Electrostatics II

Purpose

- To discover how an electroscope works and to charge it by contact and by induction
- To examine the interaction of charged objects and uncharged ones
- To encourage the building of mental models that correspond with physical reality.

Equipment

- 2 electroscopes (glass flask & disk terminal)
- 2 polystyrene rods
- 1 sheet of PVC (dark blue)
- 1 Acetate cloth (black)
- 1 eleven inch by 14 inch sheet of acrylic (transparent)
- 1 Electrophorus (a metal disk with a gray plastic handle)
- 1 Neon bulb
- 1 PVC rod (grey)
- 1 wool cloth (brown/black/checkered)

Verify that you have all of the equipment listed. Notify your TA if anything is missing.

Introduction

Continue as in the report for electrostatics I by not using the terms 'proton', 'electron' or 'neutron' to explain any effects that you see in this lab. Here are two questions that can be answered using what you saw in Electrostatics I: **From your observations in Electrostatics I, what evidence is there for the existence of at least two varieties of charge? Have you seen anything that shows that a third type of charge exists? Explain. [3]**

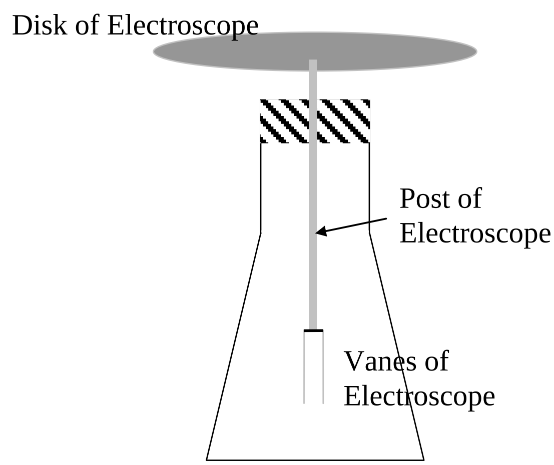
The second question for your pre-lab is: **Suppose that you have a rod that is positively charged, a rod that is negatively charged and a stand that allows rotation. If you are handed a rod of unknown charge-state, how could you determine if it has a positive charge, a negative charge or if it is uncharged? Explain what happens to the unknown rod if it has a positive charge, a negative charge or if it is uncharged. [3]**

In electrostatics I, you used a charged rod to separate two kinds of charge in an uncharged nail. <u>Making two charged regions appear in the nail is called 'polarizing the nail</u>'. The charged rod causes this behavior and is called the 'polarizing charge'. There are two possible ways in which this can happen. First, the region of positive charge that appears can be closer to the polarizing charge than any region of negative charge. Second, the region of positive charge can be further from the polarizing charge than any region of negative charge. These two possibilities can be described by drawing a vector from the negative charge to the positive charge. This direction of this vector is the direction of the electric dipole moment $\left(\vec{p}\right)$. The <u>dipole moment</u> is said to be <u>induced</u>[1] in the nail <u>by the polarizing charge</u>. (The

[1] Please be careful. There is another usage of the word *induce* that has to do with changing electromagnetic fields and has nothing to do with the electrostatic effect that we are looking at here.

magnitude of this vector is the product of the size of the induced charge and the distance by which they are separated. More may be said about dipole moments in your lecture course.) In electrostatics I, the electric dipole in the nail could have been called a temporary dipole because the induced charge in the nail disappears as soon as the polarizing charge was taken away.

The electroscope is a device that detects charge conveniently. The electroscope is not a very sensitive device but is more convenient than picking up bits of paper when we want to detect charge!



The vanes of the electroscope are pieces of conductive foil that are close together and are free to move on a hinge. The post of the electroscope is also made of a conductor and joins the vanes to the disk of the electroscope. The post is fixed in the flask with an insulating bung. The disk is also made of conductor. The vanes are enclosed in a glass flask to prevent air currents from disturbing the vanes. The primary effect is that the vanes change position when charge is near the disk of the electroscope[2]. The hinge allows the vanes to diverge from each other if they exert a force on each other or collapse if they don't exert a force on each other.

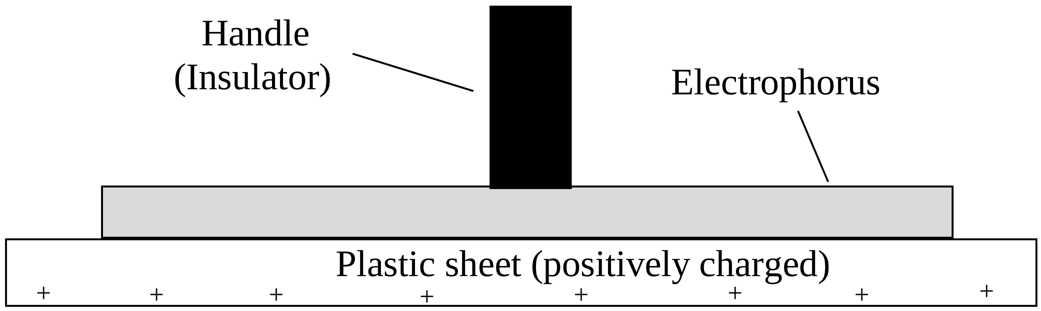
Recall that predictions are not wild guesses but are made on the basis of observations made previously. 'Predictions' are not synonymous with 'opinions'. For us, this means observations made in Electrostatics I can be used to make predictions in this pre-lab. **Predict what will happen to the disk of an uncharged electroscope when a *positively* charged object is brought near the disk. [1]** (Hint: what happened in electrostatics I when you brought a charged rod close to an iron nail?) **Continue your previous answer so that you describe what happens to charge in the other parts of the electroscope. Use this to infer what happens to the vanes. [2]**

Predict how the vanes will react when a *negatively* charged object is brought near the disk of an uncharged electroscope. Explain. **[3]**

In part C of the experiment, an electrophorus will be used to get more charge than we can from rubbing rods. An electrophorus is a metal disk (grey in the diagram below) with an insulating handle (black in the diagram below). Suppose that you have a plastic sheet that has already been *positively* charged by being rubbed with a cloth. The rubbed side of the sheet is placed face-down. **What will happen to**

[2] Actually, the glass flask that encases an electroscope becomes charged after some time. If enough charge appears on the glass flask then the electroscope doesn't respond as we expect. Use your second electroscope in these cases. In the meantime the casing of the first electroscope will lose its charge and again behave as you expect.

charge in the electrophorus if it is put on the charged plastic sheet? Explain in words what will happen. Copy the following diagram in your pre-lab and indicate the charged regions. [3]



Let's think about a different situation before returning to the electrophorus. 'Ground' is just what you think: the Earth. **Suppose that a (small) charged conductor is connected to ground**. **Explain why the conductor becomes uncharged. [2]** [It might help for you to replace the word 'ground' with the phrase 'a really big nail'. In electrostatics I, you thought about what is happening to charge inside a nail when a charged object approaches it.]

Let's return to the electrophorus. Typically, the charged plastic sheet is on a bench and the electrophorus is put on top of it. The top surface of the METAL disk of the electrophorus is briefly connected to ground and then disconnected from it. **What is the charge-state of the electrophorus after the electrophorus is momentarily connected to ground and then disconnected from it? [1]** ***Explain, assuming that the positive charge is free to move*. [2]**

Imagine the charge-state of the electrophorus is as in the previous paragraph before any connection to ground is made. Now let's change our perspective. Your previous explanation assumed that positive charge was free to move. *Now assume that positive charge is stationary and that negative charge moves*. Using this assumption to **explain the charge-state of the electrophorus after the electrophorus is momentarily connected to ground and then disconnected from it. [2]**

Instructions

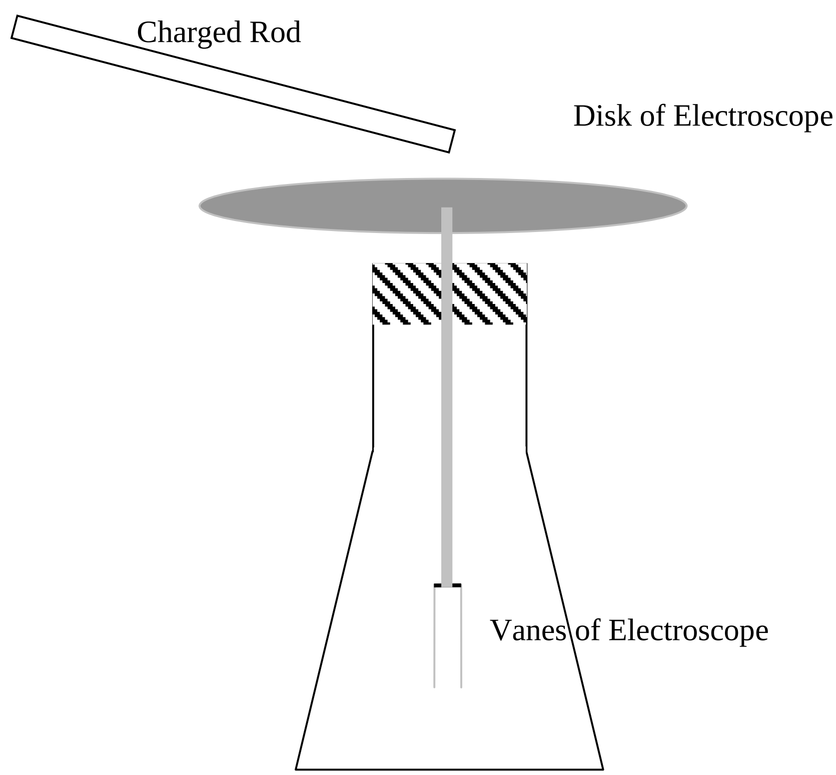
In your report, please remember to **write answers** to all **questions in bold type.** As in Electrostatics I, don't talk about electrons, protons or neutrons in your report. (These terms involve observations of sub-atomic particles that we aren't making in this lab.)

You have been introduced to the electroscope in the pre-lab and will need to confirm the predictions that you made there. I'll often ask you to "use a positively charged rod" or "use a negatively charged rod" so you'll need to recall that,

- ♦ A polystyrene (or acrylic) rod becomes positive if it is rubbed with a PVC sheet
- ♦ A PVC rod becomes negative if it is rubbed with wool cloth

Part A

In practice, if you want an uncharged electroscope then you need to discharge it by touching it before use. Bring a positively charged rod close to the disk of the electroscope (without touching the disk of the electroscope).



In the pre-lab, you predicted the behavior of the vanes of an electroscope <u>when a positively charged rod gets close to the disk of the electroscope</u>. *Do this*. **How does your prediction about the vanes compare with what actually happens? [1]** *Repeat with a negatively charged rod.* Again, **how does your prediction in the pre-lab compare with what actually happens as the negatively charged rod gets**

close to the disk of the electroscope? [1] Bring an uncharged rod near to the disk of the electroscope. Does anything happen? [1] The effect on the vanes is only temporary and the vanes collapse as soon as the charged rod is taken away.

The electroscope can be given a charge permanently. You will need an uncharged electroscope. *Charge a rod with a positive charge and roll it over the surface of the disk of an electroscope. (No pressure on the rod is needed. It might also help if you touch the sides of the rod against the edge of the disk.*) **What is the charge-state of the disk and the vanes after the charged rod has been taken away? [2]** We say that a charge has been put on the electroscope *by contact*.

Charge an electroscope by contact using a negatively charged rod (and then remove the rod). **Predict what will happen to charge in an electroscope if you approach the disk of a negatively charged electroscope with a negatively charged rod. [3]** (In your answer, say what will happen to charge and end by making a prediction about what will happen to the vanes.) *Try doing this after you have made a prediction***. Copy the following table in your report. Fill in the first row of table one. [1]**

Table 1:

Charge on Rod	**Charge on Electroscope**	**Behavior of Vanes**	
		Rod far from disk	Rod close to the disk
Negative	Negative		
Positive	Positive		

Predict what you expect to happen when you approach the disk of a positively charged electroscope with a positively charged rod. *Do this* and **fill in the second row of table 1. [1]**

The next two cases are more complicated. *Two things happen to the vanes when one kind of charge is on the rod and the other is on the electroscope. Slowly* approach the disk of a positively charged electroscope with a negatively charged rod. Begin the approach by holding the rod a few feet from the disk of the electroscope. Expect the vanes to react one way while the charged rod is distant, and react in a different way when the rod is close to the disk. (The precise distance at which the first effect disappears and the second is observed depends on the relative charges on the rod and electroscope, as well as on the environmental conditions when the lab is in progress. It is usually less than half a centimeter from the disk. Your TA will clarify if needed.)

In the following cases, describe what happens to charge in the electroscope. Use this to explain what happens to the vanes.

- **(a) When a negatively charged rod has been brought towards a positively charged electroscope but is not 'close' to the positively charged disk [3]**
- **(b) When the negatively charged rod gets 'close' to the positively charged disk [2]**
- **(c) When the positively charged rod has been brought towards the negatively charged electroscope but is not 'close' to the negatively charged disk [3]**
- **(d) When the positively charged rod gets 'close' to the negatively charged disk [2]**

Copy the following table into your report. (It looks like table 1 but look carefully at the first two columns.) **Use the previous four answers to fill it in;**

Table 2;

Charge on Rod	**Charge on Electroscope**	**Behavior of Vanes**	
		Rod far from disk	Rod close to the disk
Negative	Positive		
Positive	Negative		

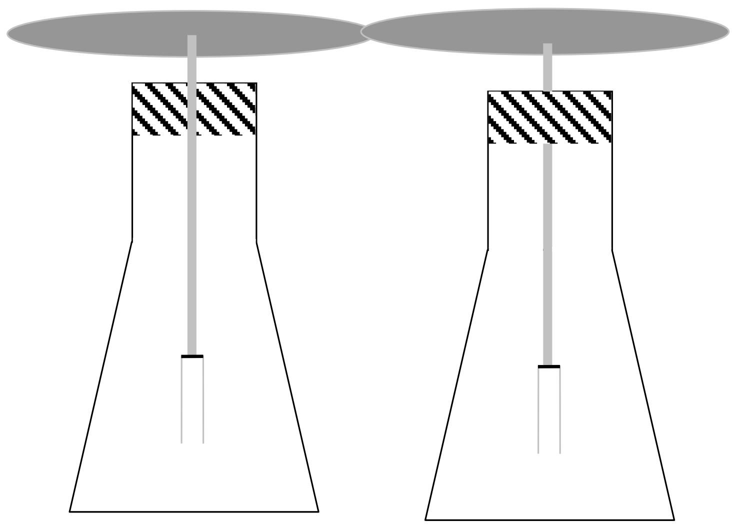
Tables 1 and 2 give you a test for finding the charge-state of an electroscope.

Ask your TA to check your answers before you go any further

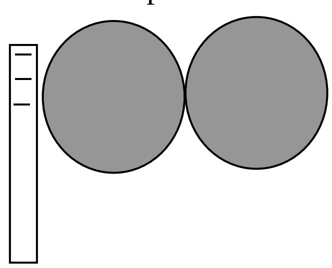
Part B

There is another way to put a charge on an electroscope but it can be tricky to do. *__Be particularly careful not to touch the disk of either electroscope with your hand or the charged rod__*. Read through the next instructions and *predict the variety of charge on each electroscope* before doing the experiment.

- Begin with two uncharged electroscopes.
- Bring two electroscopes close together so that their disks touch.

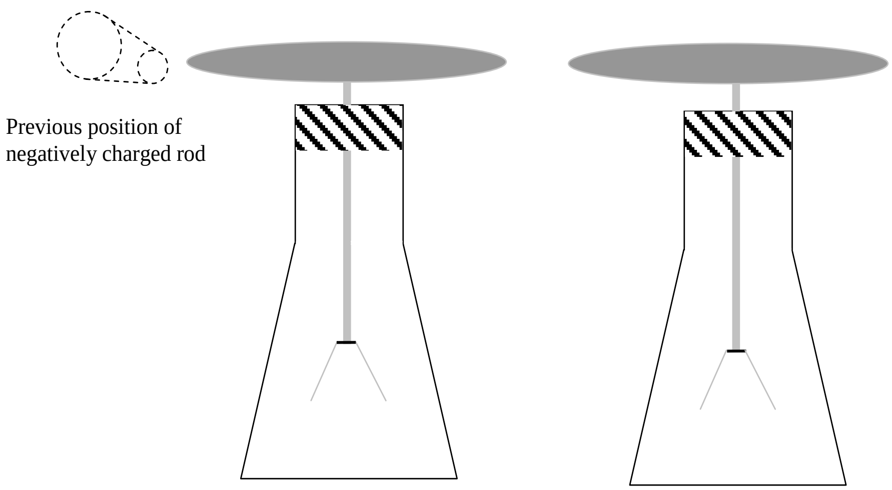


Approach the left edge of the disk of the electroscope on the left with a negatively charged rod but *don't touch the disk with the rod*. A view from the top is:



- While keeping the rod close to the disk on the left (and without touching the metal parts of either electroscope), slide *the electroscope* on the right so that the disks don't touch anymore.
- Take away the charged rod. Note the positions of the vanes on both electroscopes.
- Slide the electroscopes back together so that the disks touch. Look carefully at the positions of the vanes

Before doing the experiment, predict the variety of charge on each electroscope after the charged rod is taken away. *__Now, do this experiment__*. Both electroscopes have become charged *by induction*. Test for the variety of charge on each electroscope using the test that you summarized in tables 1 and 2. *Copy* *the following diagram into your repor***t. Draw the charged regions in all parts of the electroscope *after the charged rod has been taken away*. [3]**



The mechanical properties of the vans in the two electroscopes are probably not identical so you can't always conclude something about the relative amounts of charge on each electroscope at this stage. *Slide the electroscopes back together so that the disks touch*. (Be careful not to touch the disks with your hand when you move electroscopes. If the vanes keep flying off their hinges then move the electroscope with a plastic rod rather than your hand. You should be able to explain why this helps fix the difficulty.) **What happens to the vanes of both electroscopes? [1] (**Look carefully to see if the vanes just repel more weakly or if they collapse completely.) **What does this tell you about the relative amounts of charge that were separated before the last step (when the discs touched again). Explain how you conclude this. [2]**

The electroscope becomes charged but we have neither rubbed any part of the electroscope nor have we charged it by contact. We say that *a charge has been put on the electroscope by induction.*

Notice that the word *induce* is being used in a different sense than in Electrostatics I. In that experiment, we said we 'induced a dipole moment' to describe what was happening when we separated charge. However, the effect was temporary then: the induced dipole (or 'the separated charge') went away as soon as the charged object that did the polarizing was taken away. We are talking about something different here. The induced charge remains after the polarizing object is taken away. (There is a third sense of the word *induce* that has to do with changing electromagnetic fields and has nothing to do with the electrostatic effect that we are looking at here.) Notice too that the induced charge is opposite to the charge that induced it.

Recall that the electroscopes were uncharged before you began. **Describe uncharged objects in terms of the two kinds of charge that we have observed. Explain, using the direct evidence that you have seen in this section. [2]** (You answered a similar question last week but now you have evidence that allows you to say a bit more this time.) Uncharged objects are also described as being '<u>neutral</u>'.

Actually, only the electroscope on the left is needed to show charging by induction. The function of the electroscope on the right was to give charges from the electroscope on the left a place to go. Providing any other exit (or entry) route for charges will do.

(a) Discharge your electroscopes
(b) Bring the negatively charged rod close to the disk of a neutral electroscope. Keep the charged rod close to the disk of the electroscope. Charge stops moving quite quickly.
(c) Touch the disk of the electroscope with your finger
(d) Take away your finger
(e) Withdraw the charged rod

What do the vanes do? What kind of charge is on the electroscope? [2] (Test for the variety of charge as before.) In step (b) above, you connected the disk to ground (with a conductor). However, providing the route doesn't automatically mean that charge will take it. But the behavior of the vanes assures you that charge has left the electroscope. **Why would charge leave the disk of a charged electroscope if given the chance?** (You'll need to say more than giving some variation of 'charge always goes to the ground'.) **[2]**

The next sequence of activities will involve the electrophorus. *Rub the acrylic sheet* a few times *with wool cloth*. (This will put a small positive charge on the acrylic sheet.) Ask yourself where the charges are; are they on one side the sheet or in the 'bulk' of the sheet? *Turn the sheet over*. *Put the metal part of the electrophorus on the acrylic sheet* (but don't try and rub the metal against the acrylic sheet and don't touch the metal part yet!) *Bring the electrophorus close to an electroscope*. **Is the electrophorus charged? [1]** Now let's add a step. Put the disk of the electrophorus on the acrylic sheet as before. *Touch the metal part of the electrophorus with your finger*. *Take away your finger while the electrophorus is still on the acrylic sheet. Bring the electrophorus close to an electroscope*. **Is the electrophorus charged** (now that you have touched it when it was on the acrylic sheet)**? [1]**

Discharge the electrophorus by touching it. Charge the electrophorus repeatedly as above. Discharge it each time by touching it. (Notice that whether the electrophorus becomes charged, depends critically on when you touch it.) **Can you find a limit to the number of times that you can charge the electrophorus by induction using the same charged acrylic sheet? [1]** It is this property of the electrophorus that makes it useful. It will be our source of (more) charge for the next experiments.

When charging by *contact*, it is clear that the *charge is transferred* from one object to another so it is clear where the charge came from. **When the electrophorus (in the previous paragraph) was charged by induction, where did the charge come from? Explain. (Be careful. The step that was added involved 'grounding the electroscope'. Think carefully before you conclude that the charge on the electrophorus has its origins in the ground.) [2]**

Part C

We have seen situations in which charges move through substances. In this section we'll see if charges do anything when they move. Take the neon bulb out of its protective bag (or aluminum tumbler). *Please be gentle with it. Put it back when you are not using it*.

Rub the acrylic sheet with a wool cloth and charge the electrophorus by induction. *Bring the electrophorus close to a neutral electroscope*. *What does it tell you about charge on the electrophorus?* Put a dark background behind the bulb. *Hold the bulb by one of its wires and touch the other wire to the (charged) electrophorus*. **Does the bulb do anything? For how long does it do this? [1]** *Bring the electrophorus up to the uncharged electroscope*. **What does the electroscope tell you about charge on the electrophorus? [1]**

Ben Franklin assumed that the positive charges move. This assumption is fine unless we are thinking about sub-atomic particles when we talk about positive charge and negative charge (and I hope that you aren't!).

Is charge involved in making the bulb flicker? Explain. [2] The bulb only flickers rather than producing a steady light. **What does this suggest about the time taken for charge to move? [1]** *Put the neon bulb back in the protective bag* (or aluminum tumbler).

Remember leave the apparatus as it was when you arrived.
Ask your TA to check your apparatus before you turn in your reports.

PRE-LAB

NAME:___________________________ Course & Section _________________________

From your observations in Electrostatics I, what evidence is there for the existence of at least two varieties of charge? Have you seen anything that shows that a third type of charge exists? Explain.

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____**[3]**

Suppose that you have a rod that is positively charged, a rod that is negatively charged and a stand that allows rotation. If you are handed a rod of unknown charge-state, how could you determine if it has a positive charge, a negative charge or if it is uncharged? Explain what happens to the unknown rod if it has a positive charge, a negative charge or if it is uncharged.

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____**[3]**

Predict what will happen to the <u>disk</u> of an uncharged electroscope when a *positively* charged object is brought near the disk. (Hint: what happened in electrostatics I when you brought a charged rod close to an iron nail?)

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____**[1]**

Continue your previous answer so that you describe what happens to charge in the other parts of the electroscope. Use this to infer what happens to the <u>vanes</u>.

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____**[2]**

Predict how the vanes will react when a *negatively* charged object is brought near the disk of an uncharged electroscope? Explain.

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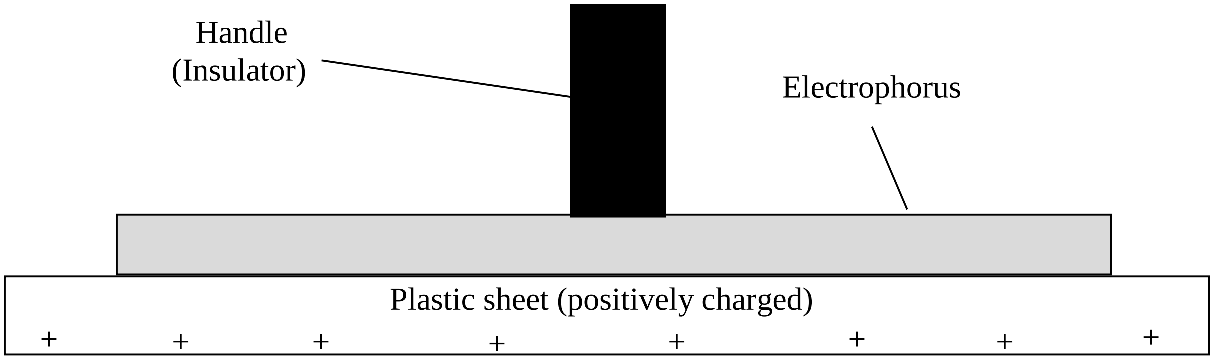
____**[3]**

What will happen to charge in the electrophorus if it is put on the charged plastic sheet? Explain in words what will happen. Draw the resulting configuration of charge on the diagram below.



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____**[3]**

Suppose that a (small) charged conductor is connected to ground. Explain why the conductor becomes uncharged. [It might help for you to replace the word 'ground' with the phrase 'a really big nail'. In electrostatics I, you thought about what is happening to charge inside a nail when a charged object approaches it.]

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____**[2]**

(The top surface of the METAL disk of the electrophorus is briefly connected to ground.) What is the charge-state of the electrophorus after the electrophorus is momentarily connected to ground and then disconnected from it? *Explain, assuming that the positive charge is free to move*.

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____**[2]**

(As in the previous question, the metal disk of the electrophorus is on the charged plastic sheet.) *Now assume that positive charge is stationary and that negative charge moves*. Use this assumption to explain the charge-state of the electrophorus after the top surface of the metal disk of the electrophorus is momentarily connected to ground and then disconnected from it.

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____**[2]**

REPORT

NAME:____________________________ Course & Section: ___________________

Feel free to draft your answers in pencil but remember that the report to be given to your TA must be in pen.

Part A

In the pre-lab, you predicted the behavior of the vanes of an electroscope <u>when a positively charged rod gets close to the disk of the electroscope</u>. How does your prediction about the vanes compare with what actually happens?

____**[1]**

How does your prediction in the pre-lab compare with what actually happens as the negatively charged rod gets close to the disk of the electroscope?

____**[1]**

Bring an uncharged rod near to the disk of the electroscope. Does anything happen?

____**[1]**

What is the charge state of the disk and the vanes after the charged rod has been taken away?

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____**[2]**

Predict what will happen to charge in an electroscope if you approach the disk of a negatively charged electroscope with a negatively charged rod. (In your answer, say what will happen to charges in the disk and end by saying what will happen to the vanes.)

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____**[3]**

Table 1:

Charge on Rod	Charge on Electroscope	Behavior of Vanes	
		During the Approach	Rod close to the disk
Negative	Negative		
Positive	Positive		

[2]

Predict what you expect to happen when you approach the disk of a positively charged electroscope with a positively charged rod. (In your answer, say what will happen to charges in the disk and end by saying what will happen to the vanes.)

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____**[3]**

In the following cases, describe what happens to charge in the electroscope. Use this to explain what happens to the vanes.

(a) When the negatively charged rod has been brought towards the positively charged electroscope but is not 'close' to the positively charged disk

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____**[3]**

(b) When the negatively charged rod gets ‘close’ to the positively charged disk

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____**[2]**

(c) When the positively charged rod has been brought towards the negatively charged electroscope but is not ‘close’ to the negatively charged disk

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____**[3]**

(d) When the positively charged rod gets ‘close’ to the negatively charged disk

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____**[2]**

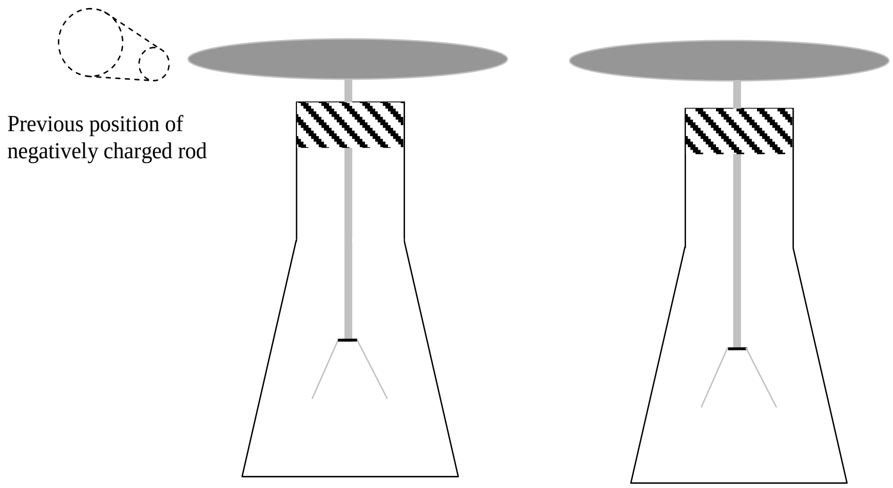
Use the previous four answers to fill in following table;

Table 2:

Charge on Rod	**Charge on Electroscope**	**Behavior of Vanes**	
		Rod far from the disk	Rod close to the disk
Negative	Positive		
Positive	Negative		

Part B

Draw the charged regions in all parts of the electroscope *after the charged rod has been taken away*.



[3]

What happens to the vanes of both electroscopes?

____**[1]**

What does this tell you about the relative amounts of charge that were separated before the last step (when the discs touched again). Explain how you conclude this.

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____**[2]**

Describe uncharged objects in terms of the two kinds of charge that we have observed. Explain, using the direct evidence that you have seen in this section.

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____

____**[2]**

What do the vanes do? What kind of charge is on the electroscope?

____**[2]**

Why would charge leave the disk of a charged electroscope if given the chance? (You'll need to say more than giving some variation of 'charge always goes to the ground'.)

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____**[2]**

Is the electrophorus charged?

____**[1]**

Is the electrophorus charged (now that you have touched it when it was on the acrylic sheet)?

____**[1]**

Can you find a limit to the number of times that you can charge the electrophorus by induction using the same charged acrylic sheet?

____**[1]**

When the electrophorus (in the previous paragraph) is charged by induction, where did the charge come from? Explain. (Be careful. The step that was added involved 'grounding the electroscope'. Think carefully before you conclude that the charge on the electrophorus has its origins in the ground.)

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____**[2]**

Part C

Does the bulb do anything? For how long does it do this?

____**[1]**

What does the electroscope tell you about charge on the electrophorus?

____**[1]**

Is charge involved in making the bulb flicker? Explain.

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____**[2]**

What does this suggest about the time taken for charge to move?

____**[1]**