Oliver Heaviside: Newcastle upon Tyne 1868-1874

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Abstract: The great Victorian 'electromagnetician', Oliver Heaviside FRS, had links with Newcastle upon Tyne from 1868 and resided there between 1870 and 1874. Heaviside shaped the future of electrical engineering science and electromagnetic theory; even the famous, 'Maxwell Equations' include their fair share of Heaviside's intellectual input. He contributed much to electrical engineering science, yet, despite his many achievements little recognition has been given to Heaviside. This paper presents some aspects of the life of Oliver Heaviside in Newcastle upon Tyne and makes the assertion that his time living within this industrial powerhouse was a critical period of influence in his life; his experiences he enjoyed whilst in Newcastle upon Tyne played a pivotal role in paving the way for his ensuing success as an eminent British scientist. Based on this assertion, the logical conclusion is that Newcastle upon Tyne was an important location in the advancement of 19th Century electromagnetic theory into its modern form and should be remembered as such. The paper explores the man, his work and his experiences during this period from various literature sources including his own personal notebooks from the period and local history resources.

1. Introduction

The work of the eminent Victorian electrical engineer Oliver Heaviside is little known today, perhaps engineers and mathematicians may know of the so called 'Heaviside step function', but will know little of the man and his other works. Heaviside was born on the 18th May, 1850 at 55 King Street (now known as Plender Street), London and lived until he was 74 years of age, eventually succumbing to long enduring illnesses on the 3rd February, 1925, in Torquay. He was born into a middle class family, who as we will find out, were 'Northerners'; he was the youngest of four. Heaviside was undoubtedly a first rate genius, but he was also a first rate 'oddity', as described by his friend of 33 years, fellow collaborator and Cavendish Laboratory physicist, G. F. C. Searle FRS. The mathematical powers and physical insight of Heaviside led him to many important scientific advancements and discoveries. Scientific achievements on the level of Oliver Heaviside's can be described as remarkable by any standard, however, Oliver, being partially deaf (due to his trouble with Scarlett fever as a youngster in 1858), being struck with many illnesses through his lifetime and the fact that he left school at the age of fifteen with no further formal education (his mathematics was good but stretched no further than trigonometry and algebra) make his achievements even more astounding. The range of his work was very wide, though was as first mainly

focussed on the great telegraphic and telephonic problems of the late 19th Century, leading him to the invention of inductive loading coils, coaxial cable, the theory of distortionless transmission of signals and the development of the distributed element model of the transmission line. He was also a mathematical pioneer, an early adopter of the vector analysis and calculus to engineering and physics, especially to electromagnetic theory, where he made substantive and very important contributions of many years, including recasting Maxwell's twenty-two quaternionic equations into four coupled partial differential equations in his vector language [1]. He also adapted complex numbers for use in electrical circuit problems and the development of his operational calculus [2] (very similar to Laplace transforms) for the solution of differential equations describing electric circuits and more generally, electromagnetic fields. A few little known areas of his work are as follows: The first is that he was the first to explore the fringes of relativistic electrodynamics, in 1888 [3], 17 years before Einstein. He communicated with G. F. C. Searle on this topic [4]. He also studied the physical implications of hyper light particle motion, leading him to the theoretical prediction of electromagnetic radiation under these conditions in 1888-89 [5], where 42 years after Oliver's paper it was experimentally 'discovered' by Soviet scientist Pavel Cherenkov, for which he received the Nobel Prize in Physics. Heaviside first studied the 'skin effect' in conductors in 1885 [6], but perhaps most importantly worked on the theory of electromagnetic waves, including making a successful prediction of a layer in the ionosphere which these electromagnetic waves could be guided in 1902; his 'wireless telegraphy'. This is now known as the Heaviside-Kennelly layer. For these achievements, among many others, he was elected a Fellow of the Royal Society in 1891, in 1905 he was awarded the degree of Doctor *honoris causa* by the University of Göttingen, Germany for his work on electromagnetic theory. The British government also awarded him a Civil List pension, in 1908 was elected an Honorary Member of the Institution of Electrical Engineers and of the American Institution of Electrical Engineers in 1918. He was awarded the very first Faraday Medal by the Institution of Electrical Engineers in 1922 [7]. Throughout his life, he corresponded and was visited by eminent scientific men of the age such as Sir Oliver Lodge, Sir Joseph Lamor, Lord Kelvin, Prof. Heinrich Hertz, Prof. George Francis Fitzgerald and J. J. Thompson [4]. He achieved much in life and although little is known of him, he clearly played a substantive role in shaping the future of not only electrical science, but the modern world.

2. The Northern Ancestry of Oliver Heaviside

Oliver Heaviside spend much of his life in Torbay, more specifically in Torquay, Paignton and Newton Abbott. However, his paternal ancestry lays in the north of the country. The family name Heaviside, is thought to be of Anglo-Saxon origin, and thought to be a locational name from Heavyside,

an estate east of Biggar, in Lanarkshire, Scotland. The components of the family name are believed to be the Old English pre-7th Century personal name "Hefa", with the Olde English "side", slope of a hill; hence, "Hefa's side" [8]. From the 1891 England and Wales Census data, the highest concentration of Heaviside families lived in County Durham [9]. His Father, Thomas Heaviside (b. 1813, d. 1896), was a wood engraver of considerable skill, who was born in Stockton in Tees, County Durham. He married Rachel Elizabeth West (b. 1818, d. 1894), who had left home in Torquay to work as a Governess – they moved to London in 1849 to find work. They had four children, Herbert Thomas, Arthur West, Charles and the youngest, Oliver Heaviside. Research has traced back at 100 years prior to his birth, tracing the paternal line through census, birth and death records [10]. His grandfather was also called Thomas Heaviside (b. 1785, d. 1859), and was born in Houghton, County Durham, his great-grandfather was a George Heaviside (b. 1755 d. unknown) and was from Wolviston, County Durham. Going further back, his great-great-grandfather, John Heaviside, was from Billingham, County Durham. Oliver Heaviside's family are rooted in County Durham, specifically in the Stockton-on-Tees district of the county, approximately 35 miles south from Newcastle upon Tyne. It is known that relatives of Oliver Heaviside live to this day, both in the Torquay and the Newcastle upon Tyne areas of the country and the authors have had the pleasure of being in contact and meeting some of them.

3. His Only Paid Employment: Northern Telegraphy

Oliver Heaviside's Uncle was the great English scientist and inventor Sir Charles Wheatstone FRS (6th February 1802 – 19th October 1875) and he undoubtedly had a large influence on Oliver and his brothers. After the development of a permanent rift between Herbert and their father Thomas Heaviside, Herbert moved to Newcastle upon Tyne to take up a position as a telegraph clerk. As Sir Charles is colloquially known as the 'grandfather of telegraphy' and someone who had a lot to do with the startup telegraph companies of the day, it is likely he helped Herbert obtain this position. Arthur Heaviside also left Paignton for Newcastle upon Tyne, who was a talented telegraph engineer who eventually rose through the profession to become the District *Superintendent* in Newcastle for the General Post Office Telegraph System. By the time Oliver was 18 years old in 1868 and had spent two years at home with his parents gaining knowledge in electricity and telegraph systems. Sir Charles most likely helped Oliver obtain his first and only job, as a telegraph clerk with the Danish-Norwegian-English Telegraph Company with a salary of £150 per year [11]. It is known that Oliver spent some of his time working in Denmark and he became proficient in the local language [4]. With his brothers in Newcastle and the Anglo-Danish undersea cable he was to work on, stretched 420 miles from Newbiggin-by-the-Sea (near Newcastle upon Tyne) and Sondervig (Denmark), his 'link' to Newcastle upon Tyne was formed. When Oliver Heaviside

first started work on the cable, the theory was based on a 'diffusion model', proposed by William Thompson [12], rather than Oliver Heaviside's later 'wave theory' [13] – this lack of understanding at the time caused confusion and sheer bafflement of both telegraph engineers and clerks. The rate and quality of telegraphic transmission of signals was unpredictable and sometimes, even a cable fault could mysteriously improve the signalling rate and quality. It was Oliver Heaviside that solved this with his distributed transmission line model, though this ground-breaking work was not developed by Heaviside until the 1880's after he left Newcastle, but must have been greatly influenced by his experiences in Demark and Newcastle. In 1869, due to the Telegraph Acts of 1869 and 1869, there was a merger of private companies and the Great Northern Telegraph Company was born. Oliver had served well as a clerk and problem solver but his work then took him to Newcastle upon Tyne full time and he moved in with his brother Arthur and his wife Isabella (census records show this address to be 1 Grafton Street, Whitley Bay – the address still exists), he was also promoted to Chief Operator and given a pay rise [14]. It is also suggested, by Wards Trade Directory of 1872 that at some point Oliver Heaviside lived at 7 Havelock Road, Blyth (still exists) and one other location (see Maxwell's Great Treatise). At the Newcastle Office of the Great Northern Telegraph Company (thought to be 36 Mosley Street), Heaviside showed his worth by diagnosing and repairing faults with cables and equipment, going off shore whilst cable repairs were made. These trips off-shore developed his interest in the weather, he made notes and was intrigued by lightning and the aurora borealis. On 11th September 1871 he wrote in his notebook [15]:

"Spent days waiting for [C.S]*'Caroline'. It was always leaving tomorrow. At last left and reached Shields. A week spent grappling, cutting and splicing cable."*

His day to day job would have consisted of testing telegraphic equipment, making repairs as well as sending and receiving signals. His experiences included working in the Newcastle Office, going off-shore on *the Caroline* and making trips to the Newbiggin-by–the-sea cable terminal to perform testing (which still exists on the seafront). All of this practical experience, coupled with his self-learning programme, gave him an excellent background for his future research career. Heaviside was in paid work from 1868 until 1874, when he was just 24 years old. In May 1874, he resigned from this paid employment and started on his journey as a prolific independent researcher back at his parents in London. This short spell of 6 years was to be his only paid employment for his 74 years of life.

4. His First Scientific Papers

During his time in Newcastle upon Tyne, he found time to write his first scientific papers, demonstrating that he spent his evenings wisely. Despite still teaching himself higher mathematics, his very first paper 'Comparing Electromotive Forces' [16], was published in the trade journal '*English Mechanic*', July 5th, 1872. It gives a neat and tidy, practical way of comparing two electromotive forces. The simple treatment eliminates any effects of the internal resistances of the batteries being compared and the galvanometer. The arrangement and method he published in this paper improved upon known methods at the time and was most likely the result of practical problems he faced through his work at the telegraph company. Though his first paper only used the simple algebra, his second published paper in the '*Philosophical Magazine'*, Feb 1873; 'On the best arrangement of Wheatstone's bridge for measuring a given resistance with a given galvanometer and battery' [17] showed quite clearly that he had by that point mastered the differential calculus: his self-study regime was clearly working. He provides an extensive mathematical treatment to the selection of the resistances in the bridge circuit in order that the galvanometer will experience a large deflection when the resistances are not balanced, giving high sensitivity. In this paper he suggests the best arrangement for measuring the insulation resistances of telegraph lines, this research was therefore likely to be based again around practical problems he faced day to day, measuring voltage and resistance. This paper received attention from William Thompson (later Lord Kelvin) and James Clerk Maxwell. Later in his life, he wrote in his notebook [18];

'*My first Philosophical Magazine paper. A very short time after it appeared, saw Sir. W Thompson at Newcastle, who mentioned it, so I gave him a copy, which no doubt he didn't read. They say he never reads papers. Cuff told me Sir W. said he had tried to work it out, but found the algebra too heavy… So paper was a good beginning. Sent Maxwell a copy and he noted it in his 2nd Edition.*'

The circumstances and location of the meeting with Sir. William is unknown. It is however very interesting as Thompson was a very famous physicist, Oliver Heaviside was an unknown 22 year old telegraph clerk. In later years, Sir. William would be Heaviside's proposer for election to be a member of the then Society of Telegraph Engineers (later the IEE now the IET). This is believed to have come about due to a comment in one of Heaviside's papers from this time 'On Duplex Telegraphy' where he poked fun at R. S. Culley, the engineer in chief of the Post Office telegraph system who had dismissed duplex telegraphy as impractical. Heaviside wrote in his paper [19];

"According to the very practical author of 'Practical Telegraphy', 'this system has not found to be of practical advantage.' "

His first application was turned down as he was a 'telegraph clerk'. Heaviside then asked Thomson to sponsor him, who was president at this time, and not surprisingly he was then admitted. Remembering that Oliver Heaviside was Sir Charles Wheatstone's nephew, it would be interesting to know if Sir Charles read his paper on the Wheatstone bridge and what he thought of it. Between July 1872 and June 1874 he had seven papers published, some in extremely good journals. This was good going for someone who had no advanced engineering education. All of these early papers were based on measurement arrangements and practical signaling along telegraph lines, he had only just come across the emerging field that is mathematical electromagnetism. His publication record for the remainder of his career was very impressive, in excess of 100 papers in magazines and journals as well as six books on electrical science (two volumes), electromagnetic theory (three volumes) and electromagnetic waves that were to reshape not only the entirety of telegraphy but the whole of electrical engineering science (see Appendix A).

5. Maxwell's Great Treatise

It has been said that Maxwell's treatise had a profound impact on Heaviside, this is most certainly true and the reason why his time spent in Newcastle upon Tyne was a channel to his future success. The great mathematical physicist James Clerk Maxwell (13th June 1831 – 5th November 1879) published his two volume work entitled 'A Treatise on Electricity and Magnetism' in 1873 [20], the same year Leazes park opened in Newcastle upon Tyne. The work contained within is often heralded as the 'second great unification in physics' after the first unification by Isaac Newton. The treatise brought together, for the first time, the concept that electricity, magnetism and light were manifestations of the same physical phenomenon. It is known (by virtue of Oliver's own notebooks from the period) that he first came across this seminal work whilst he was in Newcastle upon Tyne in 1873 and he read it as part of his 'self-study' regime in an attempt to expand his mind in the fast growing field of electromagnetic theory. Heaviside claims that it took him several years to master the book and it was only when he put the book down and developed his own way forward, things began to make true sense to him. In his own words [21];

"I remember my first look at the great treatise of Maxwell's when I was a young man... I saw that it was great, greater and greatest, with prodigious possibilities in its power... I was determined to master the book and set to work. I was very ignorant. I had no knowledge of mathematical analysis (having learned only school algebra and trigonometry which I had largely forgotten) and thus my work was laid out for me.

It took me several years before I could understand as much as I possibly could. Then I set Maxwell aside and followed my own course. And I progressed much more quickly... It will be understood that I preach the gospel according to my interpretation of Maxwell."

He did indeed make progress as his many achievements in electromagnetic theory demonstrate. One question that may be asked is 'How and where did he find this book?' It is doubtful that anyone at the Great Northern Telegraph Company was interested in this work of Maxwell, for it was mathematically beyond most telegraph engineers of the time and certainly beyond the reach of ordinary telegraph clerks. Heaviside mentions in his notebook that he found it in the 'Library' whilst in Newcastle upon Tyne. According to available sources, the first public library did not open in Newcastle upon Tyne until 1878, four years after Oliver had left for London. The only other institution that may have stocked a book like Maxwell's treatise so soon after its publication that served a 'library' function is the Literary and Philosophical Society of Newcastle upon Tyne[1]. Founded in 1793 as a 'conversation club', with the current building being built in 1825. Its president between 1868 and 1874 was the inventor, industrialist and businessman, William Armstrong, the 1st Baron Armstrong, who was president for 40 years until his death in 1900. Recent research has indicated that the Literary and Philosophical Society still hold an original copy of Maxwell's treatise, unfortunately the accessions registers for that period no longer exist to give an exact date of acquisition. More interestingly there is an 'O. Heaviside' listed as a member of the society between 1868 and 1874 inclusive, his listed address is 10 Elswick Row; this address no longer exists. On examination of the book, a number of pencil scribbles were found in the margins and based on samples of Oliver Heaviside's known handwriting, look remarkably similar. It cannot be said with certainly, but it is likely that the book currently available for loan from the Literary and Philosophical Society of Newcastle upon Tyne is the original copy that Heaviside first found and subsequently inspired him to pursue electromagnetic theory. James Clerk Maxwell was editing a second edition of his treatise when he died, it was published posthumously – Oliver Heaviside was the only other man to have his work included in the book. This work was analysis of the 'Best arrangement for a Wheatstone Bridge' [17], which, as mentioned above, was his second ever paper which received much interest. It can be seen on pg. 482 of Volume I in any copy of Maxwell's treatise bought today – it has never went out of print. His membership of the Literary and Philosophical Society from 1868 onwards suggests that he was either in or travelling to and from Newcastle before he was permanently stationed here in early 1870.

[1] Newcastle upon Tyne Literary and Philosophical Society, 23 Westgate Road, Newcastle upon Tyne, NE1 1SE

6. Personal Aspects of His life

Oliver Heaviside kept notebooks that contained both his scientific work, as well as his personal thoughts and diaries of the times. Some of the entries give some insight into his lifestyle in Newcastle upon Tyne. During his time in Newcastle upon Tyne, he solved a number of practical problems and was known for it. One interesting problem and subsequent remark by Heaviside was that of an undersea cable fault of 1871. His notebook of the time shows steps to calculate the precise location of a fault to be 113 and 2/3 knots out at sea from the English end [23]. He finished the technical entry in his notebook with joyful phrase [23] *"All over. Dined roast beef, apple tart and rabbit pie, with Claret, and enjoyed ourselves.*" From this, he was clearly a humorous fellow with a good sense of humor as is illustrated by G. F. C. Searle in his personal sketch of Oliver Heaviside which gives account after account of conversations, letters and anecdotes relating to his humorous nature. Another entry of 9th April 1871 shows both his humor and his interest in the weather, he wrote that he thought the '*Day of Doom*' had come after three earthquakes had darkened the sky with dust. Alas, the day of doom had not come and thankfully Heaviside was able to move on with advancing electromagnetic theory. As mentioned in 'His First Scientific Papers' he was starting to become at odds with certain closed-minded members of the scientific establishment. This started in Newcastle upon Tyne, but it certainly did not end there. Whilst he did actually have many high ranking friends in the scientific establishment, he made many enemies though his mockery and unsavory comments regarding certain people. Some of the people he 'annoyed' were William Preece and R.S. Culley, the Engineer in charge of the Southern Division of the telegraph system and his boss. Culley once wrote to Preece: '*We will try to pot Oliver somehow*.' [24], after Heaviside claimed that he had performed the impossible (as claimed by Preece and Culley) – practical duplex telegraphy [19]. His efforts were aided by his bother Arthur and their experiments made in 'Beckett's shop' in Newcastle upon Tyne. The location and nature of this shop is unknown, however it was clear that certain members of the telegraphy establishment '*had it in for him*'. It is clear he had an 'impish' personality, unafraid to offend people and willing to cause offence. Though it is clear that he had a softer side, a warmer and caring side to his personality as described by Searle [4]. Throughout his life he was a keen cyclist and was known to ride down large hills in Torquay with his feet off the pedals, whizzing down the hill at high speed with the pedals whipping around underneath him. It is also claimed that he went through an enormous amount of 'spoons', which is those days pressed on the front wheel in order to act as a brake. This daring and one may say 'humorous' behavior seems to tie in with his personality nicely.

7. Relevance of Newcastle Upon Tyne

It is clear that Oliver Heaviside's most impressive work was undertaken in locations other than Newcastle upon Tyne, his groundbreaking advances in electromagnetic theory, mathematics and telegraphy were all later on in his independent research career. However, the years that he spent in Newcastle upon Tyne, can be argued to be the most important, certainly the most influential, of all. He came to Newcastle upon Tyne as a Telegraph Clerk, transmitting and receiving telegraph messages, fixing apparatus and improving them through his own skill and ideas. He made the decision based upon his experiences at Newcastle upon Tyne to pursue a course of self-study in electrical science, acquiring the mathematical skills required for advanced study. The literature he was reading, coupled with his practical experience of the telegraph equipment and its associated challenges triggered the mind of one of the most productive and influential electrical engineers this country has produced. While at Newcastle upon Tyne he found Maxwell's great treatise, by chance, and started to study it. It is clear that at first reading of this treatise, it had a profound effect on him, as soon after he terminated his only ever paid employment in order to study it full time – his course was set. His first scientific papers in '*English Mechanic*', '*Philosophical Magazine*' and the '*Telegraphic Journal*' were written and published whilst he was in Newcastle upon Tyne. Here he became a member of the Society in Telegraph Engineers in 1873, later the Institution of Electrical Engineers, where he was subsequently elected an Honorary Fellow and from which he received his Faraday Medal. It was here was first recognized by the scientific community and met one of the most famous and influential physicists of the time, Sir. William Thompson. His years in Newcastle upon Tyne were undoubtedly important in the development of his ideas, his chosen research path and therefore his subsequent achievements. The first reading of Maxwell's treatise undoubtedly had a profound impact, giving Heaviside direction and inspiration to play out his genius like Maxwell did before him. Newcastle upon Tyne therefore has significant relevance in the field of Electromagnetic Theory and Electrical Science, however, this is not only due to the city's influence on Oliver Heaviside as many great mechanical and electrical engineering achievements are associated with it. Despite its relevance, Oliver Heaviside is rarely included in any discussion regarding the engineering history of the city. Hopefully this will be corrected in the future.

8. The Heaviside Memorial Project

At the School of Electrical and Electronic Engineering, Newcastle University, the Newcastle Electromagnetics Interest Group[2] in the spring of 2014 came across, by chance, the fact that the memorial to Oliver Heaviside and his family was in very poor condition and required urgent restoration in order to

[2] http://www.ncl.ac.uk/eee/research/interestgroups/nemig/

revive and preserve it[3]. An anonymous donor had it cleaned in summer 2005 [11], but it had since deteriorated rapidly. The family burial plot is in Paignton Cemetery, near Torquay, Devon where he spent the final years of his life. When he died in 1925, he was buried with his parents. The Heaviside Memorial Project was founded by the authors in July 2014 [25]. This was a not-for-profit project made possible through the Newcastle Electromagnetics Interest Group (which has an interest in the work and life of Oliver Heaviside) that successfully funded, through public subscription, and organized the restoration of the memorial. The project received overwhelming support and within two months, generous donations from individuals, industry and academia from around the globe raised the required funds for a complete restoration of the monument. The project received publicity from the Institution of Engineering and Technology, the Royal Academy of Engineering and the local press [26]. The monument was thoroughly cleaned, re-levelled and re-set. The lettering on the monument was also restored to its former glory. The project culminated in an unveiling ceremony on the 30th August 2014 [27]. It was attended by both the Mayor and the MP for Torbay, an ex-Chairman of the IET History of Technology Network, among others, including Oliver Heaviside's first cousin three times removed[4]. The Newcastle Electromagnetics Interest Group and the Heaviside Memorial Project continues to research the life and work of Oliver Heaviside and is currently in the process of republishing a personal sketch of Oliver Heaviside by G. F. C. Searle, a friend of Oliver Heaviside for 33 years. This personal sketch was discovered by British Electronics Engineer Ivor Catt[5] in the 1970's through communication with a descendent of Searle and was finally published, in small quantity, in 1987.

9. Conclusion

Newcastle upon Tyne is undoubtedly a place of large influence upon the life of Oliver Heaviside. He came to Newcastle in 1869/70 as a telegraph clerk, albeit one with an excellent reputation, but with little career prospects as he had no formal education to become an engineer. His experiences of Denmark and Newcastle upon Tyne, the telegraphy system and its associated problems and establishment, shaped Oliver Heaviside into a prolific researcher in the field of electromagnetic theory. Although not always keenly though of by the establishment, he published his first papers and gained his reputation whilst in Newcastle upon Tyne. Not to mention his local connections in County Durham and Stockton-on-Tees. It is most remarkable, the chance discovery of Maxwell's great treatise in the Literary and Philosophical society, which was quite possibly the biggest influence and perhaps the most important influence, not only for

[3] http://www.heavisidememorialproject.co.uk/
[4] www.oliverheaviside.com
[5] I. Catt famously sold his semiconductor technology to Sir Clive Sinclair in the 1970's

Oliver Heaviside, but for Science, Engineering and Electromagnetic Theory of that age. Without living out his experiences working in Newcastle upon Tyne the advancements he made may never have been made until much later on, hindering scientific and technological advancement. The education, both practical and academic that he underwent whilst in Newcastle upon Tyne was to be the basis of a career to span the next 50 years, with achievement after achievement. Despite the role Newcastle upon Tyne played in shaping the career of Oliver Heaviside, it is little mentioned in the literature, especially local literature and there is no mention of Oliver Heaviside in the City's museums. The resounding truth should be that Newcastle upon Tyne shaped the future of Electromagnetic Theory through the intellect and pen of Oliver Heaviside. And it is this that should be remembered, along with Oliver Heaviside himself, being a son, albeit a transient son, of Newcastle upon Tyne – one of the greatest scientific men of the 19th and early 20th centuries.

"Self-induction's 'in the air', Everywhere, everywhere;
Waves are running to and fro, Here they are, there they go.
Try to stop 'em if you can You British Engineering man!"

Oliver Heaviside, 1888

Additional information on the life of Heaviside cans be found in the many excellent publications listed in Appendix B.

10. References

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10. England 1841 to 1911 Census information and other records – Accessed via Ancestry.co.uk
11. B. Mahon, 'Oliver Heaviside: Maverick Mastermind of Electricity', Institution of Engineering and Technology, 2009

12. W. Thompson, ‘On the theory of the electric telegraph’ *Proceedings of the Royal Society*, 1855
13. O. Heaviside, ‘Electrical Papers: vol I’, The Electrician Series, pp. 53, 1892
14. P. J. Nahin, ‘Oliver Heaviside: Sage in solitude: the life, work, and times of an electrical genius of the Victorian age’, IEEE Press, New York, 1988.
15. O. Heaviside, Personal Notebook covering 1871, held by the IET Archives
16. O. Heaviside, ‘Comparing Electromotive Forces’, *English Mechanic*, 1872
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19. Oliver Heaviside, ‘On duplex telegraphy’, *Philosophical Magazine*, Series 4, Vol. 45, 1873
20. J. C. Maxwell, ‘Treatise on Electricity and Magnetism’ Vols. I & II, 1873, Clarendon Press
21. J. Bethenode, ‘Oliver Heaviside’ [Obituary], *Annales de Postes Telegraphs*, vol. 14, 1925 (based on a latter from Heaviside to Bethenode.
22. O. Heaviside, Personal Notebook, held by the IET Archives
23. O. Heaviside, Personal Notebook, held by the IET Archives (Note: NB1A pg.94)
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26. http://www.torquayheraldexpress.co.uk/Heaviside-memorial-project-funds-raised/story-21938512-detail/story.html
27. http://www.torquayheraldexpress.co.uk/Restored-Heaviside-memorial-unveiled-Saturday/story-22858873-detail/story.html

28. Acknowledgments

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Appendix A: Works of Oliver Heaviside (Books)

Oliver Heaviside published many books on electrical engineering science and electromagnetic field theory. Electrical papers consists mainly of a collection of his published papers on telegraphy and his interpretation of Maxwell. The Electromagnetic theory volumes are more in-depth and are mathematically difficult.

1. O. Heaviside, ‘Electrical Papers: vol I’, The Electrician Series, 1892
2. O. Heaviside, ‘Electrical Papers: vol II’, The Electrician Series, 1894
3. O. Heaviside, ‘Electromagnetic Theory: vol I’, The Electrician Series, 1893
4. O. Heaviside, ‘Electromagnetic Theory: vol II’, The Electrician Series, 1899
5. O. Heaviside, ‘Electromagnetic Theory: vol III’, The Electrician Series, 1912
6. O. Heaviside, ‘Electromagnetic Waves’, The Electrician Series, 1889

Modern copies of these books can be obtained via the Cambridge University Press.

Appendix B: Additional Information

Additional information relating to the life, work and times of Oliver Heaviside, including his time spent in Newcastle upon Tyne and in Denmark can be found in the following publications. This list is by no means comprehensive.

1. G F C Searle, ‘Oliver Heaviside: The Man’, C.A.M. Publishing, 1987 (new edition to be published Q4 2015).
2. ‘The Heaviside Centenary Volume’, Institution of Electrical Engineers, 1950
3. B. Mahon, ‘Oliver Heaviside: Maverick Mastermind of Electricity’, Institution of Engineering and Technology, 2009
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