

History of Electricity

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Preface

This paper was written in order to examine the order of discovery of significant developments in the history of electricity. It is part of my efforts to put the study of social and cultural history and social change on a scientific basis capable of rational analysis and understanding. This has resulted in a hard copy book *How Change Happens: A Theory of Philosophy of History, Social Change and Cultural Evolution* and a number of websites such as [How Change Happens](#) and [How Change Happens Rochelle Forrester's Social Change, Cultural Evolution and Philosophy of History website](#). There are also papers on [Academia.edu](#), [Figshare](#), [Mendeley](#), [Vixra](#) and [Social Science Research Network](#) websites and other papers on the [Discovery of Agriculture](#), [the Discovery of the Atomic World and the Constituents of Matter](#), and on [Guttman Scale Analysis and its use to explain Cultural Evolution and Social Change](#). Other papers by Rochelle Forrester include, [Rochelle's Philosophy Website](#), and works on Epistemology and the Philosophy of Perception such as [Sense Perception and Reality](#) and on [Slideshare](#), [Issuu](#) and [Scribd](#). Rochelle Forrester is a member of the [International Network for Theory of History](#).

Abstract

The history of electricity reveals a series of discoveries with the simplest discoveries being made first and more complex discoveries being made later. Some discoveries could not be made without certain prior discoveries having been made. The earliest forms of electricity to be experienced by people were those that occur naturally such as lightning and those resulting from simple activities like rubbing an object which causes electricity by means of friction. Systematic experimentation concerning electricity began after the scientific revolution with scientists constructing simple machines to create electricity and conducting simple experiments that showed electric charges could be positive or negative and that insulating material could stop an electric charge being lost from a charged object. Current electricity required the prior discovery of a battery such as the voltaic pile, and only when current electricity could be made, was it possible to discover the connection between electricity and magnetism. Once current electricity was produced, it was soon discovered that an electric current affected the behavior of a compass needle, leading to the invention of the electromagnet and eventually to Faraday's invention of the electric motor and the electric generator.

When practical electric generators and motors were invented, and the generation of electricity became economic, helped considerably by the invention of the electric light, the use of electricity began to spread throughout the first world and eventually the rest of the world. The order in which these discoveries were made was inevitable and given how valuable electricity is to human beings, it was also inevitable, that sooner or later in some society open to new ideas and technology, that electricity would be used to meet human needs. The order of discovery was inevitable and is an example of how social and cultural history has to follow a particular course determined by the structure of the world around us.

The magnetic properties of lodestone and the electric properties of amber had long been known and humans have always been aware of lightning. Lodestone, a magnetic oxide of iron, will align itself on a north-south axis if placed on a piece of wood floating in water. This enables it to act as a compass. Amber, if rubbed with certain materials, will attract light objects such as paper. The same phenomena can be observed with sulphur, glass, wax crystals and various gems. These natural manifestations of electricity and magnetism were first systematically studied by William Gilbert (1544-1603) in his book *On the Magnet*.

Electrical machines were made by Otto von Guericke in 1660 and Francis Hauksbee in the early 18th century. Guericke's involved a rotating sulphur ball which brushed against cloth and attracted various materials. Hauksbee's involved a rotating hollow glass ball which glowed when he touched it due to the friction between hand and ball. These types of machines were used by Stephen Gray (approximately 1670-1736) and Charles Du Fay in experiments that showed how an electric charge could be moved along a stick and a thread and that there were two types of electricity, a positive charge and a negative charge and that similar types repel each other and opposite types attract each other. Gray and DuFay also showed that insulating material could stop electricity from being lost from charged objects and anything could be provided with an electric charge so long as it is properly insulated.

The machines used by von Guericke, Hauksbee, Gray and Du Fay could collect a limited electric charge but it wasn't until 1745 when the Leyden jar was invented, that it was possible to store a substantial charge so it could be used in later experiments. The Leyden jar was a glass jar with metal foil on the inside and outside surfaces of the jar. The jar was charged by linking it to a charged body via a metal chain, causing the charged body to lose its charge to the Leyden jar. The charge when released could cause a substantial electric shock.

The next significant step in research on electricity was made by Benjamin Franklin (1706-90). Franklin conducted various experiments from which he decided all objects were normally in an electrically neutral state, but could by the use of friction gain electricity in which case they would be positively charged or lose it and be negatively charged. If an object was charged, whether positively or negatively, the electricity could be discharged to return the object to its electrically neutral state. This led Franklin to his idea of conservation of charge, that while electricity could be moved around, the amount of positive charge must be balanced by an equivalent negative charge, so that the total amount of electricity remains the same. Franklin was able to give Leyden jars both positive and negative charges and to show that the electricity was stored in the glass of the Leyden jar. Franklin's most well-known work with electricity were his experiments with lightning. His experiments, including the famous experiment of flying a kite during a thunderstorm, showed that lightning was a form of electricity.

The force between two electric charges is an inverse square law which was first discovered by Henry Cavendish in the 1760's. Cavendish however failed to publish his work which was eventually published by James Clerk Maxwell in 1879. The inverse square law is known as Coulomb's law and was first published in the 1780's when Coulomb carried out experiments on both the magnetic and electrical forces using a torsion balance. The torsion balance allowed Coulomb to measure the attraction and repulsion between two charged objects, suspended by an insulating fiber, so he could measure the force between the two charged objects.

The study of electricity in the 17th and 18th centuries had been limited to the study of static electricity. Static electricity involves a sudden rush of electricity like a flash of lightning. A steady flow of electricity along a wire is called an electric current. It was only with the invention by

Alessandro Volta of the voltaic pile in 1800 that scientists were able to study electric currents. The voltaic pile came from a mistaken discovery of animal electricity proposed by Luigi Galvani. Galvani had noticed that dead frogs jerked when they touched an iron fence while hung from a brass hook. Galvani thought the electricity came from the frog. Volta disagreed and conducted a series of experiments which suggested the electricity was caused by differences between the two metals.

All metals are reactive, in that they may lose or gain electrons, but some are more reactive than others. They can be considered as being in a reactive series running from the least reactive to the most reactive. When two metals far apart in the reactive series (one very reactive, one not very reactive) are placed on either side of a moist material, the more reactive metal, for example zinc, will lose electrons and the less reactive metal for example copper will gain electrons. This process constitutes an electric current which can flow through a wire connecting the two metals.

The voltaic pile consisted of a series of combinations of metals like copper and zinc, widely separated in the reactive series, and physically separated by a moist material, piled on top of each other and connected by a wire. It provided a flow of electric current that could be turned on and off at will. The current could be increased by adding more of the zinc, wet material, copper combinations or reduced by having fewer of these combinations within the pile. Volta's invention soon became a vital laboratory tool for studying electricity and for decomposing compounds and later when further progress was made it developed important applications outside the laboratory.

In 1820 Hans Oersted (1777-1852) discovered that an electric current affected the behavior of a compass needle. A compass needle is also affected by the force from a magnet so it seemed as though the electric current had the same effect as a magnet. This suggested electricity and magnetism were either the same force or closely related. Oersted's discovery also led to the invention of the electromagnet, a wire through which an electric current runs causing the wire to behave as a magnet.

In 1821 Michael Faraday was asked to write an article about Oersted's discovery and repeated his and others experiments. He also created his own experiments, one of which involved a vertical copper rod through which he ran an electric current. A magnet was placed near the bottom of the rod and the rod moved around the magnet. This involved the conversion of electrical energy into mechanical energy and was the world's first electric motor. In 1831 Faraday created an experiment which involved moving a magnet in and out of a circular coil of wire which created an electric current in the wire. This however only applied if the magnet was kept moving so the strength of the magnetic field near the wire was constantly changing. Oersted had discovered that an electric current that is moving electricity caused magnetism. Faraday had discovered that a moving magnet causes an electrical current. Faraday's discovery showed mechanical energy, such as motion, could be used to create electrical energy. This was the world's first electric generator or dynamo.

Faradays and others discoveries of the effects of magnets and electric currents on compass needles and on iron filings scattered around magnets or electric currents, which assume a pattern of concentric circles lead to ideas of lines of force. The lines of force were expressed mathematically by James Clerk Maxwell in 1873 in four equations which show how electric and magnetic fields behave in all circumstances. The equations applied equally to electrical phenomena as to magnetic phenomena so that the process of unifying electricity and magnetism into an electromagnetic theory was complete. A remarkable feature to come out of Maxwell's work was the electromagnetic fields traveled at the same speed as the speed of light. The speed of light had recently been measured with some accuracy by Armand Fizeau (1819-1890) and Leon Foucault (1819-1868) and Maxwell's theory showed that light was a form of electromagnetic radiation.

Faradays discovery of the electric generator and the electric motor were to change the world. The first practical electric motor was created by the American Thomas Davenport in 1835. Davenport's motor used an electromagnet, a wire through which an electric current flows, to create a magnetic field. The electromagnet, like an ordinary magnet has a north and south pole. However the poles of the electromagnet can be changed by changing the direction of the flow of the electric current. A needle placed between the poles will move in one direction and then when the current is reversed will swing all the way round in a circle, to point to the new pole. If the current of the electromagnet is constantly reversed at the right time the needle will continue going round and round. Davenport's motor could drill holes in steel and was used to run a printing press. However the motor was uneconomic due to its source of electric power being a battery.

It was not until the late 19th century when a number of developments came together that electric power and electric motors became economic. In 1873 Zenobe Gramme built a practical electric generator that allowed rotary power to be turned into electric current. Previous generators tended to overheat due to the action of the armature, the moving part of a generator. Gramme's generator solved this problem so making it practical for power generation to begin. The world's first power generation station opened in England in 1881 supplying hydro-electric power to the local city council and to private premises. The station closed down in 1884 as it was unprofitable possibly because electric lighting cost more than gas and early light bulbs did not last long. In 1882 another power station using steam power opened in London and a power station using six generators was opened in New York.

A dispute arose as to whether electricity generation should use direct current or alternating current. Direct current had the advantage that it was cheaper for urban areas and rechargeable batteries could be used with it to ensure continuity of supply if generators broke down. Alternating current had the advantage that it was cheaper to transmit over long distances. This is because when electricity is transmitted over long distances, the transmission voltage is increased in order to reduce losses of electricity. When the electricity is sent to individual consumers transformers are needed to lower the voltage. Direct current transformers are complex and expensive, while alternating current transformers are simple and cheap. Thomas Edison backed direct current and George Westinghouse supported alternating current and Westinghouse was successful when he was able to supply the machinery for the Niagara Falls hydro-electric station. Improvements in generators ensured fewer breakdowns in supply and the benefits of economies of scale with large power stations requiring long distance transmission of electricity meant alternating current was always going to be the better system in the longer term.

Around the start of the 20th century the steam turbine, invented in 1883, began to be increasingly used in electric power stations. The steam turbine had fewer moving parts than a piston driven steam engine so it could run smoothly at greater speeds than a piston driven steam engine. Modern electric power stations may be fueled by coal, oil or nuclear power or use the kinetic energy of falling water to make hydro-electric power.

A crucial development in the spread of electric power was the development of the electric light. When an electric current moves through a wire it creates heat. The heat is caused by the resistance of the wire which results in electrical energy being converted to heat energy. If the current is strong enough the wire will glow. An 1845 patent by J.W. Starr proposed the use of carbon filaments, as carbon is a good radiator of heat, inside a glass bulb containing no air so as to prevent the hot filament being burnt away. Joseph Swan tried to produce such a light but was not successful as it was not possible to create a perfect vacuum within the bulb with the vacuum pumps then available. Swan also decided the light needed a better source of electricity than batteries. The problem of creating the vacuum was solved when Herman Sprengel invented the mercury vacuum pump and in 1879 Swan produced a vacuum electric light. In the same year Thomas Edison produced his electric light and then both Swan and Edison began manufacturing the light bulbs, initially in competition, but later in partnership. The electric light was improved by the use of tungsten, which has a very high melting point in the filament when William Coolidge discovered how to create a tungsten filament, a difficult job given that tungsten is a hard and brittle material. Further improvements made were to fill the bulbs with a chemically inactive gas such as argon and to wind the filament into a coil, both improvements considerable extending the life of the light bulb.

The coming together of a reliable system of generating electricity, the invention of the electric light bulb and the invention of reliable electric motors was to result in the electrification of first world countries in the 20th century. In industry electric motors were to drive all sorts of machines such as drills, grinders, lathes, rolling mills, conveyor belts and cranes. Steam engines which originally provided the power for factories, operated by means of belts and pulleys which is far less flexible than simply plugging a machine into a power point, which became possible with electric power generation and electric motors. In transport electric trams and railways became common place. In the home electric motors powered by electricity generated far away and transmitted to the home was soon driving vacuum cleaners, washing machines, driers, waste disposal units, food mixers and dishwashers. Electricity in the home also powered lights, air conditioning, heaters, computers and televisions. Electric lighting allowed work and entertainment to take place at night and made the

streets safer at night. Electricity also operates in communication systems such as the telegraph and the telephone. The use of electrically powered lifts has allowed the building of modern skyscrapers.

It is quite apparent if it was not possible to generate electricity many of the things we take for granted in modern life would not exist. Television, telephones, radio, computers, electric lighting and heating would not be possible without the discovery of economic electricity generation and how to control and manipulate electricity.

Electricity has had an enormous effect on the modern world. It has however only been possible due to the structure of the world we live in. Our world is largely made up of objects which are made up of atoms and all atoms contain electrons. It is only because electrons exist and because objects and atoms are able to lose and gain electrons that electricity is possible. Electricity is simply the transfer of electrons from one object to another and this process can generate heat and light and by means of an electric motor can be turned into mechanical energy. It is these properties of electrons and electricity that have resulted in electricity having its revolutionary effect on human society and on human social and cultural history. If electrons did not exist or they were unable to move from atom to atom and from object to object electricity would not exist and the most convenient and possibly the only method available to humans of moving energy over long distances and using it efficiently in the home would not be available to us. If electricity did not exist there would be no telephones, television, computers, electric lighting and heating and the use of electricity in industry and transport.

The history of electricity reveals a series of discoveries with the simplest discoveries being made first and more complex discoveries being made later. Some discoveries could not be made without certain prior discoveries having been made. The earliest forms of electricity to be experienced by people were those that occur naturally such as lightning and those resulting from simple activities like rubbing an object which causes electricity by means of friction. Systematic experimentation concerning electricity began after the scientific revolution with the scientists constructing simple machines to create electricity and conducting simple experiments that showed electric charges could be positive or negative and that insulating material could stop an electric charge being lost from a charged object. This led to the invention of the Leyden jar which enabled electricity to be stored and used in later experiments. Franklin was able to do experiments using Leyden jars which further increased human knowledge of electricity. Up to this time only static electricity had been studied as it was much easier to create static electricity. Current electricity required the prior discovery of a battery such as the voltaic pile before the scientific study of current electricity could commence. It was only when current electricity could be produced and experimented with was it possible to discover the connection between electricity and magnetism. Once current electricity could be produced it was soon discovered that an electric current affected the behavior of a compass needle leading to the invention of the electromagnet and eventually to Faraday's invention of the electric motor and the electric generator. When practical electric generators and motors were invented and the generation of electricity became economic, helped considerably by the invention of the electric light, the use of electricity began to spread throughout the first world. The order in which these discoveries were made was inevitable and given how valuable electricity is to human beings, it was also inevitable, that sooner or later in some society open to new ideas and technology, that electricity would be used to meet human needs.