Benjamin Franklin: Philadelphia, Serendipity, and a Summer Storm

by Dr. Bryen E. Lorenz, *Pennsylvania Iota '76*

The eighteenth century had produced many important advances in the natural sciences that were to have a profound influence on the direction of scientific thought in later decades. This is certainly true in the case of Benjamin Franklin.

Franklin, a longtime resident of Philadelphia, was actually born in the city of Boston in January 1706. At age 17, Benjamin left home as a runaway from apprenticeship to his brother James, who owned a small printing business, to seek his fortune in Philadelphia. Through pluck, common sense, an indomitable spirit, and good fortune, he rose steadily in colonial society.

As his business interests prospered, he became intellectually restless looking for something that would stimulate his imagination. His investigations into electricity began in this way during a return trip to Boston in 1743, when he witnessed a demonstration of static electricity staged by a traveling showman. By 1751, eight years later, he published his masterwork, *Experiments and Observations on Electricity, Made in Philadelphia in America,* to which he constantly added in subsequent editions. This work was widely distributed and read by his European contemporaries with great interest, having been translated into Latin, French, German, and Italian.


Ben Franklin and son William are shown during the 1752 experiment with a kite (top right), in this painting by Charles E. Mills.

Proving His Belief

However, it was the kite experiment that was to gain him world renown by proving his belief that the brilliant lightning flashes arcing miles across the summer sky and the sparks that crackled by treading over a woolen carpet and then touching a metal doorknob on a cold winter's night were actually the result of the same electrical phenomenon. The connection between these seemingly unrelated natural events, electrical sparks and lightning, was carefully recorded in his journal. In the entries for November 1749, he listed twelve similarities, "1. Giving light. 2. Color of light. 3. Crooked directions. 4. Swift motion. 5. Being conducted by metals. 6. Crack or noise in exploding. 7. Subsisting in water and ice. 8. Rendering bodies it passes through. 9. Destroying animals. 10. Melting metals. 11. Firing inflammable substances. 12. Sulpherous smell." He concluded, "We do not know whether this property is in lightning. But since they agree in all particulars wherein we already compare them, is it not probable they agree likewise in this? Let the experiment be made."

Static Charge

His intention in performing this experiment in June 1752 was to extract static charge from the dark storm clouds as they hovered overhead through a pointed wire mounted on a silk kite.

Franklin had thought of using a church steeple for the experiment, but believed that the steeples available in Philadelphia at the time did not have the height needed for the experiment to succeed. The dramatic scheme to use a kite instead of a steeple was conceived out of desperation. It was hoped that this contrivance would place a conductor high enough into the storm clouds to collect electric charge.

As later retellings of the story would falsely claim, Franklin did not attempt to capture lightning on that hot summer day, but rather to determine the conditions for producing lightning. If he could establish the electrical content of the storm clouds, he could then argue that the lightning had a common origin with that of ordinary terrestrial discharges. It is amazing how this point has become confused, even to the present day, with Franklin credited in a recent television biography as supposedly "plucking lightning from the heavens."

The plan on that day was for William, his son who by then was a man in his early twenties, to fly the kite in the city commons. This plot of land served as a grazing pasture for cattle and other livestock. It was large enough for William to run down the field and allow gusts of wind produced by the oncoming storm to lift the kite into the heavens. Meanwhile, Benjamin was hidden in a nearby shed, presumably to avoid possible ridicule by onlookers in the surrounding neighborhood as well as to offer some protection in taking measurements. Affixed to the wire conductor that the kite carried aloft was a long length of twine connected to a key. The key was electrically isolated by a non-conductive silk ribbon. When the time was right, the ribbon could be manipulated in such a way as to allow the key to touch a Leyden jar. (The Leyden jar was constructed with metal foil fitted to the outside and inside of a glass jar. The foil covering the inside and outside of the jar was electrically isolated. The inner foil was in turn connected to a metal post that protruded from the top of the jar.)

Benjamin Franklin (1706-90) painted in France by Joseph-Siffred Duplessis during Franklin's stay in 1776-85 when he was Commissioner for the United States. This image was used for the U.S. 100-dollar bill, shown below in the 1996 version.

Store Charge

The function of the jar was to serve as a capacitor—a device used to store charge. When the twine became wet from the rain, a conductive path existed from the pointed wire attached to the kite to the Leyden jar, via the metal key. If all went according to plan, when the key came in contact with the metal post of the Leyden jar, which had been carefully discharged before the experiment began, a sampling of the electrical charge stored in the storm clouds would be captured. At that point, experiments could be carried out using the jar as if the jar had originally been charged in the conventional way by rubbing an amber rod with fur or a glass rod with silk.

Franklin confidently wrote, "…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 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 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 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 the lightning completely demonstrated." The danger that surrounded his investigation into the nature of lightning cannot be overstated. One year later, Professor Georg Wilhelm Richmann from St. Petersburg, Russia, died from electrocution attempting the same experiment. Nevertheless, Harvard and Yale Universities gave him honorary degrees a year later for his groundbreaking work. The Royal Society of London presented him with the prestigious Copley Medal, the first such medal presented to someone living outside Britain. Benjamin Franklin was now internationally famous.

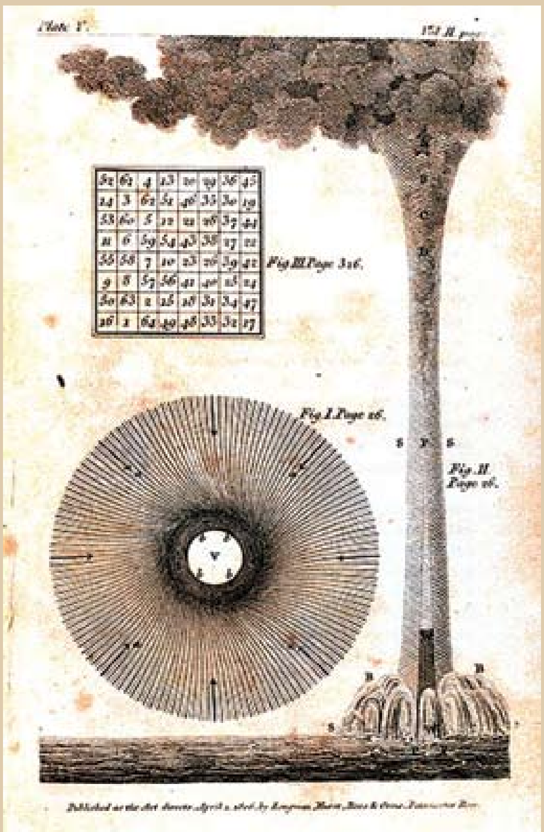
Franklin soon used this newly acquired knowledge to design a lightning rod, a simple preventative measure to protect property from fires caused by lightning strikes. We now know that a stroke of lightning averages about 40,000 amps and transfers about 1.0 coulomb of charge in a fraction of a second—an awesome force of nature. During the 18th Century, the popular belief was that the ringing of church bells as storms approached would repel them, due to the consecrated ground upon which the church stood. Walter Isaacson states in his book *Benjamin Franklin* that, during a 35-year period in the mid-1700s in Germany, 386 churches were struck by lightning and more than a hundred bell ringers were killed. Franklin commented, "The lightning seems to strike steeples of choice and at the very time the bells are ringing; yet still they continue to bless the new bells and jangle the old ones whenever it thunders."

Frightened Wife

By the end of 1752, the recently completed State House had lightning rods installed. Franklin's own version of the lightning rod that he fashioned for his own house included a six-inch gap in the wire leading from the lightning rod on his roof to a well. The gap was located by his bedroom door. In the gap, a metal ball and two bells were placed such that ringing could be heard when the lightning rod was struck. His frightened wife Deborah Read wrote to him some years later while he was visiting London complaining of this device. He responded that the problem would be solved by simply placing a wire across the gap.

The results of the experiment and who was to be given credit for the discovery were not without controversy. In the spring of 1752, a similar experiment was attempted by Messieurs de Buffon, D'Alibard, and de Lor. In the village of Marly, a town near Paris, a sentry box was outfitted with a 40-foot vertical iron rod. On the afternoon of May 10, 1752, as an electrical storm raged overhead, the apparatus set up in the sentry box was able to draw sparks from the rod. Within weeks it was replicated in other venues throughout France. Ironically, the idea for the sentry box had been first proposed by Franklin himself through excerpts from his letters that had been originally presented to the Royal Society of London and appeared in the popular British press in 1750.

Critics have argued that the kite experiment reported by Franklin was presented without independent confirmation. This could equally have been a hoax. In fact, the first public mention by Franklin appeared in October of 1752, four months after the event, in the *Pennsylvania Gazette*. He announced, "As frequent mention is made in the public papers from Europe of the success of the Philadelphia Experiment for drawing the electric fire from the clouds, 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." Much scholarly work has gone into this debate and appears to side with Franklin's account of the events on that day. Certainly history has favored Franklin, with little mention given to the French successes.



An illustration from Franklin's paper on "Waterspouts and Whirlwinds."

"Terrible Substance"

Controversy began in 1755, prompted by the Boston earthquake of the same year, which would soon surround Franklin's use of lightning rods. Because the rods had been installed on many buildings, the question arose whether lightning rods caused earthquakes. The Reverend Thomas Prince of Boston admonished his parishioners in one of his sermons, "The more Points of Iron are erected in round the Earth, so draw the Electrical Substance out of the Air; the more the Earth must needs be charged with it. And therefore it seems worthy of Consideration, Whether any Part of the Earth being fuller of this terrible Substance, may not be more exposed to more shocking Earthquakes. In Boston are more erected than anywhere else in New England and Boston seems to be more dreadfully shaken…."

The response to such criticism was typified by Professor John Winthrop of Harvard University. "Philosophy, like everything else, has its fashions, and the reigning mode of late has been, to explain everything by Electricity.… Now it seems it is the cause of earthquakes…. The two cases are in no way parallel; … the electrical substance, when in the bowels of the earth, is in circumstances essentially different from what it is, when in the clouds of the air."

The story of Franklin's investigations into electricity does not end here, but takes another interesting turn. Around the time of the kite experiment, Franklin had also noted another puzzling electrical phenomenon. By placing a silver can on an insulated stand and applying an electrical charge, a cork when moved to within a few inches of the outside of the can would be strongly attracted. However, when the same cork was suspended by a silk thread and lowered into the can, Franklin found that no electric forces were exerted on the cork—no matter where it was located within the can. He mentioned this curious behavior to his young friend, Joseph Priestley, a Unitarian minister whom Franklin had met during a stay in London.

Obey Such a Law

The cork's behavior reminded Priestley of the work of Isaac Newton, a fellow Englishman, in explaining gravitational forces. The concept that inside a uniform hollow sphere the net gravitational force on an object is zero is a direct consequence of the inverse-square-law dependence of the force. Priestley correctly proposed that the static electrical forces may also obey such a law. In 1767, he published this bold assertion in his work *History and Present State of Electricity*. Priestley was later to discover oxygen. Eventually, he was forced to emigrate to the American colonies for his unconventional religious and political views. He would settle in Northumberland, a town in rural Pennsylvania, where he lived until his death. Toward the end of the 1700s, a French military engineer, Charles Coulomb, demonstrated by using a torsion balance that the electrostatic force does indeed vary as the inverse square of the distance.

Franklin's work in electricity also brought into common use a misconception on the nature of electrical current, which still persists to this day. He imagined that electricity was some form of invisible fluid present in all matter. By rubbing insulating substances together, friction would cause the fluid to move from one material to the other. The movement of this fluid constituted an electrical current. Too little of this electric fluid caused the material to be *negatively* charged, while too much of this fluid caused the material to be *positively* charged. As an arbitrary convention, he identified *positive* with the type of charge obtained by rubbing a glass rod with silk and *negative* with that acquired by rubbing an amber rod with fur. To his way of thinking, the electrical fluid would naturally seek to flow from the positively charged material to the negatively charged material. This convention still exists today, at least in the engineering community.

However, in 1897 the British physicist Sir Joseph "J.J." Thomson discovered the electron, a subatomic particle with negative charge. The electron is the charge carrier responsible for current conducted in metal wire such as copper or iron. Textbooks in physics portray electron current as moving electrons from the negative terminal of a battery to the positive terminal, while textbooks in engineering describe current in the conventional sense moving positive charge in the opposite direction. (Actually, in some cases such as with holes and conduction electrons in doped semiconductor material, charge carriers are in the form of both positive (holes) and negative (free electrons).) Each method of analysis, if used consistently, will lead to the same results, although from different points of view.

Benjamin's interest in scientific inquiry diminished after writing his book, turning toward politics instead. Eventually, this would lead him into becoming a delegate to the Continental Congress and a patriot committed to the rebel cause. With this came his estrangement from his son William, who had risen to become the royal governor of New Jersey—only to be imprisoned during the Revolutionary War and to die in exile and in poverty in later years. The two had never reconciled. Yet an ironic turn of events would lead to the kite experiment once again. As Esmond Wright relates in his book, *Franklin of Philadelphia,* in 1776 the British Board of Ordnance had asked the Royal Society for a preferred method of securing the arsenals at Purfleet from possible explosion due to errant lightning strikes. The Royal Society appointed a committee to investigate.

Political Views

The question eventually became whether a pointed or blunt lightning rod end should be used in this application. Franklin, who was appointed a member of the committee, recommended a pointed end which was based on his earlier kite experiment. One dissenter on the committee had opted for a blunt end. Nevertheless, the committee's recommendation was for a pointed end. King George III, angered by Franklin's political views, had asked Sir John Pringle, president of the society, to give an opinion in favor of the blunt end. Pringle replied that, "The laws of Nature were not changeable at royal pleasure." To this the King indignantly responded, "…by the King's authority that a president of the Royal Society entertaining such an opinion ought to resign." Pringle promptly resigned. The London gossip soon found an apt verse to relish the moment.

While you, great George, for safety hunt,
And sharp conductors change for blunt,
The nation's out of joint.
Franklin a wiser course pursues,
And all your thunder fearless views,
By keeping to the point.

Despite his absence from active scientific inquiry in his later years, his outlook for the future of scientific progress was optimistic. One of his quotations, both wistful and insightful, that captures his feelings on this subject recounts, "Furnished as all Europe now is with Academies of Science, with nice instruments and the spirit of experiment, the progress of human knowledge will be rapid and discoveries made of which we have at present no conception. I begin to be almost sorry I was born too soon, since I cannot have the happiness of knowing what will be known a hundred years hence." In fact, 75 years after Franklin's death James Clerk Maxwell would publish his masterpiece, *A Dynamical Theory of the Electromagnetic Field,* that collected the work of many investigators in magnetism, electricity, and optics into a unified theoretical framework. Franklin would have been pleased.

As we look back at the accomplishments of Benjamin Franklin in his investigations into the nature of electricity, there is much folklore, and misconceptions that have crept in during the last 250 years have been amplified by generations of grade schoolers. In light of modern discoveries, the world views his work as marginal or maybe even irrelevant. It is hoped that the reader appreciates that what at first glance appears trivial, actually has much more substance and controversy than is generally known. I believe that the phrase attributed to Carl C. Van Doren, a 1939 Pulitzer Prize winner for his biography entitled *Benjamin Franklin,* best sums up Franklin's contribution to the understanding of electricity, "He found electricity a curiosity and left it a science." I could not agree more.

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