Franklin and Electrostatics- Ben Franklin as my Lab Partner

A Workshop on Franklin's Experiments in Electrostatics

Developed at the Wright Center for Innovative Science Teaching
Tufts University
Medford MA 02155

by Robert A. Morse, Ph.D.

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Part II. Experiments described in a letter to Peter Collinson

Franklin's first letter describing experiments with points and Leyden jars.

Letter II. Benjamin Franklin to Peter Collinson

July 11, 1747 *Bigelow vol II: p. 180-188.*
Letter XLIV

In the early editions of Franklin's book this letter was printed second with a date of September 1, 1747. It was later redated by Franklin as July 11, 1747. Cohen has now found an original manuscript dated May 25,1747.

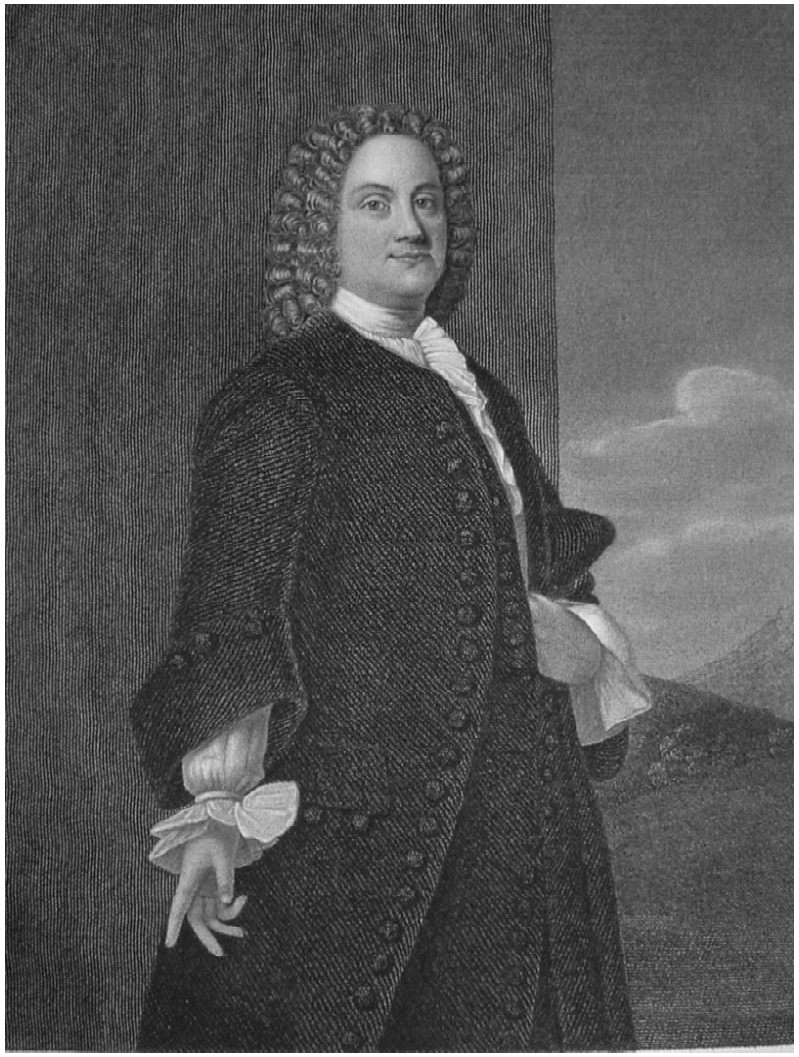
2.01

To Peter Collinson Philadelphia, July 11, 1747
(this letter now dated to May 25,1747)

SIR:–In my last I informed you that in pursuing our electrical inquiries we had observed some particular phenomena which we looked upon to be new, and of which I promised to give you some account, though I apprehended they might not possibly be new to you, as so many hands are daily employed in electrical experiments on your side the water, some or other of which would probably hit on the same observations.

Franklin's first letter to Collinson describing his experiments introduces the terminology of POSITIVE and NEGATIVE or PLUS and MINUS to represent his idea that an electrified object has either gained or lost some of its normal quantity of "electrical fire" or "electric fluid."

He also notes the effects of pointed conductors, which he later develops into his theory of lightning rods.



Benjamin Franklin by G. F. Storm
from the original in possession ofThomas W. Sumner, Esq.
Sparks, Vol. I, 1837, frontispiece (public domain)

2.02

The first is the wonderful effect of pointed bodies, both, *drawing off* and *throwing off* the electrical fire. For example:

2.03a

Place an iron shot of three or four inches diameter on the mouth of a clean, dry glass bottle. By a fine silken thread from the ceiling, right over the mouth of the bottle, suspend a small cork ball about the bigness of a marble, the thread of such a length as that the cork ball may rest against the side of the shot. Electrify the shot, and the ball will be repelled to the distance of four or five inches, more or less, according to the quantity of electricity.

2.03b

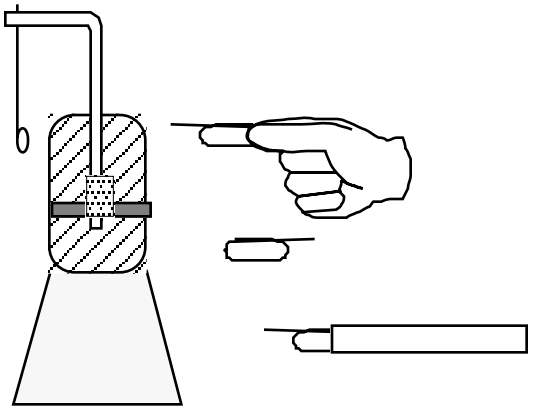
When in this state, if you present to the shot the point of a long, slender, sharp bodkin, at six or eight inches distance, the repellency is instantly destroyed, and the cork flies to the short. A blunt body must be brought within an inch and draw a spark to produce the same effect.

2.03c

To prove that the electrical fire is *drawn off* by the point, if you take the blade of the bodkin out of the wooden handle and fix it in a stick of sealing-wax, and then present it at the distance aforesaid, or if you bring it very near, no such effect follows: but sliding one finger along the wax till you touch the blade, and the ball flies to the shot immediately.

Movie file: 02 Drawing the Fire

Instead of a shot, use an empty aluminum soft drink can set on an upturned foam cup. Secure it with bits of masking tape. Take a foil bit on a thread and hang it through a slit in the end of a bendy straw, which you fasten to the can with a rubber band.



Support the can by holding the foam, and charge it from your generator or tube. Watch the foil bit. Now bring a paperclip with one leg straightened or the pointed end of an open safety pin near the can. Watch the foil bit.

Recharge the can, reverse the clip or close the safety pin so the round end is brought near the can.

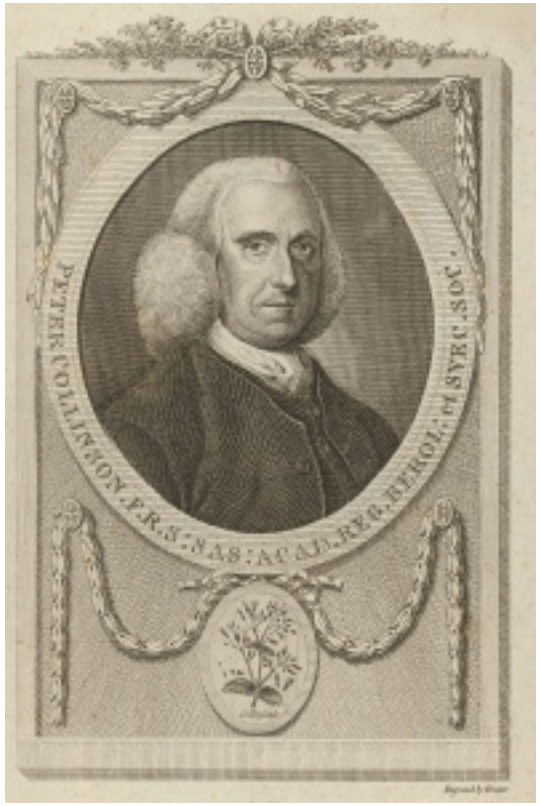
Stick the paper clip or safety pin on the end of a plastic straw-charge the can and bring the point nearby while holding the straw. Slide your finger along the straw till it touches the clip or pin.

2.03d

If you present the point in the dark you will see, sometimes at a foot distance and more, a light gather upon it, like that of a fire-fly or glow-worm; the less sharp the point the nearer you must bring it to observe the light, and at whatever distance you see the light you may draw off the electrical fire and destroy the repellency. If a cork ball so suspended be repelled by the tube, and a point be presented quick to it, though at a considerable distance, it is surprising to see how suddenly it flies back to the tube. Points of wood will do near as well as those of iron, provided the wood is not dry, for perfectly dry wood will not more conduct electricity than sealing-wax.

Try a dry toothpick and a moist toothpick as points. Describe what happens.

Try looking for a glow near a point in the dark by fastening a open safety pin or paper clip to the prime conductor of a generator and having someone turn the lights off while you turn the generator. Under dry conditions you may be able to see a discharge.



Peter Collinson
Image SIL-14-C4-07a
Courtesy of the Smithsonian Libraries
The Dibner Library for the History of Science and Technology
Washington, DC

2.04

To show that points will *throw off*[1] as well as *draw off* the electrical fire; lay a long sharp needle upon the shot, and you cannot electrize the shot so as to make it repel the cork ball. Or fix a needle to the end of a suspended gun-barrel, or iron rod, so as to point beyond it like a little bayonet[2], and while it remains there, the gun-barrel or rod cannot, by applying the tube to the other end, be electrized so as to give a spark, the fire continually running out silently at the point. In the dark you may see it make the same appearance as it does in the case before mentioned.

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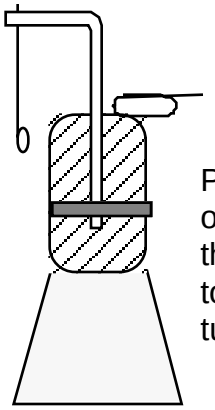
1 This power of points to *throw off* the electrical fire was first communicated to me by my ingenious friend, Mr. Thomas Hopkinson, since deceased, whose virtue and integrity, in every station of life, public and private, will ever make his memory dear to those who knew him, and knew how to value him–F.

2 This was Mr. Hopkinson's experiment, made with an expectation of drawing a more sharp and powerful spark from the point, as from a kind of focus, and he was surprised to find little or none.–F.



Put the paper clip or open safety pin on the drink can and try to charge it with the tube or generator.

The implication of Franklin's work on points for the construction of your equipment is to make everything as smooth as possible, except where you want charge to flow through the air.

2.05

The repellency between the cork ball and the shot is likewise destroyed: 1st, by sifting fine sand on it, –this does it gradually; 2dly, by breathing on it; 3dly, by making a smoke about it from burning wood; 4thly, by candle-light, even though the candle is at a foot distance, –these do it suddenly. The light of a bright coal from a wood fire, and the light of a red-hot iron do it likewise, but not at so great a distance. Smoke from dry rosin dropped on hot iron does not destroy the repellency, but is attracted by both shot and cork ball, forming proportionable atmospheres round them, making them look beautifully, somewhat like some of the figures in Burnet's or Whiston's *Theory of the Earth.*

We suppose every particle of sand, moisture, or smoke, being first attracted and then repelled, carries off with it a portion of the electrical fire: but that the same still subsists in those particles till they communicate it to something else, and that it is never really destroyed. So, when water is thrown on common fire, we do not imagine the element is thereby destroyed or annihilated, but only dispersed, each particle of water carrying off in vapor its portion of the fire which it had attracted and attached to itself.–F.

You could try this yourself - a burning splint, a candle, some fine sand, some table salt - all things to try. You could try to make rosin smoke by getting some violin rosin, or rosin for a pitcher's bag.

2.06

N.B.–This experiment should be made in a closet where the air is very still, or it will be apt to fail.

2.07

The light of the sun thrown strongly on both cork and shot by a looking-glass, for a long time together, does not impair the repellency in the least. This difference between fire-light and sun-light is another thing that seems new and extraordinary to us.[1]

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[1]This different effect probably did not arise from any difference in the light, but rather from the particles separated from the candle, being first attracted and then repelled, carrying off the electric matter with them; and from the rarefying the air, between the glowing coal or red-hot iron and the electrized shot, through which rarefied air, the electric fluid could more readily pass.–F.

In this footnote, written when Franklin was editing the printed versions of his letters, he corrects his original conclusion about the effect of candle light versus sunlight, concluding that it is not the light from the candle or fire that carries off the 'electric matter', but the smoke from the candle and the fire that carries it off.

2.08

We had for some time been of opinion that the electrical fire was not created by friction, but collected, being really an element diffused among, and attracted by other matter, particularly by water and metals. We had even discovered and demonstrated its afflux to the electrical sphere, as well as its efflux, by means of little, light windmill-wheels make of stiff paper vanes fixed obliquely, and turning freely on fine wire axes; also by little wheels of the same matter, but formed like water-wheels. Of the disposition and application of which wheels, and the various phenomena resulting, I could, if I had time, fill you a sheet.[1] The impossibility of electrizing one's self (though standing on wax) by rubbing the tube, and drawing the fire from it; and the manner of doing it by passing the tube near a person or thing standing on the floor, &c., had also occurred to us some months before Mr. Watson's ingenious *Sequel* came to hand; and those were some of the new things I intended to have communicated to you. But now I need only mention some particulars, not hinted in that piece, with our reasonings thereupon; though perhaps the latter might well enough be spared.

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[1] These experiments with the wheels were made and communicated to me by my worthy and ingenious friend, Mr. Philip Syng: but we afterwards discovered that the motion of those wheels was not owing to any afflux or efflux of the electric fluid, but to various circumstances of attraction and repulsion, 1750.–F.

Franklin uses various terms for electricity, including "electrical fire" – he seems to be thinking of it as a material substance, with properties like a fluid or a gas. At the time, he thought that he was detecting the effect of the electrical fire or fluid moving through the air. The windmill wheels he made probably turned due to the effects of corona discharge at the points creating a stream of ions, or an ion breeze.

A pinwheel sort of device that can be mounted on an electrostatic machine - often called the electric whirl - is a standard demonstration, although often not explained. Two versions of pinwheels are shown below.

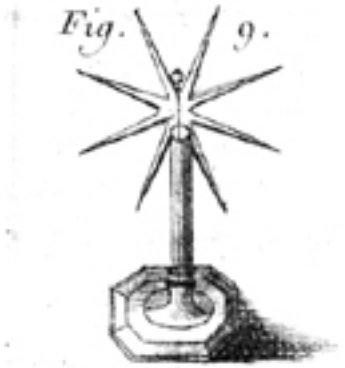


Plate II, French ed. of Winckler
Essai sur la Nature...de L'Electricité
Paris, 1748

The Burndy Library,
Dibner Institute for the History of
Science & Technology

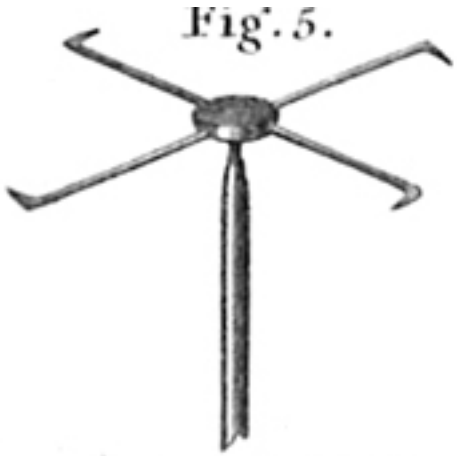


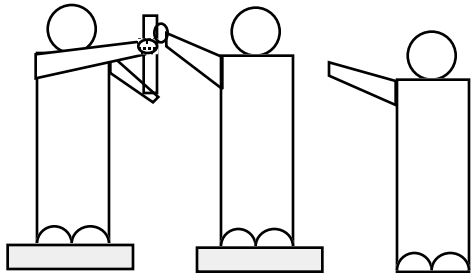
Plate II for Vol. IV, George Adams, 1799
Lectures on Natural and Experimental Philosophy, vol V. London

The Burndy Library,
Dibner Institute for the History of Science & Technology
Cambridge, Massachusetts

Ebenezer Kinnersley describes an electrical horse race device based on the pinwheel in a later letter to Franklin. (Sparks V, p. 367, 12 March 1761- see *Electrical Writings of Franklin*, collected by R. Morse, 2004, p 154 ff., <www.tufts.edu/as/wright_center>)

2.09

1. A person standing on wax and rubbing the tube, and another person on wax drawing the fire, they will both of them (provided they do not stand so as to touch one another) appear to be electrized to a person standing on the floor; that is, he will perceive a spark on approaching each of them with his knuckle.

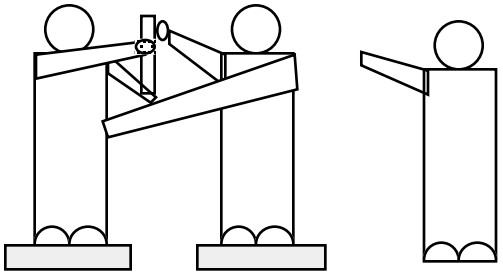


Movie file: 02 Drawing the Fire

One person stands on a 2 inch foam pad, and rubs the pvc pipe with cloth. A second person, also on a foam pad, collects the charge from the tube. A third person standing on the floor uses a neon bulb to get a flash from each of the first two or simply tests for a spark with a finger.

2.10

2. But if the persons on wax touch one another during the exciting of the tube, neither of them will appear to be electrized.



2.11

3. If they touch one another after exciting the tube, and drawing the fire as aforesaid, there will be a stronger spark between them than was between either of them and the person on the floor.

FOAM PAD SOURCE

Pink or blue polystyrene foam insulation is sold in pieces of several thicknesses. A 2 inch thick piece about one foot square makes a good insulating pad to stand on. A piece 16 inches by 12 inches gives a little more space. Check building supply stores like Home Depot, Lowes or other companies. A solid piece of plastic packing foam may also work, but make sure it is secure to stand on.

2.12

4. After such strong spark neither of them discover any electricity.

2.13

These appearances we attempt to account for thus: We suppose, as aforesaid, that electrical fire is a common element, of which every one of the three persons above mentioned has his equal share, before any operation is begun with the tube.

2.13a
A, who stands on wax and rubs the tube, collects the electrical fire from himself into the glass; and, his communication with the common stock being cut off by the wax, his body is not again immediately supplied.

2.13b
B (who stands on wax likewise), passing his knuckle along near the tube, receives the fire which was collected by the glass from *A*; and his communication with the common stock being likewise cut off, he retains the additional quantity received.

2.13c
To *C*, standing on the floor, both appear to be electrized; for he, having only the middle quantity of electrical fire, receives a spark upon approaching *B*, who has an over quantity; but gives one to *A*, who has an under quantity.

2.13d
If *A* and *B* approach to touch each other, the spark is stronger, because the difference between them is greater. After such touch there is no spark between either of them and *C*, because the electrical fire in all is reduced to the original equality. If they touch while electrizing, the equality is never destroyed, the fire only circulating. Hence have arisen some new terms among us: we say *B* (and bodies like circumstanced) is electrized *positively*; *A*, *negatively*. Or rather, *B* is electrized *plus*; *A*, *minus*.

2.13e
And we daily in our experiments electrize bodies *plus* or *minus*, as we think proper. To electrize *plus* or *minus*, no more needs to be known than this, that the part of the tube or sphere that are touched, do, in the instant of the friction, attract the electrical fire, and therefore take it from the thing rubbing; the same parts immediately, as the friction upon them ceases, are disposed to give the fire they have received to any body that has less.

Because of unfamiliar language, we need to decode what Franklin says and work through his argument. This is the first place in which Franklin seriously details his early theory.

Points of Franklin's theory in this letter:

1. All objects have a normal amount of 'electrical fire' or 'electrical fluid'.

2. A person rubs the tube and loses fluid while the tube gains it.
If the person is on an insulator, then she or he cannot get back the fluid lost.

3. Another person collecting fluid from the surface of the tube gains extra, and if insulated cannot lose it.

4. Testing for sparks or with the neon bulb should show these effects.

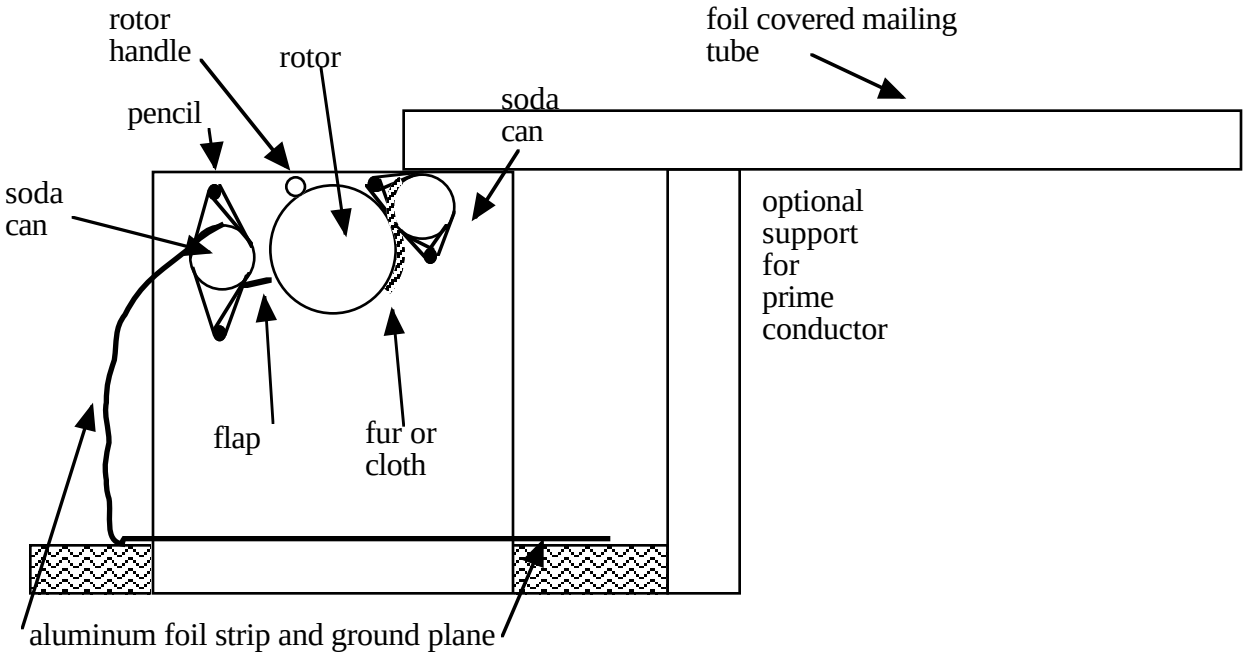
With glass tubes, the tube gets extra (positive) electrical fluid. With the PVC tubes we use, the tube loses fluid and becomes negative. Thus in our experiments we have to reverse the roles of the rubber and the collector in order that the charge flow direction agrees with Franklin.

Try the experiments. Diagram what Franklin is talking about.

2.13e
Thus you may circulate it as Mr. Watson has shown; you may also accumulate or subtract it, upon or from any body, as you connect that body with the rubber, or with the receiver, the communication with the common stock being cut off. We think that ingenious gentleman was deceived when he imagined (in his *Sequel*) that the electrical fire came down the wire from the ceiling to the gun-barrel, thence to the Sphere, and so electrized the machine and the man turning the wheel, &c. We suppose it was *driven off*, and not brought on through that wire; and that the machine and man, &c., were electrized *minus*–that is, had less electrical fire in them than things in common.

Here Franklin refers to the parts of the electrical machine of the sort that was in use at the time.

The reference to the gun barrel literally means that a gun barrel was connected to the "receiver" of the generator. We can achieve the same effect by taking a carboard mailing tube or length of PVC pipe, covering it with foil and connecting it to either the receiver or rubber of our machine.



Here the gun-barrel or "prime conductor" is supported on a stand made of either a piece of corrugated card board screwed to the wood, or a piece of Styrofoam. In use, place the barrel so that it rests on top of the rubbing can to collect positive electriciy. Make a separate stand so you can connect it to either soda can and you can collect either positive or negative electricity (see end of section I).

Check this with your neon bulb. Test for sparks.

2.14

As the vessel is just upon sailing, I cannot give you so large an account of American electricity as I intended; I shall only mention a few particulars more. We find granulated lead better to fill the phial with than water, being easily warmed, and keeping warm and dry in damp air. We fire spirits with the wire of the phial. We light candles, just blown out, by drawing a spark among the smoke between the wire and snuffers.

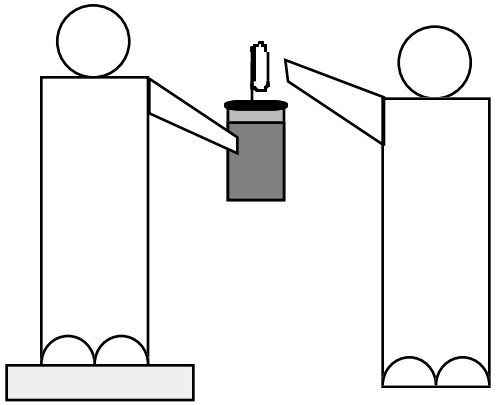
2.14b

We represent lightning by passing the wire in the dark over a China plate that has gilt flowers, or applying it to gilt frames of looking glasses, &c.

2.14c

We electrize a person twenty or more times running, with a touch of the finger on the wire, thus: He stands on wax. Give him the electrized bottle in his hand. Touch the wire with your finger and then touch his hand or face; there are sparks every time.

By taking a spark from the wire, the electricity within the bottle is diminished; the outside of the bottle then draws some from the person holding it, and leaves him in a negative state. Then when his hand or face is touched, an equal quantity is restored to him from the person touching.–F.



Try this - give a charged film can jar to someone on an insulator. Touch the wire, then touch the person. Try using a neon bulb to touch wire and person. Try and see which electrode lights.

To electrify the Leyden jar, you may use the tube or the electrical generator. Hold the jar by the outside foil and slide the paper clip along the rubbed tube.
Have one person crank the generator while the other holds the jar by the outside and touches one hand to one can of the generator (or the foil ground plane) and touches the paper clip to the other can.

2.14d

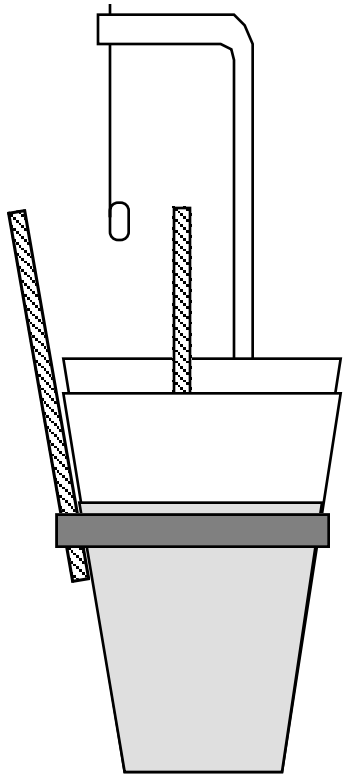
We increase the force of the electrical kiss vastly, thus; Let *A* and *B* stand on wax, or *A* on wax and *B* on the floor; let the other take hold of the wire; there will be a small spark; but when their lips approach they will be struck and shocked. The same if another gentleman and lady, *C* and *D*, standing also on wax, and joining hands with *A* and *B*, salute or shake hands.

2.14e

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 phial and wire, four or five inches from the spider; then we animate him by setting the electrified phial at the same distance on the other side of him; he will immediately fly to the wire of the phial, bend his legs in touching it, then spring off and fly to the wire in the table, thence again to the wire of the phial, playing with his legs against both, in a very entertaining manner, appearing perfectly alive to persons unacquainted. He will continue this motion an hour or more in dry weather.

A drink cup Leyden jar, with a bendy straw supporting a foil covered straw bit will simulate Franklin's counterfeit spider. Adjust the position of the outside straw to get good action from your spider. If you are ambitious, try making legs of thread or of christmas tree tinsel.

(You may just hold the foil bit by hand on the end of a long thread.)



2.14f

We electrify, upon wax in the dark, a book that has a double line of gold round upon the covers, and then apply a knuckle to the gilding; the fire appears everywhere upon the gold like a flash of lightning; not upon the leather, nor if you touch the leather instead of the gold.

Difficult to reproduce. You can buy "gilding" - very thin metal foil - at a craft store and carefully glue a thin line of it to a piece of clear plastic, or perhaps stick it to clear tape. Leave lots of little gaps in doing so. Tape it to the prime conductor of your generator, then discharge by touching the end of the tape or plastic and see what happens.

2.14g

We rub our tubes with buckskin and observe always to keep the same side to the tube and never to sully the tube by handling; thus they work readily and easily without the least fatigue, especially if kept in tight pasteboard cases lined with flannel, and sitting close to the tube.[1] This I mention because the European papers on electricity frequently speak of rubbing the tubes as a fatiguing exercise. Our spheres are fixed on iron axes which pass through them. At one end of the axis there is a small handle with which you turn the sphere like a common grindstone. This we find very commodious, as the machine takes up but little room, is portable, and may be enclosed in a tight box when not in use. It is true the sphere does not turn so swift as when the great wheel is used; but swiftness we think of little importance, since a few turns will charge the phial, &c., sufficiently.[2]
I am, &c.,

B. Franklin.

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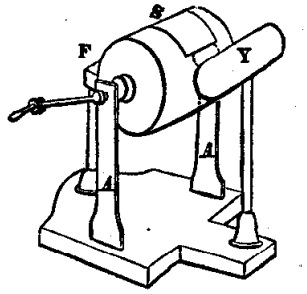
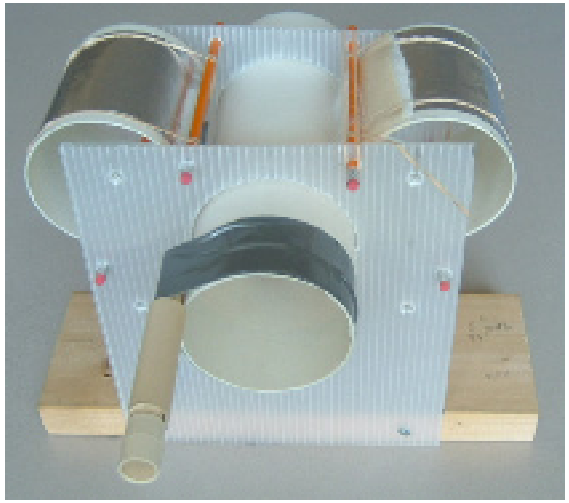
[1] Our tubes are made here of green glass, twenty-seven or thirty inches long, as big as can be grasped.–F.

[2] This simple easily-made machine was a contrivance of Mr. Syng's.–F.

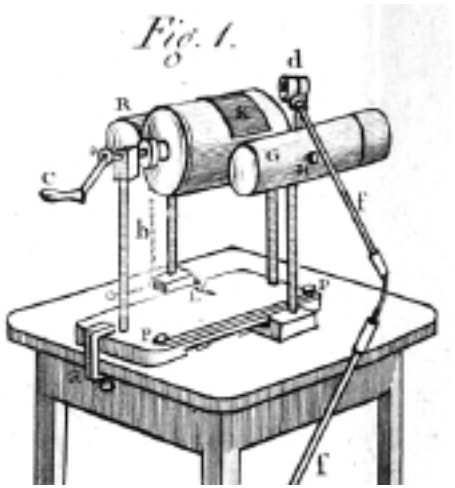


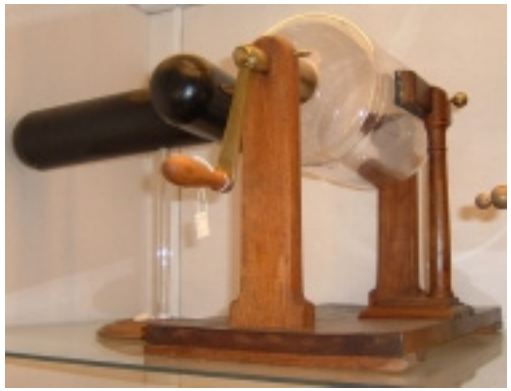
A diagram from an old textbook showing a generator of the kind referred to in Franklin's letter.



A variation of the modern homemade generator (without a prime conductor).

This one uses sections of 4 inch PVC thinwall drain pipe for the rotor, as well as the rubber and the collector, which are covered with aluminum foil. An extra flap of aluminum foil collects the charge.





19th Century U.S. made generator
The Burndy Library, Dibner Institute for the History of Science & Technology
Cambridge, Massachusetts

A generator sold by Edward Nairne for use in medical experiments. Franklin corresponded with Nairne later in his life.
The Burndy Library, Dibner Institute for the History of Science & Technology
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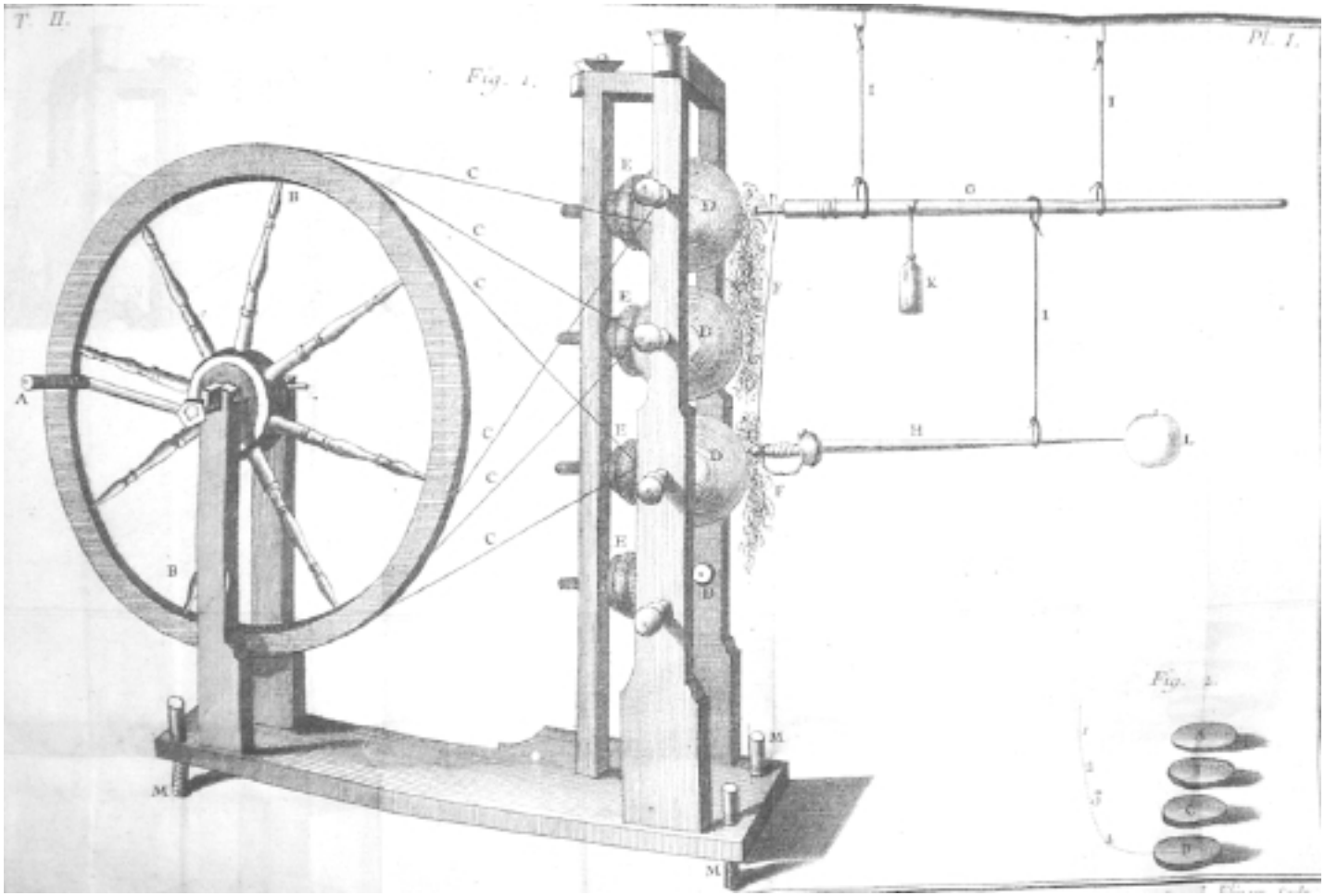

A large electrical generator with three globes. A gun barrel “collects the fire” from the top globe and a sword from the bottom.
Plate I, William Watson, trans. by Jean Freke,
Experiences et Observations, pour Servir a l’explication de la Nature et des Propriete’s de L’Electricité., Paris, 1748
The Burndy Library, Dibner Institute for the History of Science & Technology
Cambridge, Massachusetts