Module 3

Section 1

Lesson 9

**The Electrophorus**

**Learning Outcomes**

After completing this lesson, you will be able to

* construct an electrophorus
* produce a charge on the electrophorus
* describe the operation of an electrophorus using the particle model
* state some uses of the electrophorus

**Key Words**

* electrostatic induction
* electrophorus
* electron flow
* electron model

**Electrophorus**

An electrophorus is used to create a stronger charge than is possible by rubbing a rod with wool. An electrophorus can be purchased from science supply companies, but they are also easy and fun to make. An inexpensive electrophorus is made from a foam plate, an aluminum plate, a foam cup, and some tape, as shown below.

Foam cup

Straw is pushed through the cup

Aluminum plate

Foam plate

Tape

Foil ball

Make your electrophorus by

* taping a foam cup to the inside of the aluminum pie plate as shown above (The foam cup is used as a handle to move the aluminum pie without grounding it.)
* pushing a straw through the foam cup (Use a paper bit or roll a piece of foil into a ball and attach it to a piece of thread. Use scissors to cut slits on the end of the straw. Place the thread in the slits so it is easy to adjust the position of the metal foil ball.)
* adjusting the string so the metal foil ball is the same height as the lip of the aluminum pie plate

**Investigation**

**As you do the investigation, carefully answer the questions. If you do not know the answer, look it up in the answers to questions and then continue to the next part. The questions and answers are part of your notes.**

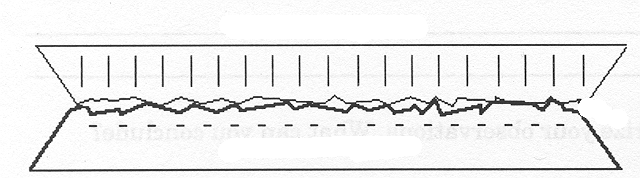
1. Rub the foam plate with wool to place a charge on the plate. Rub a plastic straw with wool and touch a pith ball on a string with the straw. What charge is on the metal foil ball? What charge is on the plate? How did you use the metal foil ball to determine the charge on the plate?
2. Place the aluminum plate on the foam plate. Be sure to move the aluminum pie plate by only touching the foam cup. What happens to the metal foil ball? What does this indicate about the charge on the aluminum pie plate?
3. Now lift the aluminum pie plate to separate it from the foam plate. Record your observations. What happens to the metal foil ball? What does this indicate about the charge on the aluminum pie plate?
4. Summarize your observations. What can you conclude?

At first the electrophorus may seem to be confusing. Alessandra Volta was the first person to correctly explain the electrophorus and it took this great scientist many years to understand how the electrophorus works.

When the aluminum pie plate rests on the charged foam plate the aluminum pie plate appears to be charged, but when it is removed from the foam plate there is no charge on the plate. You can only conclude that no charge is transferred from the foam plate to the aluminum pie plate.

How does the aluminum pie plate become charged when it rests on the foam plate? If no charge is conducted from the aluminum pie plate to the foam plate then there is only one other option, the aluminum pie plate must be **charged temporarily by induction**. Objects that are charged by induction do not touch. This forced Volta (and now you) to come to a startling conclusion; the aluminum pie plate and the foam plate are not touching.

Consider a microscopic view of the aluminum pie plate and the foam plate.



Aluminum pie plate

Foam plate

The two plates are not touching except for a few contact points

Since the foam plate is an insulator the negative charge does not move easily, only a small amount of charge could transfer near the contact points. Most of the charge on the foam plate is nearby the aluminum pie plate and the effects of induction prevail (the two plates are separated by a small distance even though they appear to be resting on each other).



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Recall our previous discussion of charging by induction; a negative charge nearby an object will cause the negative charges to move farther away creating a charge separation. As a result the metal foil ball is attracted to the charged rod.

Now consider the aluminum pie plate and the Styrofoam plate to be separate as shown (although they touch in a few points the effects of induction prevail and it is much easier to think of them as completely separated).

Aluminum plate

Foam plate

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The negative charges on the foam plate are nearby the aluminum pie plate. The negative charges on the aluminum pie plate are repelled away from the negative charges on the foam plate, into the inside of the aluminum pie plate. That is, the part of the aluminum plate closer to the foam plate becomes more positive and the part further away becomes more negative. Since the metal foil ball is further away it becomes negative as well and repels from the side of the aluminum pie plate. When the plates are separated the charge on the aluminum pie plate redistributes and the plate is neutral. No charge is transferred from the foam plate to the aluminum pie plate.

Aluminum plate

Foam plate

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When the plates are separated there is no charge left on the aluminum plate indicating a temporary induced charge.

Recall how you charged an electroscope by induction. Try it with your electrophorus.

**Investigation - Charging an electrophorus**

1. Charge the Styrofoam plate by rubbing it with wool. What charge is on the Styrofoam plate? How do you know?
2. Place the aluminum pie plate on the Styrofoam plate, the pith ball should repel. What charge is on the pith ball? How do you know?
3. Touch the aluminum pie plate with your finger. What happens to the pith ball? Explain.
4. Lift and separate the aluminum pie plate from the foam plate. What happens to the pith ball? What charge is on the aluminum pie plate? How do you know?
5. Explain your observations from question 8.

**Check your answer key.**

The negatively charged foam plate causes a charge separation by induction to occur on the aluminum plate. The electrons in the aluminum pie plate are repelled to inside of the aluminum plate and the part of the plate nearby the foam plate is left with a net positive charge. If the aluminum pie plate is now grounded with your finger, the electrons will move away from the electrophorus to the ground.

Aluminum plate

Foam plate

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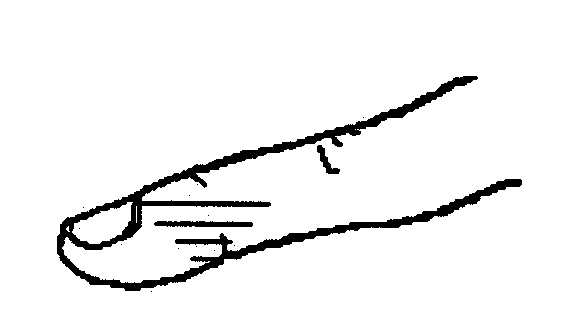
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Ground symbol

Electron flow

Your finger acts as a ground for the aluminum pie plate allowing electrons to flow out of the plate.

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When you separate the electrophorus and the foam plate the foil bit will repel indicating there is a charge on the electrophorus. Since the electrophorus has lost negative charges, it is now charged positively. The aluminum pie plate becomes positively charged by induction. You can test the aluminum pie plate for charge by bringing nearby a positively charged electroscope. You now neutralize the electrophorus by touching it with your finger to ground; a spark should jump between your finger and the electrophorus.

Since no charge is transferred from the foam plate to the aluminum pie plate, it can be charged over and over again without recharging the foam plate. All you need to do is place the aluminum pie plate on the foam and ground it with your finger.

**Questions**

1. Why is it necessary to lift the aluminum pie plate by the Styrofoam cup?
2. What happens to the pith ball as you bring your finger nearby? Use a diagram to indicate the charge movement between the pith ball and finger.

**Check the answer key.**

**Answer Key Electrophorus**

**Investigation**

Summary

The electrophorus is a device that can be used to create a large charge quickly using charge transfer by electrostatic induction. The electrophorus can be used to create a large charge over and over again with no diminishing of the net charge because the charge transfer occurs by induction and the charge always comes from the ground, not from the foam plate.

Answers to Questions

1. Rub the foam plate with wool to place a charge on the plate. Rub a plastic straw with wool and touch a metal foil ball on a string with the straw. What charge is on the metal foil ball? What charge is on the plate? How did you use the metal foil ball to determine the charge on the plate?

**The foil ball has a negative charge. The foam plate also has a negative charge. The metal foil ball is repelled by the foam plate. This tells us they have the same(negative) charge.**

1. Place the aluminum plate on the foam plate. Be sure to move the aluminum pie plate by only touching the foam cup. What happens to the metal foil ball? What does this indicate about the charge on the aluminum pie plate?

The metal foil ball is repelled by the aluminum plate. The aluminum pie plate must have a negative charge.

1. Now lift the aluminum pie plate to separate it from the foam plate. Record your observations. What happens to the metal foil ball? What does this indicate about the charge on the aluminum pie plate?

When you remove the aluminum pie plate you should feel a force of attraction between the pie plate and the foam plate. In fact, you will probably have to hold the foam plate down. The foil ball should collapse and rests against the side of the aluminum pie plate. This indicates that no charge is on the aluminum pie plate; the charge on the aluminum pie plate must have been temporary.

1. Summarize your observations. What can you conclude?

**The metal foil ball was repelled by the aluminum pie plate when it was placed on the foam plate. When the aluminum pie plate was removed from the foam plate the metal foil ball was no longer repelled by the aluminum pie plate.**

**The aluminum pie plate must have received a temporary induced charge from the foam plate. Once the aluminum pie plate was removed its charge disappeared and the metal foil ball was no longer repelled.**

1. Charge the foam plate by rubbing it with wool. What charge is on the foam plate? How do you know?

**The foam plate is negative. If you bring it near a negatively charged electroscope, the leaves will repel**.

1. Place the aluminum pie plate on the foam plate, the foil ball should repel. What charge is on the foil ball? How do you know?

The foil ball is negative. By induction the negative charges on the Styrofoam plate repel the negative charges on the aluminum pie plate towards the upper surface of the aluminum pie plate. If you bring a negative object nearby, the foil ball will repel it.

1. Touch the aluminum pie plate with your finger. What happens to the foil ball? Explain.

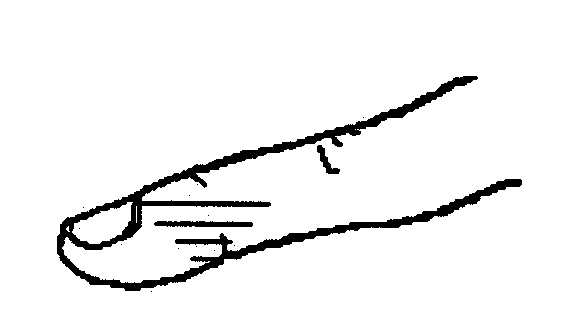
The foil ball will swing back and touch the aluminum pie plate. Negative charges from the aluminum pie plate will be repelled to the ground and the region around the foil bit will be neutral. The foil ball is no longer repelled by the aluminum pie plate.

1. Lift and separate the aluminum pie plate from the foam plate. What happens to the foil bit? What charge is on the aluminum pie plate? How do you know?

The foil ball repels from the aluminum pie plate. The aluminum pie plate is charged positively. You can test by bringing the aluminum pie plate nearby a positively charged object (like an electroscope).

1. Explain your observations from question 8.

Ground



Aluminum plate

Foam plate

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The aluminum pie plate and the foam plate only touch each other at very few points. By induction the negative charges on the foam plate repel the negative charges on the aluminum pie plate to ground. The region nearby the foil ball becomes neutral and the foil ball will swing back to the side of the plate. The negative charges on the foam plate hold the bottom region of the aluminum pie plate positive. When the aluminum pie plate is lifted from the foam plate the charges redistribute evenly across the plate and the aluminum pie plate is positively charged.

1. Why is it necessary to lift the aluminum pie plate by the foam cup?

If you touch the aluminum pie plate with your hand, it will ground the plate.

1. What happens to the foil bit as you bring your finger nearby? Use a diagram to indicate the charge movement between the foil bit and finger.

When you lift the aluminum pie plate off of the foam plate, the aluminum pie plate will be charged positively. When you bring your finger nearby, the positively charged foil bit is attracted to the neutral finger as shown in the diagram.

**Aluminum plate**

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When the foil ball touches the finger, electrons are transferred from the finger to the foil ball and the foil bit becomes neutral. The neutral foil ball is attracted by the charged electrophorus. When the foil ball touches the aluminum pie plate, electrons are transferred from the foil ball to the aluminum pie plate. The aluminum pie plate becomes a little less positive and the foil ball becomes more positive. The positively charged foil ball is repelled by the aluminum pie plate and attracted to the neutral finger. Once again the foil ball touches the finger, electrons transfer to the foil ball neutralizing the foil ball. Again the foil ball is attracted to the plate where it transfers electrons to the aluminum pie plate. This process repeats itself as the foil ball oscillates back and forth until the aluminum pie plate is neutral.