Benjamin Franklin: Natural Philosopher, Statesman, and America's First Physicist

FEATURE

Students of American history remember Benjamin Franklin because he edited and signed the Declaration of Independence, served the Colonies before the Revolution as an ambassador to England, served the newly declared United States during the Revolution as its ambassador to secure a treaty with France, and participated in drafting the U.S. Constitution. And, of course, Franklin *should* be remembered for these accomplishments of diplomacy and statesmanship!

But have students of U.S. History ever wondered *why* Franklin enjoyed the name recognition in England and France that made him welcome there among people of influence? They knew of Franklin because he was America's first physicist of international reputation. Franklin transformed the subject of electrostatics from a parlor amusement into a science, with a vast body of careful observations and a theoretical organizing principle that forms an integral part of physics to this day. His contemporary Joseph Priestly (who discovered oxygen) wrote that Franklin's work on electricity would "be handed down to posterity as expressive of the true philosophy of electricity just as Newtonian philosophy is the true system of nature in general."

Franklin was a fun-loving, yet practical man who knew his own mind and could articulate his thoughts with humor as well as pointed argument. As a postmaster, newspaper publisher, and printer, he knew the power of communicating ideas. Franklin should be the poster child for the Enlightenment. Thomas Jefferson's first draft of the Declaration of Independence began, "We hold these truths to be sacred and undeniable..." Franklin changed it to read, "We hold these truths to be self-evident..."

Franklin lived and breathed science; for example, his were the first charts of the Gulf Stream (Fig. 1), which he put together from his own observations—and conversations with sailors—while making a trans-Atlantic voyage in 1775. He was intrigued by the calming effect of oil on water, and in his study of these thin films came very close to measuring an upper limit on the size of atoms. His interest in electricity was sparked while visiting Boston in 1743, where he heard the Scottish itinerant lecturer, Dr. Archibald Spencer, present a program of demonstrations on static electricity. Intrigued, Franklin arranged for Spencer to bring his show to Philadelphia, and afterwards bought Spencer's apparatus. Having achieved sufficient success from his printing and newspaper businesses to retire from active involvement in them, and with a solid study of experimental mechanics and Newton's *Optiks* already behind him, he turned his full attention to research in electricity.

Little was known about it at the time; electricity was a parlor game, such as the activity shown in Fig. 2. The young woman stands on an insulated step, with her hand on the brass rail. Her accomplice (left) turns the crank on a large electrostatic generator (a non-conducting wheel in contact with brushes, that have leads going to the rail). When the young man on the right—who is grounded—leans up to receive a sweet kiss from the young lady, he gets an electrical shock! Franklin and his colleagues began to study electricity in earnest. Shortly thereafter the Library Company of Philadelphia (one of many civic organizations co-founded by Franklin) received a gift of electrostatic equipment from one of Franklin's London friends, the merchant Peter Collinson. Franklin began corresponding with Collinson about the Philadelphia research (Fig. 4). One of Franklin's letters first describes the principle that we call today

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Fig. 1. Benjamin Franklin's chart of the Gulf Stream.

Image credit: National Oceanic and Atmospheric Administration/Department of Commerce

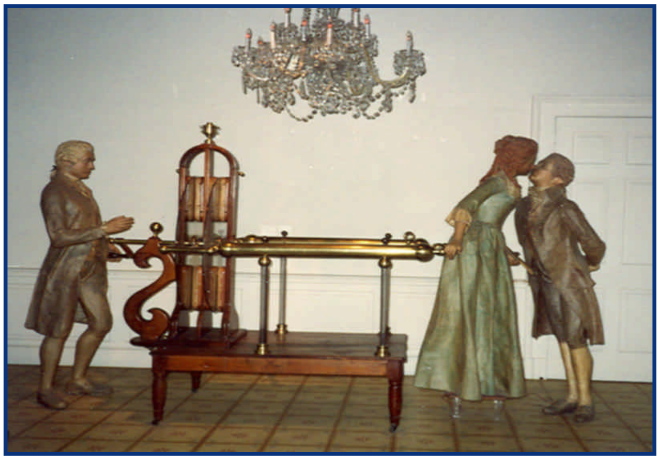

Fig. 2. Electrostatic generator for parlor game amusements, ca. 1750. This apparatus is on display at the Smithsonian Institution's American History Museum, Washington, DC.

Photo by: D. E. Neuenschwander

"conservation of electric charge." Before Franklin's researches, it was known that the "electrical fire" exhibits both attraction and repulsion; so it had been supposed two kinds of "electrical fire" existed, called "vitreous" and "resinous," after the kinds of materials one rubbed to generate the electrified state. Franklin was the first person to realize that "vitreous" and "resinous" electricities were additive inverses of one another: positives and negatives. The electrostatic generator in the parlor amusement apparatus and the rubbing of glass with fur did not *create* the charges; it merely *separated* them. Thus all matter contained electric charge. In Paragraph 6 of a 1749 letter to Collinson, in experiments with Leyden jars (early capacitors, consisting of a glass bottle layered inside and outside with foil), Franklin described how:

In this experiment the bottles are totally discharged; the equilibrium within them is restored. The abounding of [electrical] fire in one of the hooks (or rather in the internal surface of one bottle) being exactly to the wanting of the other: and therefore, as each bottle has in itself the abounding as well as the wanting, the wanting and abounding must be equal in each bottle.

Franklin also discovered the phenomena we now call the polarization of dielectrics, and at the same time invented the parallel plate capacitor by showing that planes of glass separated by lead sheets could also hold the electrical fire as well as cylindrical Leyden jars:

17. ...To find out, then, whether glass had this property merely as glass, or whether the form contributed anything to it; we took a pane of sash-glass, and laying in on the hand, placed a plate of lead on its upper surface; then electrified that plate, and bringing a finger to it, there was a spark and shock. We then took two plates of lead of equal dimensions, but less than the glass by two inches every way, in doing which, what little fire might be in the lead was taken out, and the glass being touched in the electrified parts with a finger, afforded only very small pricking sparks, but a great number of them might be taken from different places. Then dexterously placing it again between the leaden plates, and compleating a circle between the two surfaces, a violent shock ensued-which demonstrated the power to reside in glass as glass, and that the non-electrics [the conductors] in contact served only...to unite the force of the several parts, and bring them at once to any point desired: it being the property of a non-electric, that the whole body instantly receives or gives what electrical fire is given to or taken from any one of its parts.

18. Upon this we made what we called an electrical-battery, consisting of eleven panes of large sash-glass, arm'd with thin leaden plates, pasted on each side, placed vertically, and supported at two inch distance on silk cords, with thick hooks of leaden wire, one from each side, standing upright, distant from each other, and convenient communications of wire and chain, from the giving side of one pane, to the receiving side of the other; that, so the whole might be charged together, and with the same labour as one single pane; and another contrivance to bring the giving sides, after charging, in contact with one long wire, and the receivers with another, which two long wires would give the force of all the plates of glass at once through the body of any animal forming the circle with them...

With these observations, and the theoretical concept of charge conservation to provide an organizing principle and direction for further research, Franklin's group was far ahead of everyone else. In London, Franklin's researches were published in 1751 under the title *Experiments and Observations on Electricity, Made at Philadelphia* (See figure 3). In 1756 (one year before he arrived in England as an ambassador of the Pennsylvania Colonial Assembly), Franklin was elected as the first American member of the Royal Society, having been awarded the Society's Copely Gold Medal in 1753, which at the time represented the highest scientific honor awarded in England. The *Experiments and Observations* book went through five editions in English, and was translated into French, Italian, and German. In 1772 the French Academy of Sciences elected Franklin a Foreign Associate, of which there could exist only eight at one time.

Thus we can understand Franklin's fame when he was sent to France as an ambassador of the fledgling United States of America, in 1776. At age seventy, with his two grandsons to accompany him, Franklin landed in France at the tiny village of Auray. He tried to keep a low profile, "thinking it prudent first to know whether the court [of Louis XVI] is ready and willing to receive ministers publicly from Congress." Walter Isaacson,

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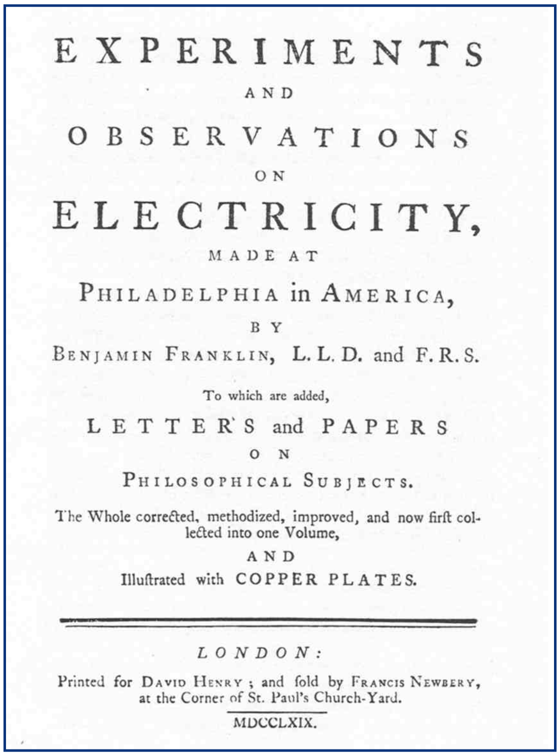
one of his biographers, notes, “France was not a place, however, where the world’s most famous American would find, nor truly seek, anonymity. When his carriage reached Nantes, the city feted him at a hastily arranged grand ball, where Franklin reigned as a celebrity philosopher-statesman and Temple [one of the grandsons] marveled at the height of the women’s ornately adorned coiffures. After seeing Franklin’s soft fur cap, the ladies of Nantes began wearing wigs that imitated it, a style that became known as *coiffure à la Franklin*.”

The scientific accomplishment for which Franklin was best known to French society, and to every American schoolchild to this day, was drawing the “electrical fire” from a kite flown in a thunderstorm. In the course of his researches in Philadelphia, Franklin had discovered how a grounded conductor sharpened to a point would draw the charge off a nearby electrically charged object; and inversely, how charge could be drawn from the point of an isolated but electrified pointed rod (in modern terms we see this in terms of the electric field being especially strong around the sharpened point). From these insights he was led to the study of lightning: Is lightning merely a colossal spark of “electrical fire?” He hypothesized that thunderstorm clouds become charged (their charges separated) through their turbulence; and if so then one could draw from them an electric spark using a grounded, pointed rod placed at a great height. The spire of Christ Church in Philadelphia was under construction, and Franklin planned to build a sentry box on top of the spire, where a grounded sharpened rod, held by a well insulated observer, would attempt to draw off the electrical fire. Before the sentry box could be completed, the experiment was done in France, confirming Franklin. Waiting no longer for the sentry box in order to do the experiment himself, Franklin improvised the kite experiment. He described the experiment in an article of 19 October 1752, in the *Pennsylvania Gazette*:


EXPERIMENTS
AND
OBSERVATIONS
ON
ELECTRICITY,
MADE AT
PHILADELPHIA in AMERICA,
BY
BENJAMIN FRANKLIN, L. L. D. and F. R. S.
To which are added,
LETTERS and PAPERS
ON
PHILOSOPHICAL SUBJECTS.
The Whole corrected, methodized, improved, and now firſt collected into one Volume,
AND
Illuſtrated with COPPER PLATES.

LONDON:
Printed for DAVID HENRY; and ſold by FRANCIS NEWBERY, at the Corner of St. Paul's Church-Yard.
MDCCLXIX.

Fig. 3. Frontispiece of Experiments and Observations on Electricity, Made at Philadelphia (England, 1751)

Image credit: Selected Papers of Great American Physicists (AIP 1976).

A 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 soft 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 [to] 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 the electric fire thus obtained, spirits may be kindled, and all the other electric experiments 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.

Jacob Bronowski notes, “Franklin loved fun (he was a rather improper man), yet he took electricity seriously; he recognised it as a force in nature. He proposed that lightning is electric, and in 1752 he proved it—how would a man like Franklin prove it?—by hanging a key from a kite in a thunderstorm. Being Franklin, his luck held; the experiment did not kill him, only those who copied it.”

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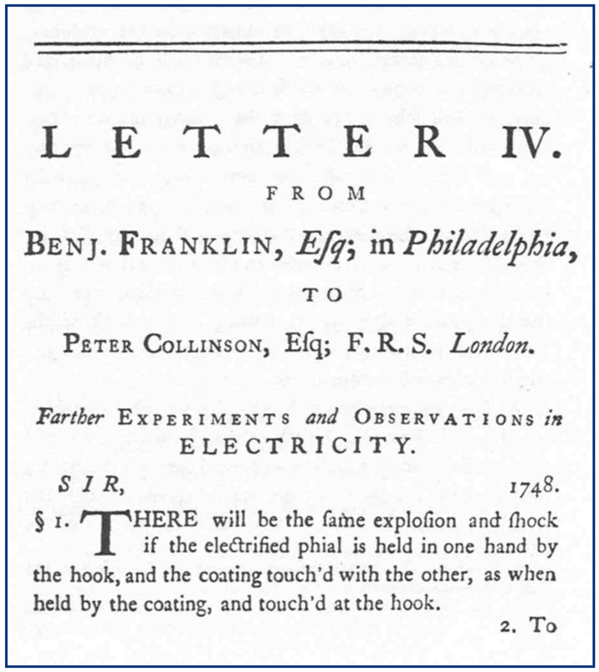
Franklin was indeed a mischievous, flirtatious, and fun-loving man who enjoyed life. At the close of his 29 April 1749 letter to Collinson, he combined humor with physics in describing the termination of the season's electrical experiments:

Chagrined a little that we have been hitherto able to produce nothing in this way of use to mankind; and the hot weather coming on, when electrical experiments are not so agreeable, is proposed to put an end to them for this season, somewhat humorously, in a party of pleasure, on the banks of the Skuylkil. Spirits, at the same time, are to be fired by a spark sent from side to side through the river, without any other conductor than the water; an experiment which we some time since performed, to the amazement of many. A turkey is to be killed for our dinner by the electrical shock, and roasted by the electrical jack, before a fire kindled by the electrified bottle: when the healths of all the famous electricians in England, Holland, France, and Germany, are to be drank in electrified bumpers, under the discharge of guns from the electrical battery.

Benjamin Franklin, 1706-1790: his 300th birthday occurred on January 17, 2006. We remember the anniversary of his birthday to honor him as a sage of the Enlightenment, philosopher of science, communicator of ideas, jolly good fellow, Framer of American democracy, and America's First Physicist.

— by Dwight E. Neuenschwander



LETTER IV.

FROM

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

TO

PETER COLLINSON, Eſq; F. R. S. *London.*

Farther EXPERIMENTS *and* OBSERVATIONS *in* ELECTRICITY.

SIR, 1748.

§ 1. THERE will be the ſame exploſion and ſhock if the electrified phial is held in one hand by the hook, and the coating touch'd with the other, as when held by the coating, and touch'd at the hook.

2. To

Fig. 4. Cover page of one of Franklin's letters to Peter Collinson.

Image credit: Selected Papers of Great American Physicists (AIP 1976).

Acknowledgements

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The Franklin Institute, Philadelphia, PA, http://sln.fi.edu/ ◆

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