Michael Faraday

British physicist and chemist

In the 1820s, British physicist and chemist Michael Faraday sprinkled iron filings on a piece of paper and guided an electromagnet beneath it to illustrate lines of magnetic force. Since then, generations of students have learned about the principle of magnetic fields and other basics of electromagnetism from repeating this simple exercise. Faraday's discovery of magnetic fields remains one of the most significant contributions to science and provided the foundation for the development of the telegraph and other important innovations.

Born: September 22, 1791; London, England

Died: August 25, 1867; London, England

Primary fields: Physics; chemistry

Specialty: Electromagnetism

Early Life

Michael Faraday (FEH-ruh-day) was born on September 22, 1791, in Newington, London, England. His family was poor; his father worked as a blacksmith. With three other children in the family, young Faraday sometimes went hungry. When he was twelve years old, Faraday took a job as an errand boy for a local bookseller, marking the end of his formal education. Two years later, he was apprenticed to a bookbinder, a position he would hold for the next seven years. A naturally curious youth with access to many books, Faraday read everything that looked engaging, including books on electricity and chemistry.

During this period, Faraday attended four of the weekly lectures given by Sir Humphry Davy, a professor of chemistry and director of the Royal Institution of Great Britain. Faraday took detailed notes at the lectures and began to conduct simple experiments by himself. When he was twenty-one years old, Faraday was hired as Davy's assistant and began working in the lab at the prestigious Royal Institution.

Davy was impressed with Faraday's enthusiasm, and offered to take him along on a cultural and scientific journey to France, Italy, Belgium, and Switzerland. This was Faraday's first trip outside of London, and it broadened his horizons immensely. He climbed Mount Vesuvius, visited a French laboratory, and experimented with

glowworms. While in Florence, Davy and Faraday burned a diamond and concluded that it was composed of pure carbon, much to the dismay of many diamond owners.

After returning from his trip, Faraday was promoted to assistant in the Laboratory and Mineral Collection and Superintendent of the Apparatus at the Royal Institution. Faraday and Davy continued to collaborate, and in 1816 they invented a safety lamp for miners.

Life's Work

By 1819, Faraday had distinguished himself as one of the most prominent chemists in England. He was the first to liquefy certain gases, such as carbon dioxide, which were previously thought to be incapable of undergoing change. Some of these experiments resulted in the discovery of tetrachloroethene, also called perchloroethene and used in dry cleaning as a water repellent, and as an industrial cleaning solution. Faraday's lab work was quite dangerous, and he suffered minor injuries from accidents with chlorine and other substances.

In the early 1820s, the British Admiralty requested the assistance of Davy and Faraday in finding a way to prevent the corrosion of copper-plated ship bottoms. After solving this problem, the chemists sought to improve optical glass used in telescopes, which would allow for more accurate navigation.

In 1825, Davy retired and Faraday was selected to replace him as the director of the laboratory at the Royal Institution. He discovered benzene and naphthalene, which later became important to the development of the pharmaceutical industry. He researched the composition and manufacture of alloy steels, and his work resulted in the first steel razors.

Despite his success, Faraday was not interested in obtaining patents or working in the manufacturing sector, which would have made him quite wealthy. Instead, he used his talents to seek out scientific truths and to share his findings freely with the world.

In December 1826, Faraday began offering a series of lectures for children at the Royal Institution, intending to spark an early interest in science. Referred to as the Christmas Lectures, they demonstrated his interest in education and his talent for communicating with

During the early nineteenth century, several scientists were studying the relationship between electricity and magnetism, first discovered by Hans Ørsted in 1820. Using the failed experiments of Davy and British chemist and physicist William Wollaston as a guide, Faraday successfully produced electromagnetic rotation, the basis of the

electric motor, in 1821. After neglecting to acknowledge their work in his paper, Faraday was assigned to work on other projects at the laboratory. However, he continued experimenting with electromagnetism in his spare time.

By the end of the 1820s, French physicists Charles-Augustin de Coulomb and André-Marie Ampère, as well as Ørsted had shown that stationary charges produce electric fields on other stationary charges. They also found that moving charges similarly create magnetic fields. Faraday believed that if electricity produced magnetic fields, that magnetic fields should somehow induce a current. In 1831, Faraday placed two coils of copper wire within the magnetic field created when a current was passed through the first coil. The coils were insulated from each other to prevent the transfer of electricity. Faraday was disappointed that he saw no effect on a magnetic needle placed by the second coil.

Faraday continued experimenting using larger coils of wire, a more sensitive galvanometer, and a more powerful battery. He was surprised by the results of his third experiment: a fast, slight movement on the galvanometer when contact was made or when contact was broken with the battery. However, Faraday noticed no effect when the current flowed steadily.

Next, he replaced the galvanometer with a nonmagnetized iron needle within a solenoid. He found similar results—the needle moved when the current through the first coil was altered. The needle was left magnetized with a polarity opposite of the first coil's field. Faraday had discovered electromagnetic induction, later known as Faraday's law.

The nonmathematical version of the law is commonly stated as the induced electromotive force (emf) across a closed-circuit of thin wire equals the time rate of change of the magnetic flux through the circuit. The emf is measured in volts and is generated by the magnetic field. Magnetic flux is basically the strength of a magnetic field across a given surface area, measured in volt-seconds. Faraday published his findings in his 1839 work *Experimental Researches in Electricity.*Scottish physicist James Maxwell later reinterpreted the law mathematically; that equation became one of four known as Maxwell's equations that explain field theory.

Faraday continued his research, rotating a copper disc on edge between the poles of a horseshoe magnet. He found a constant voltage was produced across the disc. Faraday's disc, as it became known, was the first simple generator.

Faraday's Law of Electromagnetic Induction

children. Topics included magnetism, electricity, and gravitation. Many of these lectures became standard curricular materials in schools around the world. The most well-known lecture, “The Chemical History of a Candle,” was first published in 1861 and remains in print today. The popular lecture series was continued throughout the twentieth century by Faraday’s successors, and in later generations it was transmitted to millions of children via television.

In addition to his lectures for children, Faraday began the Friday Evening Discourses for the general public and also lectured to members of the Royal Institution. He also published dozens of scholarly articles. In the late 1820s, Faraday was appointed professor of chemistry at the Royal Military Academy in London, where he spent the next twenty-five years preparing and delivering lectures.

Faraday’s interest in electromagnetism began in the early 1820s, when he surveyed all available research on the topic for a paper entitled “Historical Sketch of Electro-magnetism.”

Following in the footsteps of Hans Christian Ørsted, who discovered electromagnetism, and André-Marie Ampère, who determined that the force around a wire is circular, Faraday created a device that is considered the first rudimentary electric motor. He subsequently discovered the phenomenon known as electromagnetic rotation, or the movement of the circular magnetic force.

Faraday was distracted by other research, and it wasn’t until the 1830s that he returned to electromagnetism. On August 29, 1831, a date widely considered the birth of the electric industry, Faraday took an iron ring and wrapped separate coils of wire around the opposite sides. He connected one coil to a galvanometer, which used a needle to detect electric current. He attached the other coil to a battery. When the battery was connected, the galvanometer’s needle moved, proving that an electric current had been induced from the second coil into the first. This experiment demonstrated the principle of electromagnetic induction, and it gave the world its first transformer. Later that year, Faraday built and demonstrated the first electric generator.

From this and other experiments performed in 1831, Faraday devised three laws of electromagnetic induction: a changing magnetic field will produce an electric current within a circuit; the electrical force is proportional to the rate of change in the field; and the direction of the rate of change in the field will affect the force.

In 1833, Faraday was named professor of chemistry at London’s Royal Institution. For the rest of the decade he continued to conduct experiments that would prove his theory that all forms of electricity (voltaic, electromagnetic, and static) contained

similar properties and produced the same effects. His research provided the foundation for the new discipline of electrochemistry.

By the end of the decade, Faraday was exhibiting symptoms of stress. He took a long vacation to Switzerland and limited his work to publishing and lecturing. He returned to the lab rejuvenated, and in 1845 he made another important discovery.

In a series of experiments involving light and magnetism, Faraday demonstrated what is now called the Faraday effect, which states that the direction of the plane of polarization of light waves is dependent upon the direction of the magnetic field. The study of this phenomenon became known as magneto-optics. Faraday also discovered that glass and all other materials—not just iron, cobalt, and nickel—had the potential to be affected by magnetism. He termed this new study of magnetic materials diamagnetism.

Faraday's health began to decline in the 1850s. In 1858, he moved into Hampton Court, a palace presented to him by Queen Victoria for his lifetime of achievement. Faraday did not accept the queen's offer of a knighthood, nor did he accept the presidency of the Royal Institution, which was offered to him in 1864.

Impact

Faraday's work had a significant impact on various scientific fields and lead to several modern technologies, including generators, electric motors, benzene, and Bunsen burners. Two units of measure are named in his honor: the farad, which is used to determine the storage potential of a capacitor (a device used to store an electrical charge), and the faraday, a unit of electricity. The Faraday constant, which represents the amount of electrical charge carried by one mole of electrons, is an important constant in chemistry, physics, and electronics and is commonly symbolized by an italicized uppercase *F*.

In addition to his achievements in electromagnetism, electricity, and physics, Faraday also contributed to analytical and organic chemistry and engineering. His work carried considerable commercial applications as well. Among Faraday's last projects was his research on electric lights for lighthouses. In 1861, due to his deteriorating memory, he resigned his position with the Royal Institution. He died at his home on August 25, 1867.

Sally Driscoll

Further Reading

Hirshfeld, Alan. *The Electric Life of Michael Faraday.* New York: Walker, 2006. Print. A biography of Michael Faraday and descriptions of his discoveries.

James, Frank A. J. L. *Michael Faraday: A Very Short Introduction.* New York: Oxford UP, 2010. Print. A brief introduction to Faraday and his work. References and further reading included.

Klein, Maury. *The Power Makers: Steam, Electricity, and the Men Who Invented Modern America.* New York: Bloomsbury, 2008. Print. Narrative history describing the introduction of steam and electric power to the United States. Faraday's contributions to the study of electricity are detailed.