

MICHAEL FARADAY, F.R.S.

GRAND MASTER OF EXPERIMENT

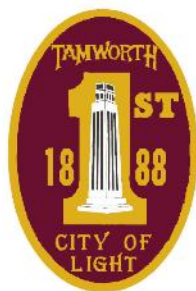
**150TH ANNIVERSARY - 25 AUGUST 2017
SPECIAL EDITION**



TAMWORTH POWERSTATION MUSEUM

**216 Peel Street
TAMWORTH - N.S.W.**

**REVISED AUGUST 2017
RON GREER**



150th ANNIVERSARY - FARADAY'S PASSING

Friday, 25th August, 2017, marks the 150th anniversary of the passing of Michael Faraday, acknowledged father of the magic electric age in which we are blessed to live. On this Friday, the Tamworth Powerstation Museum will pay tribute to this brilliant natural philosopher of the Royal Institution of Great Britain with a special display of Faraday's experimental apparatus. This will include hands-on demonstrations of Faraday's great discovery of electromagnetic induction which is at the very heart of our electrical age, with a working replica of his first dynamo of 1831..

These days (apart from the prices) we don't stop to think much about life before electricity; this strange stuff which we cannot see or hear, that does not smell and cannot be weighed, wrapped up, or put in a bottle. Whilst everyone uses electricity and knows what it can do, even today most people do not know what it is. Life without electricity only comes to mind when suddenly it's not there; like when the car won't start, the phone is dead, or the lights have gone out. Electricity is all pervading in our daily lives in this magic electric age in which we live.

It is the principles of electromagnetic induction discovered by Faraday in November of 1831 which operate in every generator, motor, telephone, radio, television, computer, etc, etc; and is the means by which we are able to generate unlimited electricity.

What do we know of Faraday? his life, his personality, his work, or his many other life changing discoveries benefiting us all?

MICHAEL FARADAY FRS

GRAND MASTER OF EXPERIMENT

1791 – 1867

Founder of the electrical age

FARADAY – WHAT FOR US?

Imagine, if you can, the consequences throughout the world of halting every electric current that is flowing at this very moment; all electricity generation would stop, as would every electric motor, radio, telephone, television, petrol engine, aeroplane, X-Ray machine, navigational aid, every computer, every light together with the machines which set up the type and printed this paper. All these things working on the principles first enunciated by Faraday.

Few men have changed the world so profoundly, enhancing the lives of so many people, as has Michael Faraday. It was the brilliant mind of this mighty experimenter which unlocked one of Nature's most closely hidden secrets - the principles of electromagnetic induction.

This astonishing discovery, uncovered in a series of brilliant experiments reaching their climax during October 1831, is the means by which electricity generation is brought about, together with the modern high technology on which our comfortable way of life depends.

RAISED IN POVERTY

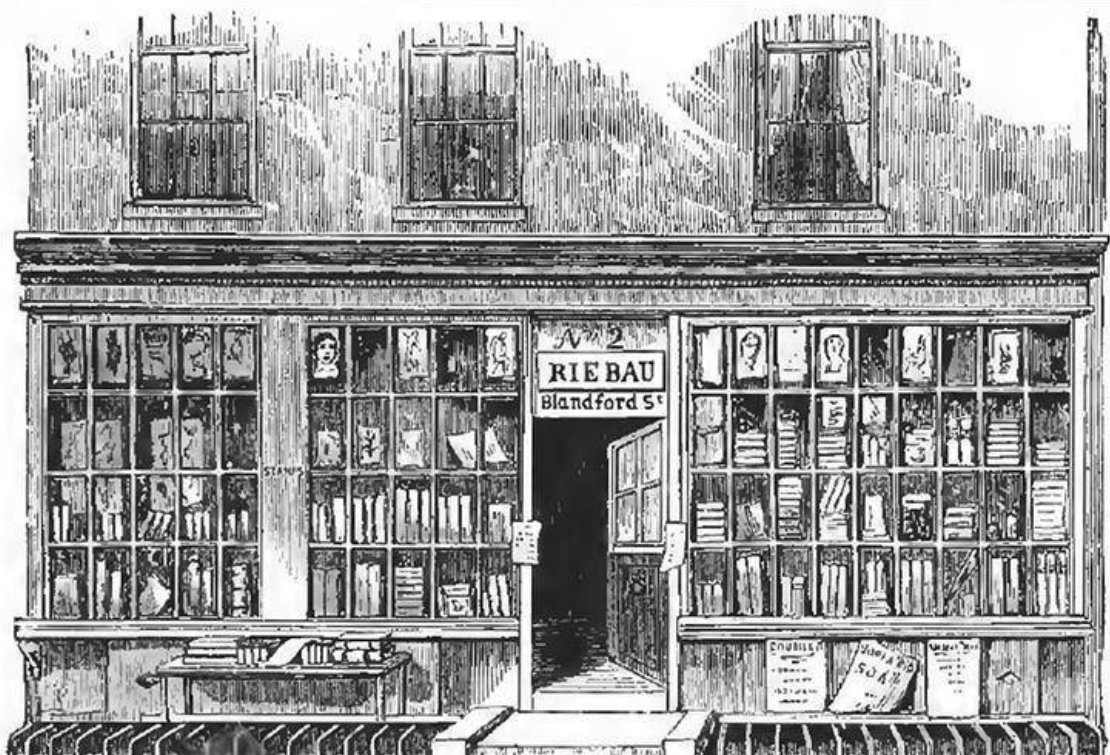
Blacksmith James Faraday and his wife Margaret (Hastwell) left their smithy at Outhgill near Kirkby Stephen, Cumberland, in early 1791 bound for London. Their third child, Michael, was born on 22nd September, 1791, at Newington Butts, Surrey, (a country village now a part of South London). James Faraday's health was failing and with the family in poor circumstances they moved to London when Michael was five years old. The long war with Napoleon had affected the whole population and extreme poverty was on the increase as the

eighteenth century drew to a close. When Michael was nine years old he was given a loaf of bread which he had to make last for a week.

His father was too ill to provide for the family and his mother could not afford to send him to school. There were no public schools so his formal education was almost non-existent. He received no more than the most elementary schooling, learning only the rudiments of reading, writing and simple arithmetic at a Sandemanian¹ church Sunday school.

In 1804 at the age of 13 Michael Faraday commenced work as an errand boy to George Riebau, a newspaper agent and bookbinder at 2 Blandford Street (near Manchester Square) who had fled from the French Revolution. It was Michael's duty to carry around the news sheet of the day to the various subscribers in turn, giving to each person the allotted time for reading it.

Riebau used to buy up job lots of printed material in sheets to bind them and sell them as books. He took a liking to his young errand boy, and after a year, apprenticed him without asking for the customary fee. Michael's apprenticeship in the trade of book binding was for seven years and, according to the custom of that time, lived in his master's house.



George Riebau's newspaper and book shop at No2 Blandford Street

SELF EDUCATION

Faraday made his book-binder's bench his school; satisfying his boundless curiosity by reading the pages as he bound them together. There was no light reading of the modern kind; the literature all being of the mature style of the day as may be found in *The Vicar of Wakefield*.

1. A small protestant Christian sect founded in Scotland about 1730 and spread into England and America by Robert Sandeman 1718 – 1781.

He enjoyed *The Arabian Nights*, however he found a deeper interest in scientific works like Mrs Marcet's² *Conversations on Chemistry* and writings which made him think, like the great Dr Isaac Watts' *The Improvement of the Mind*.

Articles concerning science particularly fascinated him. As he worked he noticed the article "Electricity" by the noted chemist, James Tytler in a copy of the 3rd Edition of the *Encyclopedia Britannica* (Founded in 1768, now in its 15th Edition) which he was putting into covers. This he read with great interest, after which he continued to read all he could possibly find on electricity, magnetism and chemistry. There were no night schools, correspondence courses or public libraries from which he could gain scientific enlightenment. He was fortunate however, to hear about the City Philosophical Society which met each Wednesday night at 53 Dorset Street in the house of its founder, John Tatum, whose custom it was to deliver a scientific lecture before opening his library to the members. In February 1810 Michael's elder brother, Robert, was able to afford to pay for his young brother's attendance; one shilling a lecture.

Here he received a basic education in the sciences, taking careful notes on lectures in electricity, galvanism, hydrostatics, optics, geology, theoretical mechanics, experimental mechanics, chemistry, pneumatic chemistry, astronomy and meteorology. These lectures were however, mostly very elementary, often being little more than a collection of facts. He practised drawing to illustrate his notes and soon mastered several experiments. It was at the City Philosophical Society that Faraday first saw Volta's pile in operation, after which he made an electric battery himself.

A CHANCE INTRODUCTION TO THE ROYAL INSTITUTION

One day he was busy working at his trade when one of Riebau's customers, William Dance, came in and saw the 20 year old studiously poring over a treatise on electricity. Dance enquired into his habits, about his aspirations and his reading. He was a member of The Royal Institution³ where its director, Sir Humphrey Davy, was giving a series of scientific lectures. Dance gave Faraday something more precious than gold; tickets to attend the last four lectures in the series for 1812.

Faraday duly attended, eagerly grasping each scientific point made by Davy and making careful notes of the lectures. These he rewrote in detail adding illustrations and an index after which he recounted what he had heard to his friends at the City Philosophical Society.

Within days of Faraday completing his apprenticeship as a bookbinder in October, 1812, an accident occurred which changed his life. Sir Humphrey Davy had been examining chloride of nitrogen, a very unstable substance, when it exploded temporarily blinding him. Faraday was recommended to take dictation from Davy and write notes for him until his eyesight recovered. In December Faraday sent Davy a carefully bound copy of the notes he had taken at Davy's lectures together with a letter in which he said he wished to devote himself to science and petitioned Davy that he might serve the lecturer.

2. Jane Marcet, 1769 – 1858, wife of a Swiss physician, wrote articles on chemistry in terms of everyday language which people generally could understand. Her *Conversations on Chemistry, Intended More Especially for the Female Sex* and first published anonymously in 1805 summarised the work of Humphry Davy, whose lectures she attended. It was one of the first elementary science textbooks and was illustrated with her own drawings of chemical apparatus, and emphasised the importance of demonstration by experiment and also of theoretical rigour.

3. The Royal Institution of Great Britain is the scientific society founded in 1799 by the American, Benjamin Thompson (Count Rumford) to encourage scientific study and the spread of scientific knowledge. It was incorporated by Royal Charter from King George III in 1800 and is located at 21 Albemarle Street, London, W1S 4BS.

Davy was flattered but there was no opening for a job and he could not help his young admirer. However, in February, 1813, Davy's only laboratory assistant was dismissed for brawling with the Royal Institution's instrument maker and Davy at once remembered the young bookbinder.

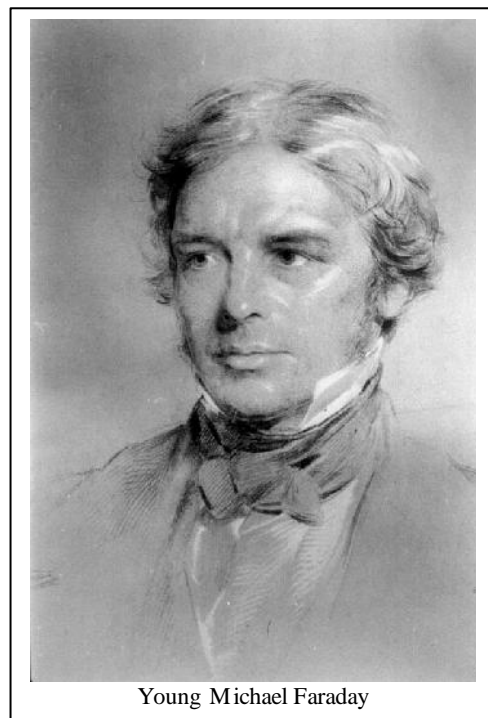
A CAREER IN SCIENCE COMMENCES

A few days later a carriage and pair drew up at Faraday's humble home at 18 Weymouth Street and a liveried footman handed the youth a letter from Davy inviting him to call at the Royal Institution, next morning. After a brief interview Davy engaged Faraday as a laboratory assistant at twenty-five shillings a week with a bedroom at the Institution and coal supplied. He commenced on 1st March, 1813 where his duties included bottle washing and other disagreeable chores, but Faraday was now in daily contact with the kind of scientific research which appealed to him above all else.

FARADAY THE STUDENT

Michael Faraday made rapid progress and seven months after his appointment accompanied Sir Humphrey and Lady Davy on an 18 month scientific tour as Davy's philosophical assistant where he assisted with experiments and researches and joined in discussions with many of the leading scientists of the Continent. Setting out on 13th October, 1813, they visited France, Italy and Switzerland where Faraday met the leading natural philosophers of the day, including Laplace, Ampère, Arago, Gay-Lussac, Volta, and De la Rue, while Davy discoursed on every scientific subject imaginable.

They returned to London in April, 1815, and on 7th May, 1815, Faraday was re-engaged at The Royal Institution where he helped Davy continue with his chemical investigations in the quiet laboratories in the basement. His salary was increased to 30 shillings a week.



Young Michael Faraday

The very next year he published his first original paper in the *Quarterly Journal of Science*, an analysis of caustic lime.

He completed his second apprenticeship (under Davy) in 1820, and a year later married Sarah Barnard, a silversmith's daughter, and sister of a friend from the City Philosophical Society, and they lived happily in two rooms at the Royal Institution.

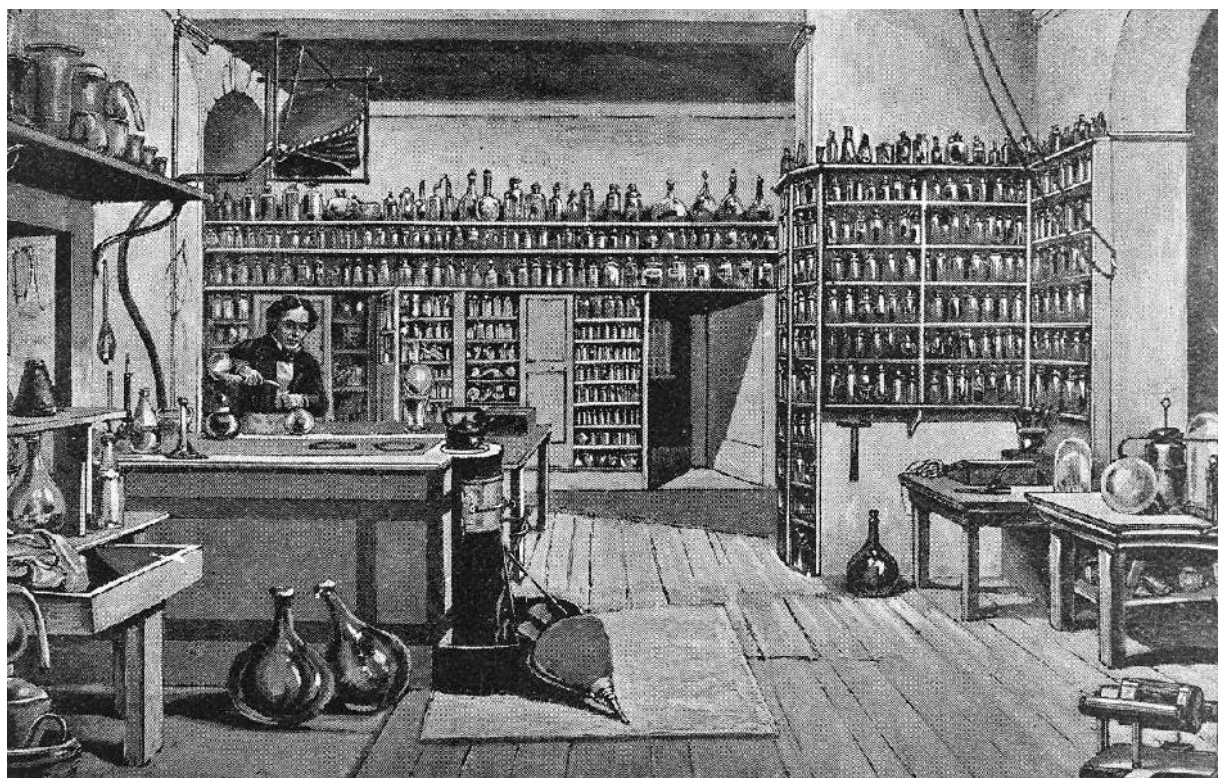
FARADAY THE TEACHER

He began to lecture to the City Philosophical Society at John Tatum's house in Dorset Street in 1816. Of the thirty or forty who attended, Richard Phillips, an editor of the *Philosophical Magazine* (and later, President of the Chemical Society) was one of his closest and surest friends.

He lectured on chemistry and his long series of lectures reviewing the knowledge of states of matter and forces of nature which ran until 1819 bear testimony to the nature and extent of Faraday's self education.

It was his friend, Richard Phillips, who persuaded him in 1821 to take-up the study of electromagnetism. Following Volta's invention of the electric battery in 1796 and Oersted's discovery in 1819 of the deflection of a magnetic needle by a wire carrying a voltaic current, Faraday pondered that if an electric current could produce a magnetic effect perhaps magnetism might somehow produce an electric current.

Later in 1821 Faraday made his first important discovery by causing a conductor carrying an electric current to revolve around a magnet and a magnet to revolve around a conductor carrying a current. For the first time electrical energy had been changed into mechanical energy.



Faraday in the laboratory in the basement of the Royal Institution

FARADAY THE RESEARCH CHEMIST

By 1819 young Faraday had become the foremost analytical chemist in Britain (he preferred to call himself a Natural Philosopher); chemistry was his principle interest and for the next 9 years he concentrated on chemistry. In 1823 he succeeded in liquefying chlorine gas leading to the liquefaction of other gases which made refrigeration possible. He discovered two new chlorides of carbon and was the first to isolate Benzene leading to the establishment of the modern dye industry and the basis for one half of all inorganic chemistry. Faraday was the first to produce stainless steel and borosilicate glass and he discovered the relationship between electricity and chemical bonding. He showed that light is an electromagnetic phenomena, rotating beams of plain polarised light by passing them through a magnetic field. Ampère thought that the magnetic force surrounding a current carrying wire acted in a circular fashion around the wire; Faraday proved it. He established the atomic theory of electricity foreshadowing the electron and laying down the laws of electrolytic action connecting chemistry with electricity.

Faraday became renowned among the scientific world for his researches, and as a lecturer, and this respect re-established the reputation of the Royal Institution following the work of Davy. He was elected to membership of the Royal Society⁴ in 1823.

In 1825 Faraday was appointed Director of the Laboratory of the Royal Institution and Fullerian⁵ Professor of Chemistry for life in 1833.

Ampère wrote to Faraday “Chemistry and physics have both been honoured by your work, and I personally owe you a great deal for your experiments on electromagnetic rotations”.

Faraday was now near, very near, to his great discovery of the relationship between electricity and magnetism.

FARADAY THE MASTER EXPERIMENTER

From 1830 onwards he accepted no outside work, devoting all his time solely to the pure science of electricity, magnetism, and chemistry, and their inter-relationship. The idea of obtaining electricity from magnetism remained uppermost in his mind.

He had already tried several times during 1824, in 1825, and again in 1828, and failed on each occasion. From his notes on these experiments however, we now know that Faraday must have produced minute induced currents whenever he connected and disconnected the battery. However, these currents were too weak to be detected by the crude apparatus for measurement available to him.

In 1831 Faraday tried again, convinced that such a relationship existed. In amongst other duties between 29th August and 5th December, he carried out a series of brilliant experiments, four of which demonstrated convincingly the principles of electromagnetic induction.

Faraday's diary records the first experiment on 29th August, 1831. “Have had an iron ring made (soft iron), iron round and $\frac{7}{8}$ inches thick and ring 6 inches in external diameter”. Around half the circumference he wound three helical coils of $\frac{1}{20}$ inch diameter insulated copper wire each about 24 feet long. On the opposite half of the ring he wound about 60 feet of copper wire in two pieces. The first three coils were connected in series with the ends taken to an electric battery of ten pairs of plates each 4 inches square, with one connection left open. The other two coils were connected in series and their ends were formed into a large loop. Three feet from the iron ring he placed a magnetic compass needle under the loop wire.



Faraday's iron ring 1831

4. The Royal Society of London for the Advancement of Science, founded in 1660 and incorporated by Royal Charter of King Charles II in July, 1662, consisted of a membership of physicians, philosophers, astronomers, engineers, mathematicians, chemists and other scientists of the day for the purpose of exchange, examination, and criticism of scientific ideas for the advancement of science. The oldest scientific society in the world, it continues to this day and meets at the Royal Institution, 21 Albemarle Street, London, W1S 4BS.

5. John Fuller, an eccentric M.P. and philanthropist, established the Chair in Chemistry at the Royal Institution with a gift of £10,000 in 1833.

When Faraday closed the battery circuit the needle flicked to one side and returned to its original position. When he opened the circuit the needle flicked to the opposite side and returned to its original position again. He had, however, expected that the needle would have been affected while ever the current was flowing.

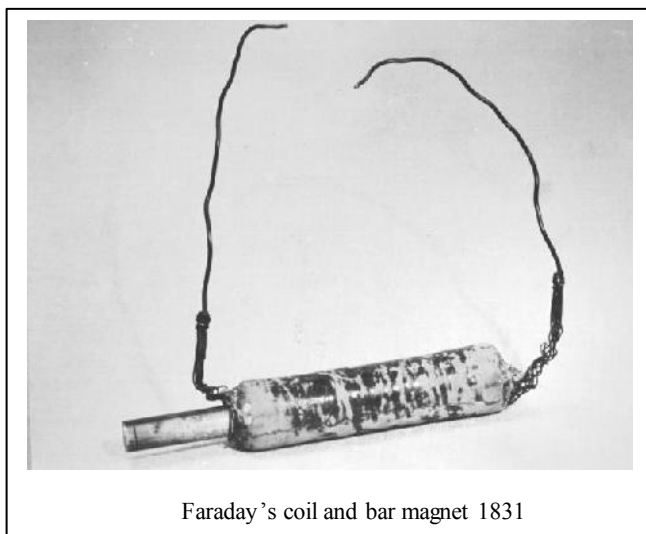
A MONUMENTAL DISCOVERY

Faraday's great discovery from this experiment was that electricity was generated while the magnetism was **changing**, either increasing or decreasing, but not while it remained constant.

This iron ring with coils was the first induction coil; the first primitive transformer.

On 23rd September he wrote to his friend Phillips, "I am busy just now again on electromagnetism, and think I have got hold of a good thing, but can't say".

Faraday's second important experiment carried out on 17th October, consisted of a coil of insulated wire wound in the form of a helix with the ends connected together by a loop which passed over a magnetic compass needle, as in his previous experiment. When he thrust a cylindrical bar magnetic, 3/4 inches in diameter and 8 inches long, into the coil causing the magnetic field to cut the wires, the needle deflected and returned to rest. On withdrawing the magnet the deflection was in the opposite direction before returning to rest.



The bar magnet in the second experiment replaced the coil, ring and battery used in the first experiment which constituted an electro magnet. The mechanical energy used in moving the magnet into and out of the coil was converted into electrical energy demonstrating clearly the principle behind every generator.

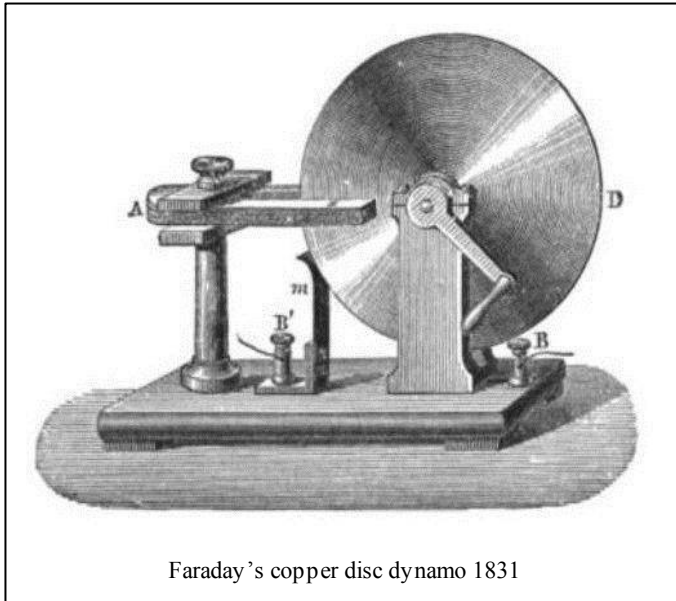
In the reverse process of the motor, electrical energy is converted into mechanical energy.

Faraday's third significant experiment was carried out on 28th October, 1831, the ninth day of his experiments. He mounted a copper disc on a spindle so that it could be rotated in the gap between the poles of a horseshoe magnet. Sliding contacts touching the shaft and the periphery of the copper disc were connected again to the large loop passing over the magnetic compass needle. When the disc was rotated the compass needle deflected continuously to one side.

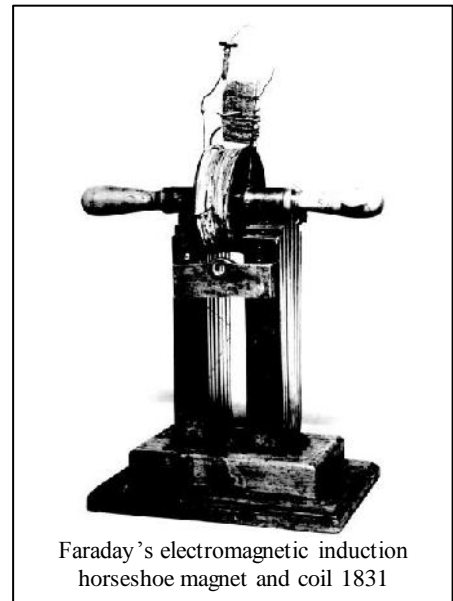
When rotated in the opposite direction the needle deflection reversed continuously.

In the reverse process of the motor, electrical energy is converted into mechanical energy.

This was the first continuous direct current generator.



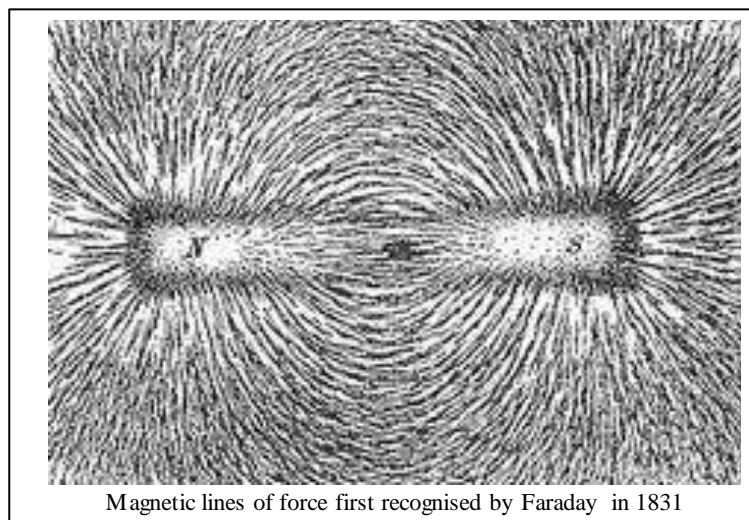
Faraday's copper disc dynamo 1831



Faraday's electromagnetic induction horseshoe magnet and coil 1831

But what, asks this brilliant mind, what is happening in the space between the magnetised iron and the copper?

The next day that he experimented, the 4th November, he found that a copper wire drawn between the poles of the magnet produced the same effect. The direction of the current was determined by the direction of the motion, the current being reversed when the motion was reversed. Faraday is now able to visualise what is happening in the space inbetween. He scatters iron filings over the magnet and the particles arrange themselves in curved lines. Magnetism is invisible; he realises it is a force, and the curved re-arrangement of the filings is due to the operation of that force. It operates everywhere.



Magnetic lines of force first recognised by Faraday in 1831

The turning copper disc is cutting across magnetic lines of force in the air. It is not the approach, he now knows, of the wire towards the magnetised iron that produced the induced current in his earlier experiment, it is the action of the wires cutting through the magnetic field.

What an illuminating discovery! The power is not in the iron of the magnet or in the copper wire; the real seat of power is in the space and the medium which fills it!

CAREFUL THOROUGH DOCUMENTATION

Within four weeks Faraday presented a comprehensive paper to the Royal Society (24th November, 1831) explaining his discovery that a varying current in one coil induces a transient current in an adjacent coil and that relative movement between a magnet and a coil or disc generates an electric current. These principles are now known as Faraday's Laws of Electromagnetic Induction.

Faraday's wire moving through a space filled with magnetic lines of force is the method used today in dynamos, generators and motors, with many such conductors being fitted to the periphery of an armature rotating in a strong magnetic field. Thus the foundation was laid whereby unlimited electrical power could be generated; it was the beginning of the electrical age we all enjoy and take for granted.

It was Faraday's vision of **what might be** which urged him forward, hacking his way through endless labours and dull details so often to emerge triumphant in the end. When the nature of electromagnetic induction dawned upon him, he said "All this is a dream. Still, examine it by a few experiments. Nothing is too wonderful to be true, if it be consistent with the laws of nature".

Faraday kept a laboratory diary in which he recorded the details of his experiments, numbering each page and numbering each paragraph. His diary between 1820 and 1862 contains 16,260 paragraphs and has been published in seven volumes. Reports on his electrical investigations were read to meetings of the Royal Society and have been published in three volumes of 3,362 of his numbered paragraphs called "Experimental Researches in Electricity".

HUMILITY - LOYALTY -- HONOUR

Michael Faraday was a quiet, modest man without worldly ambitions. He declined many honours pressed upon him, including a knighthood, Professor of Chemistry at London University, and the Presidency of the Royal Society. He could have engaged in a lucrative consulting practice but refrained, passing up an income eleven times his modest salary at The Royal Institution. His sense of loyalty to his employers may be gauged from his reasons given to the London University when he declined the offered appointment of Professor of Chemistry in 1827:

Faraday wrote:

"I think it a matter of duty and gratitude on my part to do what I can for the good of the Royal Institution in the present attempt to establish it firmly. The Institution has been a source of knowledge and pleasure for me for the last fourteen years, and though it does not pay me in salary what I now strive to do for it, yet I possess the kind feelings and goodwill of its authorities and members and all the privileges it can grant or I require: and, moreover, I remember the protection it has afforded me during the past years of my scientific life. "

In 1832 he received the degree of Doctor of Civil Law from the University of Oxford on the occasion of the second meeting of the British Association⁶.

6. The British Association for the Advancement of Science was founded in 1831 and is dedicated to the promotion and professionalism of British Science.

In 1856 he was made a Commander of the Legion of Honour by Emperor Napoleon III and was later elected one of the eight foreign members of the French Academies des Sciences. Among those in close contact with him were Arago, Dumas, Becquerel, De la Rive and Fresnel.

Faraday was known for his hearty laugh, his mastery of the Irish brogue, and for his veracity. He had a soft spot for children and they for him. For nineteen years he delivered special courses of lectures for young people which alone made him and The Royal Institution famous. Young boys so loved a word with the old man that they used to waylay him on a Sunday morning on his way to church. Having benefited by one lot of kindly greetings they would let him walk on and then run past him through the back streets to intercept him again. During the Crimean war (1853 – 1856), the British Government asked Faraday to advise on the production of chemical weapons. He refused.

As a scientist, Faraday pressed on with his researches into electro-chemistry, electro-optics, electro-magnetic phenomena and other pure sciences. He left it to engineers of later years to develop more practical means of turning his principles into the commercial electrical machines which serve us today. He stands out however, as the Father of the Electrical Industry.

REMEMBERED THEN, REMEMBERED NOW

After 49 years with the Royal Institution he retired in 1861 due to failing health. He died quietly on 25th August, 1867, at the age of 76 at Hampton Court in a house on the green with all expenses paid, given to him by Queen Victoria.

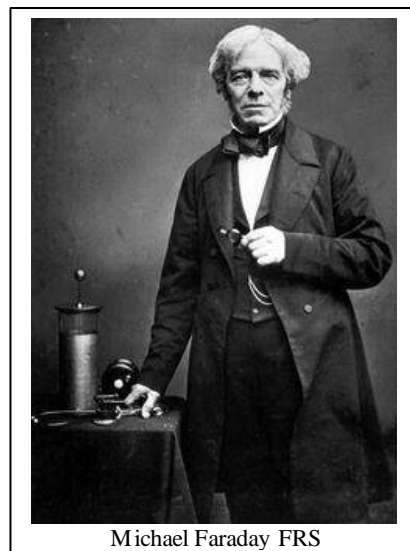
As the 25th August, 2017, passes us by, we remember the brilliant natural philosopher who died 150 years ago, who without a formal education started work as an errand boy to a newsagent and rose to become a world renowned analytical chemist in his twenties.

Is this great lecturer able to teach us something today from his simplicity of faith and purpose, his breadth of vision, humility of thought and kindly generosity. His first thought was for the quality of what he gave and only later of what he might receive in return.

What magnificent qualities! His gentleness, intellectual energy and exactitude, his technical virtuosity, his ability to speak lucidly about his work, the magic of his writing, his honesty, integrity, and his loyalty shedding light around him.

Could there be any following more certain to bring us through these periods of doubt and depression into more prosperous times?

Let us then bless
and praise such famous men,
Men of little showing,
For their work continueth.
And their work continueth,
Broad and deep continueth,
Great, beyond their knowing.



Michael Faraday FRS

To mark the centenary of his birth in 1991, the Bank of England featured Michael Faraday at the Royal Institution of Great Britain on the twenty pound bank note.



Some discoveries of Faraday:

Borosilicate lead Glass

Benzine 1820

Liquefaction of chlorine and ammonia – first to liquefy a gas.

The electric motor

The laws of electrolysis – electroplating – electrochemistry, the interaction of electrical energy and chemical change,

Stainless steel

First known compounds of chlorine and carbon

The laws of electromagnetic induction 1831

The first transformer 1831

Lines of magnetic force 1831

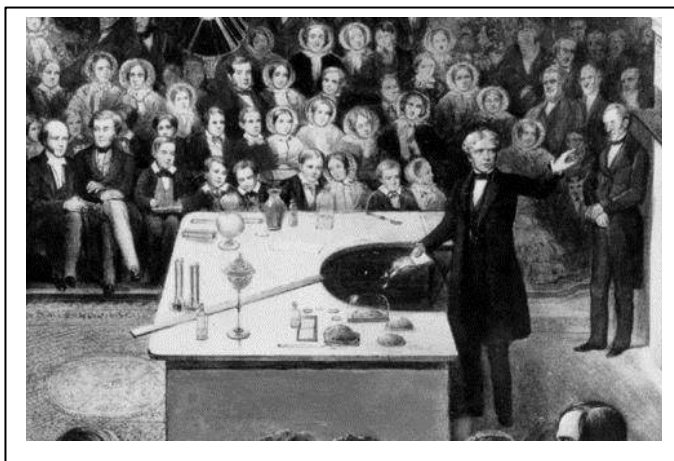
Rotation of polarised light – the first experimental evidence linking electromagnetism with light. 1845

That electric charges reside on the external surfaces of bodies (Faraday Cage) 1843

Coined the terminologies:- anode, cathode, electrode, ion

Diamagnetism - a property of all matter.

Bending light using magnetism.



Faraday lecturing at the Royal Institution of Great Britain