Lab 7: Electrostatics

Introduction

Objective

To compare the properties of insulators and conductors and study polarization, charge by contact, and charge by induction.

Theory: Insulators & Conductors

All materials can be classified as *insulators*, *conductors*, or *semiconductors*. In an insulator, electrons are bound to their atoms, making it difficult for charge to travel through the material. In a conductor, some electrons are free to leave their atoms, making it easy for charge to travel. Semiconductors are materials which can switch between the properties of insulators and conductors. The majority of everyday objects are insulators, while common conductive materials are metals. Semiconductors, such as silicon, are used in electronic devices.

Both insulators and conductors can be polarized. *Polarization* occurs when a charged object is brought near another object. The charged object will push like charge away while attracting opposite charge. The result is that the charged object will attract the other object! In an insulator, polarization causes each of the atoms to undergo a slight charge separation. The greater the surface area or volume of the insulator, the more atoms there will be to shift and the stronger the attraction will be. In a conductor, polarization causes electrons to leave their atoms. While there is a larger charge separation in conductors, polarization only occurs on the surface of the conductor, making the resulting attraction generally weaker than in insulators.

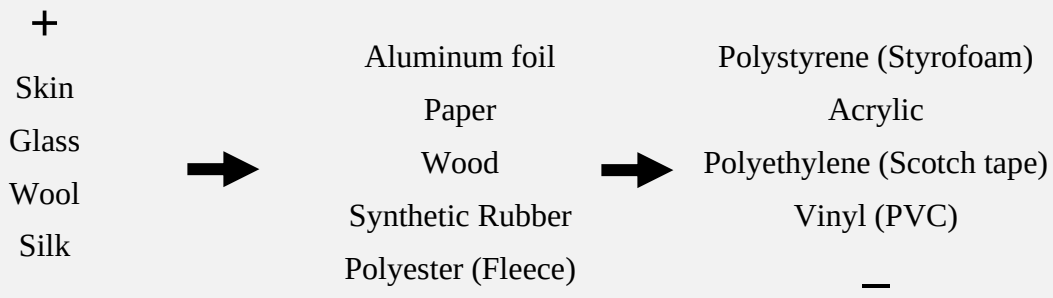
Conductors are very easy to discharge because charge is free to move through the whole material. In contrast, insulators can be very difficult to discharge because electrons are not free to leave their atoms. This is especially true for synthetic materials. Most fabrics leak charge quickly despite being insulators. Common sources of discharge are contact with the body and loss of charge to ions in the air.

Theory: Charge by Contact

There are in general two ways to charge objects by contact. Conductors can be charged by touching them to another charged conductor. This is known as *conductive charging* and is typically used to create electric circuits.

The other way to charge objects by contact is to rub them together, also known as *triboelectric charging*. One object will take electrons from the other, making one positively charged and one negatively charged. We can predict the charges on the objects using a *triboelectric series*. The object highest in the series will acquire a positive charge while the lower object will acquire a negative charge. The further apart the two objects in the series, the stronger the charge separation will be.

Triboelectric Series



Theory: Charge by Induction

An alternative method to charge conductors is by induction. If two conductors are placed in contact with each other, a charged object, or *inducer*, can be brought near one of the conductors. This will polarize the two conductors as if they were a single object! Separating the two conductors while keeping the inducer in place will leave each conductor with a net charge. The conductor closest to the inducer will have the opposite charge as the inducer, while the conductor furthest will have the same charge.

A slightly different method exists where a single conductor is grounded, allowing electrons to either flow in or out as the inducer is brought close. This can happen by accident if two conductors are used but not insulated from their surroundings.

Apparatus

- Scotch tape
- Sheet of printer paper*
- PVC pipe
- Silk cloth
- String
- Acrylic rod
- Aluminum foil*
- Scale (00.0 g resolution)
- 2x Metal rectangles
- Polyester fleece (blue)
- Scissors
- Glass rod
- Insulating foam pad

**It's best for the paper to have similar density to the aluminum foil.*

Procedure

Part 1 – Polarization

1. Stick a long piece of tape to an acrylic rod. Fold it back on itself to cover the sticky side. Charge the tape stick by stroking the tape with the blue cloth a few times on each side.

   Note: *Since the tape is an insulator, only the part of the tape that has been rubbed will be charged. It should be difficult to discharge the tape but try to minimize contact with other objects.*

2. Observe the tape's interactions with 5 or more neutral objects in the room. Include at least one insulator and one conductor. Rank the interactions from strongest to weakest.

   Note: *Electrostatic forces are generally weak and easy to confuse with other forces.*

   Q1: Were there any objects the tape didn't interact with? Was it repelled by any objects?

3. Next, cut a piece of printer paper into four quadrants. Crumple one piece into a ball and set another aside (the other two won't be used). Cut two pieces of aluminum foil which are similar in size to the paper quadrants and crumple one into a ball.
4. Charge the PVC pipe with the blue cloth. One at a time, place the pieces of paper and foil on the scale and hold the PVC pipe above them. Note the changes in the weight of the objects as the pipe is brought close to, but not touching, the objects. Using your observations, rank the attractions from strongest to weakest.

   Q2: What impact does surface area seem to have on the attractive force due to polarization?

   Q3: Was polarization stronger in the paper or the aluminum? Did it matter whether the paper and aluminum were flat or crumpled?

5. Remove any objects from the scale and hold the pipe close above it but not touching. Note any change in the reading on the scale.

   Q4: What implications does this finding have for your previous observations?

Part 2 – Charge by Contact

6. Refresh the charge on the tape stick. Charge just the top half of the glass rod with the silk.
7. Hold the tape near each end of the glass rod and note the interactions.

   Q5: Why is the tape more attracted to one end of the rod than the other?

8. Charge the tape stick. Attempt to discharge it each of the following ways, recharging it after each attempt:

   - Hold it in your hand.
   - Brush it several times against the table or wall.
   - Rinse it off with water.

   Q6: How did you check whether the tape was discharged?

   Q7: Which method(s) was most effective for discharging the tape? Why?

9. Use the triboelectric series to determine the sign of the charge for the tape when rubbed with the blue cloth.

10. Observe interactions with the tape to determine the sign of the charge on the following objects:
    - The PVC pipe rubbed with the blue cloth.
    - A glass rod rubbed with silk.
    - The silk used to rub the glass rod.

    Q8: Is the sign of the charge for each object consistent with what the triboelectric series predicts? Explain any exceptions.

    Q9: Without the triboelectric series, would it be possible to determine if the tape were positively or negatively charged?

Part 3 – Charge by Induction

11. Place the two metal rectangles side-by-side on the insulating foam. Attach a piece of tape as a handle to one of the rectangles (tying a piece of string will also work).

    Q10: Why are we using two conductors instead of two insulators?

12. Charge the PVC pipe with the blue cloth. Hold the pipe near the rectangle without a handle. Pull the other rectangle away using the handle while holding the PVC pipe in place.

    Important: *Make sure the PVC pipe and your hands don't touch the metal rectangles!*

    Q11: Should the PVC pipe be held perpendicular or parallel to the rectangle?

13. Charge the tape stick. Hold it near each metal object without touching them. Record whether it was attracted to or repelled by each rectangle.

14. Using the handle, touch the rectangles together. Listen closely; did you hear a spark?

    Q12: Do your observations show the metal rectangles were charged? Are the observations consistent with each other?

15. Charge the rectangles by induction again. Observe the tape's interaction with each rectangle, but this time hold the tape parallel to the surface of the rectangle and make sure the tip of the tape stick is closer to the rectangle than the tape.

    Q13: Did the tape interact differently from before? Why or why not?

Group Report

Turn in one report for each group. Include each group member's name, the lab number, the lab section and the instructor's name. Include all plots, calculations and data tables in the report.

Data

A. Observations of interactions with 5 neutral objects and rankings (Step 2).

B. Noted weight changes and rankings (Step 4).

C. Noted change in scale reading (Step 5).

D. Interactions with both ends of glass rod (Step 7).

E. Determination of tape charge with triboelectric series (Step 9).

F. Observed interactions with charged objects (Step 10).

G. Interactions with metal rectangles (Step 13).

H. Observation of spark (Step 14).

I. Interactions with metal rectangles from second attempt (Step 15).

Post-Lab Questions

Give answers in complete sentences.

14. Were there any objects in the exercise which couldn't be polarized?
15. Was it important for the pieces of paper and aluminum to be similar in mass? What about volume? Explain.
16. Is it possible for a charged object to repel an uncharged object?
17. If two objects electrostatically attract, does that mean both are charged? What if they repel?
18. Is it possible to distinguish between whether an object has been polarized or charged? How?
19. Why is it important to hold the rod as close as possible to the metal objects when charging by induction? Is this proximity important when polarizing objects?
20. Illustrate the charge by induction process using a three-step diagram.

Lab Maintenance

Remember to organize your lab station and save a copy of your group report before leaving for the day. Delete any files created during lab. Remove all tape. Other items may be left out for other groups.