



Title:	Snap, Crackle and Pop! A Shocking Experience
Original:	26 July 2009
Authors:	Jon Nale, Gene Gordon
Appropriate Level:	10-12 grade
Abstract:	Students will use inquiry with electrostatic experimentation along with a qualitative investigation of the electrostatic forces.
Time Required:	80-120 minutes
NY Standards Met:	<p>S1 The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.</p> <ul style="list-style-type: none"> • develop extended visual models and mathematical formulations to represent an understanding of natural phenomena • clarify ideas through reasoning, research, and discussion • evaluate competing explanations and overcome misconceptions <p>S2.1 Devise ways of making observations to test proposed explanations.</p> <p>S2.4 Carry out a research plan for testing explanations, including selecting and developing techniques, acquiring and building apparatus, and recording observations as necessary.</p> <p>S3.1 Use various means of representing and organizing observations (e.g., diagrams, tables, charts, graphs, and equations) and insightfully interpret the organized data.</p> <ul style="list-style-type: none"> • use appropriate methods to present scientific information (e.g., lab reports, posters, research papers, or multimedia presentations) • identify possible sources of error in data collection and explain their effects on experimental results <p>S3.3 Assess correspondence between the predicted result contained in the hypothesis and the actual result, and reach a conclusion as to whether or not the explanation on which the prediction was based is supported.</p> <p style="text-align: right;">(Continued on page 2)</p>

Xraise Outreach for CLASSE

161 Synchrotron Drive, Wilson Lab, Cornell University, Ithaca, NY 14853
 xraise.classe.cornell.edu

<p>NY Standards Met:</p>	<p>S3.4 Based on the results of the test and through public discussion, revise the explanation and contemplate additional research.</p> <p>4.1b Energy may be converted among mechanical, electromagnetic, nuclear, and thermal forms.</p> <p>4.1j Energy may be stored in electric* or magnetic fields. This energy may be transferred through conductors or space and may be converted to other forms of energy.</p> <p>5.1s Field strength* and direction are determined using a suitable test particle.</p> <p>5.1t Gravitational forces are only attractive, whereas electrical and magnetic forces can be attractive or repulsive.</p> <p>5.1u The inverse square law applies to electrical* and gravitational* fields produced by point sources.</p> <p>5.3b Charge is quantized on two levels. On the atomic level, charge is restricted to multiples of the elementary charge (charge on the electron or proton).</p> <p>5.3h Behaviors and characteristics of matter, from the microscopic to the cosmic levels, are manifestations of its atomic structure. The macroscopic characteristics of matter, such as electrical and optical properties, are the result of microscopic interactions.</p>
<p>Special Notes:</p>	<p>Snap, Crackle and Pop! Is a kit available from the CIPT Equipment Lending Library, Xraise.classe.cornell.edu.</p> <p>Created by the CNS Institute for Physics Teachers via the Nanoscale Science and Engineering Initiative under NSF Award # EEC-0117770, 0646547 and the NYS Office of Science, Technology & Academic Research under NYSTAR Contract # C020071</p>

Behavioral Objectives:

Upon completion of this lab a student should be able to:

Special Notes:

Class Time Required:

Teacher Preparation Time Required:

Materials Needed:

Part 1:

- Scotch brand "invisible" tape
- Tinsel
- Votive candle (just the metal casing needed)
- Styrofoam peanuts
- ½" pvc cut into 1' lengths
- Cut up wool sweaters or rabbit fur
- Rice Crispies
- Large sheet of clear plastic at least 1'x 2'
- Aluminum pie tin
- Dixie cup
- Masking tape
- Watch glass
- Wooden ruler or flat stick 1' long
- 1'x 1' by 1" thick sheets of styrofoam
- Empty soda can

Part 2:

- Faraday Cage
- 2 Charging Paddles
- Charge Sensor (Vernier) and accompanying cords
- Lab Quest (Vernier)
- Electrical outlet (extension cords if one is not near each set up)
- Banana plug with alligator clip adapter
- Empty soup type can
- Text book or something to set the empty can on
- Two index card sized sheets of aluminum foil

Assumed Prior Knowledge of Students:

Background Information for Teachers:

Answers to Questions:

Equipment List

Item No.	Quantity	Item
1	1	Roll of Scotch brand "invisible" tape
2	1	Cut up wool sweaters or rabbit fur
3	1	Small amount of styrofoam peanuts
4	1	Votive candle metal casing (wax not needed)
5	1	½" pvc cut into 1' length
6	1	Rice Crispies
7	1	Large sheet of clear plastic at least 1'x 2'
8	1	Aluminum pie tin
9	1	Empty soda can
10	1	1' x 1' x 1" thick sheet of styrofoam
11	1	Wooden meter stick
12	1	Watch glass
13	1	Roll masking tape
14	1	Dixie cup
15	1	Faraday Cage
16	1	Charge Sensor (Vernier) and accompanying cords
17	1	Lab Quest (Vernier)
18	1	2 Charging Paddles (Vernier)
19	1	Banana plug with alligator clip adapter
20	1	Empty soup type can
21	1	Two index card sized sheets of aluminum foil
22	1	Text book or prop to set the empty can (supplied by teacher)
23	1	Electrical outlet (extension cords if one is not near each set up) (supplied by teacher)

SNAP, CRACKLE AND POP! A SHOCKING EXPERIENCE



Prelab: Jumping Crispies

Your teacher will show you a very interesting electrostatic event, and your job will be to record as much of what you observe as possible. Use the following 3 column sheet to make your observations. No detail is too small to note. As a rule, record enough so that someone who didn't see the event could tell what happened. Then, as you progress through the lab, you will discover you are uncovering key Physics that explains how the Jumping Crispies works. Your task is to make the discoveries necessary, to accurately describe how the Jumping Crispies did what you observed.

What I Did	What I Observed?	Why Did This Happen?

As you make your way through this lab, you'll be examining pieces to the puzzle to explain the "Jumping Crispies" event. At each step, the opportunity is yours to gain understanding into the physics of electrostatics that caused the Crispies to respond as you observed. Your task is to make careful observations and assemble the details to uncover how the pre-lab event works.

Part 1: Qualitative & Quantitative Observations of Static Charges

Equipment Introduction:

You will measure the charge on objects with a **Charge Sensor** (Figure A), which is connected to a **Lab Quest** (Figure B) and a **Faraday Cage** (Figure C). When a charged object is lowered within the *inner* cage, the charge sensor will measure the charge and display it on the Lab Quest.



Figure A



Figure B



Figure C

Be sure to zero the charge sensor before every sampling for accurate results. (See Figure A)

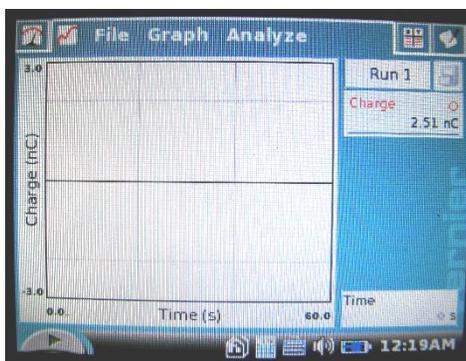
If a charged object is accidentally touched to the inner cage, re-zero the charge sensor.

The outer cage is connected to Earth ground¹ (grounded). You can get rid of any unwanted charge on an object (at any time) by touching it to the outer cage.

Getting Started:

Your computer should be on, and Lab Quest opened to a screen similar to the one seen below.

¹ This connection is made by attaching a banana plug to the round grounded prong of an outlet, and attaching the other end to the outer cage (via an alligator clip).



When you are ready to begin sampling charge, select the PLAY button, denoted by the green triangle.



If the sensor is properly zeroed, it will read 0 nC of charge before sampling begins. This will look like a horizontal line following the black one in the center of the screen.

Go ahead and test this now.

You're using sensitive equipment. If things don't turn out as expected, it isn't broken; it's real physics and requires closer examination to get at the actual explanation. Think Well! Push up your sleeves (literally) and have fun.

Activity 1: Scotch Tape Electrostatics

- Cut two 3" pieces of Scotch tape.
- Securely tape one piece to a desk or table. Leave about 1" hanging off the edge of the table.
- Lay the second piece of tape **on top of the first piece** again leaving about 1" hanging free. NOTE: make sure that the two free ends do not stick to one another.
- Press the pieces of tape firmly together on the desk.
- **Note ALL observations on the 3 column sheet for the following actions:**
 - Holding the bottom piece down, quickly rip the top piece of tape off the bottom – leaving the bottom piece on the table or desk.
 - Bring the tape near other objects.
 - Slowly peel off the first piece off the table. Bring it near the same objects that you used in step above.
 - Bring the two pieces of tape near each other.

Measuring the Charged Tape:

- With the stylus, tap the *Play* triangle on the Lab Quest to begin collecting data. A line will appear on the charge graph. Push the *ZERO* button on the *Charge Sensor*.
- Insert the piece of tape you quickly ripped off, into the inner cage. It's important that you insert charged objects the same depth into the cage each time. Observe if the charge is positive or negative, this is called the charge's polarity.
- In a similar fashion, insert the other piece of tape that was on the bottom and slowly peeled off the table. Observe if the charge is positive or negative.

- To find out if you are still neutral, place your hand near the top of the cage to find out. If you've picked up a charge, you can get rid of it by touching the outer cage.
- Hang your "charged up" tape from the table as a detector to use in the next parts of the lab.

Activity 2: First Law of Electrostatics

Note ALL observations on the 3 column sheet for the following actions:

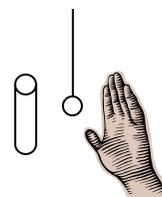
- Take the PVC pipe and wipe it briskly with the fur or wool that you have been given. What do you hear? See? Feel? Smell?
- Bring the pipe near your "tape detectors."
- Insert the pipe into the inner cage.
- Bring the PVC pipe close to other objects (metals and insulators) in the room (lint, paper, paperclips...).
- Bring the pipe near your skin. How does it feel?
- Bring the pipe near your hair or a partner's hair. What happens? Does the same thing happen to everyone's hair? To the same degree?
- Bring the pipe near a piece of paper after wiping the PVC with the fur/wool. What happens? What if you ripped up the paper into small pieces? Look carefully at the little pieces of paper during this experiment. Remind you of anything "*crispy*"?
- Bring the fur near your detectors.
- Bring the fur (the part you wiped) near the top of the inner cage (may be difficult to insert).

Activity 3: Conductors and Insulators

Pick **one** set of hardware from the list below and devise experiments you can do with it. Feel free to test charge quantity and polarity with the cage and charge sensor. Compare your results with other groups who did a different experiment.

List of hardware and some suggestions for experiments (choose one):

1. an empty aluminum tea light container and your charged pipe
2. soda can
 - a. Experiment with the soda can standing up and on its side.
3. pith ball on a string
 - a. Have a partner hold the string.
 - b. Bring the pipe near but not too close to the ball.
 - c. Let the ball touch the pipe.
 - d. From opposite sides, close in on the ball with the pipe and your palm.
 - e. Perform as many different experiments as you can with the ball.
4. Put a wooden or plastic ruler on a watch glass or flat end of a pen, so that it balances.
 - a. Bring the pipe near the ruler.



5. Turn on a water faucet so that water is pouring out in a slow, thin stream.
 - a. Bring the pipe near the stream what happens?
6. Vertically dangle a strand of tinsel.
 - a. Bring it near the charged pipe.
 - b. Try the top, middle and bottom of the tinsel.
 - c. Pass a length of the tinsel between your two fingers and see how it interacts with the charged pipe.

Activity 4: Electrophorus

Note ALL observations on the 3 column sheet for the following actions:

- Take the Styrofoam sheet that you were given and *gently* wipe it with the fur/wool (it doesn't take much pressure).
- You may want to experiment with the Styrofoam and see that it behaves similarly to previous experiments.
- After wiping the Styrofoam, place the pie plate very close to the Styrofoam (hold onto the cup/handle), but not touching it.
- Next, pick up the pie plate by holding onto the cup/handle.
- Have your partner touch the pie plate with his or her finger.
- After wiping the Styrofoam, place the pie plate very close to the Styrofoam (hold onto the cup/handle), but this time touch the pie plate with your finger (other hand) once it very close to the Styrofoam. (It should be no more than 1cm above the Styrofoam).
- Pick up the pie plate by holding the cup/handle and again have your partner touch the pie plate.
- Test the polarity of the pie plates charge by bringing near (but not into) the inner cage.
- Test the polarity of the Styrofoam by bringing it near (but not into) the inner cage.
- Continue charging the pie plate and your partner by repeating the 6th and 7th steps at least 15 times. Then, touch your partner's hand.
- Repeat this procedure, but have someone else touch your partner's hand.

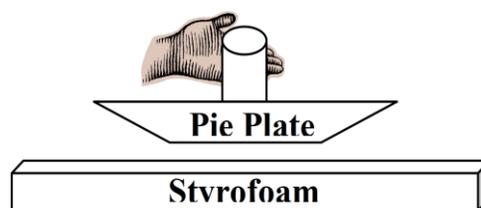


Figure D

Part 2: Quantitative Measurements of Charge

Introduction

You will continue using *Vernier* software and sensors to make measurements of *electric charge*. From these measurements you will clarify your understanding of how charge can be “produced,” how one object may be charged by another through conduction or induction, how charge distributes itself on an object, and what is meant by an electrical ground.

Equipment:

We’ll continue on with the same basic equipment, and some new additions. Some objects are too large to fit into the Faraday Cage. These objects are tested by touching them with a **Proof Plane** (Figure E), which is then measured in the Faraday Cage. Remember, the outer cage is “grounded” and therefore a place to discharge objects that have developed a charge, by touching them to the outer cage. Hold the paddles about $\frac{3}{4}$ the way up.

The proof plane (used to sample charge) is either of the two paddles that you have available at your station, wrapped in aluminum foil. The faces of the paddles are different, and determine their use:

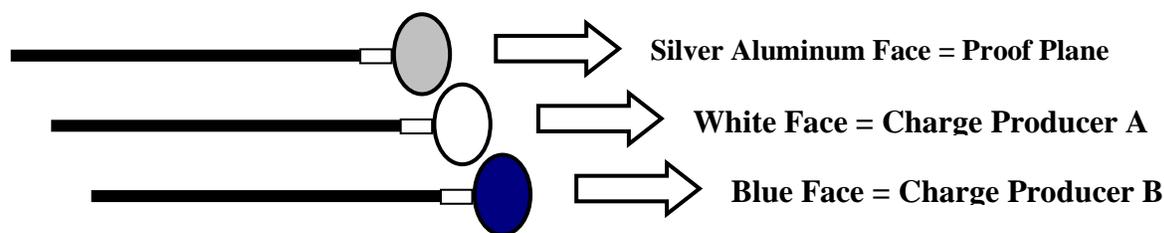


Figure E



The surfaces of the paddles are soft and easily damaged by misuse --- please take care with them. Also, the black handles of the paddles are easily broken by applying too much pressure.

Charge is supplied by the **Electrophorus** we used earlier in the lab (Figure D).

Activity 5: Charging Objects with Friction

First, we’ll investigate electrically neutral objects. There are several ways for electrically neutral objects to develop a net charge, and one is by rubbing it with another object. Whenever there is friction between two surfaces, charge in the form of electrons may be transferred from one material to the other (...like scuffing your socks across a carpet and zapping someone on the nose with your finger!). Charge imbalance developed in this way is called **triboelectricity**.

1. With the stylus, tap the **Play** triangle on the Lab Quest to begin collecting data. A line will appear on the charge graph. Push the **ZERO** button on the *Charge Sensor*.
2. Make sure the white and blue paddles have virtually no charge by **Grounding** them. This is accomplished by touching the face of the paddle to the outer (grounded) screen of the Faraday Cage.

3. **Measure** the paddles, one after the other, by lowering them just into the inner Faraday Cage. Always dip the paddle quickly in, and quickly out, and by the same distance inside the cage. [... press the ZERO button again if charge is accidentally transferred to the Faraday Cage.]

There should be little or no charge on either paddle. This is the normal electrical state of most matter, “neutral charge.” If you discover a decent amount of charge on a paddle, do your best to eliminate it by following the above steps again.

Charged paddles

1. Make sure the Lab Quest is collecting data by pressing the play triangle, and press the ZERO button on the Charge Sensor.
2. Gently rub the faces of the white and blue paddles together several times. Hold the paddles $\frac{3}{4}$ the way up while rubbing to reduce the torque on the paddle end, OTHERWISE ---- they will BREAK !!!!
3. **Measure** the paddles, one after the other, by lowering them into the Faraday Cage. Continue to follow the instructions from the last page for this part. [... press the ZERO button again if charge is transferred to the Faraday Cage.]

- Answer questions on the Student Data Sheets.

Activity 6: Charge Conservation

1. Make sure *Lab Quest* is collecting data, and press the ZERO button on the Charge Sensor.
2. Rub the paddles together. Without touching the charge producer paddles to each other, insert them both into the Faraday Cage at the same time.
3. Raise one paddle up out of the cage, and then lower it back in and raise the other. Observe the charges measured.

In this next section, we will make use of the proof plane, the aluminum covered paddle. Go ahead and wrap one of your paddles with a small piece of aluminum foil. The face and back of the paddle should be fully covered. Below is an EXAMPLE to assure good results when measuring a large charged object:

1. **Ground** the proof plane by touching the metal surface to the grounded outside of the Faraday Cage. [This ensures that the proof plane starts with zero charge. Test it to be sure.]
2. **Sample** the test surface by laying the metal surface of the proof plane flat against the charged surface to be measured (Figure F). [As flat as possible on curved surfaces.]
3. **Measure** the charge on the proof plane by lowering it just into the inner Faraday Cage, without touching the sides or bottom. Dip it quickly in, then quickly out. Be sure to also go the same distance into the cage each time.

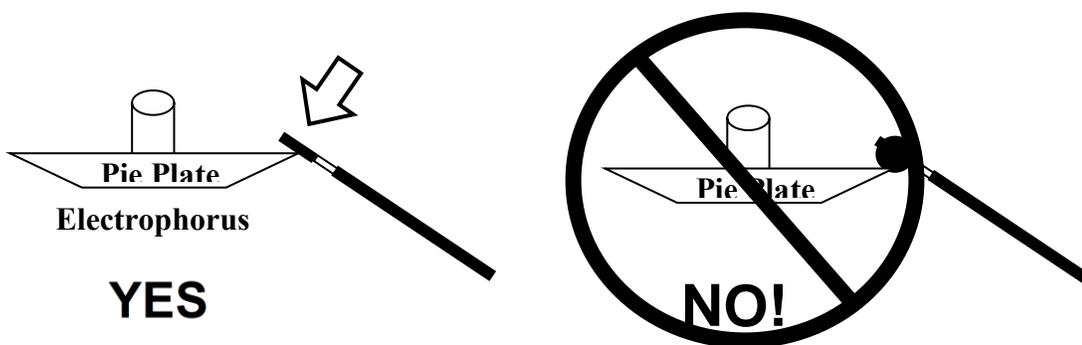


Figure F

- Answer questions on the Student Data Sheets.

Activity 7: Charge Distribution on a Uniform Surface: Let's Try It!

You will use the charged electrophorus (Figure D) for the following measurements.

1. Make sure Lab Quest is collecting data, and press the ZERO button on the Charge Sensor.
2. Charge the electrophorus using the method described earlier in the lab (once)
3. **Ground, sample** and **measure** (insert into the cage) with your proof plane, sampling 3 or 4 various locations on the bottom surface of the *charged electrophorus, away from the corners*. Make careful observations of your measurements. (Be sure you insert the proof plane the same distance each time).

- Answer questions on the Student Data Sheets.

By the way, you charged the Proof Plane using a method called Conduction. That's simply when you touch a charged object to a neutral object to transfer charge.

Activity 8: Charge Distribution on Non-Uniform Surfaces

What about the distribution of charge over other, non-uniform surfaces?

1. Make sure Lab Quest is collecting data, and press the ZERO button.
2. Charge up the electrophorus again, in the usual manner.
3. Ground, sample & measure using your proof plane, sampling the upper corner of the electrophorus. Compare it to the charge on the bottom flat surface. Carefully observe your measurements.

- Answer questions on the Student Data Sheets.

Activity 9: Charging by Induction

The only object that should be initially charged is the electrophorus. Go ahead and charge it now. Wrap the other paddle in aluminum foil so that you essentially have two proof planes. They both should be neutral. Test them in the cage to be certain.

Step 1:

1. Make sure Lab Quest is collecting data, and press the ZERO button.
2. Touch the two proof planes together, and bring them very close (but not touching) to the upper corner of the charged electrophorus. Your partner should be holding the pie plate by the cup handle. If a spark jumps from the electrophorus, ground the proof planes and start over.
3. **Separate the proof planes, THEN move them apart and away from the electrophorus. (The correct order here is very important.)**
4. Sample each proof plane (one at a time) into the inner faraday cage, to see if it is now charged, and what the polarity of the charge is.

Step 2:

1. Make sure Lab Quest is collecting data, and press the ZERO button. Recharge the electrophorus.
2. **Touch one of the proof planes** to ground it. (Yes – you can function as a ground). Make sure it's now neutral.
3. **Move it close to (but not touching) the charged electrophorus. With your other hand, ground the proof plane (while it's near the electrophorus). Now, move the proof plane away from the electrophorus.**
4. Sample the proof plane into the inner faraday cage, to see if it is now charged, and what the polarity of the charge is.

- Answer questions on the Student Data Sheets.

Activity 10: Charge Distribution on Inner and Outer Surfaces

You will now examine the charge distribution on and in the metallic cup (a Faraday Cage made of solid metal, instead of mesh.)

1. Make sure Lab Quest is collecting data, and press the ZERO button on the charge sensor.
2. Set the cup onto a book, and touch charged electrophorus momentarily to the **metal cup**. The cup has now been charged by conduction.
3. **Ground, sample** and **measure** your proof plane, sampling the inner and outer surfaces of the *charged cup* (Figure G). Carefully observe.

- Answer questions on the Student Data Sheets.

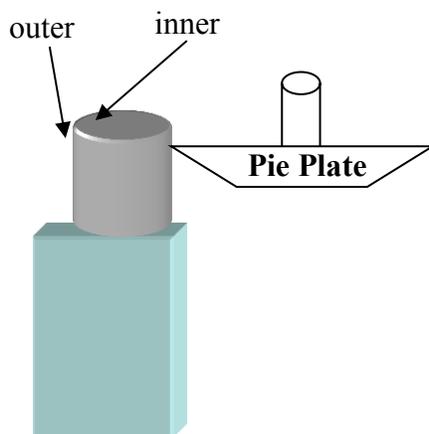


Figure G

Activity 11: Wrapping Up: Putting it All Together

1. Get a battery from your teacher. What do you expect will happen when you lower it into the inner cage?
2. Try it. What do you observe? Why?
3. How about those crispies? Do you think they had a charge?
4. Grab a few crispies and lower them into the cage. Make sure you are neutral first.

- Answer questions on the Student Data Sheets.

Snap, Crackle and Pop! A Shocking Experience

Student Data Sheets

Name _____

Part 1: Qualitative Observations of Static Charges

Activity 1: Scotch Tape Electrostatics:

1. What is the polarity of each piece of tape?
2. How does this help explain the effect the 2 pieces of tape had on each other?
3. Does this help explain why the tape is attracted to uncharged (neutral) objects? Explain.
4. Are you still neutral?

Activity 2: First Law of Electrostatics

5. What types of materials were attracted to the pipe? What types of materials were repelled?
6. Describe the charge on the pipe and the fur. Could they both be the same polarity? Explain briefly.
7. From your observations here, identify which part of the Jumping Crispies event was most similar, and explain how it worked.

Activity 3: Conductors and Insulators

Hardware I chose:

What I Did / Will Do	What I Predict	What I Observe

--	--	--

8. Give a brief synopsis of your results for this activity. In your synopsis, describe how this relates to any aspect of the Jumping Crispies event.

Activity 4: Electrophorus

7. What is the polarity of the pie plates?
8. What is the polarity of the Styrofoam?
9. Why is the “shock” more severe when the person charging the pie plate touches their partner’s hand who’s receiving the charge of the plate (as opposed to someone else touching the partner’s hand)?
10. Where is the charge on the pie plate coming from? (Consider your answers to 8th and 9th steps).
11. How many times can you repeat the 6th and 7th steps without wiping the Styrofoam again and still get the same result? Why do you think this can be done?
12. Revisit your description of the Jumping Crispies event from your 3 column table. Which answers under the “Why Did This Happen” column would you like to change or add to. Go ahead and do this below:

What I Did	What I Observed?	Why Did This Happen?

Part 2: Quantitative Observations of Static Charges

Activity 5: Charging Objects with Friction

- 13. What do you think electrically neutral means?
- 14. Which charge producer is negative after rubbing? (white or blue?)
- 15. Which charge producer is positive after rubbing? (white or blue?)
- 16. What do you observe about the amount of charge on each paddle?

Activity 6: Charge Conservation?

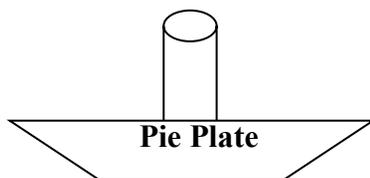
- 17. What is the combined charge of the two paddles, and why is this? (Positive, Negative, Zero?)
- 18. Where does the charge on each charge producer paddle come from? Is it really “produced”?

Activity 7: Charge Distribution on a Uniform Surface: Let's Try It!

19. How does the quantity of charge at a point on the bottom of the plate, compare to any other point?
20. Why does the charge distribute itself in this fashion?

Activity 8: Charge Distribution on Non-Uniform Surfaces

20. Where do you find the greatest amount of charge? The lowest charge? (Sketch the charge distribution on the diagram.)



21. Why does the charge distribute itself in this way on the corners?

Activity 9: Charging by Induction

Step 1

22. What is the polarity of the charge on the paddle closest to the electrophorus?

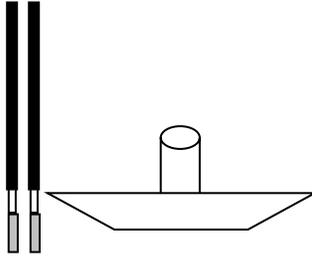
What is the polarity of the charge on the paddle furthest from the electrophorus?

What causes this?

23. Something similar happened during the Jumping Crispies event. Determine which part of the Crispies event was similar to this. Explain.

24. What is the overall charge of the two proof planes together? Why? (Test it)

25. Sketch the way the charge is distributed on your neutral proof planes on the figure below.



Step 2

26. What is the polarity of the charge now? Why?

27. What do you think a “ground” actually is?

28. This once neutral proof plane has been charged by induction. Outline the procedure for charging an object by induction (according to what you just did):

Activity 10: Charge Distribution on Inner and Outer Surfaces

29. On what part(s) of the cup was the amount of charge lowest? highest? Why is this so?

Activity 11: Wrapping Up: Putting it All Together

30. What do you expect will happen when you lower the battery into the inner cage?

31. Try it. What do you observe? Why?

32. Did the crispies have a charge?

Post-lab Analysis:

- 1.a. What are characteristics of Insulators and Conductors?
 - b. What makes some materials good insulators and some good conductors?

2. Draw a diagram showing how a net positive charge can be created on a sphere.

3. Answer the following about the Jumping Crispies event:
 - a. How does wiping the fur charge the Plexiglas?

 - b. What do you suppose is the polarity of charge on the Plexiglas? How could you test it? Go right ahead.

 - c. Is the Plexiglas an *Insulator* or a *Conductor*? Explain how this property of the Plexiglas helps the event work in the way you've observed.

 - d. Why do more "crispies" jump after removing the fur from the surface of the Plexiglas?

 - e. Explain how some of the "crispies" stand upright, on end, before jumping. Use a diagram to aid your explanation.

4. Explain why the "crispies" jump toward the glass, instead of being repelled by the glass.

5. If you bring your finger next to the glass, but not touching it, some of the “crispiers” fall. Explain what is happening here.

6. Explain the mechanism that causes some of the “crispiers” hanging from the glass, to actually be forcibly repelled back down to the table.