Solutions

20 points
-0.5 pts wrong each

Electrostatic Charges
Spring 20xx

Introduction

The objective of these experiments is to observe the behavior of electrostatic charges on insulators and conductors. Keep in mind that like charges repel and opposite charges attract. Also, both negative and positive charges can stick to the surface of an insulator, but in a solid conductor the positive charges are bound to the lattice structure of the metal, and therefore only the *negative* charges are free to move. WRITE YOUR ANSWERS DIRECTLY ON THESE INSTRUCTIONS. EACH PERSON IN YOUR GROUP WILL HAND IN THEIR OWN COPY OF THIS EXPERIMENT.

Experiment

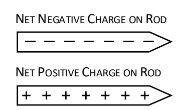
1. *Using an oscilloscope to identify the net charge*:

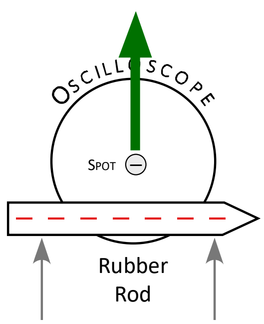
Charges usually are left on the surface of insulators (e.g. plastic, glass, rubber) after they are rubbed with a piece of silk, paper towel or fur. You will use an oscilloscope to test two different insulators (rubber and glass) after they have been rubbed with different materials to see whether the net charge on the insulator is positive or negative. The oscilloscope has been set up to show a bright spot at the center; the spot is caused by electrons (negatively charged) striking a phosphor coating on the back of the glass screen.

a. *Vigorously* rub the rubber rod with a piece of fur, and carefully bring it close to the face of the oscilloscope. Use the *side* of the rod, not the tip, for the best results; don't let the rod touch the glass surface of the oscilloscope. Move the rod up and down, parallel to the glass screen. Briefly describe your observations in the space below.

b. Now vigorously rub the glass rod with a piece of paper towel, and again bring the side of the rod close to the glass screen of the oscilloscope. Again describe your observations.

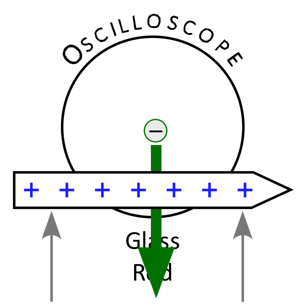
c. What does the behavior of the oscilloscope spot tell you about the net charge on each rod? Draw a series of charges on the sketch of each rod below (*refer to the sketches at right*).





DESCRIPTION/EXPLANATION:

The oscilloscope spot seems to move *away from* the charged rubber rod. Since like charges repel each other, and the spot is negatively charged electrons, the rubber rod has a net negative charge

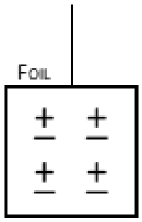


DESCRIPTION/EXPLANATION:

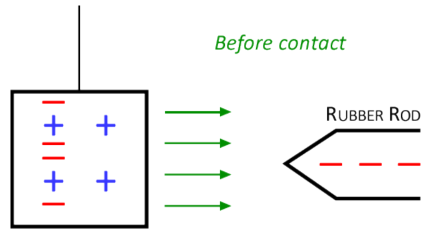
The oscilloscope spot seems to move *towards* the charged glass rod, following the rods' motion as it moves. Since opposite charges attract, and the spot is negatively charged electrons, the glass rod has a net positive charge

2. *Charging conductors and insulators*:

a. Begin by touching the suspended foil conductor with your fingers to ground it (removing any excess charge). The foil starts off electrically neutral – an equal number of positive and negative charges – as shown in the figure at right. *Note that the sketch shows only four pairs of charges, but obviously there are many more.*

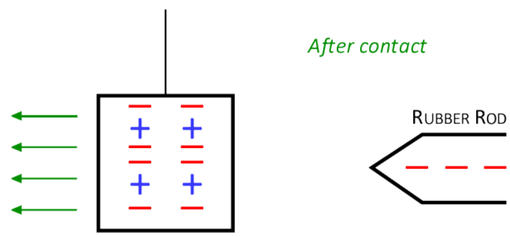


b. *Vigorously* rub the rubber rod with a piece of fur, and carefully bring it close to the *neutral* piece of foil (don't let the foil touch the rod!) Is the foil attracted to, or repelled from the rod? In the sketch at right, draw (i) an arrow showing the direction the foil moves; (ii) the charges on the rod; (iii) the distribution of charge in the foil (does it change, or remain the same?) Which charges move where, and why?



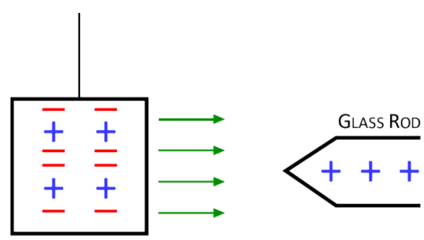
The *neutral* foil is attracted to the (negative) rod. Negative charges in the foil are repelled from the rod, inducing the opposite charge (positive) on the foil closest to the rod (*note position change in negative charges*). Therefore, the foil is attracted to the rod.

c. Allow the foil conductor to touch the charged rod, and observe the effect. You have just transferred charge from the rod to the foil by direct contact. Is the foil attracted to, or repelled from the rod? In the sketch at right, draw (i) an arrow showing the direction the foil moves; (ii) the charges on the rod; (iii) the distribution of charge in the foil (*are there the same number as before?*) Which charges move where, and why?



After contact, the *charged* foil is repelled from the (negative) rod. Extra negative charges are transferred to the foil during contact; note that the sketch shows *eight* negative charges in the foil. Since both the foil and rod now have a net negative charge, the foil is repelled from the rod.

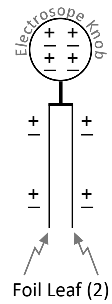
d. DON'T GROUND THE FOIL YET – KEEP ITS CHARGE FROM THE STEP (C)! Rub the *glass* rod with a paper towel. In the sketch at right, draw (i) an arrow showing the direction the foil moves; (ii) the charges on the rod; (iii) the distribution of charge in the foil. Describe the result when the charged glass rod is brought close to the charged piece of foil (don't touch the foil with the glass!). Use this information to again explain whether the glass and rubber rods have the same or opposite charge.



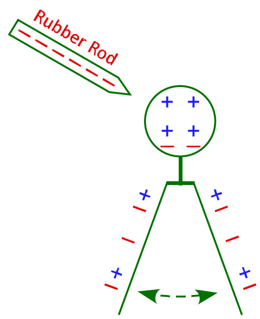
The foil, which still has a net *negative* charge, is now attracted to the glass rod. Since opposite charges attract, is again shows that the glass rod has a net positive charge.

3. *Charging an electroscope by charge transfer*:

a. Touch the knob on top of the electroscope to ensure that it is electrically neutral, as shown at right. The foil leaves should hang downward (don't worry that each leaf curls.) *Note that initially there are* ***eight*** *charged pairs in the sketch, evenly distributed throughout the electroscope.*

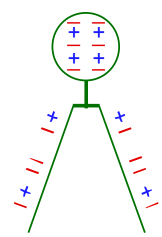


b. Charge the rubber rod with a piece of fur and bring it close to the knob of the (neutral) electroscope. On the sketch at right, draw (i) the leaves and an arrow showing how they have moved; (ii) the net charge on the rod (iii) charges on the knob and leaves. Be consistent with the total number of charges and *their expected position*. Briefly explain what happens to each foil leaf.



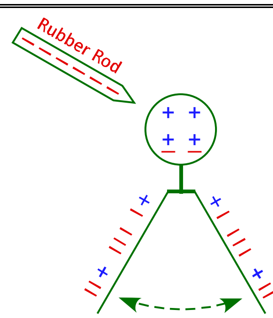
The rubber rod (negatively charged) causes the leaves to separate in the neutral electroscope. Some of the negative charges move out of the 'ball', down into the leaves. There are still the same 8 pairs of charges, but since extra negatives are forced down into the leaves, the leaves gain a net negative charge. Since the leaves are free to move, they repel each other and raise a little bit.

c. *Transfer charge from the rod to the electroscope as follows*: Scrape the flat part of the metal disc (with insulated handle) on the charged rubber rod, then touch the metal disc to the knob of the electroscope. Draw (i) the leaves to show their position; (ii) the expected number and position of charges in the knob and leaves.



Negative charges have been transferred from the rubber rod into the electroscope. In the figure there are now a total of 14 negative charges, but still only 8 positive charges. The leaves stay separated.

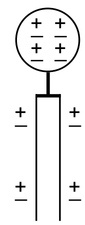
d. Now you will see if the charged electroscope has the same or opposite charge as the rubber rod: bring the charged rod close to the knob *without making contact*. Draw (i) the leaves and an arrow showing how they have moved; (ii) the net charge on the rod (iii) charges on the knob and leaves. Briefly explain the cause of the leaves movement.



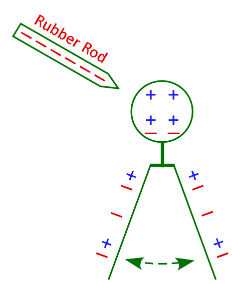
Bringing the rubber rod close to the charged electroscope causes the leaves to raise up further. Even more negatives are forced down into the leaves, increasing the repulsion between the leaves. The electroscope has a net negative charge, <u>the same</u> as that of the rod used to charge it up.

4. *Charging the electroscope by induction*:

a. Discharge the electroscope with your finger so that the electroscope is neutral. *Note that initially there are **eight** charged pairs in the sketch, evenly distributed throughout the electroscope*

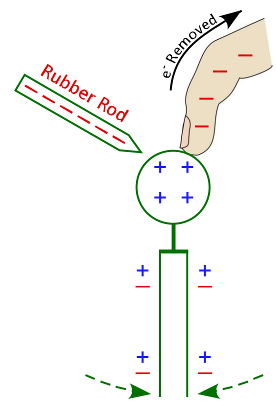


b. Charge the rubber rod with a piece of fur and bring it close to the knob of the (neutral) electroscope. On the sketch at right, draw (i) the leaves and an arrow showing how they have moved; (ii) the net charge on the rod (iii) charges on the knob and leaves. Be consistent with the total number of charges and *their expected position*.



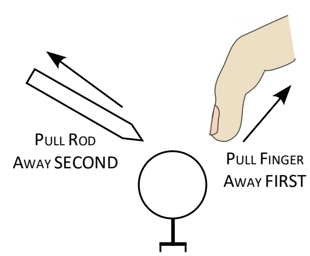
The leaves in the neutral electroscope separate when the rubber rod is brought near. Same as in step (3b) above.

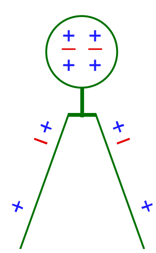
c. Touch the knob with your finger while keeping the rubber rod close to the knob. This will remove some of the negative charge from the electroscope (***four** negative charges are removed in the sketch*.) Draw (i) the leaves and an arrow showing how they have moved; (ii) the net charge on the rod (iii) charges on the knob and leaves. Keep track of the total number of charges.



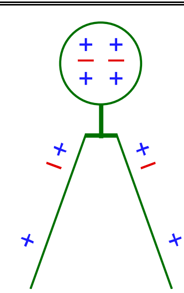
The leaves drop to their relaxed state once 4 negative charges are removed. The leaves remain neutral, but there are fewer negative charges overall.

d. **First**, remove your finger, keeping the rod nearby. **Second**, remove the rubber rod. Draw leaves and charges on the sketch of the knob at the far right.





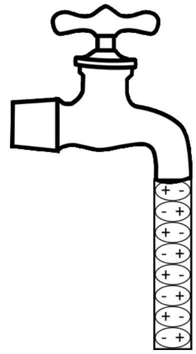
e. Now you will see if the charged electroscope has the same or opposite charge as the rubber rod: bring the charged rod close to the knob *without making contact*. Draw (i) the leaves and an arrow showing how they have moved; (ii) the net charge on the rod (iii) charges on the knob and leaves. Briefly explain the cause of the leaves movement.



The leaves again separate after pulling away your finger and the charged rod. The electroscope now has a net positive charge, opposite that of the rubber rod used to charge it. When the rubber (negative) rod is brought close, negative charges are forced down into the leaves, and the leaves drop down. The charge in the leaves becomes more neutral when negatives are forced downward.

5. *Fun with water!*

a. Turn on the faucet in the sink to produce a smoothly flowing stream of water. You want a flow rate just fast enough not to give drops but slow enough not to give turbulence. The figure at right is a simplified representation of a neutral stream of charged water molecules (the small ovals)



b. *Predict*: What will happen when you hold a charged *rubber* rod next to the water stream: Will the stream of water bend towards the charged rod (Figure A1) or away from it (Figure B1)? Circle the sketch that will represent the movement of the water stream

c. *Observe*: Try it (*but don't get the rod or fur wet!*). Circle the figure (A2 or B2) that represents your observation. On the correct figure, draw charges on (i) the rubber rod (ii) the water molecules.

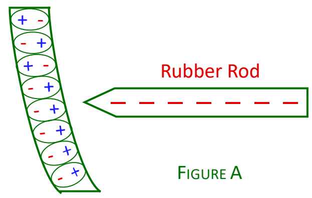


Figure A is correct – the water stream bends toward the charged rubber rod. Since water molecules are polar, and free to rotate, the opposite charge is induced in the water stream on the side closest to the rod. Therefore, the water is attracted to the charged rubber rod.

d. *Predict*: What will happen when you hold a charged *glass* rod next to the water stream: Will the stream of water bend towards the charged rod (Figure C1) or away from it (Figure D1)? Circle the sketch that will represent the movement of the water stream

e. *Observe*: Try it (*but don't get the rod or paper wet!*). Circle the figure (C2 or D2) that represents your observation. On the correct figure, draw charges on (i) the glass rod (ii) the water molecules.

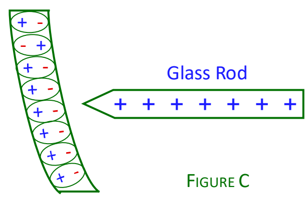


Figure C is correct – the water stream also bends toward the charged glass rod. The opposite charge is induced in the water stream on the side closest to the rod. Therefore, the water is attracted to the charged glass rod.

f. Briefly summarize your observations from this part: Why did the water stream react the way it did for each charged rod?

In both cases, the water stream is attracted to the charged rod, regardless of the charge on the rod. Since water molecules are polar, and they are free to rotate, the charged rod induces the opposite charge on the neutral water stream. Since the opposite charge is induced on the side of the water stream closest to the charged rod, the water will be attracted to the rod. The same attraction occurs with the positive and negative rods.

6. *<u>Where are the charges on a charged conductor</u>?* Your instructor will assist you with this experiment. On the side bench in the lab you will find the electrostatic generator, a large hollow sphere with a hole in it and an electroscope.

a. Charge the electroscope by charge transfer from the rubber rod. Discharge the metal disc on the insulated handle by rubbing your fingers on the disc, and then wave the (neutral) disc close to the knob of your electroscope (*don't touch the knob with the disc!*) Record your observations of any motion of the leaves in the electroscope at right.

The leaf on the electroscope <u>does not react</u> to the neutral metal disc. Sometimes a slight motion is noticed in the leaf, which is probably due to induction.

b. *Gently* turn the electrostatic generator by hand to charge the large sphere; try it again if there is a static discharge (a spark) across the gap between the two small metal spheres. *Note that a small, suspended Styrofoam ball in contact with the large sphere will visually show that the sphere is charged*. Move the small Styrofoam ball out of the way.

c. Again discharge the metal disc with your fingers, and touch the flat side of the disc on the outer surface of the large sphere. Wave the metal disc near the knob of your charged electroscope, noting any motion in the leaves. What does this observation tell you about the charge on the *outside* surface of the large sphere?

The leaf on the electroscope <u>does react</u> to the metal disc after it has been rubbed on the outside of metal sphere. The electroscope was charged directly, so it has a negative charge. The leaf raised up further, so the outer sphere has a *negative* charge (note that sometimes the leaf drops, indicating a *positive* charge on the outside of the sphere. Beats me why this happens.)

d. Discharge the metal disc and *hold the insulated handle by the end*. Without touching the edge of the hole, *<u>carefully</u>* insert the disc into the hole in the large sphere until the disc touches the inside of the sphere; start this step over if a spark jumps between the sphere and your finger.

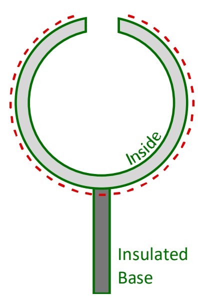
e. Scrape the metal disc around the inside of the sphere (to make sure you've made good contact), then carefully withdraw the disc, again without touching the edge of the hole. Wave the metal disc near the knob of your charged electroscope, noting any motion in the leaves. What does this observation tell you about the charge on the *inside* surface of the large sphere?

After scraping the metal disc on the inside of the sphere, no reaction is noticed in the electroscope leaf. That means that there is no charge on the inside of the hollow sphere.

f. Again discharge the metal disc with your fingers, and touch the flat side of the disc on the outer surface of the large sphere. Wave the metal disc near the knob of your charged electroscope, noting any motion in the leaves. Did you find the same results as in part (c)?

Yes! The electroscope leaf again moves, showing that the outside of the sphere is still charged, and was not grounded during any of the other steps.

g. On the sketch at right, draw charges representing the net charge on the outside and/or inside surface of the sphere.



If the leaf on the electroscope raised up, then the outside of the sphere has the same charge as the electroscope. The inside of the sphere appears to have no charge at all. All of the excess charge will distribute itself so that it is on the outside of the closed conducting surface