

AAPT

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RODNEY LABRECQUE

MILTON ACADEMY
MILTON, MA 02186

BEN FRANKLIN'S ELECTROSTATIC EXPERIMENTS WORKSHOP

Like most representations of Franklin's kite experiment, this 1830 painting from a fire wagon panel is thoroughly inaccurate. Franklin, at forty-six, was not a white-haired old man, and the boy with him was his son William, who was actually twenty-six at the time.

THE BANCY COMPANY OF NORTH AMERICA

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BEN FRANKLIN REVISITED

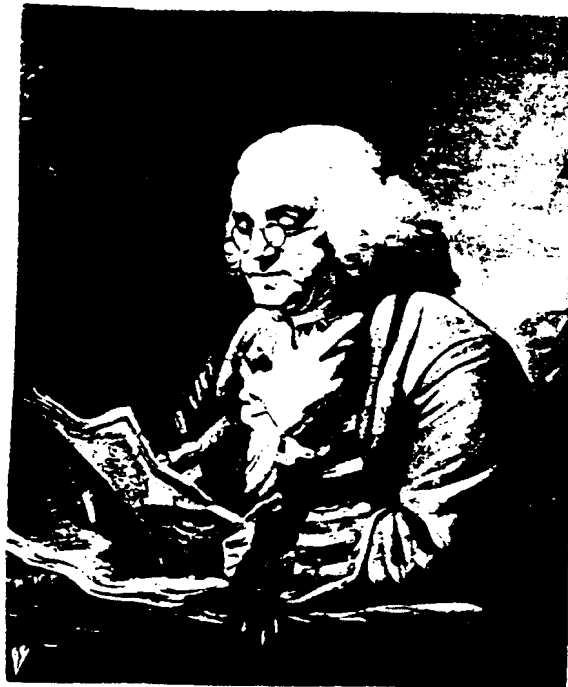
INTRODUCTION

In these exercises you will be recreating the experiments of Ben Franklin. Ben Franklin really knew about lab work. He knew the lab was a place to explore, test, and, above all, learn what makes things behave the way they do.

Listen to what Ben had to say in a letter to Peter collinson July 29th 1750, when talking about theory, observation, and experimentation. In addition he displays his passion to always be useful to mankind. "Even a bad solution read, and its faults discovered, has often given rise to a good one, in the mind of an ingenious reader. Nor is it of much importance to us to know the manner in which nature executes her laws; it is enough if we know the laws themselves. It is of real use to know that china left in the air unsupported will fall and break; but how it comes to fall and why it breaks, are matters of speculation. It is a pleasure, indeed, to know them, but we can preserve our china without it.

In another letter to Cadwallader Colden on April 23, 1752 Ben Franklin says, "Frequently in a variety of experiments tho' we miss what we expect to find, yet something valuable turns out, something surprising, and instructing, tho' unthought of."

You are to try and learn how nature's laws of electrification work and to seek some pleasure in speculation on the how's and why's. The essential element of laboratory work is honest, perceptive, and accurate observations. All preconceptions should be laid aside when actually making observations. (Theories and ideas may determine what sort of phenomena you explore...even how you set about exploring them: but they should never color or determine what you see).



Record observations when you see them. At the same time, you may also want to write down some queries, some suggestions (to yourself) for further experiments, and some (tentative) conclusions. But first and foremost you must set down your observations in a manner in which you could expect to understand in, say, three months time. It is a good plan to keep your lab record in the form of a diary with the date on each page. In this way it should be clear to you what observations are made and recorded in the lab and won't be confused with inferences and conclusions made subsequently on the basis of your lab work. The apparatus in this laboratory is, on the whole, quite simple. However, don't be fooled; the phenomena are not therefore necessarily simple, and certainly not trivial.

There is an old saying in science that the easiest things to observe are the hardest to understand. Care, patience, and persistence are often required to determine genuine from spurious effects; to distinguish the reproducible from the accidental. Experiments rarely prove anything categorically but they should teach you something. (the complaint that the "experiment doesn't work" or the "apparatus doesn't work" is usually as apt as complaining that the piano doesn't work if the issuing music is unsatisfactory.) Keen eyes, skilled hands, open mind, and judicious, accurate observations and recording are the hallmarks of good experimenters.

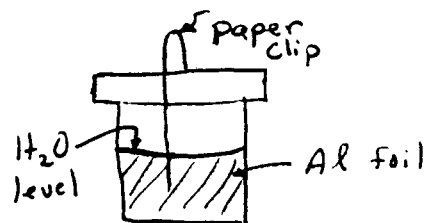
Now begin your experiments with the leyden jar and electrophorus and see if you reach the same conclusions as Mr. Franklin.

THE LEYDEN JAR

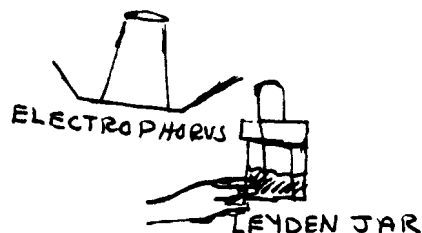


To construct the Leyden jar, cover the lower half of the plastic film cannister with aluminum foil. Make sure the bottom is also covered. Tape the foil to the sides of the can if necessary. Pierce the cap of the cannister with a needle or awl and insert a straightened paper clip into that

hole you've just made. You might want to leave the protruding portion of the paper clip curved. Fill the jar halfway with water; it should be about the same level as the aluminum foil. **KEEP THE OUTSIDE DRY.** Place the cap back onto the cannister making sure that the paperclip is in the water. See the diagram of the Leyden jar.



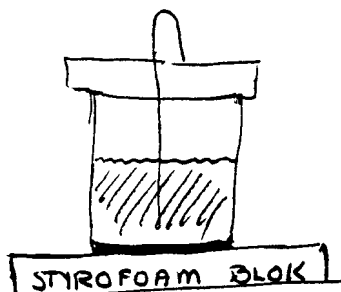
You should make two Leyden jars of this type. To charge the jar, hold by the aluminum foil while bringing a charged electrophorus up to the paper clip. A small spark should show you that the Leyden jar is charging. Check them both for proper operation; they need to hold a charge long enough for you to perform the experiments of the investigation. In fact, you might try charging the Leyden jar and leave it over night to see if it can keep a charge for twenty-four hours.



THE FIRST INVESTIGATION

1. Charge the Leyden jar once. Discharge by holding the base in your left hand while bringing the finger of the right hand slowly toward the paper clip. Record what is observed. Do it in a dark place. What do you see? Charge the jar several times and repeat the discharge. Any differences? Is the effect reproducible? How much can the Leyden jar be charged up? Franklin called this phenomena the "throwing off or drawing off" of the "electrical fire." To what extent can the jar be charged? How strong is the strongest spark you can receive?

2. Charge the Leyden jar while it is standing on a table, then pick up and discharge in the usual manner. Remember: a single observation is rarely reliable. Observations should be repeated a significant number of times to establish what is reproducible.



3. Repeat the charging but this time place the Leyden jar on a block of styrofoam, glass, or wax (Franklin used beeswax for this). Compare the size of the shocks received to #1 and 2.

4. Repeat the charging but this time place the Leyden jar on a large sheet of aluminum foil. Pick up and discharge. Compare the shocks to those in parts #1, #2, and #3.

5. Repeat #4 but now place an insulating sheet between the jar base and the aluminum foil sheet. Compare to the previous shocks. (You can test the insulating characteristics of the plastic sheet by placing it between the finger and the Leyden jar in the discharging procedure.)

6. Repeat procedure #5 but this time place a strip of aluminum foil from the base portion of the jar to the aluminum sheet. After charging remove the strip. Do you feel a shock? Now pick up the jar by its knob. Do you feel any shock? Replace the jar on the plastic and pick up the jar by the base. Feel any shock? With the jar base in your left hand, bring your right finger near the knob. Feel any shock? If there is no effect try bringing the knob near an electroscope.

7. Slightly larger Leyden jars can be made by using plastic soft-drink containers (the twelve ounce type) and placing the wire knob through a cork which can fit in the neck opening. However, these can hold **DANGEROUS** amounts of charge. (See the accompanying letter of Ben Franklin's near electrocution.) Go slowly when charging these by applying a few charges at a time and discharging them until the point is reached where it is too uncomfortable to so do. These larger devices are not toys! and should be treated with healthy respect much as you treat the wall outlets around your house!!

SOME QUESTIONS TO PONDER

How does the Leyden jar store a charge? Ben Franklin was the first to apply the terms plus and minus when talking about electricity and used these terms in his explanation of the workings of the Leyden jar. You should try to use such ideas as you talk about the operation of the jar. Try to back up any explanation with experimental observations. Proof is what is needed more than opinion.

Dear Friend,

I have lately made an experiment that I desire never to repeat. Two nights ago, being about to kill a turkey by the shock from two large glass jars, containing as much electrical fire as forty common phials, I inadvertently took the whole through my own arms and body, by receiving the fire from the united top wires with one hand while the other held a chain connected with the outside of both jars. The company present (whose talking to me and to one another, I suppose, occasioned my inattention to what I was about) say that the flash was very great, and the crack as loud as a pistol, yet, my senses being instantly gone, I neither saw the one nor heard the other; nor did I feel the stroke in my hand, though afterwards found it raised a round swelling where the fire entered, as big as half a pistol bullet, by which you may judge the quickness of the electrical fire, which by this instance seems to be greater than that of sound, light, or animal sensation.

What I can remember of the matter is that I was about to try whether the bottles or jars were fully charged by the strength and length of the stream issuing to my hand, as I commonly used to do, and which I might safely enough have done if I had not held the chain in the other hand. I then felt what I know not how to describe... a universal blow throughout my whole body from head to foot, which seemed within as well as without; after which the first thing I took notice of was a violent quick shaking of my body, which gradually remitting, my sense as gradually returned, and then I thought the bottles must be discharged, but could not conceive how, till at last I perceived the chain in my hand, and recollected what I had been about to do.

That part of my hand and fingers which held the chain was left white, as though the blood had been driven out, and



remained so eight or ten minutes after, feeling like dead flesh; and I had a numbness in my arms and back of my neck, which continued till the next morning, but wore off. Nothing remains now of the shock but a soreness in my breastbone, which feels as if it had been bruised. I did not fall, but suppose I should have been knocked down if I had received the stroke in my head. The whole was over in a minute.

You may communicate this to Governor Bowdoin as a caution to him, but do not make it more public, for I am ashamed to have been guilty of so notorious a blunder; a match for that of the Irishman whom my sister told me of, who, to divert his wife, poured the bottle of gun powder on the live coal; or that of the other, who, being about to steal powder, made a hole in the cask with a hot iron.

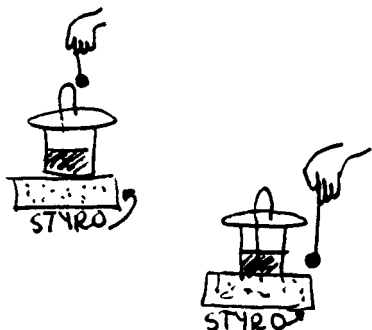


B. Franklin

Franklin communicated his observations on electrical phenomena to the Englishman Peter Collinson (above), a Quaker merchant and member of the Royal Society. Franklin had corresponded with him for twenty-five years before they met in London in 1757.

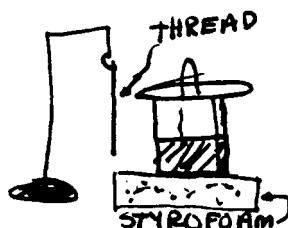
SOME FURTHER EXPERIMENTS WITH THE LEYDEN JAR (SEPT 1747)

EXPERIMENT 1



Place a charged leyden jar on a styrofoam block. Bring to the knob a small graphite covered styro ball suspended on a nylon thread held in your hand. After the ball has touched the knob and is in the repelling state, lower your hand so the ball may be brought towards the base of the Leyden jar. Observe the effect. What does this imply about the knob? the base?

EXPERIMENT 2



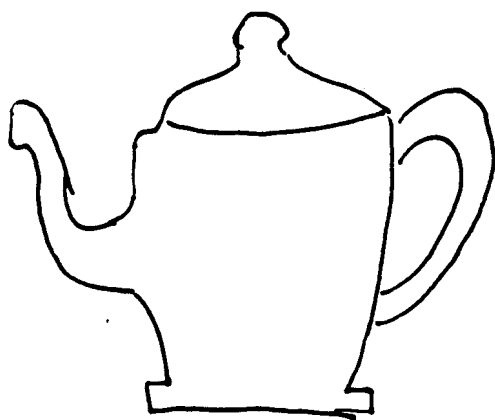
Let a small linen cotton thread hang down within a half inch of the charged Leyden jar which is sitting on a styrofoam block. Touch the knob or the base repeatedly with your finger and note what happens to the linen thread at every touch.

EXPERIMENT 3 "The Counterfeit Spider"

Suspend by fine silk thread a counterfeit spider made of a piece of burnt cork with legs of linen thread and a grain or two of lead shot stuck in him to give him more weight. (You can use a graphite covered styrofoam peanut with an embedded BB and cotton legs.) Attach a wire to the base of the Leyden jar and run it as high as the knob but 4 or 5 inches away. Place the spider in-between this wire and the knob and watch his behavior.



Where does the electrical fire reside. "The Teapot Investigation"



In connection with the Leyden jar, Ben Franklin was keenly interested in where the electrical fire resided. The following investigation should help you come to some conclusions about how the Leyden jar might work.

I. Take a Leyden jar and charge it in the usual manner. Place it on a styrofoam block. Carefully take the top off without touching the knob or wire and lay the top aside on another styrofoam block. Holding the base of the jar in one hand, bring the finger of the other hand to the water. What is observed?

II. Replace all parts of the Leyden jar and charge it. Now place it on the styrofoam block and remove the top again. This time, carefully pour the water into another topless, yet uncharged, Leyden jar. Now touch this water. What do you observe? What does this mean? Are you confused?

III. Take fresh water (Franklin got his fresh water from a teapot and so referred to this investigation as the "teapot experiment") and refill the original Leyden jar that has been sitting on the styrofoam block. Replace its top carefully, being sure not to touch the knob. Now see if it has any stored charge. What do you infer from this observation? Is some of your confusion cleared up?

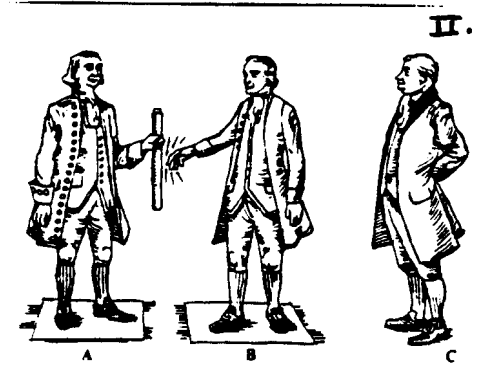
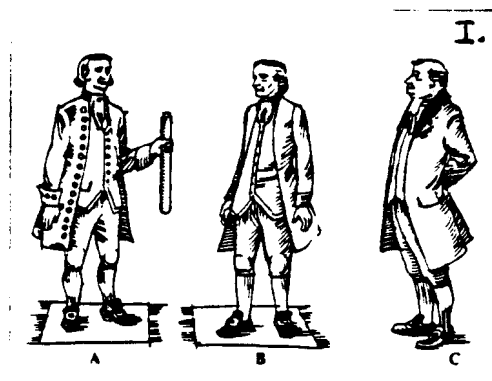
IV. Franklin would have thought the charge resided in the plastic. What do you think?

PERFORMING THE PLUS/MINUS EXPERIMENT

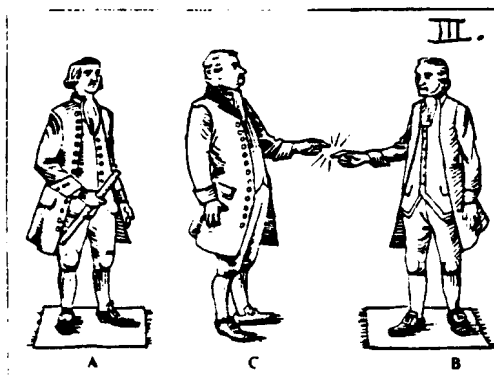
This experiment calls for three participants, one with a glass rod and fur, and two styrofoam platforms salvaged from packing materials from some large object which has been shipped. The diagrams will help you follow the instructions.

1. In Diagram I, person A rubs the glass rod with the fur and then presents the glass rod to B who touches it. When B presents his knuckle, a spark jumps between it and the glass rod, as shown in Diagram II.

In Franklin's terms, one person has an "over" amount of electrical fire and the other an "under" amount.



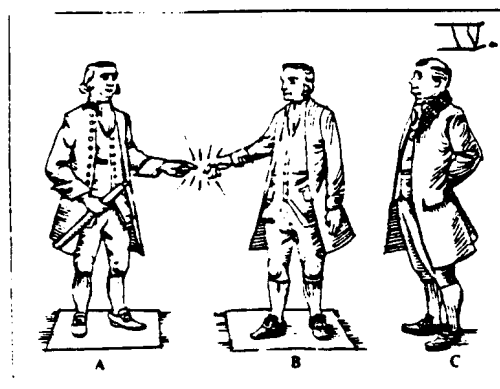
2. In Diagram III, Person C standing on the ground puts his knuckle toward person B. A spark is exchanged. (C could also try this with person A.)



3. If the procedure from part 1., above, is repeated but this time, after B touches the rod, they touch each other, a shock will be exchanged but much greater than that that passed to C. See Diagram IV.

4. If while A is rubbing the glass rod with the fur, B touches him, there will be no exchange of shock when B presents his knuckle to the glass rod.

Now read the letter, To Peter Collison, 11 July 1747, wherein Franklin talks about this experiment and uses the terms plus and minus for the first time.



THE FIRST MENTION OF PLUS AND MINUS

Philadelphia, 11 July 1747

To Peter Collinson:

Dear Sir:

1. A person standing on wax and rubbing a glass 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.

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

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.

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

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. 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 immediately supplied. 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. 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 underquantity. 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.

FRANKLIN'S EXPLANATION OF THE LEYDEN JAR

This explanation was created before Franklin performed the teapot experiment. As a side-light you might note that Franklin mentions what work it is to write all this out by long hand. Just imagine what xerox could have done for him. Also note, that he bemoans the fact that the research on electricity is proceeding faster than he can keep up with in communication. Do you see the parallels with today's research situation, for example as in high temperature superconductor research?

Philadelphia, 1 September 1747

To Peter Collinson, Esq., F.R.S.

Sir:

The necessary trouble of copying long letters, which perhaps, when they come to your hands, may contain nothing new, or worth your reading (so quick is the progress made with you in electricity), half discourages me of writing any more on that subject. Yet I cannot forbear adding a few observations on M. Muschenbroek's wonderful bottle (the leyden jar.)

1. The non-electric (what we call today a conductor) contained in the bottle differs, when electrized, from a non-electric electrized out of the bottle, in this: that the electrical fire of the latter is accumulated on its surface, and forms an electrical atmosphere round it of considerable extent; but the electrical fire is crowded into the substance of the former, the glass confining it.



2. At the same time that the wire and the top of the bottle, &c., is electrized positively or plus, the bottom of the bottle is electrized negatively or minus, in the exact proportion; that is, whatever quantity of electrical fire is thrown out of the top, an equal quantity goes out of the bottom. To understand this, suppose the common quantity of electricity in each part of the bottle before the operation begins, is equal to twenty; and at every stroke of the tube,

suppose a quantity equal to one is thrown in; then, after the first stroke, the quantity contained in the wire and upper part of the bottle will be twenty-one, in the bottom, nineteen; after the second, the upper part will have twenty-two, the lower eighteen; and so on until after twenty strokes, the upper part will have a quantity of forty strokes, the lower part none; and then the operation ends, for no more can be thrown into the upper part when no more can be driven out of the lower part. If you attempt to throw more in, it is spewed back through the wire, or flies out in loud cracks through the sides of the bottle.

3. The equilibrium cannot be restored in the bottle by inward communication or contact of the parts; but it must be done by a communication formed without the bottle, between the top and the bottom, by some non-electric, touching or approaching both at the same time; in which case it is restored with a violence and quickness inexpressible; or touching alternately, in which case the equilibrium is restored by degrees.

4. As no more electrical fire can be thrown into the top of the bottle, when all is driven out of the bottom, so, in a bottle not yet electrized, none can be thrown into the top when none can get out of the bottom; which happens either when the bottom is too thick, or when the bottom is placed on an electric per se (what we call a non-conductor today.) Again, when the bottle is electrized, but little of the electrical fire can be drawn out from the top, by touching the wire, unless an equal quantity can at the same time get in at the bottom. Thus, place an electrized bottle on a clean glass plate or dry wax, and you will not, by touching the wire, get out the fire from the top. Place it on a non-electric (a conductor), and touch the wire, you will get it out in a short time, but the soonest when you form a direct communication as above.

So wonderfully are these two states of electricity, the plus and the minus, combined and balanced in this miraculous bottle situated and related to one another in a manner that I can by no means comprehend! If it were possible that a bottle should in one part contain a quantity of air strongly compressed, and in another part a perfect vacuum, we know the equilibrium would be instantly restored within. But here we have a bottle containing at the same time a plenum of electrical fire and a vacuum of the same fire, and yet the equilibrium cannot be restored between them but by a communication without, though the plenum presses violently to expand, and the hungry vacuum seems to attract as violently in order to be filled.

B. Franklin

SOME QUESTIONS TO PONDER

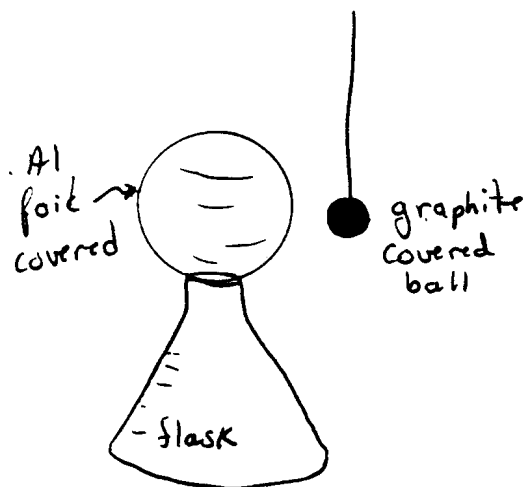
How closely does your explanation of the workings of the Leyden jar compare to this explanation of Ben Franklin's.

Can you go a step further than Franklin and use what you know about electrostatic induction to explain the workings of the Leyden jar on an electron level?

THE EFFECTS OF POINTED BODIES IN DRAWING OFF AND THROWING OFF ELECTRICAL FIRE JULY 1747

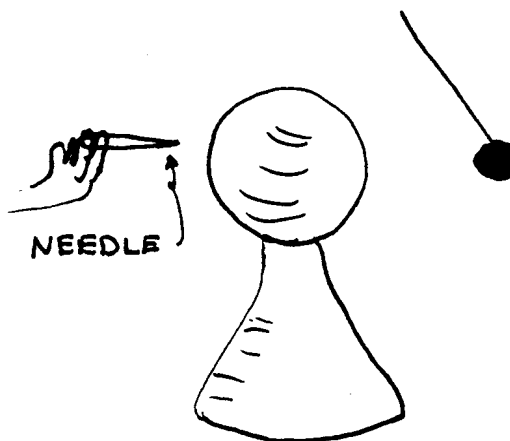
While you perform this investigation, you should be thinking about one of Ben Franklin's major contributions to society, the lightning rod.

1. Place an aluminum foil covered styrofoam ball, three or four inches in diameter, on the mouth of a clean, dry Erlenmeyer flask. By a fine nylon thread (dry cotton will also do) suspend a smaller (marble-sized) graphite covered styrofoam ball so that the smaller ball will rest firmly against the side of the larger ball.



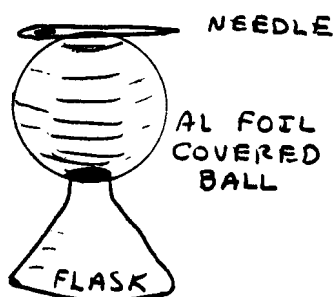
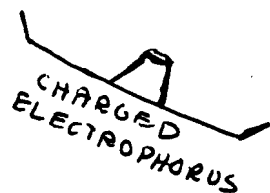
2. Electrify (using the electrophorus) the aluminum covered ball and observe the smaller ball. Make sure the contact between the two balls is good to see the full effect. You can carefully drag the smaller ball by the thread until it touches the larger ball to insure good contact.

3. When in this state, if you present to the aluminum foil covered ball the point of a "long, slender, sharp, metallic bodkin" (needle) at several inches distance and slowly bring it closer to the larger ball, what do you observe? How close must a blunt metallic object be brought to the aluminum covered ball to accomplish the same effect?



4. To prove that the electrical fire is drawn off by the point, take the needle and stick it part way into a

styrofoam peanut and then present it at the same distance above. Observe the effect. Now slide one finger along the styrofoam peanut until you touch the needle and the effect should be instantly recognizable. (If done carefully in a very dark place, a faint glow or light can be seen on the needle, especially if very sharp.) Franklin called this drawing off the electrical fire.



5. To the same experimental design as before add a long sharp needle upon the aluminum covered ball. Try to electrify the aluminum ball to make it repel the smaller ball. What do you observe? Franklin declared that this was proof that the needle was "throwing off the electrical fire."

6. What happens to any repellency between the aluminum covered ball and the smaller ball when

- * fine sand is sifted on the aluminum ball.
- * one breathes on the aluminum ball.
- * when making smoke about the ball.
- * by bringing a lit candle near the aluminum ball. (Franklin noticed that shining sunlight on the foil covered ball does not have the same effect as the candle... "This difference between fire-light and sun light is another thing that seems new and extraordinary to us.")

7. When the small ball is repelled by the larger ball, bring your hand close to the small ball and note its subsequent action. Bring the charged metal half of the electrophorus near the small ball. Observe. Then bring the styrofoam half of the electrophorus near the small ball. Any noticeable effect?

8. You should think about the difference bringing your finger near the charged ball and bringing the needle. How can you connect this behavior to lightning rods?

Personal research notes from November 1749 reveal Franklin's thoughts that led to his prediction that a pointed metal rod would draw lightning, thus enabling experimenters to "ascertain its sameness with the electric fluid." In these informal, but portentous, notes he wrote:

Electrical fluid agrees with lightning in these particulars: 1. Giving light. 2. Colour of the light. 3. Crooked direction. 4. Swift motion. 5. Being conducted by metals. 6. Crack or noise in exploding. 7. Subsisting in water or ice. 8. Rending bodies it passes through. 9. Destroying animals. 10. Melting metals. 11. Lighting inflammable substances. 12. Sulphureous smell. -- The electric fluid is attracted to points. We do not know whether this property is in lightning. But since they agree in all the particulars wherein we can compare them, is it not probable they agree likewise in this? Let the experiment be made." (Physics History from AAPT Journals, ed Melba Phillips, 1985)

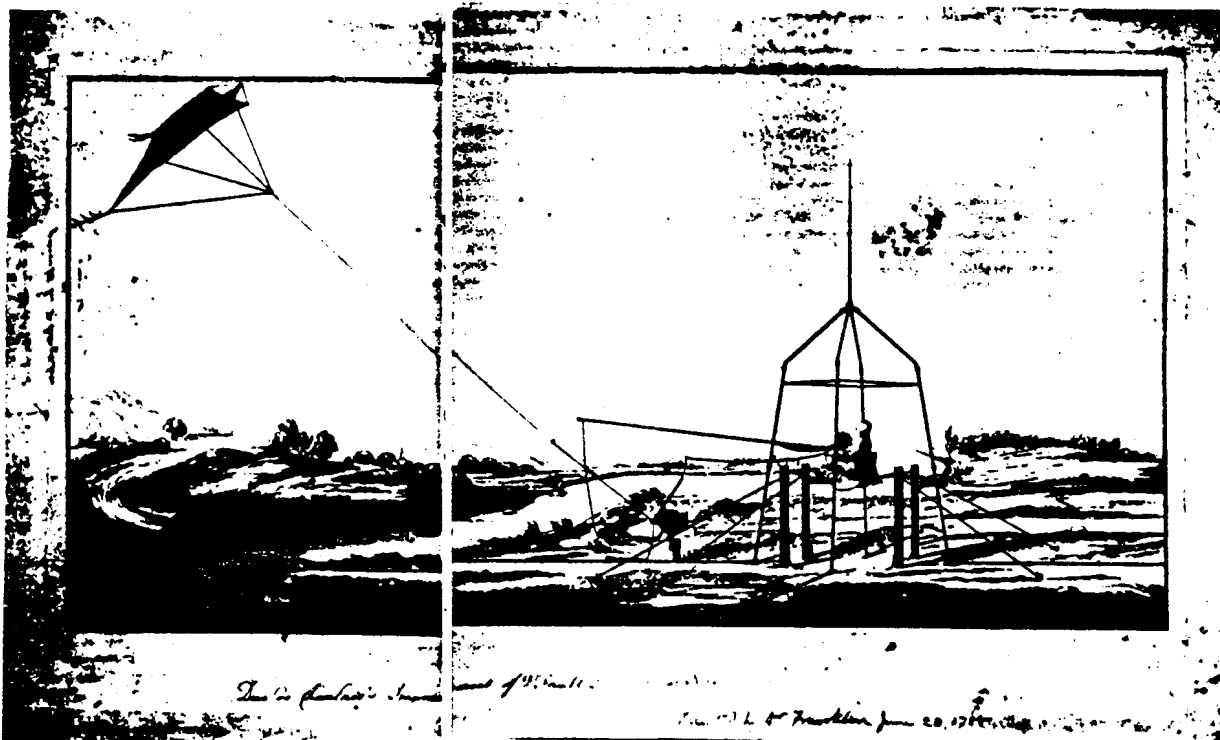
THE CLASSIC LETTER EXPLAINING THE KITE EXPERIMENT

Mr. Peter Collinson, Esq, F.R.S.
London, England

October 19. 1752

Sir:

As frequent mention is made in public papers from Europe of the success of the Philadelphia experiment for drawing fire from clouds by means of pointed rods of iron erected on high buildings., &c., it may be agreeable to the curious to be informed that the same experiment has succeeded in Philadelphia, though in a different and more easy manner, which is as follows:



The dangerous kite experiment was carried out by several Europeans, once even before Franklin made the proposed test himself. Above, in an engraving Franklin gave to the Philosophical Society, is a safeguarded version of the test by the Duc de Chaulnes, a French scientist. He sits suspended and insulated from the ground, a protective lightning rod overhead, handling his kite through a remote-controlled winch

Make a small cross of two light strips of cedar, the arms so long as to reach the four corners of a large thin silk handkerchief to the extremities of the cross, so you have the body of a kite; which, being properly accommodated

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with a tail, loop, and string, will rise in the air, like those made of paper; but this being of silk is fitter to bear the wet and wind of a thundergust without tearing. To the top of the upright stick of the cross is to be fixed a very sharp-pointed wire rising a foot or more above the wood. To the end of the twine, next to the hand, is to be tied a silk ribbon, and where the silk and twine join, a key must be fastened. This kite is to be raised when a thundergust appears to be coming on, and the person who holds the twine must stand within a door or window, or under some cover, so that the silk ribbon may not be wet; and care must be taken that the twine does not touch the frame of the door or window. As soon as any of the thunderclouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with the twine, will be electrified, and the loose filaments of the twine will stand everyway, and be attracted to an approaching finger. And when the rain has wetted the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of a knuckle. At this key the phial may be charged; and from the electric fire thus obtained spirits may be kindled, and all other electric experiments be performed which are usually done by the help of a rubbed globe of glass or tube, and thereby, the sameness of the electric matter with that of lightning be completely demonstrated.

B. Franklin

LETTER XI.

FROM

BENJ. FRANKLIN, *Esq;* of *Philadelphia*.

Oct. 19, 1752.

AS frequent mention is made in public papers from *Europe* of the success of the *Philadelphia* experiment for drawing the electric fire from clouds by means of pointed rods of iron erected on high buildings, &c. it may be agreeable to the curious to be informed that the same experiment has succeeded in *Philadelphia*, though made in a different and more easy manner, which is as follows :

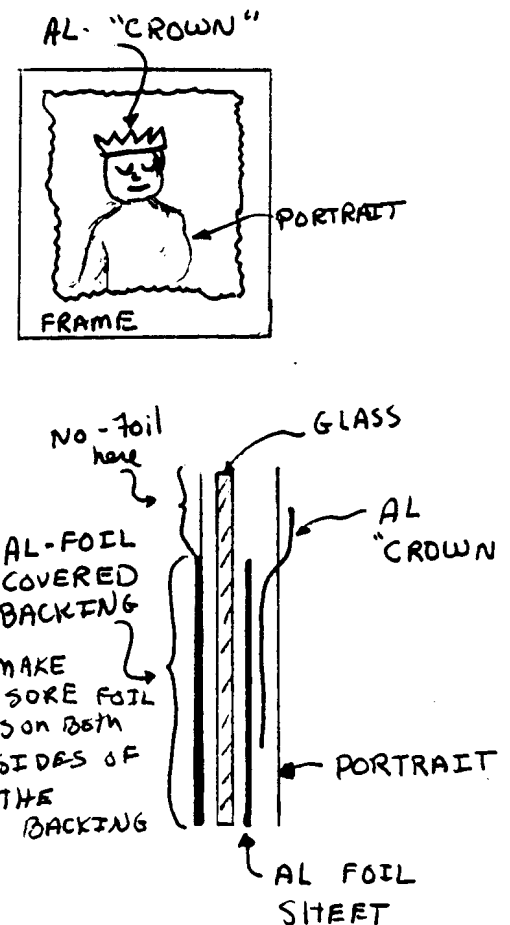
Make a small cross of two light strips of cedar, the arms so long as to reach to the four corners of a large thin silk handkerchief when extended ; tie the corners of the handkerchief to the extremities of the cross, so you have the body of a kite ; which being properly accommodated with a tail, loop, and string, will rise in the air, like those made of paper ; but this being of silk, is fitter to bear the wet and wind of a thunder-gust without tearing. To the top of the upright stick of the cross is to be fixed a very sharp pointed wire, rising a foot or more above the wood. To the end of the twine, next the hand, is to be tied a silk ribbon, and where the silk and twine join, a key may be fastened. This kite is to be raised when a thunder gust appears to be coming on, and the person who holds the string must stand within a door or window, or under some cover, so that the silk ribbon may not be wet ; and care must be taken that the twine does not touch the frame of the door or window. As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine, will be electrified, and the loose filaments of the twine will stand out every way, and be attracted by an approaching finger. And when the rain has wet the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key the phial may be charged ; and from electric fire thus obtained, spirits may be kindled, and all the other electric experiments be performed, which are usually done by the help of a rubbed glass globe or tube, and thereby the sameness of the electric matter with that of lightning completely demonstrated.

B. F.

THE MAGICAL PICTURE OR THE EXPERIMENT OF TREASON

The Magical picture is adapted from a letter of Ben Franklin's which follows. It makes a very effective class demonstration especially for the unaware classmember accused of treason. The charge which this device holds is nowhere near that of the device described in the letter.

To construct the picture take a picture that depicts a "king" and cut a slit over the head where the crown will go. Take the glass and tape aluminum foil to one side. The picture will be placed on top of this foil and the frame should hold it to the glass. Take the cardboard backing and wrap it with aluminum foil being careful to leave a portion of the backing foil free near the top side of the picture. Place the frame, picture, glass, and backing back together so it remains in one piece. The aluminum crown is shaped using a longer piece of foil that has been folded several times so as to be stiff. You can cut the crown shape as ornately as you wish. Place the crown into the slit and while holding the foil of the backing bring a charged electrophorus to the crown. Do this as many times as is needed to charge the device. The diagram to the right shows a side view of the magical picture.



THE LETTER OF BEN FRANKLIN

Dear Sir:

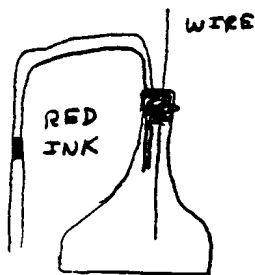
The magical picture is thus made. Having a large metzotinto with a frame and glass, suppose of the King (God preserve him), take out the print, and cut a pannel out of it near two inches distant from the frame all around. If the cut is through the picture it is not the worse. With thin paste, or gum water, fix the border that is cut off on the inside of the glass, pressing smooth and close: then fill the vacancy by gilding the glass well with leaf gold, or brass. Gild likewise the inner edge of the back of the frame all around, except the top part, and form a communication between that gilding and the gilding behind the glass: then put in the board, and that side is finished. Turn up the

glass, and gild the foreside exactly over the back gilding, and when it is dry, cover it, by pasting on the pannel of the picture that hath been cut out, observing to bring the correspondent parts of the border and picture together, by which the picture will appear of a piece, as at first, only part is behind the glass and part before. Hold the picture horizontally by the top and place a little moveable gilt crown on the king's head. If now the picture be moderately electrified, and another person take hold of the frame with one hand, so that his fingers touch its inside gilding, and with the other endeavor to take off the crown, he will receive a terrible blow, and fail in the attempt. If the picture were highly charged, the consequence might perhaps be as fatal as that of high treason, for when the spark is taken through a quire of paper laid on the picture by means of a wire communication, it makes a fair hole through every sheet, that is through forty-eight leaves, though a quire of paper is thought good armour against the push of a sword, or even against a pistol bullet, and the crack is exceedingly loud. The operator, who holds the frame by the upper end, where the inside of the frame is not gilt, to prevent its falling, feels nothing of the shock, and may touch the face of the picture without danger, which he pretends is a test of his loyalty. If a ring of persons take the shock among them, the experiment is called, THE CONSPIRATORS.

B. Franklin

EXPERIMENT ON THE ELECTRIC ATMOSPHERE

The experiment here mentioned was thus made. An empty phial was stopped with a cork. Through the cork passed a thick wire, as usual in the Leyden experiment, which wire almost reached the bottom. Through another part of the cork passed one leg of a small glass siphon; the other leg on the outside came down almost to the bottom of the phial. This



phial was held a short time in the hand, which, warming and of course rarefying the air within, drove a small part of it out through the siphon. Then a little red ink in a tea-spoon was applied to the opening of the outer leg of the siphon; so that as the air within cooled, a little of the ink might rise in that leg. When the air within the bottle came to be of the same temperature of that without, the drop of red ink would rest in a certain part of the leg. But the warmth of a finger applied to the phial would cause the

drop to descend, as the least outward coolness applied would make it ascend. When it had found its situation, and was at rest, the wire was electrified by a communication from the prime conductor. This was supposed to give an electric atmosphere to the wire within the bottle, which might likewise rarefy the included air, and of course depress the drop of ink in the siphon. But no such effect followed.

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