Exploring Science In Colonial America

Using Primary Sources to Recreate Ben Franklin's Experiments in Electricity

The Big Idea

Working with a teacher and Mount Clare educator, students will recreate a series of electrical experiments originally performed by Benjamin Franklin between 1746 and 1754.

Students use facsimile primary source materials and reproductions of scientific instruments to experience electrical phenomena just as Franklin and his contemporaries did. These experiments form the foundation of our modern electrical world.

Using his five senses, Franklin noted similarities between electricity and lightning. To demonstrate these properties of static electricity, students may experience an exciting but harmless static electric shocks, see miniature lightning or electrical "sparks", and even smell ozone, a byproduct of static electricity.

Supplies and Materials

- Clear acrylic tubes (27" to 36" length)
- Paper towels
- Wrapped drinking straws
- Aluminum foil
- Disposable plastic plates
- Tape or glue sticks
- Scissors
- Plastic soda or water bottle
- George II templates
- Latex balloons (optional)
- Nail, screw, or paper clip
- Block of wax or plastic 2' x 2'

Franklin's Method of Generating Electricity

Ben Franklin found that the simplest way to generate a static electric charge was by rubbing a piece of buckskin against a hollow glass tube. He refers to this tube as his **Electric Tube**.

Glass tubes and buckskin were the best materials available to Franklin in 1740's Philadelphia. Rubbing a balloon against your hair produces similar results, and is a phenomenon somewhat familiar to most students.

To authentically demonstrate how Franklin generated a static charge, substitute a 3' section of PVC pipe for the glass tube and a clean paper towel or cotton cloth for the buckskin.

Your kind present of an electric tube, with directions for using it, has put several of us on making electrical experiments, in which we have observed some particular phenomena that we look upon to be new.

I was never before engaged in any study that so totally engrossed my attention and time.

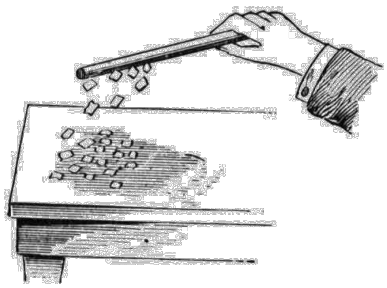
—Letter from Benjamin Franklin to Peter Collinson, March 28, 1747

Experiment #1

Generate a Static Charge

Hold the plastic tube in one hand and rub a clean paper towel or cotton cloth against the length of the tube. Continue sliding the cloth back and forth against the tube until you can feel the static charge or hear it crackling.

While you won't be able to see the static electricity, you can see the effects of the charge by holding the charged tube over a pile of shredded paper. If the charge is sufficient, the paper will begin to "dance" as it is alternately attracted to the static charge and then repelled back down.



Drinking Straw Version

Franklin's method for generating static electricity can also be replicated on a smaller scale with a wrapped drinking straw and a paper or cloth napkin.

Unwrap the straw and tear the paper wrapper into small bits (the smaller the better). Collect the paper bits into a pile. Holding the straw with one hand, rub the straw with the napkin for a few seconds. Then hold the charged straw over the pile of paper bits. The paper bits should begin to "dance".

Reinforce learning by encouraging students to show this experiment to friends and family at home or even at a restaurant. It only takes drinking straws and curious minds.

ELECTRICITY AND MATERIALS

Franklin experimented with many different materials in order to find out how they responded to electricity. Some materials allow electricity to pass through them easily. Franklin referred to these as **conductors.** Materials that electricity could not pass through were called **non-conductors**. These terms were proposed by Franklin in 1751, and are still used today.

EXPERIMENT #2

TESTING MATERIALS: CONDUCTORS AND NON-CONDUCTORS

Gather the following items:

- Block of wax, foam insulation or plastic block (milk crate or step stool)
- Electric Tube
- Paper towels
- Cloth hand towels
- Two volunteers

While searching for materials that were non-conductors, Franklin discovered that he could electrify objects by charging them with his electric tube while the objects were sitting on a "cake of wax". Franklin literally used a large block or "cake" of beeswax.

Place your block of wax or plastic of the floor. Ask a volunteer to stand on the block. Charge your electric tube and transfer the charge to the hand or elbow of the volunteer. Continue this process for a minute or so to properly electrify the volunteer. As long as the volunteer stays on the block, they will not feel the electric charge.

Ask a second volunteer to touch the nose of the electrified volunteer. Both volunteers should feel and slight shock and hear a "snap" sound. Since the block is a non-conductor, the static electric charge you are applying to the volunteer cannot escape through the block or through the air (also a non-conductor). People are conductors, so as soon as a person standing on the ground touches the volunteer on the block, the electric charge travels through the person standing on the ground.

Examples of conductors:

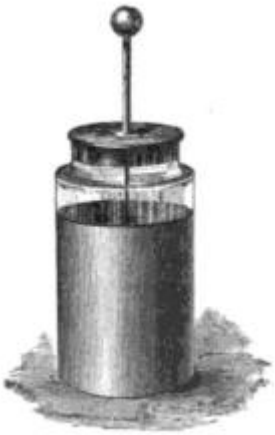
- Metals
- Water
- People and Animals
- Trees

Examples of Non-conductors (Insulators):

- Wool
- Wax
- Plastic
- Rubber

PLUS AND MINUS:

FRANKLIN AND THE FIRST ELECTRIC BATTERIES



Ben Franklin and his friends did extensive experimenting with what is known as a **Leyden jar**. The first Leyden jar was accidentally invented by Dutch scientist Pieter van Musschenbroek of Leiden, the Netherlands, and was named after this city. Leyden jars were used in Franklin's day to store and transfer electric charge. While Franklin did not invent the Leyden jar, he was the first to correctly understand how it works.

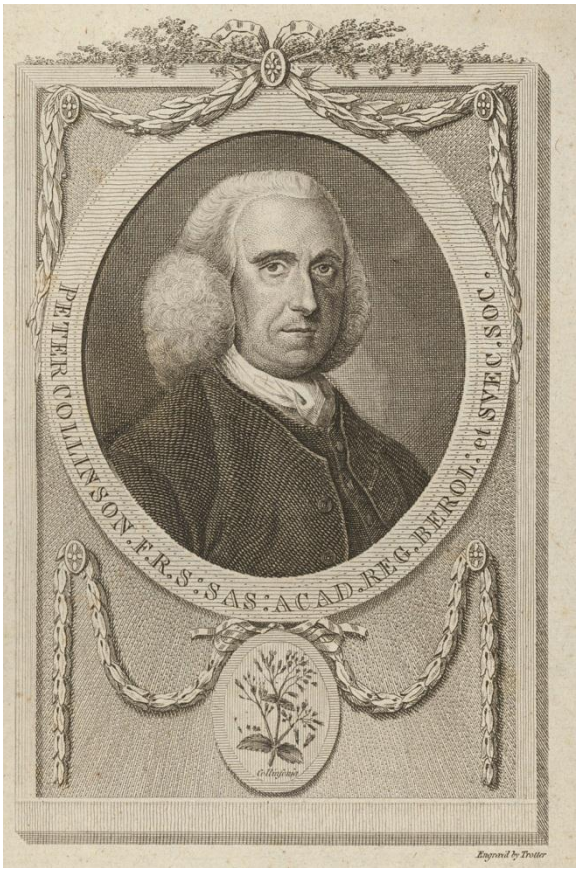
The typical Leyden jar was a glass bottle filled with water and a metal foil covering the outside of the bottle with a metal rod extending from the inside of the bottle to the outside through a cork plug.

An electric charge was stored in the jar by touching the conducting rod to a charged "electric" tube. Positive (+) electrons gather inside the jar, negative (-) on the outside, which produce a perfect electronic storage device. Tiny versions of the Leyden jar can be found in most electronic devices. They are now called **capacitors**.

It was initially thought that the electricity was stored in the water, but Benjamin Franklin found that it was actually stored on the surface of the glass. Later it was determined that other materials could act as the storage device, but that different materials conduct and store electricity at different rates.

In a letter written in 1748, Franklin described to British botanist, Peter Collinson, how the Leyden jar could be ***positively (+)*** and ***negatively (-)*** charged, the first time these terms were used in relation to electricity. He also coined the terms ***charging*** and ***discharging*** when describing the transfer of electricity from one object to another. He described his discovery that the charge was held on the glass surface of the jar itself.

In order to further study the properties of the Leyden jar, Franklin constructed what he called an ***electric battery*** of glass window panes and thin lead plates. With them he demonstrated how electricity could be passed through and stored in the glass itself. This is the first description of an electric battery and the first time such a term was used.



Peter Collinson

Prominent member of The Royal Society in London, and primary correspondent with Franklin on his electrical experiments.

EXPERIMENT #3

BUILD AND TEST A LEYDEN JAR

Gather the following materials:

- One soda or water bottle filled with tap water
- One strip of aluminum foil
- one nail
- one rubber band

Step 1: Push the nail through the cap of the bottled water.

Step 2: Wrap the aluminum foil around the outside of the bottled water.

Try to make the foil as smooth and closely connected to the bottle as possible. There should be about two to three inches of space between the lid of the water bottle and your aluminum foil.

Step 3: Use a rubber band to hold the foil in place.

YOU NOW HAVE A FUNCTIONAL LEYDEN JAR.

EXPERIMENT #4

USING THE LEYDEN JAR AS A SCIENTIFIC INSTRUMENT

The Leyden jar you just made is capable of storing static electric charges for short periods of time (a few minutes). This stored static electric charge can then be released, or discharged, suddenly.

CHARGING THE LEYDEN JAR

Charging your Leyden jar is the process of storing electricity in the jar. This may take some practice, but it is worth it!

Ask a friend to hold the Leyden jar. Make sure they are holding the jar on the foil-covered section.

Charge your electric tube as you did in Experiment #1, but this time transfer the charge from the electric tube to the nail on top of your Leyden jar. Gently slide your charged electric tube against the nail. If the charge is transferring, you might notice a crackling sound or even see a small spark as you slide the charged tube against the nail.

Recharge your electric tube with a paper towel and transfer the charge to the Leyden jar again. Each time you transfer the charge from the electric tube to the Leyden jar, you are storing more electricity in the jar.

DISCHARGING THE LEYDEN JAR

If you've stored enough static electricity in your Leyden jar, when you discharge the Leyden jar, you should be able to feel and sometimes see the electricity you've stored in the jar.

Discharge the jar by holding onto the foil covered portion of the jar with one hand, and then touch the nail with your other hand. If you've stored enough static electricity in the Leyden jar, you should feel a slight shock as soon as your finger touches the nail.

USE THE LEYDEN JAR AND ELECTRIC TUBE TO RECREATE 18TH CENTURY SCIENCE EXPERIMENTS AND PARLOR GAMES

Equipped with several Leyden jars and other simple tools, Franklin and other scientists studying electricity, known as "electricians", began to better understand electricity and how it behaves. The Leyden jar allowed electricity to be captured and stored!

Using copies of Franklin's letters about his experiments with Leyden jars, we can recreate these experiments to discover properties of electricity for ourselves.

EXPERIMENT #5

ELECTRIC CHARGE AND FORCE: ATTRACTION AND REPULSION

Associated Parlor Game
The Conterfeit Spider

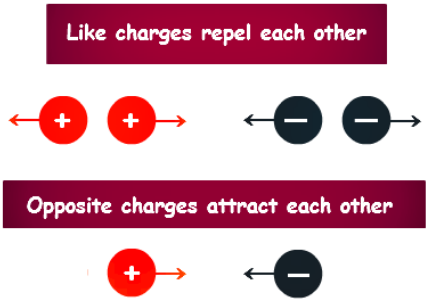
Gather the following items:

- ½" cork balls or moth balls (4)
- Cotton or silk thread
- Sewing needle
- Leyden Jar
- Electric Tube
- Cloth towel

In an early experiment, Franklin used small cork balls hanging from the ceiling with silk string. Using the cork balls, Franklin was able to observe and record some important properties of electricity.

Excerpt from LETTER II, July 11, 1747
Ben Franklin writing to Peter Collinson

"We suspend by fine silk thread a counterfeit spider made of a small piece of burnt cork, with legs of linen thread, and a grain or two of lead stuck in him to give him more weight. Upon the table, over which he hangs, we stick a wire upright, as high as the vial and wire, four or five inches from the spider; then we animate him by setting the electrical vial at the same distance on the other side of him; he will immediately fly to the wire of the vial, bend his legs in touching it, then spring off and fly to the wire of the vial, playing with his legs against both, in a very entertaining manner, appearing perfectly alive to the persons unacquainted. He will continue this motion an hour or more in dry weather."



Using his sense of humor and understanding of electricity, Franklin and a friend, Ebenezer Kinnersley, modified one of the cork balls so that it would resemble a small spider, called the counterfeit spider. By bringing an electric charge near the counterfeit spider would make the spider appear to jump around.

Facsimile Document

Newport, March 16. 1752.

Notice is hereby given to the Curious,

That at the COURT-HOUSE, in the Council-Chamber, is now to be exhibited, and continued from Day to Day, for a Week or two;

A COURSE of EXPERIMENTS, on the newly-diſcovered

Electrical FIRE:

Containing, not only the moſt curious of thoſe that have been made and publiſhed in *Europe*, but a conſiderable Number of new Ones lately made in *Philadelphia*; to be accompanied with methodical LECTURES on the Nature and Properties of that wonderful Element.

By *Ebenezer Kinnerſley.*

LECTURE I.

I. OF Electricity in General, giving ſome Account of the Diſcovery of it.

II. That the Electric Fire is a real Element, and different from thoſe heretofore known and named, and *collected* out of other Matter (not created) by the Friction of Glaſs, *&c.*

III. That it is an extreamly ſubtile Fluid.

IV. That it doth not take up any perceptible Time in paſſing thro' large Portions of Space.

V. That it is intimately mixed with the Subſtance of all the other Fluids and Solids of our Globe.

VI. That our Bodies at all Times contain enough of it to ſet a Houſe on Fire.

VII. That tho' it will fire inflammable Matters, itſelf has no ſenſible Heat.

VIII. That it differs from common Matter, in this; its Parts do not mutually attract, but mutually repel each other.

IX. That it is ſtrongly attracted by all other Matter.

X. An artificial Spider, animated by the Electric Fire, ſo as to act like a live One.

XI. A Shower of Sand, which riſes again as faſt as it falls.

XII. That common Matter in the Form of Points attracts this Fire more ſtrongly than in any other Form.

XIII. A Leaf of the moſt weighty of Metals ſuſpended in the Air, as is ſaid of *Mahomet's* Tomb.

XIV. An Appearance like Fiſhes ſwimming in the Air.

XV. That this Fire will live in Water, a River not being ſufficient to quench the ſmalleſt Spark of it.

XVI. A Repreſentation of the Senſitive Plant.

XVII. A Repreſentation of the ſeven Planets, ſhewing a probable Cauſe of their keeping their due Diſtances from each other, and from the Sun in the Center.

XVIII. The Salute repulſed by the Ladies Fire; or Fire darting from a Ladies Lips, ſo that ſhe may defy any Perſon to ſalute her.

XIX. Eight muſical Bells rung by an electrified Phial of Water.

XX. A Battery of eleven Guns diſcharged by Fire iſſuing out of a Perſon's Finger.

LECTURE II.

I. A Deſcription and Explanation of Mr. *Muſchenbrock's* wonderful Bottle.

II. The amazing Force of the Electric Fire in paſſing thro' a Number of Bodies at the ſame Inſtant.

III. An Electric Mine ſprung.

IV. Electrified Money, which ſcarce any Body will take when offer'd to them.

V. A Piece of Money drawn out of a Perſon's Mouth in ſpite of his Teeth; yet without touching it, or offering him the leaſt Violence.

VI. Spirits kindled by Fire darting from a Lady's Eyes (without a Metaphor).

VII. Various Repreſentations of Lightning, the Cauſe and Effects of which will be explained by a more probable Hypotheſis than has hitherto appeared, and ſome uſeful Inſtructions given, how to avoid the Danger of it: How to ſecure Houſes, Ships, *&c.* from being hurt by its deſtructive Violence.

VIII. The Force of the Electric Spark, making a fair Hole thro' a Quire of Paper.

IX. Metal melted by it (tho' without any Heat) in leſs than a thouſandth Part of a Minute.

X. Animals killed by it inſtantaniouſly.

XI. Air iſſuing out of a Bladder ſet on Fire by a Spark from a Perſon's Finger, and burning like a Volcano.

XII. A few Drops of electrified cold Water let fall on a Perſon's Hand, ſupplying him with Fire ſufficient to kindle a burning Flame with one of the Fingers of his other Hand.

XIII. A Sulphurous Vapour kindled into Flame by Fire iſſuing out of a cold Apple.

XIV. A curious Machine acting by means of the Electric Fire, and playing Variety of Tunes on eight muſical Bells.

XV. A Battery of eleven Guns diſcharged by a Spark, after it has paſſed through ten Foot of Water.

As the Knowledge of Nature tends to enlarge the human Mind, and give us more noble, more grand, and exalted Ideas of the AUTHOR *of Nature, and if well purſu'd, ſeldom fails producing ſomething* uſeful *to Man, 'tis hoped theſe Lectures may be tho't worthy of Regard & Encouragement.*

☞ *Tickets to be had at the Houſe of the Widow* Allen, *in* Thames *Street, next Door to Mr.* John Tweedy's. *Price* Thirty Shillings *each Lecture. The Lectures to begin each Day preciſely at* Three *o'Clock in the Afternoon.*