STATIC ELECTRICITY

PROBLEM PRESENTATION / EXPLORATION

A. Balloons
   1. Blow up and tie off a number of balloons. Prepare some of them by rubbing them against a sweater or other article of clothing. Do not charge the others. Have students come up to the board and try to stick them in a horizontal row. Obviously, some will stick to the board while others won't.
   2. Solicit reasons from the class. As soon as someone suggests that you must rub the balloon before attempting to stick it to the board, ask them to predict against which kind of substances a balloon should be rubbed to make it stick. (Most substances will successfully charge the balloon. Wool, cotton, and hair are the most common materials used to charge balloons.)
   3. Possibly before you finish this investigation some of the balloons that originally stuck to the board will fall to the floor. Ask the students to offer explanations for this behavior. [Over a period of time electrons will transfer from the balloon to the board and the induced positive charge on the board will be neutralized resulting in the balloon falling down

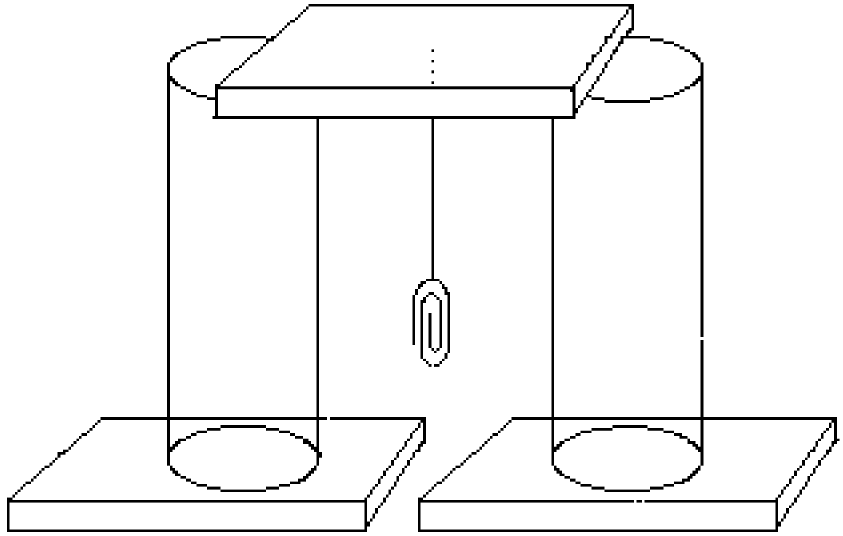
B. More Balloons
   1. Blow up four identical balloons and tie a thread to each. Hold two of the balloons together by the two threads and show that the balloons will hang down against each other. (Do not rub the balloons beforehand.)
   2. Take two balloons and rub them with a wool cloth. Ask students to predict what will happen when they are brought side by side. [They will repel each other so that they can not touch. Both balloons were charged by friction.]
   3. Take the other two balloons and rub only one of them with the wool. Ask students to predict what will happen when they are brought side by side. [They will be attracted to each other. One of the balloons was charged by friction and the other by induction.]

C. The "Magnetic" Ruler
   1. Place on a flat table a hollow cardboard roll that toilet paper comes on.
   2. Take a plastic ruler and rub it vigorously with a handkerchief for 30 seconds.
   3. Approach the roll slowly with the ruler until the roll begins to move, then move the ruler away from the roll in the same direction that the roll started to move. In other words, it will look like the ruler is pulling the roll across the table.
   4. [The ruler has been charged negatively by friction (rubbing) and as it approaches the roll it induces a positive charge on the leading edge of the roll. This in turn is attracted to the ruler. As long as the ruler and the roll are not allowed to touch, the ruler can pull the roll along.]
   5. Students will probably be puzzled about how this works. This should all be cleared up in the Concept Invention phase of the lesson.

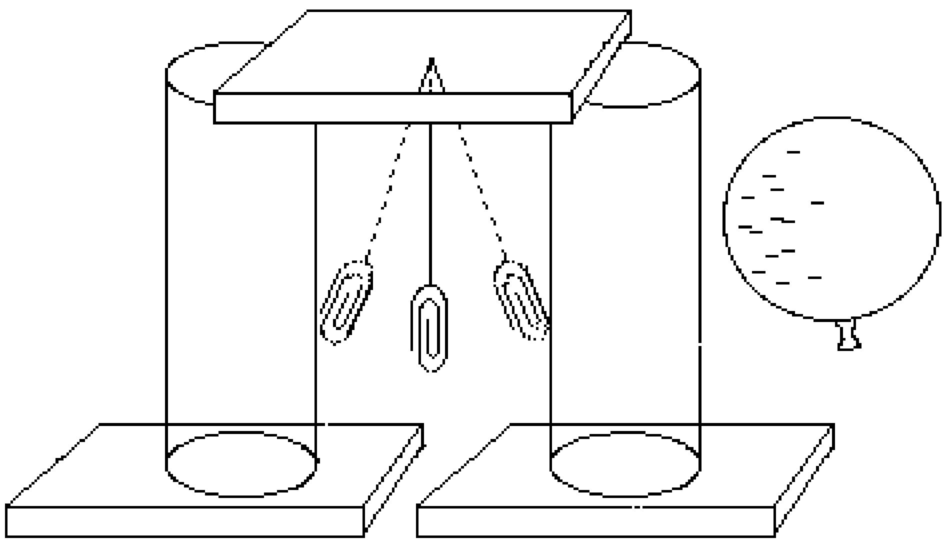
D. The "Magnetic" Meter Stick
   1. Place a watchglass on a table.
   2. Balance the flat edge of a meter stick on the watchglass so that it may rotate in a plane parallel to the table..
   3. Charge up a glass or hard rubber rod by rubbing it with silk (glass rod), wool flannel (rubber rod).
   4. Bring the rod close to the end of the meter stick but not touching it.
   5. Advance the rod in front of the meter stick. It should interact with the meter stick and make it slowly twirl.

E. The Electrostatic Pendulum
   1. For this exercise you will need two tall tin cans, three pieces of paraffin wax, thread, a paper clip, a rubber balloon, and wool cloth.
   2. Set each can on one of the blocks of paraffin. Balance the third block of paraffin on the open ends of the two cans. Suspend from this block the paper clip by means of the thread in such a way that the paper clip hangs

down in between the two cans.



3. Rub the balloon with the wool cloth and bring it close to one of the cans. Observe. [The clip will move back and forth between the cans.]



4. The negatively charged balloon when brought close to one of the cans repelled the electrons to the other side of the can (the side closer to the paper clip). The neutral charged paper clip is then attracted to this charged can and moves to make contact with it. In making contact the clip receives electrons making it the same charge as the can and then moves away since like charges repel. The paper clip now negatively charged induces a positive charge in the second can and is attracted to it. Upon making contact it gives up its charge to the second can and is attracted again to the first. The back and forth motion is repeated a number of times.
5. It is very important that the paraffin be used. It serves as an insulating agent so that electrons can not be drained off too readily. **This, as most of the electrostatic demonstrations, works better on a cold, dry day in the middle of the winter.**

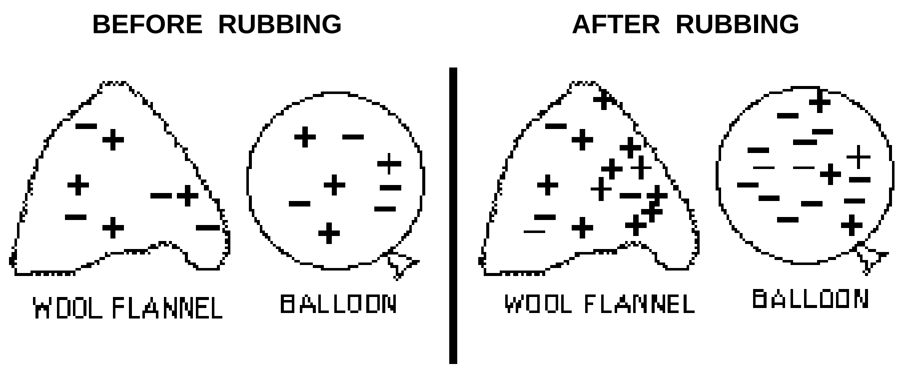
F. The Confused Pithball

1. If pithballs are unavailable, they can be made from a Styrofoam® ball covered with pencil lead or aluminum spray paint. Suspend the pithball from a thread attached to a support.
2. Rub the comb with the wool cloth and approach the pithball. Ask students whether they think it will be repelled or attracted. [It will be attracted.]
3. After showing that the comb will attract the pithball, bring the comb close enough to touch the pithball. Immediately the pithball will be repelled from the comb.
4. After the pithball has settled down approach it with your finger. [It will be attracted to your finger.] Finally, touch it with your finger. [As soon as the pithball is touched by the finger the charges are neutralized and there is neither repulsion nor attraction by the finger.]
5. Each of these observations should become understandable in the next section of this lesson.

CLASS RESPONSE / INVENTION

A. Matter Is Made Up of Charged Particles
   1. Matter is made up of particles having positive charges and negative charges. The negative particles are called electrons. Matter is neutrally charged when there are just as many positive charges as there are negative charges.
   2. Neutral matter can become charged by removing or adding electrons. All of the phenomena experienced in the PROBLEM PRESENTATION / INVENTION section above can be explained in terms of matter being charged and the interactions it had when coming in contact with other neutral or charged matter.

B. Charging by Friction
   1. Many objects can be charged by rubbing them with another substance. Friction between unlike materials causes electrons to move from one to the other substance.
   2. Rubbing a balloon with wool causes electrons to leave the wool and move onto the balloon which makes the balloon negative. Even though the balloon has both positive and negative charges, the overall charge is negative. This would mean that the resulting charge on the wool would be positive since electrons were removed from the originally neutral wool.



   3. Rub a balloon with some wool. Tie some thread to the balloon and hang it from a support. Bring the wool close to the balloon. What will happen? [The balloon and wool will be attracted to each other due to their opposite charges.]
   4. Rub two balloons with wool. Hang them from a support. Since both balloons are negative in charge, it should not be surprising that the balloons will be repelled from each other.
   5. Next, rub a hard rubber rod (a hard plastic comb works well if you don't have rubber rods) with some wool flannel. (What charge will the wool have? [+] What charge will the comb have? [-]) Bring the charged comb close to the

charged balloon. Did it act the same way that the two balloons did? [Yes])

6. Take a piece of glass rod and rub it a few times with a piece of silk. What charge will develop on the glass rod? What charge will develop on the silk? How could you find out? [Bring the silk close to the charged balloon. Did it repel or attract? It should have repelled. Bring the glass rod close to the balloon that has been charged. It should attract. These observations should allow us to conclude that the glass rod becomes (+) when rubbed with silk, and the silk becomes (-) when rubbed with the glass rod.]
7. Knowing the charges developed on the comb and glass rod or the wool and the silk the students should be able to find out what the charges are on different substances that have been rubbed together. If they are repelled by the charged comb or the charged balloon, they are (-). If they are repelled by the charged glass rod, they are (+). They never will be repelled by both rods.
8. The charge on the rubber rod or comb works much better than the charge on the glass rod. The glass rod does not hold a charge very well unless the experiment is done in a very dry, non-humid room, conditions that are more probable in the winter.

C. Charging by Induction

1. Cut up tiny bits of paper and scatter them out on the table. Rub a hard rubber comb through your hair a few times or rub it vigorously with some wool flannel. Bring the charged comb near the bits of paper. What happens? [They are attracted to the negatively charged comb.]
2. Rub a piece of glass rod with silk. Bring the charged glass rod near the bits of paper. Will they be attracted to the charged glass rod? Students may guess that they won't since the paper was attracted to the negative rod or comb in #1. It probably would seem logical that the positive rod would repel the paper instead of attracting it. However, the bits of paper are also attracted to the positively charged glass rod. [Remember, if you can't get the glass rod to work, just use the wool that you used to charge the rubber rod or comb. Because the comb became negative, the wool has to be positive.]
3. The paper is neutral meaning that it is made up of an equal number of positive and negative charges. When the negatively charged comb is brought near the paper the electrons in the paper are free to move away from the comb (like charges repel) but they remain in the paper. The part of the paper closest to the comb must be positively charged. (The only charged particles that move are electrons; the positive charges can not move.) The part of the paper farthest away from the comb was then negative.
4. The negatively charged comb is now attracted to the side of the paper next to it which is positive. When the comb is taken away the electrons in the paper will spread out through the paper just as they were before coming close to the negatively charged comb.
5. If the positively charged glass rod comes close to the paper the electrons in the paper move to the part of the paper closest to the comb (unlike charges attract.) The part of the paper farthest away from the glass rod is then positive. The positively charged comb is now attracted to the side of the paper next to it which is negative.
6. The paper is attracted to either a negative or positive rod. The reason, as we have seen, is because the charged rod temporarily influenced the charge distribution in the neutral substance. This is known as creating a charge by **Induction**. Induced charges are ones that result from an object being near another strongly charged object.
7. Making a Condiment Copier
    a.) Place some pepper into a petri dish. Place the lid on it. Cut a circle of paper to fit the lid of the petri dish. Cut out a design in the middle of the paper.
    b.) Hold the paper against the top of the dish and rub the open area with a wool cloth for at least 30 seconds.
    c.) Remove the paper stencil and invert the dish for a couple of

seconds. Upon turning the dish over what happens?

d.) Only the area where the wool rubbed the dish became charged (-). When the pepper came in contact with the negatively charged area it became charged by induction. The side in contact with the dish was positive which allowed the pepper to adhere to the charged part of the dish which made the design when the dish was turned over.

e.) This principle is central to electrostatic photocopying as well as other industrially important processes.

8. "Magnetic" Water?

a.) Open the tap and allow a small stream of water to run into the sink. Charge a hard rubber comb by running it through your hair a few times or rubbing it with some wool. (This will be negatively charged.)

b.) Hold the back of the comb about 2 cm from the stream of water. Predict what will happen. [The stream of water is bent toward the comb.]

c.) Charge a glass rod by rubbing it with silk or use the wool that was used to charge the comb (this will be positively charged).

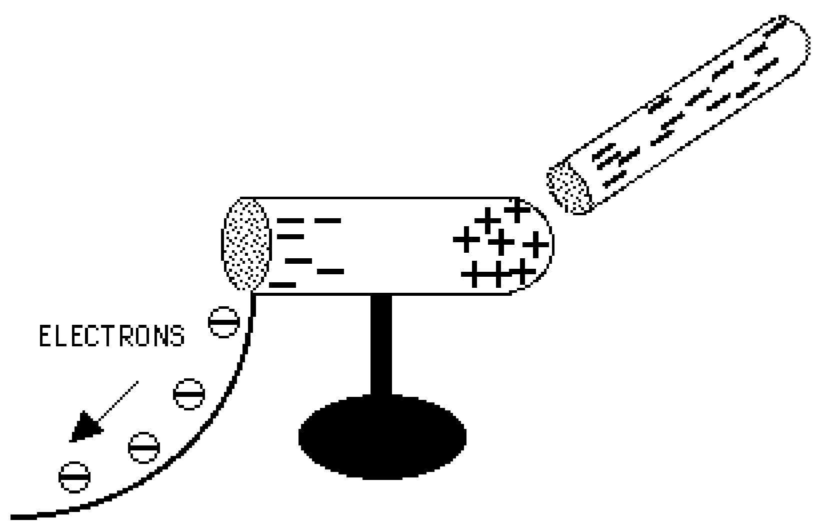
d.) Hold the glass rod about 2 cm from the stream of water. Predict what will happen. [The stream of water will bend toward the glass rod just like it did when the charged comb was used.]

e.) Both the negative comb and the positive glass rod were capable of inducing the water molecules so that they lined up in a manner that the charge on the comb or rod was opposite to the molecules being attracted to the comb or rod. Water molecules have the advantage of having both a slightly positive and slightly negative end. When the negative comb came close the molecules turned so that their positive ends were facing the charged comb and the water stream bent. When the positive glass rod came close the molecules turned so that their negative ends were facing the charged rod and once again the water stream bent.

9. Grounding

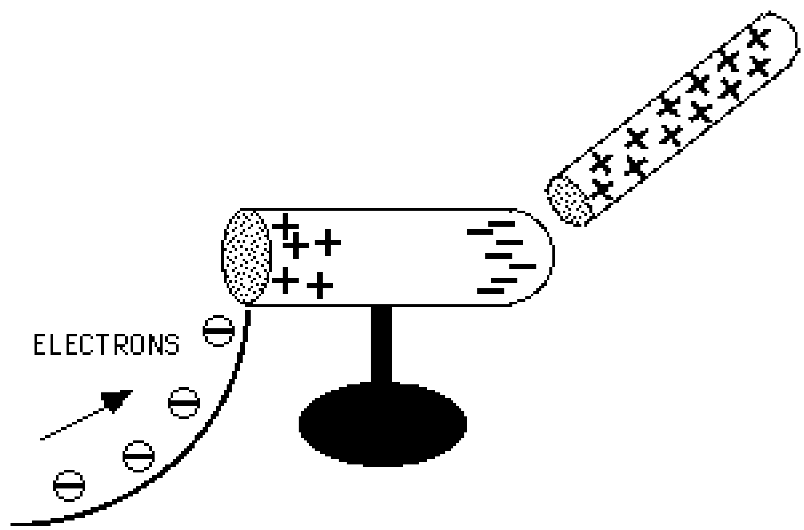
a.) A conductor such as a piece of metal can be permanently charged by induction. The examples of the bits of paper, the particles of pepper, and the water molecules all experienced an induced charge but this charge was temporary. Upon the removal of the originally charged object the electrons making up the particle returned to their normal distribution.

b.) A piece of metal can be induced by bringing a negatively charged rod or comb close to it in the same way the bits of paper were induced.



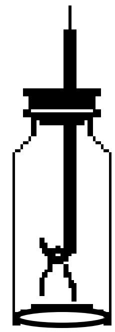
The electrons move away from the end close to the rod. However, if while still under the influence of the charged rod a new conductor is touched to the metal, electrons can flow out of the metal. No longer does the metal have equal numbers of negative and positive charges. Now upon removing the charged rod (remember, it never came in touch with the metal) the metal has developed an overall positive charge. Bringing the rod near to the metal results in attraction rather than repulsion. [Metal is (+) and the rod is (-)] The conductor which was briefly attached to the piece of metal that allowed excess electrons to leave (or enter as we will see in the case below) is called a **ground** because the conductor is often attached to the earth or ground.

c.) What would happen if a positively charged glass rod was substituted for the negatively charged comb? This time the end of the metal close to the glass rod would be negatively charged as the electrons would have migrated in this direction. If while still under the influence of the charged glass rod a new conductor is touched to the metal, electrons will flow from the conductor to the positive side of the metal. No longer will the metal have equal numbers of negative and positive charges. Now upon removing the charged glass rod the metal will have an overall negative charge. Bringing the glass rod near to the metal results in attraction rather than repulsion. [Metal is (-) and rod is (+)]



D. Electroscope

1. If you have a commercial electroscope, use if; but if you don't, you can build one.
2. Make a J-like hook out of the uninsulated end of a piece of electrical wire. From both ends of the wire remove the insulation
3. Obtain some Christmas tree icicle material. This material is made of aluminized Mylar® film. A strip of the icicle material should be placed, aluminizied side down, on the hook so that the two leaves can hang straight down.
4. Lower the hook with icicle into a jar with a narrow neck (a 12 oz glass soft drink bottle works find). The wire should project out of the jar about 5 cm. Seal the neck of the jar with an appropriate rubber stopper or by carefully packing piece of clay or Play Doh® around the wire.



5. During the use of the electroscope students should be instructed to never open the bottle in an effort to adjust the position of the leaves. NEVER touch the leaves.
6. Test the electroscope by rubbing a comb through your hair or rubbing it with some wool and slowly bringing it near the uninsulated wire at the top of the electroscope. Do not touch the wire with the comb. The leaves (pieces of icicle) should spread apart. Upon removing the comb the leaves should move back together.
7. Predict and explain the following:
   a.) What happens when the comb comes close to the exposed wire and actually touches it? [The leaves spread apart and stay apart. The charge on the leaves is the same as the charge on the comb or glass rod used to charge them.]
   b.) What will happen when you touch the exposed wire with your finger? [The electroscope will discharge since your finger is acting as a ground.]
   c.) How could you put a negative charge on the electroscope so that the leaves remain spread apart <u>without touching the wire with the charged object (charged comb</u>)? [Bring the charged comb up to but not touching the wire and touch the wire with your finger. Without moving the comb away remove your finger. Then move the comb away. The negatively charged comb forces the electrons down into the leaves and causes them to spread apart but leaves the top of the wire positive. Touching the wire at this point draws electrons from your finger into the top of the wire. The electroscope has now picked up more electrons than it started with. When the charged comb is removed the leaves remain separated.]
   d.) What would happen if you now touched the wire at the top of the charged electroscope with your finger? [This time your finger will drain off excess electrons and the leaves will drop back down to their neutral positions.]
   e.) How could you put a positive charge on the electroscope so that the leaves remain spread apart <u>without touching the wire with the charged object (charged glass rod</u>)? [Bring the charged glass rod up to but not touching the wire and touch the wire with your finger. Without moving the glass rod away remove your finger. Then move the glass rod away. The positively charge glass rod draws electrons up from the leaves to the top of the wire leaving the lower portions of the leaves positively charge causing them to spread out. Touching the wire with your finger allows a path for the electrons to drain off. The electroscope now has fewer electrons than it started with. When the charged glass rod is removed the leaves remain separated.]
   f.) What would happen if you now touched the wire at the top of the charged electroscope with your finger? [This time your finger will supply electrons and the leaves will drop back down to their neutral

positions.]

E. Why did the balloons stick to the board?
   1. Rubbing the balloons charged the balloons with a negative charge. As these balloons approached the neutrally charged board the electrons on the surface of the board were repelled. This left a positive charge at the surface of the board. The negatively charged balloon was then attracted to the positively charged surface of the board.
   2. Over a period of time electrons will transfer from the balloon to the board and the induced positive charge on the board will be neutralized resulting in the balloon falling down.

F. Why did the balloons repel?
   1. The first two balloons from the EXPLORATION phase of this lesson were charged by friction. By rubbing them with wool electrons were transferred to the surface of the balloons. This gave both of the first two balloons a negative charge. When the two balloons were put side by side they repelled because like charges repel.
   2. The neutral balloon and the negatively charged balloon illustrate an important principle. This is a good way to demonstrate induction. It is effective because students may think that a neutral object can't be attracted by a charged object. The evidence of the charged balloon inducing a charge on the neutral balloon without ever touching it is extremely important for students to understand.

G. The magnetic ruler can be explained in the same way as the neutral balloon being attracted to the negatively charged balloon in that a charge was induced on the paper roll by the negatively charged ruler. This allowed a close ranged attraction to occur so that the ruler can pull the roll along.

H. The electrostatic pendulum is a good exercise to allow the students to analyze the charges developing on both the cans and on the paper clip during the oscillations between the two cans. This involves charging by friction (the original balloon), by contact (when the paper clip touches the can electrons flow because both the can and the paper clip are metal conductors), and by induction (both the balloon and the paper clip induce charges on the cans).

I. The confused pithball can be explained in much the same way as the electrostatic pendulum.
   1. When the comb first attracts the pithball it is due to induction.
   2. When the comb actually touches the pithball the pithball is charged by contact and obtains a negative charge. Immediately the two negatively charged objects (comb and pithball) repel each other.
   3. The pithball induces a charge on your finger when it is brought near to the pithball. The negatively charged pithball is attracted to your finger which has a positive charge on its surface.
   4. Touching the pithball allows electrons to drain away off the pithball returning it to a neutral charge. At this point the attraction ceases and the pithball will hang down in its starting position.

CONCEPT EXTENSION

A. Making an Electrophorus
   1. Have you ever noticed during the winter that after shuffling your feet on the carpet and upon approaching a metal doorknob that sparks travel between your finger and the doorknob? We want to build an instrument that can store up some electricity even better than you shuffling your feet across the carpet. It is called an **electrophorus**.
   2. Glue a small block of wood or paraffin to the inside center of the pie pan. This will be your handle for picking up the pie pan without discharging it.
   3. Cut out a rubber circle from an old inner tube with the same diameter as the pie plate. Lay it flat on the table. Rub it vigorously with wool or fur for at least 30 seconds.
   4. Lift the pie pan by the wooden handle, keeping your fingers away from the

metal, and hold it close to the charged rubber sheet.

5. While it is in this position, touch the pan briefly with the tip of your little finger. What do you hear?
6. Charge the aluminum pan again. Try discharging it again in a darkened room. What do you think will happen?
7. Prepare a **dead** fluorescent tube by putting it on a table. Allow the one end to touch a large metal object such as a locker, radiator, or a pipe. After charging the pie pan again bring it close to the other end of the florescent a tube. When it touches the end of the tube what happens? [It really lights up!]
8. The explanation for the action of the pie-pan generator (electrophorus) is straightforward. First, what charge did the rubber inner tube receive when rubbed with the wool? [The wool became (+) and the rubber sheet became (-).] When the pie pan was held near the rubber sheet and you touched the metal, the negative charge on the rubber sheet caused the electrons in the metal to be repelled from the pan to your finger which made the spark. [Now, what charge must the pie pan have? Remember, electrons have been discharged in the spark. The pan is now (+). Finally, when you touch the pan to the fluorescent tube electrons jump back from the fluorescent tube to the pie pan. When the charge moved from one end of the fluorescent tube to the end touching the pie pan the electrons were moving and the tube lit up for a short time.]

B. Lightning

1. In many ways the discharge we saw from the fluorescent tube to the pie pan is the same thing that happens when lightning occurs.
2. Lightning is a rapid discharge of electrons through the air that can release as much as 3,750,000,000 kilowatts of power. The interaction of the electrons with the air causes the glowing spark we call lightning. The temperature of the air can rise 30,000 degrees. This tremendous change in temperature causes the air to expand rapidly resulting in what we call thunder.
3. Although lightning is not fully understood, some things are clear. During a thunderstorm the charge distribution in clouds is arranged so that the bottoms of clouds become negatively charged. They in turn induce a positive charge on the surface of the earth below. When the difference in charge is great enough the air becomes a conductor. The kind of discharge with which we are most familiar is that between the clouds and the oppositely charged ground below. But the more frequent type of discharge is between oppositely charged parts of different clouds.

C. Can you explain the following?

1. What makes plastic wrap such as Saran Wrap stick to food storage containers? Is it due to static electricity? How would you go about testing to see if this is plausible? [Electric charges on the plastic wrap attract the sides of bowls causing it to cling. The charge was probably put on the plastic wrap when it was pulled off the roll quickly. One way to check the probability of this explanation would be to lay a piece of plastic wrap on the table and rub it with wool and then try to determine whether the cling was more intense. To check which substances the plastic wrap more readily clings to could possibly be investigated in terms of whether the bowl is a conductor or insulator. The bowls that are conductors will be more easily induced and form a stronger attraction. Aluminum, glass, plastic, and wooden bowls could be used.]
2. What causes clothes in a clothes dryer to get all mixed up and stick together when you take them out of the dryer? [By the clothes tumbling over and over and coming in contact with each other there is a lot of transfer of electrons due to friction. When the dryer stops different parts of the clothing have opposite charges and tend to cling to each other.] A good research project would be to have students find out how anti-static-cling products that we put in our dryer work.

3. Picture the following. Boy and girl are on opposite sides of the front seat of the car. After awhile he scoots across the plastic seat cover towards the center. She also scoots toward the middle. Still more time goes by, he scoots, she scoots. Slowly their lips are approaching each other, and SNAP, CRACKLE, POP they undergo an electric experience. What happened?? [As they scooted across the plastic seat cover they both were being charged due to friction. When their lips made contact there was a sudden discharge creating the electric experience.]