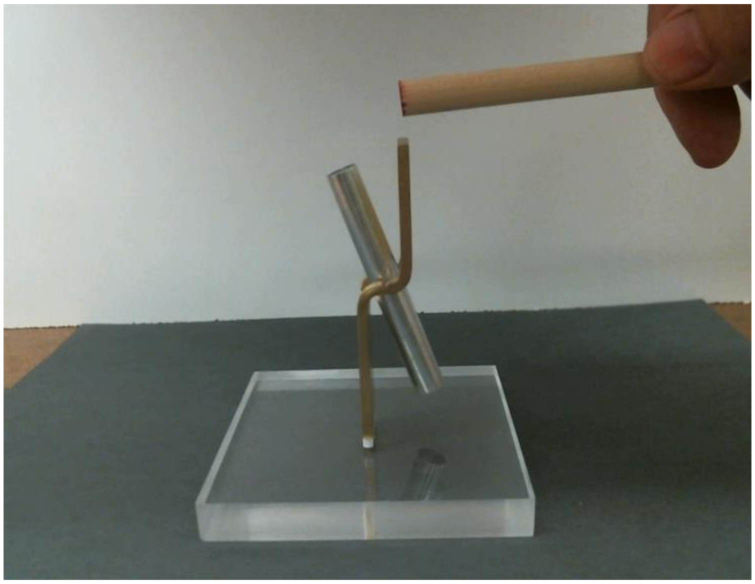

Fig. 6 Charged electroscope about to be touched with wooden rod

3. Substitute the acrylic rod for the wooden rod. Do not forget to neutralize the acrylic rod before it touches the electroscope. Repeat step 2. Describe the behavior of the electroscope and record results in **Table 2**.

4. Substitute a Teflon rod for the acrylic rod. Charge the electroscope up with the Teflon rod. Now neutralize the Teflon rod thoroughly by rubbing your finger up and down it. Repeat step 2. Describe the behavior of the electroscope tube and record in Table 1.

5. Substitute a metal object for the Teflon rod. You may also use a piece of aluminum foil. Repeat step 2. Describe the behavior of the electroscope in **Table 2**.

6. Substitute a plastic object for the metal object. Repeat step 2. Describe the behavior of the electroscope and in **Table 2**.

7. How do you decide whether a material is a conductor or insulator based on the behavior of the tube in the experiments above? State your line of reasoning.
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6. Sometimes wood is a conductor and sometimes an insulator. Explain why?
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9. Fill in **Table 2** with your conclusions.

Table 2 Conclusions and Observations

Material	**Conductor or Insulator and Observations**
Your Finger	
Wood	
Acrylic	
Teflon	
Metal object	
Plastic object	

Activity 6-3: Adding positive charge to negative charge

Objective: Use the electroscope to determine the effect of adding positive charge to negative charge**.**

Materials:
- Electroscope
- 1 Acrylic Rod
- 1 Teflon Rod
- Silk

State of Virginia SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Procedure:

1. Set the tube in the vertical position by touching the top of the brass support with your finger as in **Fig. 5.** Your finger is a conductor and therefore it will drain all the electric charge off the electroscope so it becomes neutral after you touch it.

2. Touch the charged Teflon rod to the top of the brass support on the electroscope. Describe the behavior of the electroscope.

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3. Repeat the process of charging the Teflon rod and touching the electroscope several times to accumulate more charge. Describe how the angle of the tube changes as you add charge. Is there a maximum angle?

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4. Touch the top of the brass support with your finger to make it become neutral. Now the rub the acrylic rod with silk and repeat step 3 and 4. You may have to repeat the process a few times for the effect to be evident. Describe the behavior of the electroscope.

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5. Touch the upper lip of the brass support to make it neutral. Then, using the Teflon rod, charge up the electroscope until the tube goes out as far as it can.

6. Rub the acrylic rod on silk. Then slowly slide the rod on the upper lip of the brass support while watching the movement of the tube very closely. Describe the behavior of the tube as more charge gets rubbed off the acrylic tube.

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Explanation

1. Explain why the tube of the electroscope rotates away from the vertical position when a charged rod touches the top of the brass support.

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2. In Step 4, explain why there is a maximum angle that the tube of the electroscope will rotate through.

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3. Compare the behavior of the electroscope after being charged by a Teflon rod and an acrylic rod. Explain the reasons for the similarities and differences.

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4. When the polarity of the charge on the electroscope was negative what real particle was being transferred to or from the electroscope? When the polarity of the charge on the electroscope is positive what real particle was being transferred to or from the electroscope?

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5. What happens when an equal amount of positive charge meets an equal amount of negative charge?

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Activity 6 – 4: Movement of Charges in a Conductor

Introduction:
We already know that the fundamental characteristic of a conductor is that charges can move freely through it. That is electrons are free to move through the conductor. If a charged object is placed close to a conductor, it will affect the spatial distribution of the charges in the conductor by attracting opposite charge while pushing similar charge away. See **Fig. 6 and Fig. 7**

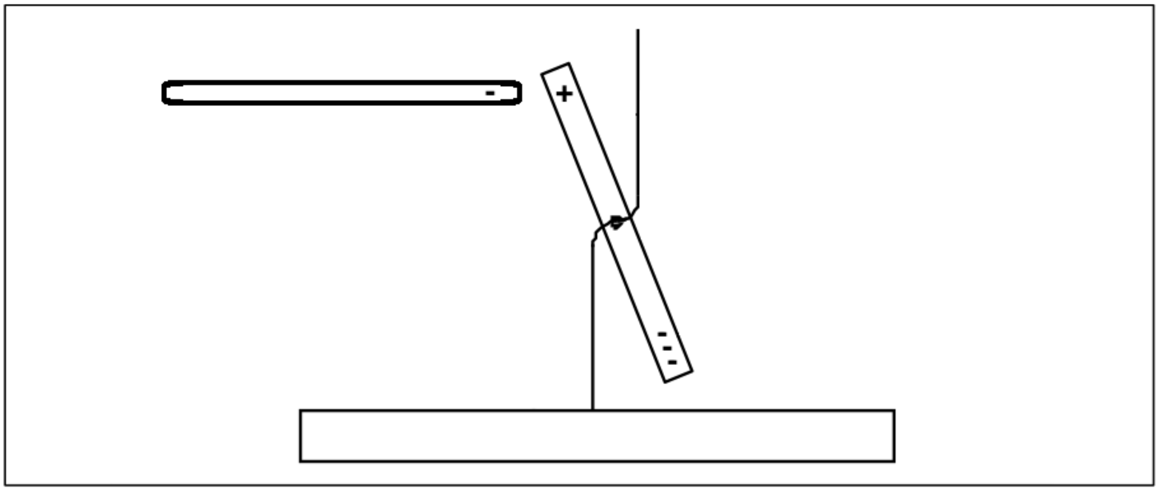

Fig. 6 A negatively charged rod is brought near a neutral electroscope. Some of the electrons from the top of the electroscope tube are repelled to the opposite end of the tube leaving a net positive charge behind.

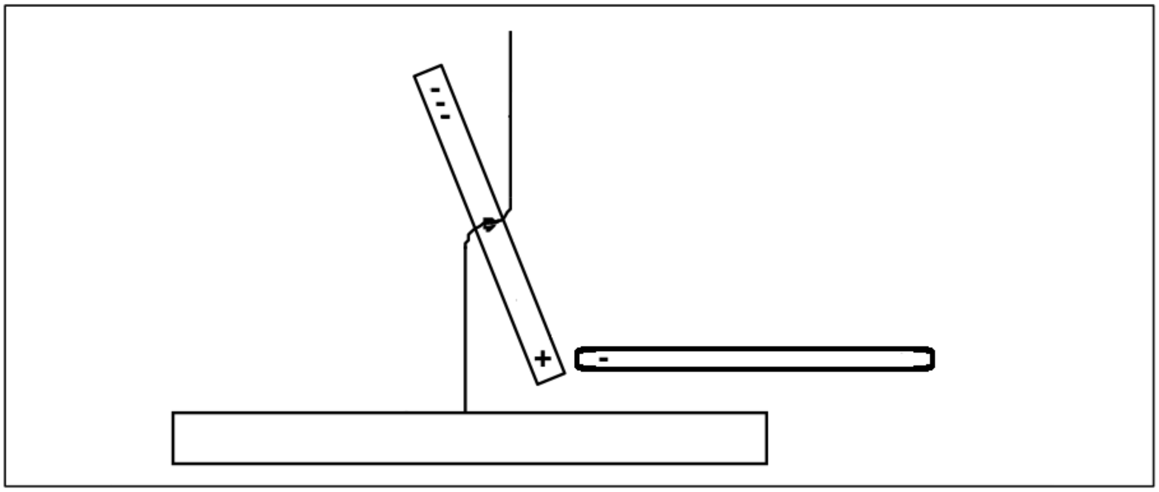

Fig. 7 A negative rod is brought near to an initially neutral electroscope. Some of the electroscope's electrons are repelled to the opposite side of the tube leaving a net positive charge behind. This is similar to the situation **Fig 6**.

Objective: Show that the spatial distribution of charges in a conductor can change easily.

Materials:

- Electroscope
- Teflon Rod
- Silk

State of Virginia SOLs: PS.11 a, 3.1a, 3.1j, 4.1a, 4.1b, 4.3a, 4.3c

Prediction:

1. Predict the behavior of the electroscope when the charged Teflon rod is brought near to the top of the similarly charged electroscope tube. Explain your prediction.

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Procedure:

1. Rub the Teflon rod on silk. Rub the Teflon rod across the lip of the electroscope to charge it up.

2. Rub the Teflon rod on silk again. Starting from 10 cm away, slowly move the Teflon rod close to the top of the electroscope *tube*. Describe the behavior of the tube in the entire process.

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3. Pull the rod away. If the electroscope is still charged, move on to Step 4. If the electroscope seems to have lost its charge, recharge it as in Step 1 before moving on to Step 4.

1. Recharge the Teflon rod and slowly move it close to the bottom of the tube, also starting from 10 cm away. Describe the behavior of the tube in the entire process.

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Explain

1. Were your observations in Step 2 in agreement with your prediction? Why or why not?

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2. Were your observations in Step 4 similar to those you observed in Step 2? Why or why not?

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3. How can the tube be repelled and then attracted, while having the same amount of net charge on it? Explain the mystery by drawing reference to the movement of charges in a conductor.

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