Supplement to the HISTELECT NEWS No. S52
December 2012

"James Clerk Maxwell – A Short Biography"

By Peter Lamb

Clerk Maxwell has cropped up in my readings on electricity history for years, but strangely I have always found him elusive in the general panoply of scientific development. Again when a new member joined us some years ago, Dr Ian Hopley, he deposited some technical papers of his own with us on Clerk Maxwell's achievements. This brief appraisal may help to rectify that omission.

JAMES CLERK MAXWELL

James Clerk Maxwell is probably the most unsung hero of the theory of electricity, but should be included in the gallery of great scientists, who analysed the electricity phenomenon in the very early years of its development. He should be ranked more highly alongside Volta, Faraday, Ampere and Gauss.

Maxwell was a Scot born in Edinburgh in 1831 of fairly well-off parents John and Frances, since they owned a 1500acre estate, Glenlair, in Dumfries in south west Scotland on which they built a new house. His father, a lawyer, John Clerk had changed his surname to Clerk Maxwell, in order to inherit the Maxwell estate and therefore was a gentleman of means and able to afford to pay for James to be educated initially at home. At the age of ten he was sent to Edinburgh staying with an Aunt being enrolled at the Edinburgh Academy. It was sad that his mother had died when he was only 8 years old.

Amazing for a 14 year old, but at that age, he wrote his first paper on the theory behind "Oval Curves", which he demonstrated using pins and string. His paper was read to the Royal Society of Edinburgh for him, since he was too young. At 16 he transferred to Edinburgh University, having been helped in his application by a cousin, Jemima, who was married to Hugh Blackburn, Professor of Mathematics at Glasgow University. Blackburn then introduced him to Professor William Thomson, who had been appointed to the chair of Natural Philosophy at the tender age of 22. Thomson, who later became Lord Kelvin, became a great influence on Maxwell's development. He had originally intended to do law, encouraged by his father and uncle, but was persuaded to study Natural Philosophy and Mathematics. This he did for three years, but the term times were only 6 winter months, unusual in this day and age; thus he spent a considerable part of that period at Glenlair, which he devoted to reading. In his time there he nevertheless published a paper on "Rolling Curves", which was again read for him at the Royal Society and another on "Equilibrium of Elastic Solids", setting out the theory of photo-elasticity. During his time at the Academy he had befriended two young men, Lewis Campbell and Peter G. Tait, who became lifelong friends. Campbell went to Oxford and Tait went to Cambridge. Largely influenced by the latter, the family eventually agreed for him to go to Cambridge, a decision which would have a long lasting impact on his career.

He arrived at Peterhouse College, Cambridge in October 1850 at the age of 19, but soon transferred to Trinity College, where he found a more suitable environment for his type of study. He finished his undergraduate studies as Second Wrangler and joint winner of Smith's Prize and was accepted as a post graduate student. His third major paper in 1855 was entitled "Experiments in Colour as Perceived by the Eye". In this paper he was expanding Newton's Theory of Sunlight's Composition. He found that mixing pigments was a subtractive process, whereas mixing light colours is an additive process. He devised a diagram to represent this with the necessary equations to satisfy the process. His basic logic explaining how this works is still used today, known as the Chromaticity Diagram associated with red, green and blue primaries, a system which is used in TV technology. He even went back to Edinburgh and was this time allowed to read his paper to the Royal Society.

He then moved into the theory of electricity established by Michael Faraday as he saw Faraday as one of his heroes. He studied Faraday's experiments on magnetism and electrostatic forces and devised mathematical equations to satisfy the processes involved. He consulted William Thomson in Glasgow, who had compared electrostatic forces with heat flow taking the idea further and coined the word flux for the reaction of magnetic fields, a term still used today. His fourth paper was therefore on electricity entitled “Faraday’s Lines of Force”. He was made a Fellow of Trinity and was asked to prepare lectures on his subjects, but at the same time was urged to put in for a vacant Chair of Natural Philosophy at Aberdeen.

This he did and in 1856 he was appointed Professor of Natural Philosophy at Marischal College, Aberdeen. During the four years he was at Aberdeen, he made two noteworthy studies, but also got married to the daughter of the Principal of the College, a lady who was seven years his senior called Katherine. His first study to mention was in answer to an astronomical problem set by his previous university of Cambridge, for which they offered a prize, which was solving the stability of Saturn’s Rings. No one-else submitted a paper, but Maxwell’s paper was so well received by the adjudicators that they awarded him the prize. His next noteworthy study was experimenting with gases and devising a statistical law now known as “Maxwell’s Distribution of Molecular Velocities”. His paper was presented to the British Association for the Advancement of Science in Aberdeen in 1859.

His work at Aberdeen was suddenly curtailed, since he was made redundant. This happened because it had been decided to amalgamate the two colleges in Aberdeen, Marischal and Kings into one unit and they only needed one Professor in Natural Philosophy and he was unsuccessful. At that time he contacted smallpox and retired to Glenlair for a year. However he was not long out of work, since Kings College, London needed a Doctor of Natural Philosophy and he was awarded the post. He and his wife moved to London establishing a home in Kensington. He walked to work at Kings, which was then situated in the Strand, but also he was able to visit the occasional lectures at the Royal Institution by his hero Michael Faraday, who was then in his 70’s. A fellow professor at the College was Charles Wheatstone. Not long after establishing himself there, he was awarded the Rumford Medal by the Royal Society for his work on colour vision and then was invited to give a lecture in May 1861 at the Royal Institution on same subject. He was helped by a colleague Thomas Sutton, who projected three pictures of the same subject through red, green and blue filters. Thus the Royal Institution became the first place for members to see a colour photograph. All this resulted in his being elected to the Royal Society, a prestigious membership at the young age of 30 years.

Clerk Maxwell in his 40’s with his Coil for Measuring Resistance accurately

Whilst at Kings he extended his theories of Faraday’s Lines of Force, by attempting to find a mechanical analogy between magnetism, static electricity and current electricity culminating in his proposing a complete system of units, defining quantities of mass, length and time, M, L & T and resistance.

In 1861 the British Association set up a committee to inquire into the methods of defining electrical resistance and to decide upon the most suitable standards and not surprisingly Clerk Maxwell was invited onto the committee and he was entrusted with the experimental determination of the resistance of a coil of wire in an absolute measure. He carried out these experiments at Kings College and the coil so used is kept by the Science Museum. A year later the British Association announced that they would widen the research into the standards of electrical system units and again Clerk Maxwell was involved. The results of some of these researches were later published. Ian Hopley analysed these and published three technical papers on Clerk Maxwell’s studies, the first of which formed a part of his thesis for a Ph D in 1957. (Details are given at the end)

Clerk Maxwell's work activity was prodigious writing a paper on "Reciprocal Figures and Diagrams of Forces" for devising simple methods of analysing civil engineering structures, which with the advent of computers enabled complex structures – such as the Olympic stadia to be analysed for stress in detail".

Then he followed with a paper on the "Dynamical Theory of Electromagnetic Field", which was published in seven parts. This was so successful that he was invited to make a presentation to the Royal Society in 1864. All these theories involving numerous equations still stand the test of time today and therefore it was a massive step forward in electricity theory at that time.

Extraordinarily he then resigned his chair in London retiring to Glenlair in Scotland at a mere 34 years of age. It is not known why he took this decision but his father had died nine years earlier and his estate was falling into disrepair and needed some attention. He spent seven years at Glenlair putting the estate into good order as the Laird, but also he did not forget his mathematical studies, which were very dear to him. He published five papers in that time. He visited London in 1868 being allowed to carry out some experiments in electricity using a large number of cells to measure electrostatic and electromagnetic units. He may have been getting restless by this time, since he applied for the post of Principal at St. Andrews University, but did not get it. He published a paper on the mathematical relationship of various geographical contours now known as Topology and also a paper on the "Theory of Heat". Whilst at Glenlair he wrote the "Treatise on Electricity & Magnetism", which was later published in 1873. The amount of output from this man was quite amazing even in the rarefied air of his country estate!

Then in 1871 he was offered a new Professorship of Experimental Physics at Cambridge University. It transpired that the Duke of Devonshire (family name Cavendish) who as Chancellor of the University had offered them a large sum of money to set up a special laboratory to be called the Cavendish Laboratory, named after the Duke's great uncle, Henry Cavendish. This uncle had been a keen scientific experimenter leaving behind a mass of unpublished technical papers amassed between 1771 & 1781, which had inspired the Duke to be a passionate supporter of scientist and engineering. The Duke believed that Britain was falling behind in this scientific field and wished to do something positive about it.

The House at the Glenlair Estate

James Clerk Maxwell was considered to be the most suitable person to create this laboratory, although many were hostile to his ideas of research involved considerable amount of experimentation and study.

The architect WM Fawcett was engaged and Maxwell visited the best university laboratories in the Country in order to assist in designing the most suitable research and lecturing accommodation and building work commenced. This was a very difficult time for Maxwell since he didn't have any suitable accommodation for lecturing having to use other facilities when available. Nevertheless he promoted his theories of magnetism and electricity encouraging his student researchers to cover an ever wider field. The laboratory was finished by 1874 and the resulting programme of research work consisted of high-precision measurement of fundamental physical properties. Many of his students went on to distinguish themselves much later. Many of those who had opposed this development were persuaded by Maxwell's charm and enthusiasm that the laboratory would be of great benefit to science and thus the Cavendish Laboratory became the birthplace of much modern physics.

Unfortunately he did not take full advantage of his position at that time as he had been given Henry Cavendish's papers and spent many years editing them to make them suitable for publication. Sadly four years later he became ill and again retired to Glenlair but was persuaded to return in order to get suitable treatment all to no avail and died in 1879 at a relatively young age of 48. The Cavendish Laboratory was taken over by JJ Thompson who went on to discover the electron.

Still later Rutherford researched nuclei physics there with its powerful potential.

The Original Cavendish Laboratory

Dr Hopley has said that Clerk Maxwell regarded the setting up and maintenance of electrical standards as an important function of his new laboratory. His untimely death prevented this from being realised, however several unpublished manuscripts have survived giving details of his plans for these measurements and these have been studied by Ian, who published the details in his own papers listed below.

Throughout his life he wrote a great deal of poetry, since he was very keen on Scottish poetry. He was also a keen Christian, being in later life an elder of the Church of Scotland.

As has been said, he published his Treatise of Electricity and Magnetism in 1873 and his theories and equations he created are still valid today. He was mathematical genius who converted Faraday's theories into a usable format and these and many others are extensively used in engineering projects the world over. The formulaic connection between light and electro-magnetism is considered by many to be one of the great achievements of 19th century mathematical physics.

His legacies live on in many spheres, but the four major areas which are regularly emphasised are as follows :-

1. Theories on Electricity, Magnetism & the connection with Light.
2. Electro-magnetic Properties of Light involving his Colour Analysis & Colour Photography.
3. Reciprocal Theorem for analysing structures.
4. Kinetic Theory of Gases – Ideal Gas Law.
5. Cavendish Laboratory.

The last named legacy, one could write a book about it alone. Many famous scientists have made their name there, the most notable being the New Zealander Ernest Rutherford, who arrived there in 1919 as Cavendish Professor of Science. He had already made a name for himself at both Manchester and McGill (Canada) Universities being awarded the Nobel Prize for Chemistry in 1908 and splitting the atom using a particle accelerator in 1917. The last 18 years of his life was spent at Cavendish and he left laboratories very contaminated, so much so they were closed for 40 years afterwards, due to the excessive radiation there.

Clerk Maxwell's Statue in Edinburgh

References :

1. "The Man Who Changed Everything – the Life of James Clerk Maxwell" by Basil Mahon 2003.

2. "The Natural Philosophy of James Clerk Maxwell" by PM Harman Cambridge Press 1998

3. Dr Ian Hopley's Papers in the SWEHS Archive:-
Annals of Science Vol.13 No.4 1957
Annals of Science Vol.14 No.3 1958
Annals of Science Vol.15 No.1 1959
Annals of Science Vol.15 No.2 1959

Also you may wish to visit the Museum devoted to his memory situated in the house, where he was born : - 14 India Street, Edinburgh.