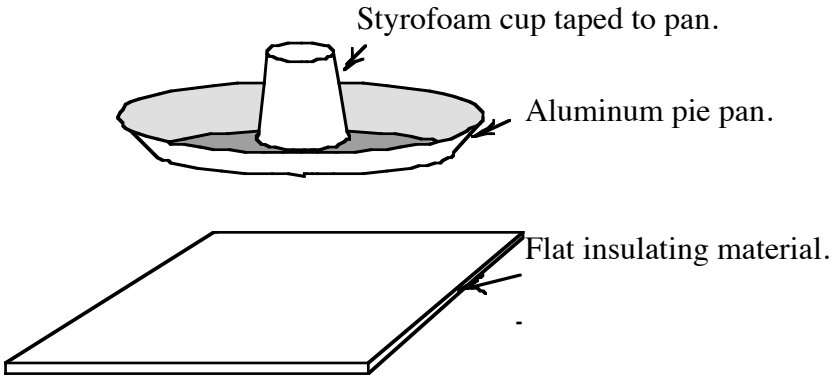
How does the electrophorus work?

(With notes for teachers Questions? layton@physics.ucla.edu)

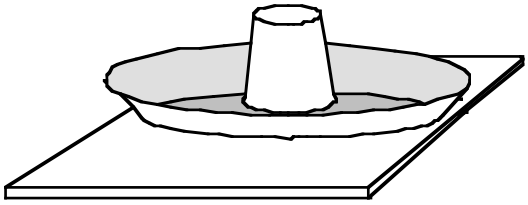
Materials:

An electrophorus can be easily constructed using an aluminum pie pan, a flat piece of insulating material, a Styrofoam cup and some scotch tape. Simply tape the cup to the center of the pie pan. See the illustration below:

Procedure for making the electrophorus work:



The first step is to charge the insulating plate by rubbing it with a cloth or paper towel. After charging the insulating plate, place the pan on top of it. (This should be the last time you will have to rub the insulated plate no matter how many times you repeat the following steps.



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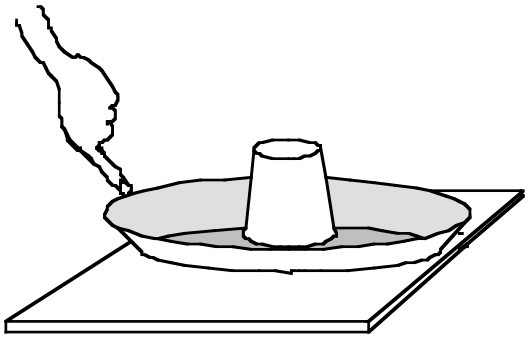
1.With the pan resting on the charged plate,

2. Touch the pan to ground it.



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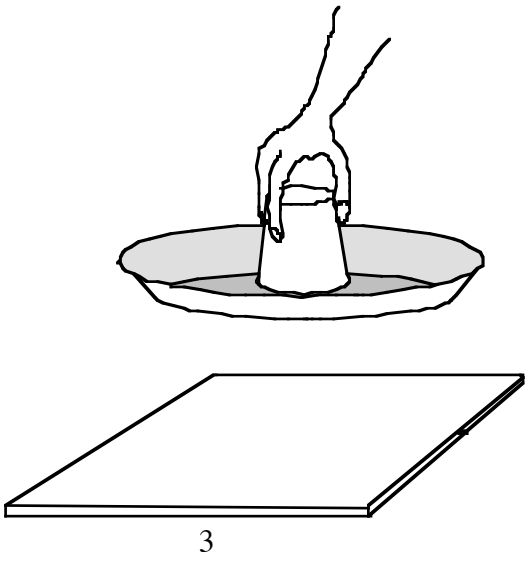
3. Remove your grounding finger and with your other hand, lift the pan by gripping the Styrofoam cup, to a distance of 10cm, or more, from the charged plate.



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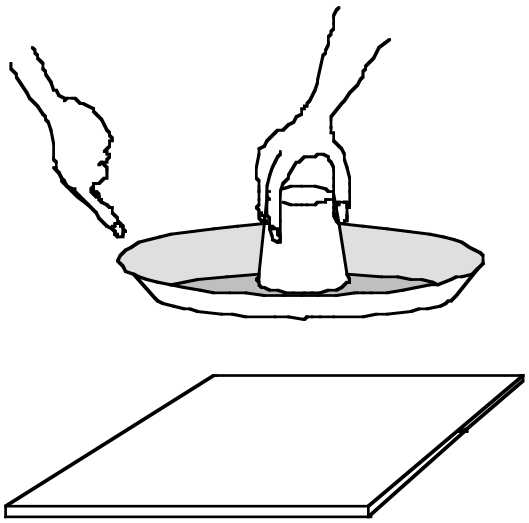
4. With the pan held above the plate, again touch the pan with your other hand. You should experience an electrical discharge from your finger.



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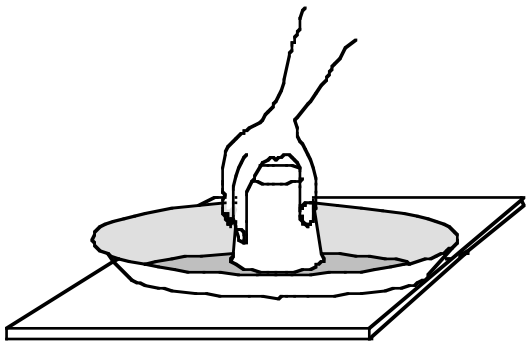
5. Remove your finger from the pan and return the pan back to the surface of the insulated plate. Return to step one and repeat. (However, it will be unnecessary to rub the insulated plate to charge it again.) You should experience no decrease in the strength of the electrical discharge no matter how many times you repeat the cycle.



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Suggestions for student experimentation to discover why the electrophorus works:

The electrophorus can appear to be a magical device since it never seems to run out of charge. You should design some sort of experiment to see if you can discover how it works. An important hint that most people need is that the charge you place on the flat insulating plate never leaves this plate. (You should devise some sort of experiment to test this assertion.)

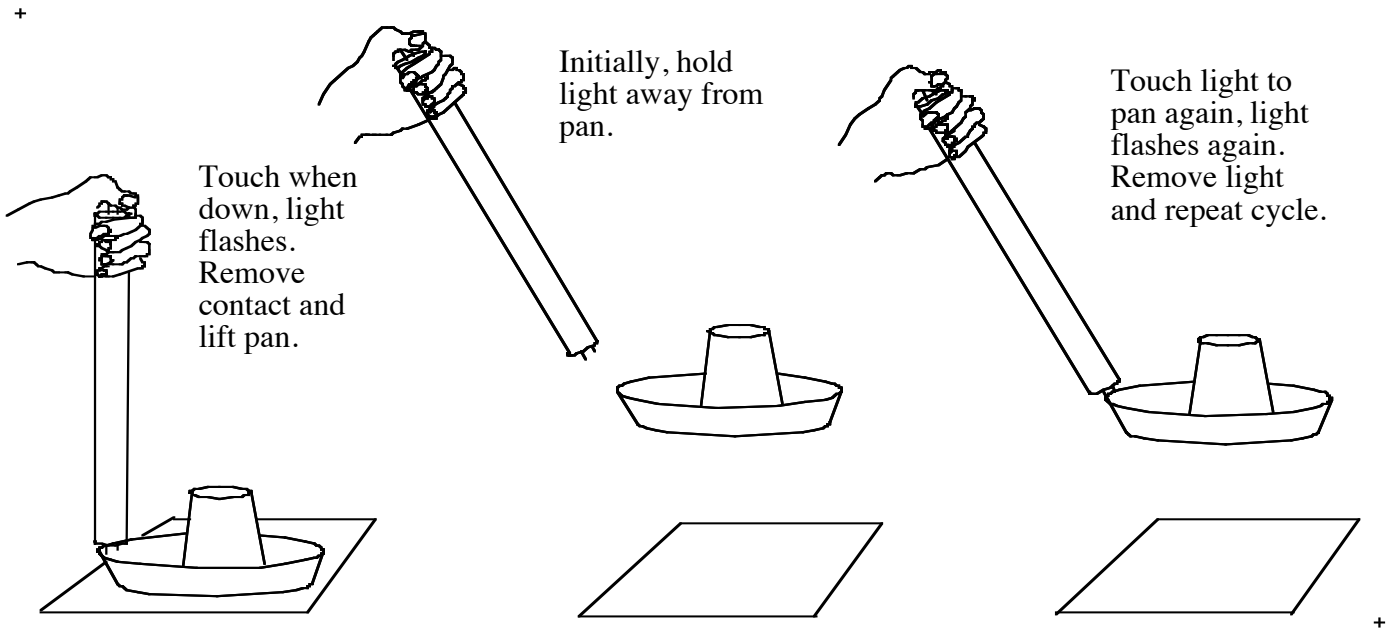
A suggested way to proceed is to have one or two rotating cradles (thus is discussed in the triboelectric handout given out today) with known charged rods in the cradles (one plus and one minus) to examine the charge on the pie plate at each step used in operating the electrophorus. Carefully record your results and make sure you know the difference between when the plate is really charged and when it is only neutral. After you have a fairly good idea of what charge is on the pie plate in each step, attempt to construct some sort of explanation of why the device seems to work again and again without a loss in charge. Make diagrams of where the charge must be, whether the charge is plus or minus, etc., for each step of the cycle.

Another hint that might be useful is that charge can be transferred even without the snapping sound usually associated with charge transfer. The cracking sound you hear when a spark jumps from one object to the next usually requires that there be a large potential difference (or voltage) between the two objects. You will be learning more about potential difference later but keep in mind, an electrostatic charge can be transferred between two objects without making a sound if there is only a small potential difference between the two objects.

Here is where the notes intended for the students to use as a lab guide END! What follows are notes and suggestions for teachers:

On the following page are a series of illustrations that attempt to explain how the electrophorus works.

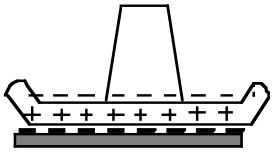
An interesting demonstration can be done to show that charges are transferred each time the pan is grounded by taking a small fluorescent tube (the kind you find in desk lamps), hold your thumb on the electrical contacts on one end and touch the other end on the pie pan. The lamp will flash both when you ground it initially and again when you hold it above the charged insulated plate. This should illustrate that charge is transferred in each case. If you discover that the sharp pointed contacts on the lower end of the tube causes premature sparking, try to place some sort of smooth rounded conductor over the end you touch to the pie pan. Sharp points always act to spoil electrostatic demonstrations.



Explanation of how the electrophorus works and "never" looses charge

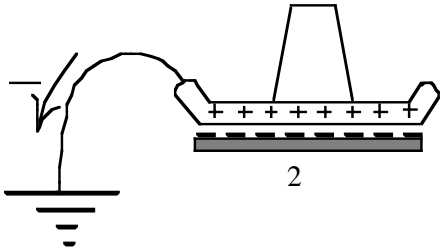
Step "0" begins the cycle with a flat insulated material that has been charged by rubbing. Here the insulator is shown charged negatively.

0



In step "1" the conducting pie plate is brought in contact with the charged insulator and the charges in the pie plate separate by induction.

The conducting pie plate is grounded and the negative charges leave. Since the flat insulating plate is a good insulator, the charges on it do not leave. (Step 2)



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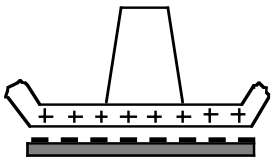
The conducting plate is now positive. (3)



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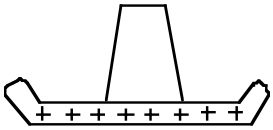

In step 4, the charged pie plate is lifted by the insulated cup. In this step the charges remain the same but work is done on them. This means the work you do in separating the charges creates a large potential difference. (This is one of the few situations where mechanical work can actually be experienced as a potential difference is created.)

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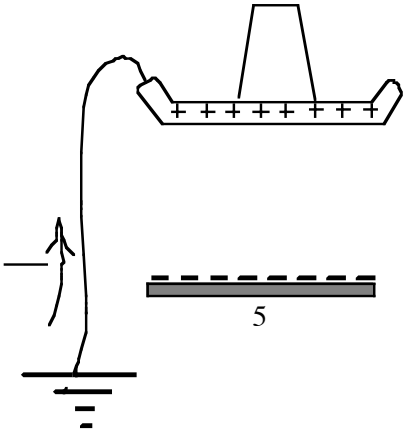

In step 5 a snapping sound is heard since the charge is transferred at a large potential difference.

Now when you ground the pan, the original charges return.

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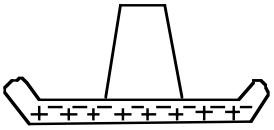

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In step 6 the pie pan is now neutral and as you lower it, electrostatic induction will again separate the charges and you will be ready to repeat the cycle as you return to step 1.

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