ACTIVITY 1
Opposites Attract
(Static electricity)

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Safety

Please note that while following the precautions in this guide can help teachers foster inquiry in a safe way, no manual could ever predict all of the problems that might occur. Good supervision and common sense are always needed.

Warning: These activities work best in low humidity. If humidity in your classroom is high, consider relocating to an air conditioned room or rescheduling these activities for another day.

Dancing Fleas

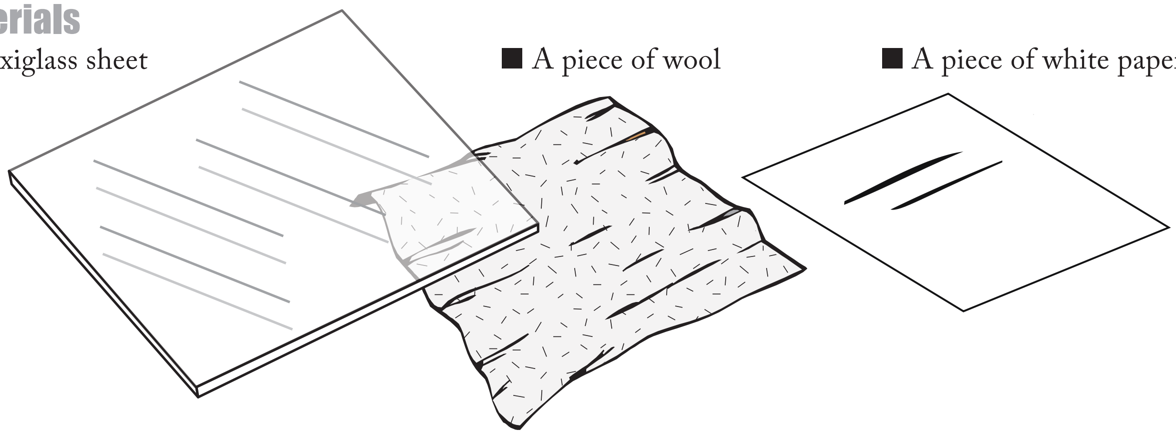
Use static electricity to make objects dance.

Safety

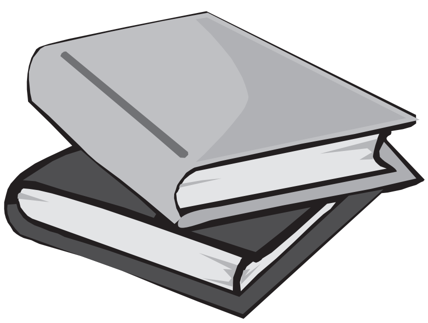
The edges of the plexiglass sheet may be sharp, especially if it was cut down to size for you, so be careful.

Materials

- Plexiglass sheet
- A piece of wool
- A piece of white paper



- 2 textbooks, each about 2.5-cm thick

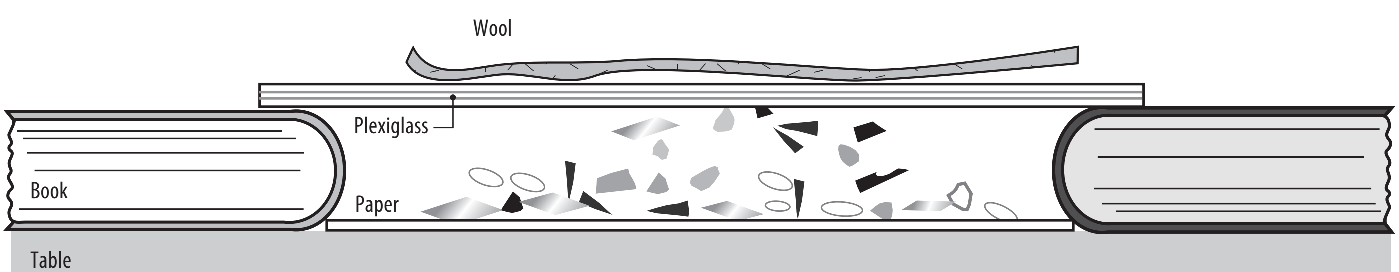


An assortment of tiny objects, for example:

- Paper squares (colored paper is easier to see)
- Aluminum foil squares
- Puffed rice cereal
- Grains of rice

Instructions

1. Tape the piece of paper down on a desk and sprinkle some of the "tiny objects" over the paper.
2. Use the textbooks to suspend the plexiglass sheet directly over the paper, as shown below.
3. Rub the top of the plexiglass sheet with the wool and record what happens.



Graphics by Kerry G. Johnson

Discussion questions

- How can we use static electricity to make objects move?
- What kinds of materials are affected by electric charges?
- How strong is the force of an electric charge compared to the force of gravity?
- How could you test this?

FOR THE TEACHER

(Level 1)

Dancing Fleas

Materials

■ 12-inch x 12-inch or larger sheet of 1/8-inch thick plexiglass (acrylic)
Available at hardware stores. Often you order the sheet at the check-out counter and they cut it to size for you. Approximately $5.

■ A piece of wool, approximately 10-cm x 10-cm or larger*
You can purchase wool felt by the yard at most fabric stores. You can also purchase wool cloths from science supply stores, such as Science Kit & Boreal Labs, www.sciencekit.com, part number WW2742300. $6.60 / 12-inch x 24-inch cloth.

■ 2 textbooks, each about 2.5-cm thick

■ 1 piece of white paper

An assortment of tiny objects, for example:
■ Paper squares (colored paper is easier to see)
■ Aluminum foil squares
■ Puffed rice cereal
■ Grains of rice

Discussion

Materials are attracted to the plexiglass after it is rubbed. This is because the wool deposits extra electrons on the sheet, giving it an overall negative charge. The electrons in the tiny objects are then repelled by the sheet and move to the bottom of the pieces, leaving the positively charged protons near the sheet. The objects move up toward the plexiglass (as long as they are not too heavy) because the protons are attracted to the negatively charged plexiglass.

Students may notice that some of the bits of paper stick completely to the plexiglass sheet while others hang by an edge. The bits that hang by an edge have a high concentration of electrons in part of the paper farthest from the sheet; if you remove the electrons by touching the paper, it will then stick completely to the plexiglass.

Another notable result is that the aluminum foil bits often bounce back and forth rapidly between the paper taped to the desk and the plexiglass, while other materials move much slower or stick completely to the plexiglass the first time they hit it. This is because the conducting foil quickly picks up electrons from the plexiglass. This causes the foil bits to be repelled from the sheet, so they fly back to the paper They deposit the electrons on the paper, and then are attracted to the plexiglass again. To magnify this effect, place a large piece of aluminum foil under the plexiglass instead of the paper.

Suggested resources

Bell, Trudy E. *"Crackling Planets"* Science@Nasa, 2005.
http://science.nasa.gov/headlines/y2005/10aug_crackling.htm?list78675
Article about charging by rubbing as a concern for exploration of the Moon and Mars.

"Static Electricity: What causes static shocks?" Science Made Simple, Inc., 2005.
http://www.sciencemadesimple.com/static.html
Static electricity basics with background information on atoms and charge.

Bibliography

"Electrical Fleas: Start your own electric flea circus." Exploratorium Snacks.
http://www.exploratorium.edu/snacks/electrical_fleas.html

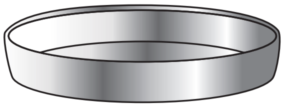
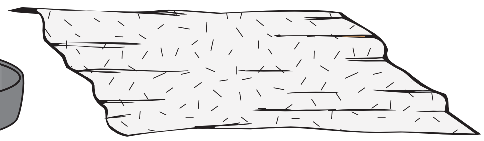
The Electrophorous

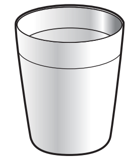
Create your own electrophorus – a device developed over 200 years ago for creating static charge.

Safety

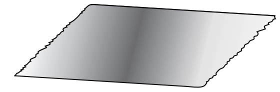
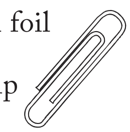
You will be building up small amounts of static charge in this activity and could receive shocks.

Materials



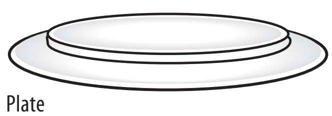
- An aluminum pie pan
- A piece of wool
- A Styrofoam plate
- A Styrofoam cup

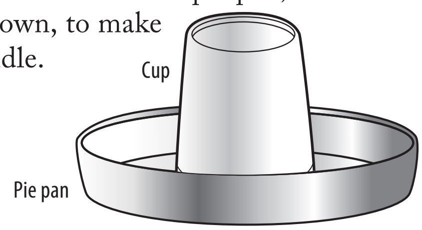
- Adhesive tape
- Aluminum foil
- A paper clip

Making the electrophorus

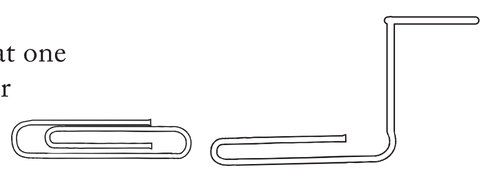
1. Tape the plate upside down to the center of a desk.

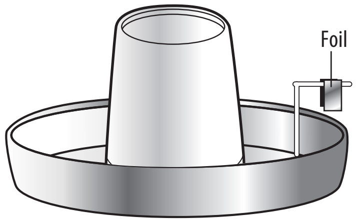


2. Tape the cup to the middle of the top of the aluminum pie pan, top down, to make a handle.

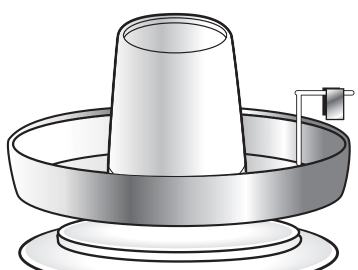


3. Bend the paper clip so that one end is a base and the other makes a horizontal arm.





4. Tape the base of the paper clip to the top of the pie pan next to the cup, and hang a small strip of aluminum foil (about 0.5-cm x 4-cm) over the horizontal arm.



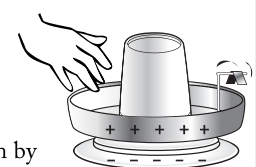
5. Place the pie pan on top of the plate. Your electrophorus should look like the picture above.

Using the electrophorus

A. Set aside the top (pie pan / Styrofoam cup) and rub the surface of the Styrofoam plate with wool for a full minute.

B. Touching only the Styrofoam cup handle, set the pie pan back on top of the plate.

C. Touch the pie pan (you should feel a slight shock).



D. Lift up the pie pan by the Styrofoam cup handle. The foil should flip away from the pan.

E. Touch the pie pan again. You should feel a shock and see the foil flip back down.

The pie pan can be charged multiple times without recharging the Styrofoam plate by rubbing, but the Styrofoam plate will loose charge slowly to the air and surroundings, especially in humid weather.

Discussion questions

- Why doesn't the Styrofoam plate loose all its charge to the pie pan?
- Do you think there is a limit to the amount of charge you can build up on the plate?
- What is the role of the foil strip?
- How can you turn this static electricity into useful energy?

Graphics by Kerry G. Johnson

(Level 2)

FOR THE TEACHER

The Electrophorous

Materials

- An aluminum pie pan. *Available in the baking section of the grocery store for a few dollars.*
- Piece of wool, approximately 10-cm x 10-cm or larger. *You can purchase wool felt by the yard at most fabric stores. You can also purchase wool cloths from science supply stores, such as Science Kit & Boreal Labs, www.sciencekit.com,part number WW2742300. $6.60 / 12"x24" cloth.*
- Styrofoam plate
- Styrofoam cup
- Aluminum foil
- Adhesive tape
- A paper clip

Discussion

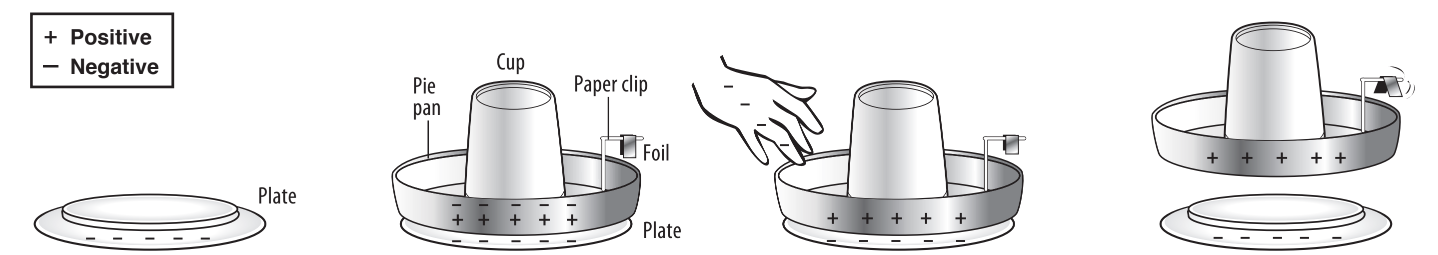
Rubbing the Styrofoam plate with wool transfers electrons to the plate, where they stay because the plate is an insulator (A). When the intially neutral conducting pie pan is set on top of the insulating plate, its extra electrons move to the top surface because they are repelled by the plate's negatively charged extra electrons (B). This leaves the bottom of the pan positively charged.

When you touch the plate (C) the negative charges on the pie pan are drawn off. This happens because you act as a ground. Even though the body is electrically neutral, its positive charges attract the free electrons in the pie tin. Because you are connected to the ground, the negative charges (electrons) flow through you to the earth without building up a charge on the body. This process leaves the pan with an overall positive charge.

When the pan is lifted, the positive charges redistribute evenly on its surface and the aluminum foil strip (D). This causes the aluminum foil strip to flip up, since it is repelled from the similarly charged pan.

If you (or any other conductor) now touch the pie pan, electrons will flow back to the pan, creating another spark and leaving the pan neutral once again. When the pan discharges, the foil flips back down because it and the pan are now neutral and no longer repel one anther.

Note that the Styrofoam plate does not lose any charge in this process; only the charges in the pie pan move around. This is called charging by induction, and explains why the pan can be recharged without rubbing the plate again.



A. The Styrofoam plate is negatively charged by the wool. The electrophorus is initially electrically neutral.

B. Electrons on the electrophorus are repelled by the negatively charged plate and move toward the top surface. This leaves the bottom surface positively charged.

C. Electrons near the top surface of the pan are drawn off by the ground.

D. The electrophorus is left with an an overall positive charge that redistributes when the plate is lifted.

Suggested resources

"Charge and Carry: Store up an electric charge, then make sparks." Exploratorium Snacks. http://www.exploratorium.org/snacks/charge_carry.html
Another form of the electrophorus and Leyden jar activities with a good explanation.

"Static Electricity." The Physics Classroom, 2004.
http://www.physicsclassroom.com/mmedia/estatics/estaticTOC.html
Use the menu on the left to find out more about various forms of electrostatic induction, including the electrophorus.

Bibliography

"Charge and Carry: Store up an electric charge, then make sparks." Exploratorium Snacks. http://www.exploratorium.org/snacks/charge_carry.html

Graf, Rudolph F. *Safe and Simple Electrical Experiments.* New York: Dover Publications, Inc. 1973. Pages 16-18.

Henderson, Tom. *"Charging an Electrophorus by Induction Using a Negatively-Charged Object."* Multimedia Physics Studios, 1998.
http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/estatics/epn.html

Jones, Thomas B. *"Electrophorus and Accessories."* 2005. http://www.ece.rochester.edu/~jones/demos/electrophorus.html

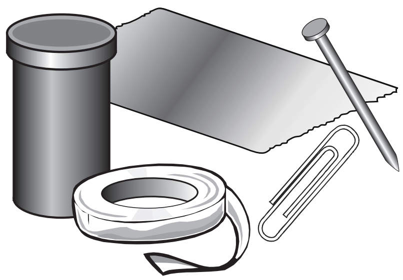
The Leyden Jar

Make your own Leyden jar for storing charge.

Safety

You will be building up small amounts of static charge in this activity and could receive shocks. In addition, be very careful when working with the nails.

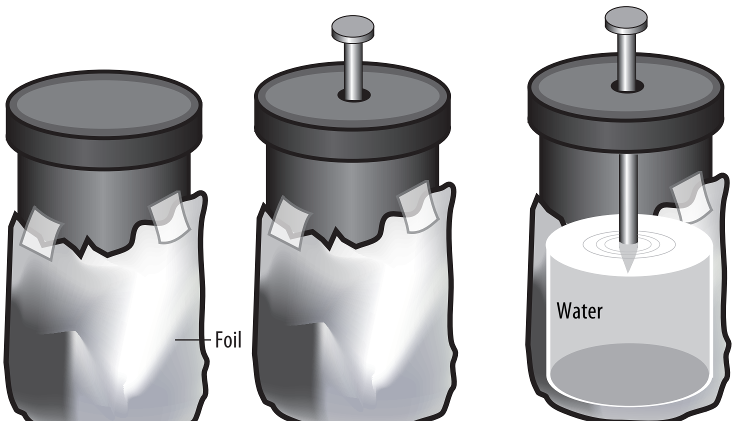
Materials



- 35mm film canister
- A 2-inch nail or a paper clip with one leg straightened
- Aluminum foil
- Adhesive tape
- Tap water
- Electrophorus or other static electricity source

Making the Leyden Jar

1. Cut a 4-cm x 12-cm piece of aluminum foil and smooth it out with your fingers.
2. Neatly wrap the bottom two thirds of the film canister in the foil and tape it in place securely.
3. Push the nail (or paper clip) through the top of the canister, so that the tip of the nail points toward the inside of the canister. The head of the nail should stick out a few centimeters.
4. Fill up the canister most of the way with tap water and snap the lid in place. The point of the nail should be immersed in water.



Using the Leyden Jar

A. Charge the electrophorus as in Extension 1, but do not discharge it.

B. Lift the pie pan off the Styrofoam plate. Hold the Leyden jar by the foil and drag the top of the the nail along the edge of the pie pan. Note that the aluminum foil charge tester on the electrophorus flips down as the pie pan touches the nail.

C. Charge the pan again and repeat step 2. Do this several times.

D. Discharge the Leyden jar by touching the nail and the foil on the jar at the same time (you will get a shock, but it is not large enough to be dangerous).

Discussion questions

- Is there a maximum charge that your jar can hold? How might you test this?
- Can you discharge the Leyden jar into other objects? Try discharging it into a fluorescent tube or light emitting diode (LEDs) in a dark room. Do this by touching one lead to the nail and one lead to the foil.
- Can you discharge the Leyden jar without touching it? Sparks should be able to jump between your fingers and the charged object if you hold your fingers close enough. How far you can make the sparks jump?

Graphics by Kerry G. Johnson

FOR THE TEACHER

(Level 2)

The Leyden Jar

Materials

- 35mm film canister
  Usually a camera store will give you empty film canisters
- A 2-inch nail or a paper clip with one leg straightened
- Aluminum foil
- Adhesive tape
- Tap water
  Not purified or distilled
- Electrophorus or other static electricity source such as a PVC pipe rubbed with wool

Discussion

The pan has a positive charge on it when it leaves the Styrofoam plate. When you drag the nail along the pan, electrons in the neutral nail are attracted to the positively charged pie pan. These electrons go from the nail to the pan, neutralizing the pan and leaving the inside of the Leyden jar positively charged. Repeating the process increases the charge inside the jar.

As the inside of the jar becomes positively charged, the charges in foil on the outside of the jar are also affected. The electrons in the foil move to the inside-facing side of the foil because they are attracted to the positively charged interior of the jar. This leaves the outside-facing side of the foil positively charged. Since you are holding the can by the foil, negative charges in your hand are attracted to the positively charged foil, and they flow into the foil. This leaves the foil with an overall negative charge.

When you touch the aluminum foil and the nail at the same time, electrons flow through your hand from the foil to the water, neutralizing the charge inside the jar and giving you a shock.

If you are working with a more advanced class, you may wish to challenge your students to write an explanation of how the charges are moving throughout the process of charging and discharging the Leyden jar. This exercise will be most effective when groups discuss their explanations and use pictures to visualize how the charges flow.

Suggested resources

"Charge and Carry: Store up an electric charge, then make sparks." Exploratorium Snacks.
http://www.exploratorium.org/snacks/charge_carry.html
Another form of the electrophorus and Leyden jar activities with a good explanation.

Katz, Eugenii. *"Leyden Jars."* http://chem.ch.huji.ac.il/~eugeniik/instruments/archaic/leyden_jars.htm
History of the Leyden jar and pictures of various types of jars.

Bibliography

"Charge and Carry: Store up an electric charge, then make sparks." Exploratorium Snacks.
http://www.exploratorium.org/snacks/charge_carry.html

FOR THE TEACHER

(Level 2)

Franklin's Bells

This is a simple device for detecting static electricity that works with a television or CRT (non-flatscreen) computer monitor. Franklin used a similar device in his house to let him know when static electricity was in the air, like during a thunderstorm.

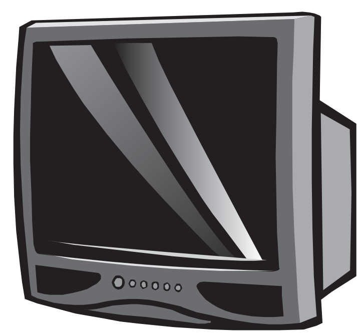
It is recommended that Franklin's Bells be done as a demonstration because there are safety concerns about having students work with the static charges on TV / computer screens. Construction is simple enough that inspecting the finished product enables students to understand how the bells are made.

Safety

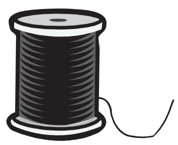
An uncomfortable and possibly dangerous shock can result from discharging the electric charge of a TV screen or computer monitor through your body. Be sure to connect the second can to a ground (such as the metal on the back of a computer or the metal leg of a table or chair). Only touch the bells and screen when the screen is turned off and the bells have stopped ringing.

Materials

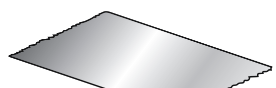
- Two empty soda cans, at least one with a pull tab



- Sewing thread or thin string



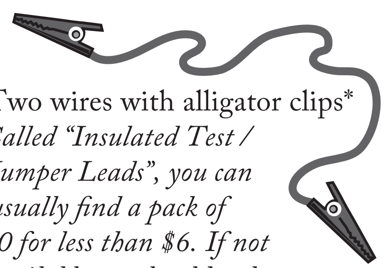
- Aluminum foil



- Plastic pen

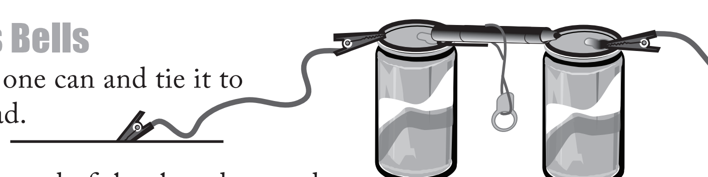
- Adhesive tape

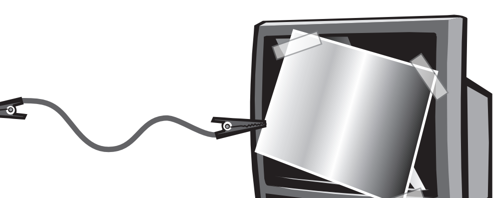
- Two wires with alligator clips*
  Called "Insulated Test / Jumper Leads", you can usually find a pack of 10 for less than $6. If not available at a local hardware store or RadioShack, you can purchase them from RadioShack.com, model 278-1156.



- TV or CRT computer monitor (some newer screens are "non-static" – these won't work. If you are having trouble making the bells ring, try another screen)

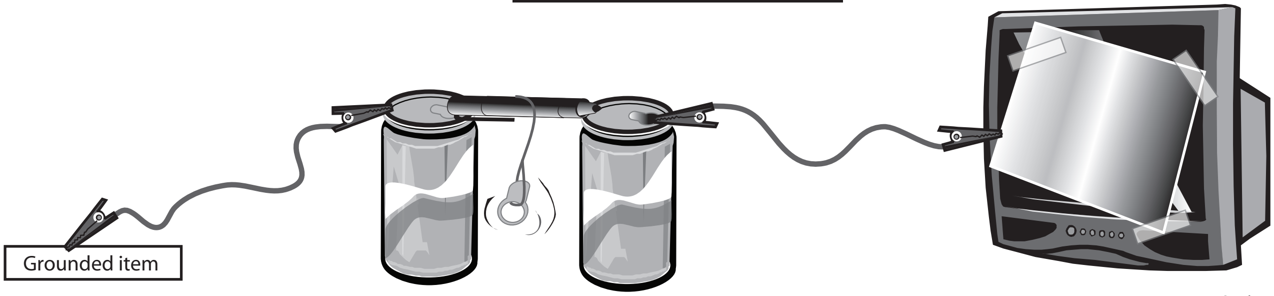
Making Franklin's Bells





1. Break the tab off of one can and tie it to one end of the thread.
2. Tie or tape the other end of the thread around the center of the pen so that when hanging from can level, the tab does not touch the table.
3. Place the cans about thee centimeters apart, and lay the pen on top of them so that the tab is suspended between the cans. Make sure the tab is not touching either can.

Graphics by Kerry G. Johnson



Graphics by Kerry G. Johnson

4. Connect one can to a ground, such as the metal part of a computer frame, using one of the alligator clip wires.

5. Use the other wire to connect the other can to a sheet of aluminum foil about the size of the TV or computer screen.

6. Turn the screen off, and tape the foil directly to the screen.

7. Turn the screen on – the tab should swing back and forth hitting the cans and creating a bell-like sound until the charge on the screen is dissipated. You can make the tab continue moving by turning the screen on and off repeatedly.
Note that the screen becomes charged when it is switched off as well.

If you have access to a source of constant static electricity, such as a Van de Graaff Generator or Wimshurst Machine, try connecting the bells to it after using the TV. The bells should ring constantly as long as the machine is turned on.

Discussion questions

■ What causes the bells to ring?

■ What would happen if you used a metal pen instead of a plastic one?

■ What do you need to connect the second can to ground?

■ How else could you detect static electricity?

Discussion

The tab moves because it is made of conducting metal and therefore attracted to charged objects. When the screen is turned on, a static charge accumulates on it (students may have noticed that they can get small shocks from TV screens). The aluminum foil / wire set-up transfers most of this charge to the first soda can. The hanging tab is uncharged, and therefore attracted to the charged can by induction.

When the tab strikes the can, some of the can's charge is transferred to the tab, and the tab is then repelled from the first can. The charged tab is then attracted to the neutral second can by induction. When it strikes this can, it transfers its charge to the second can and into the ground through the second wire. After the tab touches the second can, both the tab and second can are neutral, as at the start of the experiment, and the tab is attracted to the first can once again. This cycle repeats until all of the charge from the screen has been moved to the ground by the tab.

Suggested resources

"Franklin Bells." The Bakken Library and Museum, 2004
http://www.thebakken.org/artifacts/Franklin-Bells.htm
History of Franklin bells and explanation of their use detecting thunderstorms.

Bibliography

Field, Simon Quellen. *"Electromagnetism: A High Voltage Motor in 5 Minutes."*
Science toys you can make with your kids.
http://www.scitoys.com/scitoys/scitoys/electro/electro4.html