LEYDEN JAR

OBJECTIVE:

You will understand how a Leyden jar stores static electricity and will demonstrate charging and discharging a Leyden jar.

INTRODUCTION:

The Leyden jar was an early type of capacitor—a device for storing electrical charge. In the early days of experimenting with electricity, scientists had no batteries with which to make electricity. Instead, they made it by rubbing certain materials together and creating static electricity. The Leyden jar allowed them to store this electrical charge.

The device is named after Leiden, the town in the Netherlands where it was developed by physicist Pieter van Musschenbroek (1692–1761) in 1745. In the late 1740s, the Leyden jar's ability to store electricity was demonstrated in a number of dramatic ways, one of which involved releasing the stored electrical charge into volunteers—including monks—and making them jump.

The modern equivalent of the Leyden jar is the Van de Graaff generator, which stores charge from a hand- or motor-driven belt. Such devices can store millions of volts of electricity, and are used in laboratories to investigate the properties of stored charge and the effects of its sudden release. In industry, such generators are used to test the ability of electrical components to withstand high voltages. Research physicists use these generators to accelerate atoms at high speed, so that they can study the particles produced when atoms are smashed together. Of more obvious everyday importance are the smaller capacitors used in everything from microelectronic circuitry to power lines. Such capacitors are incorporated in electrical circuits to store charge and release it when required. They also resist the passage of a direct current but allow passage of an alternating one.

A capacitor is made from two conductors, called plates, separated by an insulator—usually paper, air, or glass—called a dielectric. In a Leyden jar, the glass of the jar is the separating substance, and the outer and inner metals are equivalent to the plates. Capacitors are the only electrical devices, other than batteries, that can store electrical energy.

TIME NEEDED:

1 hour

MATERIALS:

- wide-mouthed glass jar, about 4 in. in diameter at the mouth and 6 in. tall (e.g., a large pickle jar)
- 6 in. x 6 in. square of thick, corrugated cardboard
- 6-in. length of coathanger wire or 2mm-diameter copper wire
- pliers
- 2mm-diameter awl
- 1.5m length of bell wire
- wire strippers
- 20cm length of 1/16-in.-diameter insulated copper wire
- masking tape
- scissors
- glue
- 5 metal paper clips
- plastic metric ruler
- cotton rag or dust cloth
- wooden ruler
- 3 sheets of aluminum foil, two of 12 in. x 12 in. and one of 20 in. x 20 in.
- a darkened room or postcard-size piece of black cardboard or construction paper
- metal faucet or radiator pipe

Original Materials:

Musschenbroek's original Leyden jar consisted of a glass vial that was partially filled with water and contained a thick conducting wire capable of storing a substantial amount of charge. One end of this wire protruded through the cork that sealed the opening of this vial. The Leyden jar was charged by bringing this exposed end of the conducting wire into contact with a friction device

that generated static electricity. William Watson, an English physician and scientist, in 1747 constructed a more sophisticated version of the Leyden jar. He coated the inside and outside with metal foil to improve its capacity to store charge. The device you are constructing is of this type.

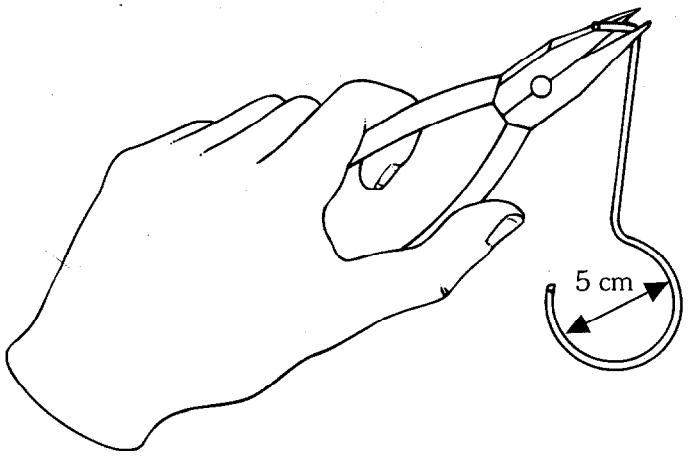
Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. WARNING: Do not attempt to discharge (release the electrical charge from) the Leyden jar by touching it with any part of your body.

PROCEDURE:

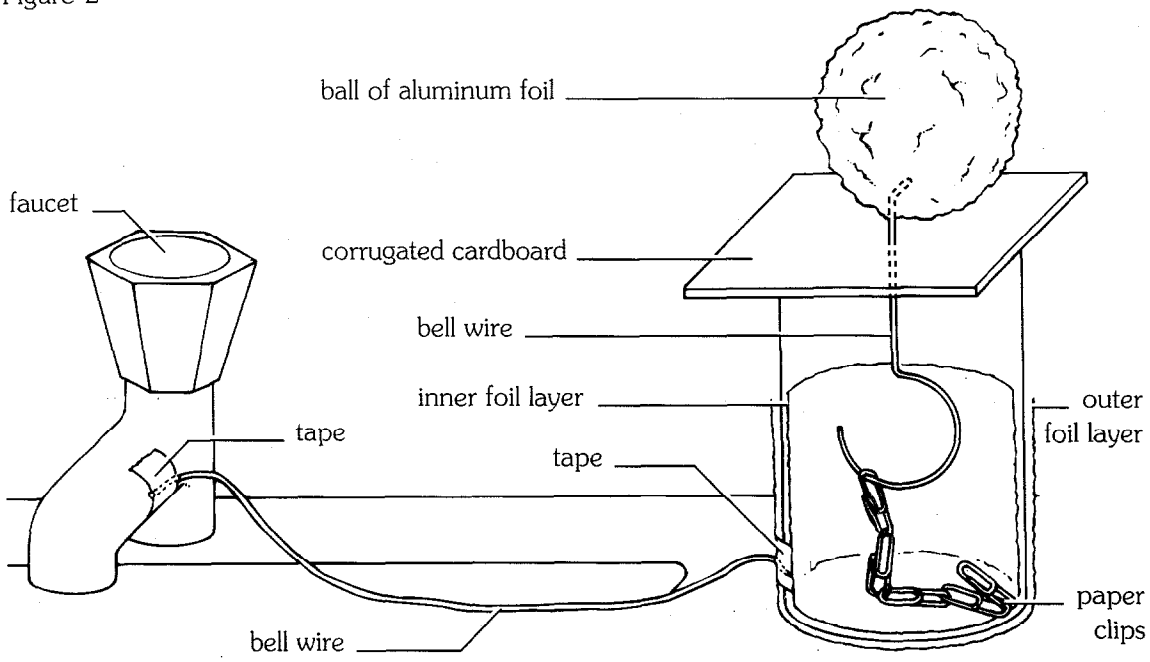
1. Using pliers, bend one end of the 6-in. length of coathanger or copper wire into a hook with a diameter of 5 cm and bend the other end into an L-shape (see figure 1).

Figure 1



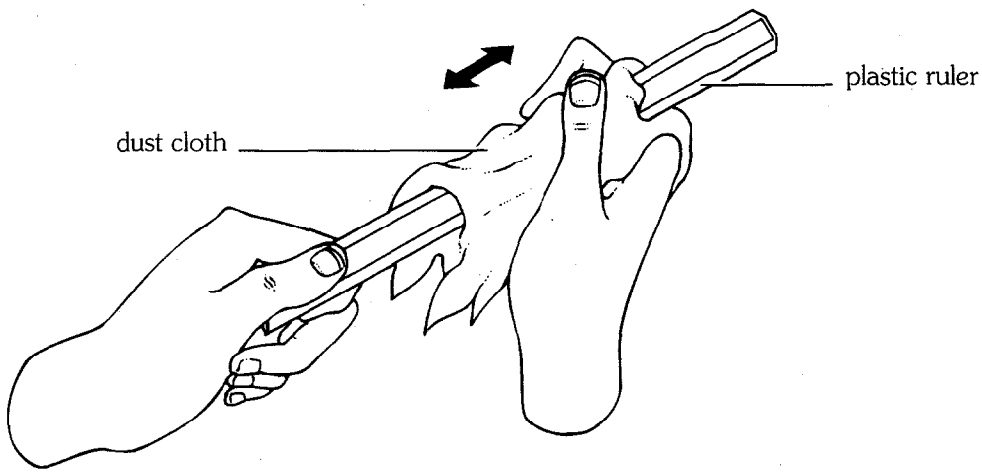
2. Use the awl to pierce a hole in the center of the 6 in. x 6 in. piece of corrugated cardboard. Push the bent wire through this hole so that only the L-shaped bend protrudes from one side, and glue it in position.
3. Squeeze the larger sheet of aluminum foil into a ball and mold the ball around the L-shape of the wire.
4. Put spots of glue on the outside of the bottom and lower half of the glass jar, and then tightly wrap one smaller sheet of aluminum foil around the jar and press it into place. Fold or trim the foil to a height of 9 cm. Repeat this procedure with the second smaller sheet of aluminum foil on the inside of the jar.
5. Make a chain of five paper clips and hang this on the wire hook.
6. Place the corrugated cardboard, with the wire hook and paper clip chain downward, on top of the jar so that the chain hangs down and touches the aluminum foil. Then tape the corrugated cardboard to the top of the jar to keep it in place.
7. Use wire strippers to strip 3 cm of insulation off both ends of the 1.5m length of bell wire. Tape one end of the wire to the foil on the outside of the jar. Tape the other to a metal faucet or radiator pipe (see figure 2). The Leyden jar is now complete and ready to be charged with static electricity.
8. Use wire strippers to strip 3 cm of insulation off both ends of the 20cm-long copper wire. Tape one end of this wire to the outer foil coat on the jar, and leave the other end hanging. This is the discharge wire.

Figure 2



9. To charge the jar, vigorously rub a plastic ruler 20–30 times with the cotton dust cloth using an up-and-down movement (see figure 3). This will give the ruler a negative electrical charge, as electrons are removed from the cloth and deposited on the ruler. Touch the aluminum foil ball with the ruler, and you will transfer the charge from the ruler to the foil. The charge flows from the ball of foil, through the wire and down the paper clips to the inner layer of foil, where it is stored. CAUTION: Once the jar is charged, do not touch it or allow any part of your body to go within a few centimeters of it. Use only the special discharge wire to release the charge.

Figure 3

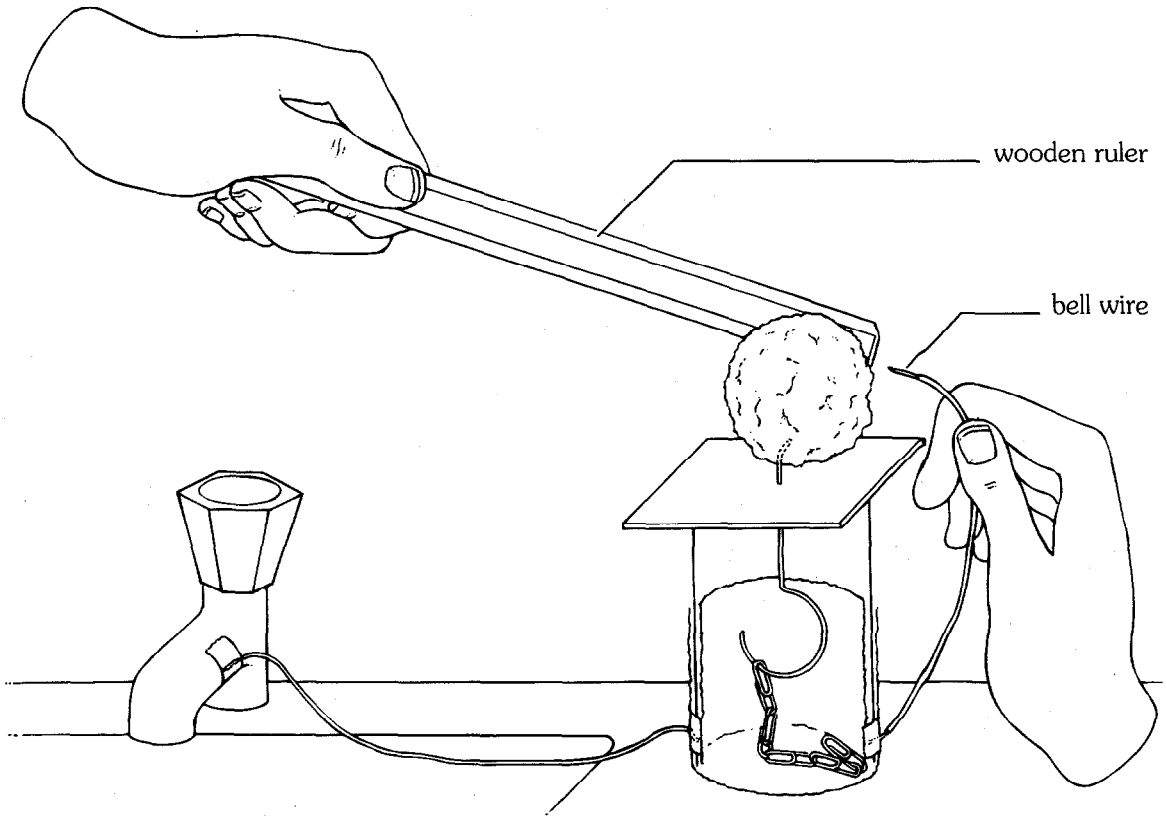


10. Darken the room slightly, or hold the piece of black cardboard behind the aluminum foil ball (this will allow you to see the spark when you discharge the jar).

11. To discharge the jar (remove the charge from the jar), hold the free end of the discharge wire about 10 cm from the end and bring this end of the discharge wire close to the aluminum foil ball. Just before the wire touches the ball, a spark will jump from the ball to the wire, showing that the electricity is discharged.

12. Repeat steps 9–11 several times, each time rubbing the ruler in exactly the same way. Each time you should get a similar result. If you do not, you are probably not repeating exactly the same procedure. Repeat steps 9–11 until you keep getting a similar result. Once you have standardized your technique, charge the jar five times without discharging it. When you come to discharge the jar, hold a wooden ruler alongside the wire as you bring it close to the aluminum foil ball (see figure 4). Measure the distance the spark jumps across the gap.

Figure 4



13. Repeat steps 9–12 but with the jar charged ten times, fifteen times, and then twenty times respectively before discharging. Record all your findings.

ANALYSIS:

1. What keeps the jar from discharging before the discharge wire is brought close to the aluminum foil ball?
2. What is the function of the bell wire running between the outside of the jar and the metal faucet or radiator pipe?
3. Is there a relationship between the amount by which the jar is charged (the number of times you charged it), and the distance across which the spark jumps? How do you account for this? (Note: You may have to do some research to come up with a suggestion.)

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES