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FARADAY BICENTENARY

Tribute to Michael Faraday

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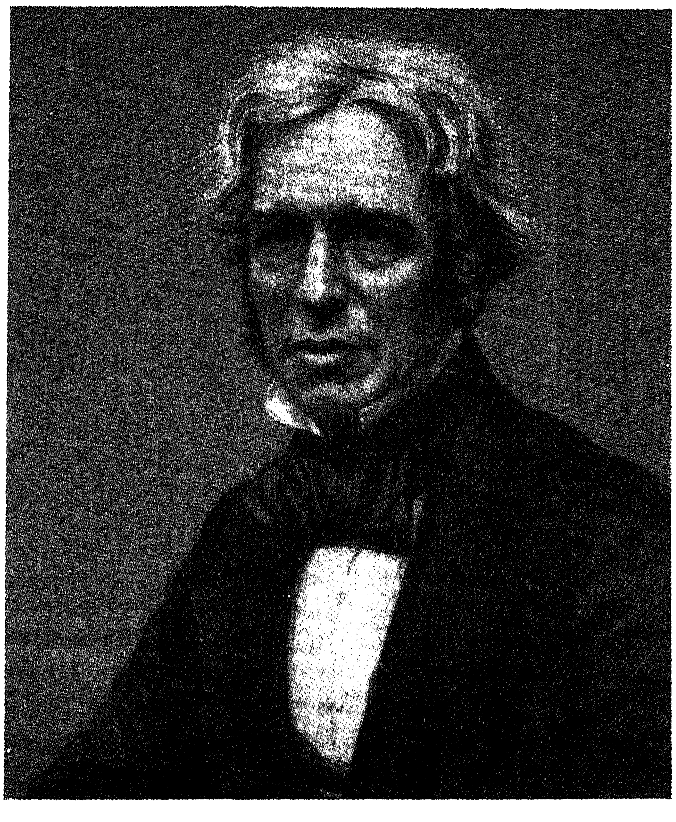
Michael Faraday was an experimental genius with unparalleled accomplishments. His inexhaustible thirst for knowledge led him to explore a variety of vital problems in chemistry and physics. He has left a legacy of such splendour that it continues to evoke admiration and awe from every generation. Faraday was 'not of an age, but for all time'.

The year 1991 marked the bicentenary of the greatest experimental philosopher the world has known, Michael Faraday. It is difficult to think of another experimental scientist who has left such an indelible mark of achievement in pure and applied science as Faraday. His monumental contributions to science span a variety of fields, including chemistry, physics, materials science and engineering. One is left wondering whether such an individual ever lived. Clearly Faraday was a unique human being gifted with extraordinary imagination and experimental creativity. His life has elicited a romantic response one generation after another. We get some insight into the personality of Faraday through his own words:



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> Do not suppose that I was a very deep thinker or was marked as a precocious person. I was a very lively imaginative person and could believe in the Arabian Nights as easily as in the Encyclopaedia. But facts were important to me and saved me. I could trust a fact and always cross-examined as assertion.

He possessed a child-like awe and a great sense of purpose combined with humility. Faraday was not spoiled by formal education; he was self-taught. He left school at the age of thirteen and started his career as an errand boy, then as a bookbinder, and rose to become one of the greatest scientific giants. He was a prolific writer and wrote about 450 research publications. There is not a single mathematical equation in any of his works, because he knew no mathematics. Yet, as Albert Einstein remarked, Faraday was responsible, along with Maxwell, for the greatest change in the theoretical basis of physics since Newton.

Biography

Faraday was the third child of a blacksmith, born in Newington Butts near London on 22 September 1791. After merely learning elementary reading, writing and arithmetic, he left school and worked first as a newspaper boy and then learnt the art of bookbinding. While doing so, he also took interest in the contents of scientific books and began to do simple experiments in chemistry by spending a few pence every week. He attended some of the lectures of Sir Humphry Davy in 1812 at the Royal Institution in London and became so impressed by what he heard and saw that he sought an appointment under Davy. He accompanied Davy as his secretary and scientific assistant for 18 months on an European tour during 1813–15. During this period, although France and Britain were at war, Napoleon had decreed that scientists were free to meet and exchange ideas. On this tour Faraday met great scientists such as Ampère, Dumas, Gay-Lussac, Humboldt and Volta. On his return from Europe in 1815, Faraday was appointed assistant and superintendent of apparatus at the Royal Institution. He wrote his first research paper in 1816 on the analysis of native caustic lime. He was married in 1820, and was elected fellow of the Royal Society in 1824.

During the mid-1820s, Faraday initiated his educational experiments and his communication with the public through popularization of science. Faraday's evening discourses soon became famous. His Christmas lectures became legendary. Faraday was not a born lecturer. Yet, by common consent, he became easily one of the greatest lecturers. He had much to say on how to lecture (see box). Faraday's most famous lecture series on 'The chemical history of a candle' (first published in 1850) has become a classic.

Faraday became the first Fullerian professor of chemistry at the Royal Institution in 1834 and continued to work there till his retirement. His last major publication in chemistry was in 1857 on 'Experimental relations of gold and other metals to light' and dealt with colloidal metals. (Some of the metal sols made by Faraday are still preserved.) His last major papers in physics were in 1862 on the influence of a magnetic field on the spectral lines of sodium, and on the lines of force and the concept of a field.

In 1855 Queen Victoria granted Faraday the favour of a house at Hampton Court, where he died peacefully on 25 August 1867. He was buried in a simple grave not far from that of Karl Marx. On the grave of Karl Marx is written, 'Philosophers interpret the world, the task however is to change it.' Today, it is not difficult to decide who really changed the world, Karl Marx or Michael Faraday.

The art of lecturing

A lecturer should exert his utmost effort to gain completely the mind and attention of his audience and irresistibly make them join in his ideas to the end of the subject. He should endeavour to raise their interest at the commencement of the lecture and by a series of imperceptible gradations, unnoticed by the company, keep it alive as long as the subject demands it.

His whole behaviour should evince a respect for his audience, and he should in no case forget that he is in their presence.... He should never, if possible, turn his back to them, but should give them full reason to believe that all his powers have been exerted for their pleasure and instruction.

A lecturer should appear easy and collected, undaunted and unconcerned, his thoughts about him and his mind clear for the contemplation and description of the subject. His action should be slow, easy and natural, consisting principally in changes of the posture of the body, in order to avoid the air of stiffness.

The most prominent requisite to a lecturer, though perhaps not really the most important, is a good delivery; for though to all true philosophers science and nature will have charm innumerable in every dress, yet I am sorry to say that the generality of mankind cannot accompany us one short hour unless the path is strewed with flowers.

A lecturer may consider his audience as being polite or vulgar ... learned or unlearned (with respect to the subject) listeners or gazers. Polite company expect to be entertained.... The vulgar ... wish for something that they can comprehend.... Listeners expect reason and sense, whilst gazers only require a succession of words.

In lectures and, more particularly, experimental ones, it will at times happen that accidents or other incommoding circumstances will take place. On these occasions, an apology is sometimes necessary, but not always. I have several times seen the attention of by far the greater part of an audience called to an error by the apology.

Digressions and wanderings produce more or less effects of a complete break or delay in the lecture.... For the reason (that the audience should not grow tired), *I disapprove of long lectures*; *one hour is enough for anyone and they should not be allowed to exceed that time.*

Scientific contributions

Faraday's contributions to science are truly mind-boggling, considering their originality and quality and also the fact that they were all carried out by a single person. One can classify his contributions under the broad headings of physics and chemistry, although many would fall under both categories. Some would come under what in recent times is considered to be materials science. It is therefore not surprising that the Faraday Society, when it was established, was chartered to explore interdisciplinary areas related to different divisions of natural philosophy. Faraday himself did not want to be considered a physicist but wanted to be known as an experimental philosopher.

The range and number of major breakthroughs accomplished by Faraday are stupendous (see boxes). If ever there were Nobel prizes during Faraday's time, it is my guess that he could have won at least five (for electromagnetic induction, laws of electrolysis, magnetism and Faraday effect, discovery of benzene, and the notion of a field). Many people forget that it was Faraday who coined the words diamagnetism and paramagnetism. The idea of a field that physicists use all too frequently today was first conceived of by Michael Faraday. What is amazing is that he did so without recourse to mathematics. Faraday felt that Coulomb's law was not sufficient to describe the forces between charges; to understand what occurred in the intervening space, he invoked induction, permittivity and so on. It is Faraday's notion of a field that led to Maxwell's great discoveries at a later date. Here it would be most appropriate to recollect the providential statement of Faraday (1845) where he says,

> I have long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent that they are convertible, as it were, one into another, and possess equivalents of power in their action.

Major contributions to physics

1821	Electromagnetic rotation
1831	Electromagnetic induction
	Acoustic vibrations
1832	Identity of electricity from various sources
1835	Discharge of electricity through evacuated gases (plasma physics)
1836	Electrostatics
1845	Relationship between light, electricity and magnetism; diamagnetism and paramagnetism, magneto-optics
1849	Gravity and electricity
1857	Time and magnetism
1862	Influence of a magnetic field on the spectrum of sodium
	Lines of force and the notion of a field

Major contributions to chemistry and materials science

1816	Evolution of miners' safety lamp (with Humphry Davy)
1818–24	Preparation and properties of alloy steels
1812–30	Purity and composition of clays, native lime, water, gunpowder, rust, various gases, liquids and solids (analytical chemistry)
1820–26	Discovery of benzene, isobutylene, tetrachloroethylene, hexachlorobenzene and isomers of naphthalenesulphonic acids (organic chemistry).
	Photochemical reactions
1825–31	Production of optical-grade glass
1823, 1845	Liquefaction of gases (H_2S, SO_2, etc.); Existence of critical temperature and continuity of state.
1833–36	Electrochemistry; laws of electrolysis
	Equivalence of various forms of electricity
	Thermistor action
	Fused-salt electrolytes; superionic conductors
1834	Heterogeneous catalysis; surface reactions
	Adsorption; wettability of solids
1835	Plasma chemistry
1836	Dielectric constant, permittivity
1845–50	Magnetochemistry, magnetic properties of matter
	Faraday effect, diamagnetism, paramagnetism, magnetic anisotropy
1857	Colloidal metals, sols and hydrogels.

Faraday's contributions to chemistry are extraordinary. Many chemists believe that Faraday was one of their kind, which, apart from being correct, draws our attention to how this great chemist also did great physics. Some of the important chemical compounds discovered by Michael Faraday are benzene, tetrachloroethylene, isobutylene and hexachlorobenzene.

It is revealing to analyse the productivity of Faraday during different periods. When one does so, the year 1833 particularly stands out. From his laboratory notebooks, one sees that he discovered fused-salt electrolysis in February 1833 and identified superionic conductivity in silver and other halides the same month. In early November, he did some work on catalytic activity of platinum and, on 22 November, he worked on the separation of gases such as ethylene and carbon dioxide. On 25 November Faraday carried out investigations on the wettability of solids such as quartz. In mid-December, he worked on the equivalence of electricity from various sources and, later that month, carried out studies that led to the laws of electrolysis. On 24 December, he did experiments on chemical changes brought about by the passage of electricity through molten tin chloride. On 26 December he did an important experiment on the decomposition of lead halides and other salts. There was no entry for the 25 December (Christmas day).

Epilogue

Clearly Faraday was a genius propelled by an urge to explore. He was painstaking, hard-working, dedicated and incorruptible, and was a storehouse of intellectual energy. His creative contributions spanned a period of around 50 years since his first publication in 1816. He was a great builder of instruments and a daring experimentalist. He would demonstrate static electricity to the public by locking himself in a 'Faraday cage'; he burnt diamond to show that it was nothing but carbon. His accounts of the various experiments are a marvel of thoroughness. In some of his papers, Faraday suggested how best to attack a problem (for example, in his paper 'Two new compounds of chlorine and carbon'). Faraday did not have to worry about pure and applied research (as many do now). Most of Faraday's research found application and one cannot better his record of spin-offs from fundamental research. His contribution to modern electrical industry is obvious. The laws of electrolysis govern all that has happened in electrochemical technology and industry. Faraday was the first to discover thermistor action. He was one of the earliest to identify superionic conductivity. He liquefied gases, purified them, and carried out catalytic reactions. Faraday believed that experiment provided the only way to understand nature. As he said,

> Nothing is too wonderful to be true, if it be consistent with the laws of nature and in such things as these, experiment is the best test of such consistency.

There is no better way of paying tribute to Michael Faraday than by recounting the words of Rutherford:

> The more we study the work of Faraday with the perspective of time, the more we are impressed by his unrivalled genius as an experimental and a natural philosopher. When we consider the magnitude and the extent of his discoveries and their influence on the progress of science and of industry, there is no honour too great to pay to the memory of Michael Faraday—one of the greatest scientific discoverers of all time.

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