

**Franklin and Electricity**

An Honors Thesis (HONRS499)

By

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## **Abstract**

The basis of any knowledge is what came before, and in order to understand a complex idea you must first understand the basics. The basics of electricity were primarily discovered by the observations of Benjamin Franklin, who is largely publicly known for his diplomatic works. To know where Franklin's work began, I looked at the life of Franklin before he began work on electricity and the work done in electricity before Franklin began his work. Then I looked at Franklin's experiments through his own writings to discover what is said to be the foundation of modern electric physics.

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The interests of a child can grant insight into the kind of person that they will grow up to be. This is definitely the case for Benjamin Franklin, who grew up to be a leading scientist and diplomat for the emerging United States of America. Although his personal writings do not discuss much of his early life, other sources can provide a basic look at his early years. His family life and education as a youth and young adult provide a look at the origins of the man he was to become.

Benjamin Franklin was born January 17, 1706, in Boston, Massachusetts. He had a large family, having fourteen older siblings. His parents were Josiah Franklin and his second wife, Abiah Franklin. Josiah worked as a soap boiler and tallow chandler, after emigrating from England in 1683. His family was middle class, and “enlightened by self interest”(Seeger 3). Abiah’s family was the Folgers, who emigrated from England in 1635 and were easily described as puritanical (Seeger, 3-4). The influence of his puritanical parents can be seen in the later Benjamin, among other places in his ideas about superstition that influenced his work with lightning.

From his own writings, Benjamin’s childhood was full of innovation and joy in the simple things. Franklin writes later that as a boy of seven years, he became charmed with a whistle, for which he paid more than what it was worth. He was then laughed at by his siblings and cousins, while he “cry’d with Vexation”(Franklin Autobiographical, 3). He also writes of a sort of hand-held swimming paddle that he developed, which helped him to swim faster but tired him more quickly. This shows that Franklin was an innovator at an early age. In the same letter, he tells about how he was swimming with a kite, and the kite pulled him across the pond. This shows that Franklin was interested in finding practical uses for things that most people considered to be toys. His observations

on soap bubbles and the fact that they always drop in the air show that he took note of the natural phenomena around him (Franklin 1952,, 3-4).

From an early age, the highly religious Franklin family had intended for Benjamin to become a minister. By the age of 8, Benjamin was being educated toward this purpose (Seeger 4). In his own words, “I was put to the grammar-school at eight years of age, my father intending to devote me, as the title of his sons, to the service of the church” (Franklin 1952,, 220). He attended grammar school in Boston, at what would later come to be known as the Boston Latin School. He excelled in all subjects, and became the head of the class. However, his favorite subject was reading—something that would follow him through the rest of his life. His family transferred him to another school a year into his education due to the high cost of the education compared to the low income of a minister. He transferred to George Brownell’s school for writing and arithmetic, where he failed arithmetic (Seeger 4). Franklin later in life wrote “Under [George Brownell] I acquired writing pretty soon, but I failed in arithmetic and made no progress in it” (Franklin 1952,, 220). Later in his life, he mastered arithmetic, but mathematics was always a challenge for him (Seeger 4).

Franklin’s formal education ended at the age of ten, when he had to quit school to help with his family business. While working for his father, Franklin learned to handle tools and work with his hands. Franklin says that he “was employed in cutting wick for the candles, filling the dipping mold and the molds for cast candles, attending the shop, going of errands, etc” (Franklin 1952,, 221). At the age of twelve, he was indentured to his older brother James as a printer’s apprentice due to his obvious love of books (Tanford 14.) Franklin was interested in going to sea, but his father wanted to see him

bound to his brother. Franklin later in life wrote that he “stood out some time, but at last was persuaded, and signed the indentures when I was yet but twelve years old”(Franklin 1952,, 224). He spent four years working under James and learning the profession that would be his primary source of income for many years. While an apprentice printer, Franklin began to develop his writing style, imitating Joseph Adams. His stylistic goal was to be “clear, smooth, and short”(Seeger 5). The first pieces published were a series of letters under the pen name “Silence Dogood” published in the *New England Courant*, which was printed by James Franklin. Even at the age of sixteen, Franklin had made an impact on the writing world and is now considered to be one of the best writers in eighteenth century America, and one of the establishers of the American style of literature.

At the age of sixteen, Ben Franklin ran away from his brother’s printing shop because his apprenticeship “inhibited his natural growth” (Seeger 5). His brother saw to it that he would not get a job in Boston, so Franklin moved on (Tanford 14). He went to New York and tried to find a job there, and when that failed Franklin went to Philadelphia. He became a journeyman printer in 1723, working under Samuel Keimer (Seeger 5). Franklin had enormous popularity in Philadelphia, mostly due to his literacy and book collections (Tanford 14). During his stay in Philadelphia, Franklin was brought to the notice of the governor, Sir William Keith. This proved to be somewhat problematic for the young Franklin, as Keith sent him to London to buy the necessary equipment to open his own shop, funded by Keith (Tanford 15). Keith promised money and letters of introduction, and Franklin arrived in London with neither. At only eighteen years old, Franklin was stranded in London. However, Franklin was resourceful and

found a job that enabled him to make the money needed for his own printing equipment (Tanford 15). First he worked as a journeyman printer for Samuel Palmer and then under John Watts (Seeger 5). While he was in London, Franklin became a skilled printer and also gained many notable friends that would help him later in life (Tanford 15). Some notable people were Henry Pemberton, and Sir Hans Sloane, both of whom were notable scientists (Seeger 5). Later in his life, he writes of his stay in London: “Thus I spent about eighteen months in London; most part of the time I work’d hard at my business, and spent but little upon myself except in seeing plays and in books.” Also that he “had by no means improv’d my fortune; but I had picked up some very ingenious acquaintance, whose conversation was of great advantage to me; and I has read considerably” (Franklin 1952,, 252). His travels away from Boston helped him to become a more skilled printer and gain some of the contacts that could help him later in life.

Franklin returned to Philadelphia in 1726, after two years in London (Tanford 15). After holding a few other jobs, he opened his own printing shop with a partner, Hugh Meredith, whose father provided the necessary start-up funds (Tanford 15). Franklin worked endlessly in the printing shop, founding *The Pennsylvania Gazette*, most of which he wrote himself (Tanford 15). Two years after opening his own print shop, he bought out his partner and married Deborah Read (Tanford 15). In 1732 he began publishing *Poor Richard’s Almanack* (Seeger 6). For twenty years, Franklin prospered as a publisher (Seeger 6). He retired from publishing in 1748, leaving the business in the hands of David Hall. Hall had been working for Franklin since 1743, and continued to run the business until 1766(Seeger 6).

Franklin retired from his printing business so that he could make a contribution to the knowledge of the world (Tanford 16). A look at his early life is a good window into the man he would become, from his early love of reading to his early interest in science and his willingness to work at whatever came his way. His growth as a person was just beginning when he retired from full time business, and many of his true contributions to the world came after that.

Franklin was not the true father of electricity, but he was one of the first to really begin to understand the nature of electricity. Much work had been done before Franklin began his studies of electricity, starting with the ancients. Franklin's developments would not have been possible without the effort that had come before him, from ancient times until the time that he began his studies of electricity.

Electric phenomena were first observed by the ancients in Greece, Rome, and Egypt in four forms, although they were not connected until more recently (Roller 1). The true start of electricity comes from the "amber effect." The amber effect is the fact that, when rubbed, a piece of amber will attract small, lightweight objects in the nearby area (Roller 2). The first person said to observe the amber effect is the Greek philosopher Thales (Meyer 4). Some people say that Plato is the first written record of the amber effect in the 4<sup>th</sup> century BCE, where he mentions the attractive powers of amber and lodestone, which is a natural magnet, in his dialog called the *Timaeus* (Roller 1). Others say that the first written record belongs to Theophrastus or Pliny the Elder (Meyer 4). Although Plato claims that the attractive powers of the two stones are related, this is not proven until twenty centuries later (Roller 2). The early explanations of the amber effect were anthropomorphic, especially among the Greeks. They thought that amber was given a life when it was rubbed, and attracted objects to itself because it developed a " 'longing' or 'need' for these objects, as if they served as 'food' for the amber"(Roller3). However, later Greek philosophers such as Plutarch tried to explain the amber effect in terms of a "flameous and spirituous nature" that is drawn from the amber when it is rubbed, which is more similar to the later ideas of an electric fluid present in the amber (Roller 3).

Interest in secular knowledge was regained in the 12<sup>th</sup> and 13<sup>th</sup> centuries after losing focus to the religious education. The new interest brought with it new information on the field of electricity, including more substances that displayed the “amber effect” (Roller 4). Jet and diamond were added to the list by the 16<sup>th</sup> century, and people began to look for an explanation for this phenomena (Roller 4). By the middle of the 16<sup>th</sup> century, there is an effort to separate magnetism and electric phenomena due to the obvious differences in the two attractions—lodestone will only attract iron while amber will attract many different substances and lodestone will always point in the same direction when allowed to rotate while amber does not (Roller 4). Jerome Cardan and other physicians were some of the leading contributors to the study of the amber effect, probably due to its proposed medicinal value (Roller 5). Cardan was one of the leaders in the movement to separate magnetism and electricity, and published his proofs in the treatise *On subtlety* where he summarized the current knowledge about amber (Roller 4-5). He proposed the first hypothesis for the amber effect alone, that amber emits a liquid humor that other, dry objects absorb (Roller 5).

Another physician who made contributions to the study of the amber effect was William Gilbert. He is said to be the father of modern electricity, although his original interest was in magnetism (Whittaker 6). Gilbert was the court physician to Queen Elizabeth the First (Meyer 10). He discovered many other substances that exhibit the amber effect, listing many gems and resins, and used the term *electrics* to describe these substances (Roller 6, Meyer 9, Turner 11). He developed the first tool for the study of the amber effect, the *versorium*. The *versorium* is a light needle made of any type of material that is balanced so that it could turn (Turner 7). He also spent some time

eliminating sources of the amber effect, concluding that the attraction was not due to heat, fatty humors, drafts, or any singular quality of amber after performing many different tests (Roller 8-9). Gilbert concludes that the attractive force of these electrics is due to their fluid nature and the fact that they emit an effluvium when they are rubbed that attracts other objects (Whittaker 36). Gilbert proposed many experiments that would support his hypothesis (Roller 10).

The next major work done in electricity was done by Niccolo Cabeo, an Italian Jesuit (Roller 14). He claimed that Gilbert was wrong, and went back to an ancient explanation of electrics—that these substances emit an effluvium that pushes air away from the electric object and the air rushes back toward the electric object and brings small objects with it (Roller 14). Cabeo was the first person to notice that sometimes an electric will repel an object that it had attracted (Whittaker 6). Cabeo's hypothesis that it was the air around the electric that caused the attraction soon had French scientists testing this in the newly developed barometer, which contained an approximately airless chamber, which proved to be inconclusive (Roller 14-15). The Florentines performed a more successful experiment, using the amber as a pendulum and watching as the amber swung toward a small object placed in proximity. This experiment showed that the attraction of the amber and the object is mutual, proving Gilbert to be wrong (Roller 16).

After the work done by the Florentine academics, the next proofs in electricity were made in England. Robert Boyle proved Cabeo's hypothesis to be incorrect by use of the recently developed vacuum pump, showing that the attraction occurs in vacuum as well as in open air (Roller 17). Boyle's successor Francis Hauksbee was the next notable name in electricity, even if he did start his studies with optics (Roller 18). Hauksbee

worked with the “barometric light,” a glow or flash in a mercury tube when it is shaken or jarred (Meyer 13). He discovered the conditions necessary for the barometric light, pressure of less than half that of open air and motion of the mercury, then hypothesized about what other substances will create this same light to occur (Roller 19). He discovered that he could create the same light by simply rubbing an evacuated glass globe that is spinning (Roller 19). He inadvertently created the first generator when he created a device to spin the glass vessels so that he could create light or attraction in them (Meyer 14). His later work shows that this light is related to the electrification of the glass tube, a tube that has been evacuated to produce light does not attract small objects as well as one that has not been evacuated (Roller 23). Hauksbee also showed that an electrified tube creates a field, when placed among threads that are free to move they all line up so that one end points straight toward the tube (Roller 26). Hauksbee published 45 papers in his lifetime, and eleven dealt with electricity and barometric light (Roller 28). He was considered to be “ ‘the most active experimentalist of his time’ ” (Roller 18).

The next experimentalist of note is Stephen Gray, who expanded upon Hauksbee’s work. He was the first to recognize and describe electric conduction when the cork at the end of one of his electric tubes was discovered to attract a feather, despite it having not been rubbed (Meyer 15). This discovery led to the hypothesis that anything that touches something that is electrified will become electrified, opening up a new area for experimentation (Turner 19). He also determined that there are some substances that will conduct electricity more easily than others, somewhat by accident in the course of other experimentation (Roller 36, Whittaker 42). Gray also took Hauksbee’s discovery that some objects become electrified by merely being near an electrified tube and

expanded upon it, showing that several substances including water exhibit this trait (Meyer 16).

After Gray, Charles DuFay was the lead experimenter in electricity. DuFay worked in Paris with the French Academy of Science, reporting his results during the years of 1773 and 1774 (Meyer 17). DuFay worked in the gardens of Louis XV of France, allowing him access to the royal courts (Turner 21-22). He showed that all bodies could be electrified, although conductors needed to be insulated (Meyer 17). DuFay also noted that a wet string would conduct electricity much better than a dry one, and created a circuit that conducted electricity 1256 feet (Meyer 17). He also electrified the human body after insulating it from the ground (Meyer 17-18). This was, upon at least one occasion, a child suspended by silk cords (Turner 21). He then observed the charge passing from the electrified person to an approaching uncharged person (Meyer 17-18). The most notable contribution of DuFay to the field of electricity, however, was the idea of two separate electricities: vitreous, coming from glass, rocks, gems, and animal hair, and resinous, coming from amber, copal, thread, and paper. These two electricities repel similar charges and attract opposite charges (Whittaker 44).

The most important discovery for Benjamin Franklin's work in electricity was the Leyden jar, although who actually created the first is controversial. Some claim that E.G. von Kliest in Germany made the discovery on November 4, 1745 (Meyer 18). Others say that the discovery was made by Pieter van Musschenbroek, who is said to have discovered this while attempting to discover a way to preserve electric charges (Whittaker 45). It was discovered that a bottle filled partially with water and having a metal rod projecting through the neck would collect a large charge from an electrical

machine, and a person touching the metal rod would receive a large shock (Meyer 18- 19). This discovery spread rapidly through Europe, and was improved upon by Sir William Watson in England. Sir Watson coated the glass with leaf silver, and made jars that could hold a powerful charge (Meyer 19). Watson also was the first to observe that two unequally electrified charges will electrify if joined, and the first to use the terms “plus” and “minus” when referring to electrical polarities (Meyer 20).

A contemporary of both DuFay and Franklin was Abbé Nollet, who worked with the effect of an uninsulated object into an electric field. He observed that if the object was sharp, it gave off light, and that any uninsulated object would become electrified (Meyer 20-21). Nollet was also noted for sending the charge from a Leyden jar through lines of people holding hands, including a line of “several hundred Carthusian monks”(Turner 23). Nollet built upon DuFay’s concept of two fluids, saying that the fluids were always present in materials and that they flowed in opposite directions (Whittaker 44). When Franklin began publishing his works on electricity, Nollet became upset because he thought that Franklin was writing specifically to refute his works (Turner 24).

These men, from ancient Greek philosophers to French courtiers, were the foundation of electricity upon which Franklin would build. It is not possible to grasp the magnitude of what Franklin discovered in electricity without seeing what works had been done before. Electricity was a field full of conflict and uncertainties when Franklin began his works in that area.

Although there had been a marked increase in the study of electricity in Benjamin Franklin's time, Franklin made some significant advances in the field of electricity. His experiments and explanations laid the foundation for what is seen as modern electricity, even though he only was able to devote a few years to this work. After he retired from business to devote his time to science, Franklin spent a few years working with electricity, including developing a positive or negative view of electricity, explaining how a Leyden jar works and extensive work proving that lightning is electrical.

Franklin decided at the age of forty to retire from his successful printing business to devote his time to science, leaving his business under the control of David Hall in 1743 (Cohen 5, Tanford 16). Most of Franklin's work with electricity was done before the year 1749, at which point he was called to assist his country through some of its early turmoil (Cohen 5). He was asked to help with propaganda, which began to draw him into political movements for independence (Cohen 5-6). He held other political roles, such as the deputy postmaster general, before he became a diplomat (Tanford 19). By 1754, Franklin was a well-known public figure (Tanford 19). He had hoped to slip back into his private life where he could study science, which was his choice of pursuits, but could not in good conscious leave the country to fend for itself (Cohen 7). At the end of his life, Franklin returned briefly to science, once others could fulfill his political obligations (Cohen 11).

Franklin began his work in electricity when he retired from the printing business, with his initial experience being the experiments of a Dr. Spence, a traveling lecturer on electricity (Cohen 49). However, this Dr. Spence is something of a mystery to historians, with the only hard evidence being what Franklin presents himself in his autobiography

(Cohen 49). There is evidence of a Dr. Spence who bills himself in the Boston newspapers as a lecturer of science at approximately the time that Franklin speaks of his Dr. Spence lecturing in that area, although Dr. Spence never gave his lectures in Boston due to a lack of interest (Cohen 49-50). Spence did lecture in Philadelphia, covering the topics of sight and electricity (Cohen 51). However, when the evidence of Spence in Philadelphia is compared to Franklin's "Dr. Spence," the times do not line up—Spence was in Philadelphia in 1744, and Spence is said to have been in Philadelphia in 1746 (Cohen 52). There are not enough facts to prove whether Dr. Spence and Dr. Spence are the same person, although it seems probable that Franklin had some experience with electricity before receiving some experimental equipment that he could use for his own experiments.

Franklin was a founder of a club in Philadelphia that was called the Junto, whose members were devoted to the study of literature, philosophy, civics, and science (Cohen 14). Some members of the Junto began a subscription library called the Library Company, which is where Franklin first came into contact with Peter Collinson (Cohen 14-15). Peter Collinson made few direct contributions to science, but made several indirect ones. He was a member of the Royal Society of London, and was primarily a botanist (Cohen 15). Collinson is the person responsible for having Franklin's work published and recognized, as well as providing some of the inspiration and equipment that Franklin needed to start his works in electricity (Cohen 19). Franklin began his work in electricity around the year 1746, when the Library Company received an electric tube for experiments from Collinson and the Royal Society of London (Cohen 57). The gift also came with instructions for experiments, which Franklin readily mastered and showed

to other people, saying “my house was continually full, for some time, with people who came to see these new wonders” (Cohen 57, from Franklin’s Autobiography). Franklin was sharing this apparatus with three of his friends, Ebenezer Kinnersly, Philip Syng, and Thomas Hopkinson, until Franklin had more electric tubes made by the local glass blowers (Cohen 58). The experimenters received the notice of the Proprietor of the Colony, Thomas Penn, who sent the Library Company another electrical device (Cohen 59).

It has been said that Franklin had little knowledge of electricity before he began his experiments, and this can be seen in the letters that Franklin wrote to Collinson about his work. Most of the writings that we still have from Franklin’s work on electricity come from the letters that Franklin wrote to Collinson, which were later published by Collinson as Experiments and Observations on Electricity. Franklin writes that the experimenters in Philadelphia “have observed some particular phaenomena that we look upon to be new” in his thank-you letter to Collinson (Franklin 1941, 169). Franklin himself says that these observations may not be new discoveries, and that the experimenters in Europe may have already made these discoveries in both his first and second letters to Collinson (Franklin 1941, 169, 171).

The first discovery that he speaks of when writing his second letter to Collinson in July of 1747, is that a pointed body can draw off or throw off “electric fire” (Franklin 1941, 171). He proposes an experiment to show what he is explaining, showing that a sharp object will draw a spark from six or eight inches, while a blunt object has to be within an inch to create the same effect (Franklin 1941, 172). He also discusses the repellency of a piece of cork and electrified iron shot, giving several ways that the

repellence can be destroyed (Franklin 1941, 173). Franklin lists ways to destroy the repellence, including sifting sand on it, breathing on it, putting smoke around it, and light from a candle or hot coal (Franklin 1941, 173). On the theory of electricity, Franklin says that the experimenters “had for some time been of opinion, that the electrical fire was not created by friction, but collected...” which is the first statement that Franklin made regarding the nature of electricity (Franklin 1941, 174). Later in the same letter, Franklin describes some new terms that were being used among the experimenters in Philadelphia. He describes two people or objects, called *A* and *B*, where *A* is electrified by rubbing a glass tube and *B* who was electrified by touching the rubbed glass tube, then says that the experimenters “...say *B*, (and bodies like circumstanced) is electricised *positively*; *A* *negatively*” (Franklin 1941, 175). This is believed to be the first use of positive and negative to describe electric states (Cohen 64). Franklin explains some experimental procedures that the Philadelphia experimenters have tried, including lighting a candle using an electric spark and making a counterfeit spider dance using the powers of attraction and repulsion (Franklin 1941, 177). Franklin also describes a simple device that is used to charge a phial, using a handle to make the sphere turn more quickly (Franklin 1941, 177-178).

Franklin’s third letter to Collinson was written in September of 1747, and talks of his work with a Leyden jar (Franklin 1941, 179). Franklin shows his understanding of the Leyden jar, with several remarkable observations. A Leyden jar, at the time of Franklin, was a bottle covered in foil and filled with water or another conducting material with a wire coming out the mouth of the bottle (Cohen 45). He says that the non-electric inside a Leyden jar holds the charge inside the matter due to the glass on the surface

while a normal non-electric holds a charge on the surface (Franklin 1941, 180). Franklin also writes of the charge distribution on a Leyden jar, saying "...the wire and top of the bottle &c. is electricised *positively* or *plus*, the bottom of the bottle is electricised *negatively* or *minus*, in exact proportion..." (Franklin 1941, 180). This helped to prove Franklin's idea that electricity was not created by friction, but just moved due to the rubbing (Cohen 64). He provides a series of twelve experiments to show how he discovered these properties of a Leyden jar using his definitions of positive and negative electrification (Franklin 1941, 182-185). He further explains the Leyden jar in his fourth letter to Collinson, which was written in 1748 (Franklin 1941, 189). It begins with a discussion of charging and discharging phials, and the effects of these actions (Franklin 1941, 189). Franklin uses these experimental examples to show that, in the case of a Leyden jar, "...the whole force of the bottle, and power of giving a shock is in the GLASS ITSELF..."(Franklin 1941, 191). This was demonstrated by placing a plate of glass between two lead plates and electrifying the lead plates, and observing that the glass plate would give off sparks when the upper lead plate was removed (Franklin 1941, 192). Always looking for a chance to make electricity useful, Franklin then used this principle to build an electrical battery, using eleven sheets of plane glass with lead plates on both sides of each plane of glass all connected in a row (Franklin 1941, 193). Franklin used this idea to create what he calls a "magical picture," a picture with gilding inside the border of the frame on the front and back of the glass, and a gilt crown on the head of the subject. If this picture is electrified, someone holding onto the frame and trying to remove the frame will receive a shock (Franklin 1941, 194). Many uses for electricity were shown at a picnic described in the fourth letter, which included using electricity to

kill a turkey and to turn the spit upon which it was being roasted, with toasts being made with electrified glass tumblers which would shock the drinker (Franklin 1941, 200).

Franklin's fifth letter is the first to describe lightning as being electrical in nature, saying that the water rising from the ground to the clouds carries with it an electric charge (Franklin 1941, 205). The electric fire is discharged when the clouds approach a mountain, which will have less electrical fire than the clouds (Franklin 1941, 205).

Franklin also compares lightning to the electrical sparks created by electrical apparatuses, showing that both can be used to start fires, fuse metals, and rend bodies proportional to the power of the strike of the spark (Franklin 1941, 210-211). From a paper it is believed that he wrote in the same year as the fifth letter, Franklin repeats his proof of lightning as electricity, and proposes a needle-like apparatus to draw lightning off of buildings (Franklin 1941, 221). He asks "Would not these pointed rods probably draw the electrical fire silently out of a cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrible mischief?" (Franklin 1941, 222). Franklin then proposes an experiment to prove that lightning is the same as electricity, by using a metal rod to draw lightning to a person and observing to see if sparks come off the metal rod (Franklin 1941, 222). Later in this published work, letters from French experimenters confirm this experiment is valid and produces the expected results, for which Franklin received recognition from the French king (Franklin 1941, 256). He also received commendation from the Royal Society for this work after one of the members had replicated this experiment (Franklin 1941, 263). Franklin later wrote of his own modified performance of this experiment, his famed kite experiment (Franklin 1941, 265).

Franklin's kite was made of silk and cedar crossbars, with a piece of wire at the top and a

piece of silk ribbon with a key tied to the end of the twine (Franklin 1941, 265-6). The electrification can be seen by watching the hairs of the twine stand up, and the key can be used to show sparks or to charge electric phials (Franklin 1941, 266). These charged phials can then be used to repeat any electric experiments that had previously been performed, proving finally that lightning is the same as the electric sparks that had been produced by scientists (Franklin 1941, 266). Franklin uses this proof to his advantage, “I erected an iron rod to draw the lightning down into my house, in order to make some experiments on it, with two bells to give notice when the rod should be electrify’d” (Franklin 1941, 268). He planned to use this electricity to perform experiments, including attempts to discover whether lightning is positive or negative (Franklin 1941, 268). The results of this experiment were inconclusive, as the results came back as positive at times, and negative at others (Franklin 1941, 270). Franklin also proposes lightning rods, “Metalline rods, therefore, of sufficient thickness, and extending from the highest part of an edifice to the ground... will, I think, secure the building from damage, either by restoring the equilibrium so fast as to prevent a stroke, or by conducting it in the substance as far as the rod goes, so that there shall be no explosion but what is above it’s point, between that and the clouds” (Franklin 1941, 277). Franklin discovered a lot about the nature of lightning, and some protections against lightning due to its electric nature.

In his sixth letter to Collinson and the Royal Society of London, Franklin compares St. Elmo’s fire, the glow seen on ships around the mast, to electricity (Franklin 1941, 242). He provides an example where a mariner’s compass changes polarity after this phenomena had been observed, and then tells of how he and other experimenters in Philadelphia have polarized needles using an electric shock, both creating and reversing

the polarization (Franklin 1941, 242-3). Letter VII to Collinson was answers to questions that were put to him by the Royal Society of London, which Franklin answered, providing an experiment as part of his answer (Franklin 1941, 245-249). The eighth letter in the collection, published by Collinson as *Experiments and Observations*, made by Franklin was written to Franklin. It was written by Kinnersly, another member of the Library Company and a fellow experimenter of Franklin's (Franklin 1941, 250). Kinnersly writes of some observations that he has made that surprised him, mostly concerning the repulsion and attraction of electrified bodies (Franklin 1941, 250-251). The next few letters are a brief discourse on the attractions and repulsions between Franklin and Kinnersly, during which Franklin attempts some of the experiments that Kinnersly proposed and proved that some of the experiments were accurate (Franklin 1941, 252-254). Franklin's last letter to Collinson before he had to give over his studies of electricity for politics says that Kinnersly was able to repeat the experiment to determine the state of lightning, with a report that within a single storm the polarization changed from positive to negative several times, and gave a improvement to the original experiment that is simpler to perform (Franklin 1941, 280-281). The end of the book is a collection of letters from other people. One letter is written by David Colden, defending Franklin against Abbé Nollet, a French scientist who thought that Franklin was writing purposefully to refute his findings (Franklin 1941, 282). John Canton wrote a paper that was included of his observations and experiments proving Franklin's theories about lightning to be true, which Franklin later wrote an explanation for (Franklin 1941, 293, 303). Toward the end of his work, it becomes apparent that Franklin had to abandon his

experimentation and leave it in the hands of some of his contemporaries such as Kinnersly and Canton.

Franklin was called away from his studies to work for his newly forming country as an ambassador. His ambassadorial work would not have been as successful if it were not for the fame gained from his writings on electricity, especially in France. Franklin made several important contributions to the field of electricity, the single-fluid theory, an explanation of the Leyden jar, and confirmation that lightning is electricity in nature. Without Franklin, modern electricity would not exist in its current form.

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