The Enigmatic Oliver Heaviside

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The Enigmatic Oliver Heaviside

- Who is Oliver Heaviside and what are his contributions? Why is he important to the scientific community?
- Born in Camden Town, London.
- Grew up in poverty with 3 brothers and a domineering father.
- Nearly deaf due to a bout of scarlet fever, he regains some hearing in his teens
- He attended school until age 16
- He had strong dislike of some school subjects
  - Geometry - “Eulid is the worst”
  - Grammar - “I always hated Grammar”

55 King Street Camden Town
London, England
2.5 miles North of Charing Cross
Very Near Birthplace of Charles Dickens

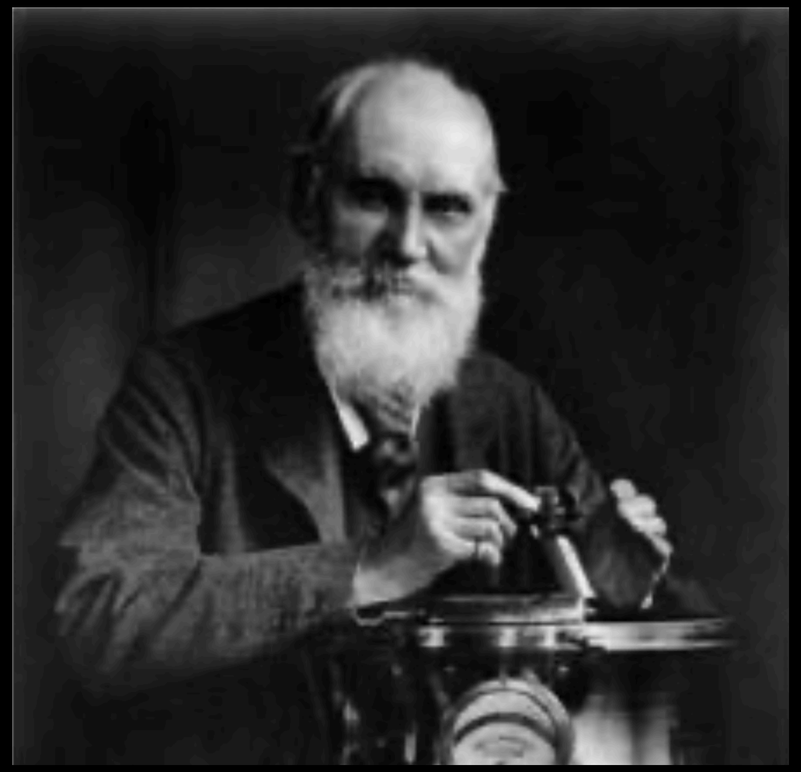
Breaking Away From the London Slums

- Oliver's Sister married Charles Wheatstone in 1847
- Wheatstone was a famous electrical scientist and inventor
- Wheatstone helped Oliver & his brothers find good jobs
- Wheatstone had a most profound influence on young Oliver

Sir Charles Wheatstone (1802-1875)
Best known as inventor of the Wheatstone Bridge

Heaviside’s First (and Last) Real Job

- With Wheatstone’s help, Oliver gets a job with a Danish telegraphy company in 1868
- Began work as a telegraph operator (at 150 pounds/ month)
- Observes the rates of intelligible telegraph signals over the 347 nautical mile Anglo-Danish cable
- Found that the rate was 40% higher in the England-Denmark direction
- Before his analysis, the Professor William Thomas’s telegraph theory was unchanged since 1855
- Transfers to Newcastle-on-Tyne office and became Chief Operator in 1871
- Spends time away from the office on cable laying ship maintaining undersea cables



Sir William Thomas, later Lord Kelvin
(1824-1907)
Devised the Absolute Temperature Scale
Formulated the 2nd Law of Thermodynamics
Worked to lay telegraph cables under the Atlantic

Heaviside's First (and Last) Real Job

- Publishes 1st Paper "Comparing EMFs" in *English Mechanic* in 1872
- Publishes 2nd Paper on *Optimal Arrangement of the Wheatstone Bridge* in *Philosophical Magazine* in 1873
  - He discusses 2nd paper with Sir William Thomas
  - He sends copy of 2nd paper to James Maxwell
- During this period he masters books on calculus, partial differential equations, and solid geometry at home

Heaviside Discovers His “Hero”

- James Clerk Maxwell published his *Treatise on Electricity and Magnetism* in 1873

- This masterpiece gives direction and inspiration to the genius of Heaviside

- “I remember my first look at the great treatise of Maxwell’s when I was a young man. Up until that time there was not a single comprehensive study, just a few scraps; I was struggling to understand electricity in the midst of great obscurity. When I saw on the table the work that had just been published (1873), I browsed through it and was astonished! I read the preface and the last chapter, and several bits here and there; I saw it was great, greater, greatest, with prodigious possibilities in its power. I was determined to master the book and set to work….”

- Heaviside resigned his telegraph operators job in 1874 and returned home to live with (and off) his parents to continue his self-education. The next 5 years after his retirement were the most productive of his life.

James Clerk Maxwell (1831-1879)

Heaviside Discovers His “Hero”

- He wrote 3 remarkable papers
  - In *Philosophical Magazine*, he extend the mathematical understanding of telegraph theory far beyond the William Thomas cable theory
  - In 1877, he addressed signal rate asymmetry (such as he saw in the Danish telegraph office) and showed that the differences in signal retardation were not due to cable parameters, but due to sending and receiving asymmetries.
  - In 1879, he showed how adding an “artificial fault” to a telegraph line could greatly increase transmission speed. He proposed adding a small inductor at regular intervals along the transmission line.
  - Unfortunately, he didn’t patent the idea, it could had made him wealthy. In 1899, another engineer claimed the idea was his and sold it to AT&T for $500,000.

Oliver’s Bete Noire

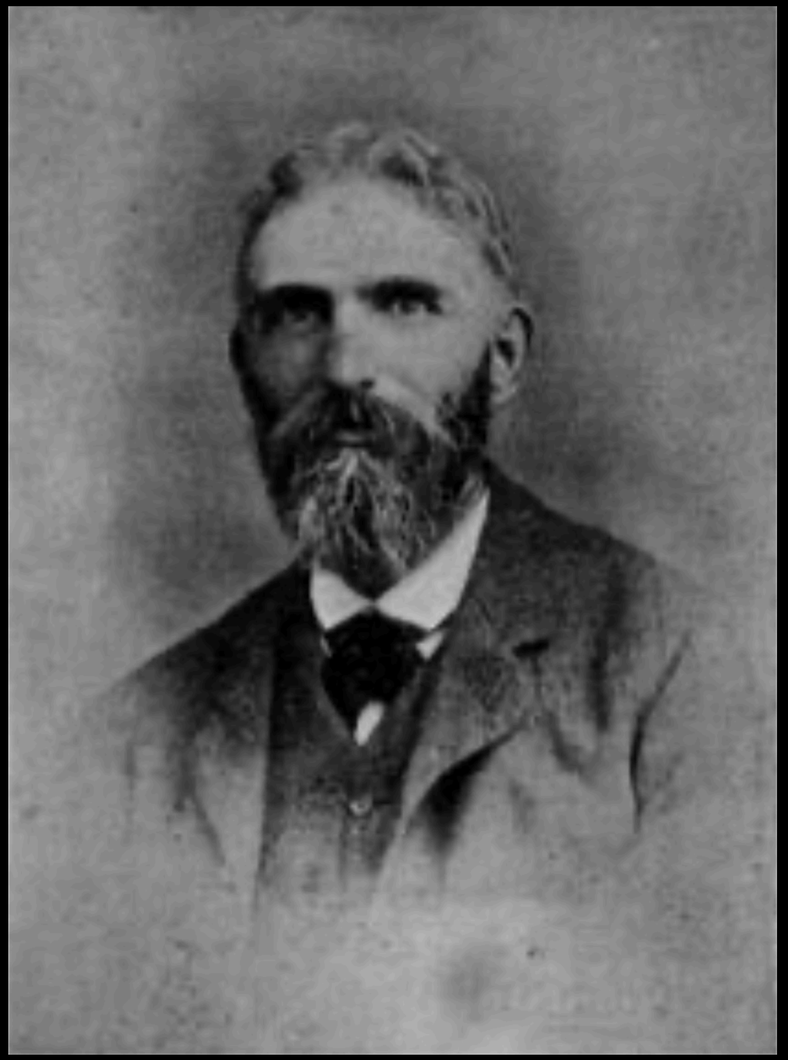
- Born in Wales in 1834 to a wealthy family
- Starting at 19, rose rapidly through the ranks of the communications business
- Became Engineer-in-Chief of General British Post Office in 1892
- Learn his trade in the school of hard knocks
- Had little understanding of the nature of electricity
- Thought electricity was like water flowing through a pipe, refused to accept other ideas even in the 1890s.
- Scorned theory. Heaviside and his scholarly papers were natural targets of Preece’s wrath
- Famous Quote: “Americans have need of the telephone, but we don’t. We have plenty of messenger boys.”
- In 1893, Preece became President of the Institution of Electrical Engineers (IEE)

William Preece
Oliver’s Principal & Most Powerful Adversary

The Electrician

- Heaviside responded to Preece's attacks in 1883 in *The Electrician* with comments like "the man of brass","Mr. Prigs", and his favorite "The Emminent Scienticultist".

- These comments caused Preece to force the firing of C.H.W. Biggs, the editor, who allowed their publication.



C.H.W Biggs,
Oliver's First Editor at *The Electrician*

Heaviside Simplifies Maxwell's Equations

- About 1882, Heaviside turns from the linear equations he developed for telegraph transmission lines to the physics of electro-magnetic fields
- Heaviside spent 8-years studying Maxwell's equations. He never really understood them until he rewrote them.
- Maxwell expressed most of his equations in Cartesian Coordinates
- Maxwell gave some equations in quaternions - a number system developed by William Hamilton in 1843. These consist of a scaler and three components of a vector
- Heaviside thought these were anti-physical and unnatural. With the scaler and vector products along with gradient, divergence, and curl Operators, he setup a simple and powerful set of tools for solving electromagnetic problems
- He expressed EM relations solely in terms of EM fields, E and H
- Heaviside's simplified equations are still used in modern undergraduate electrical engineering courses

$e+\frac{df}{dx}+\frac{dg}{dy}+\frac{dh}{dz}=0$	(1)	Gauss' Law
$\mu\alpha=\frac{d\mathrm{H}}{dy}-\frac{d\mathrm{G}}{dz}$ $\mu\beta=\frac{d\mathrm{F}}{dz}-\frac{d\mathrm{H}}{dx}$ $\mu\gamma=\frac{d\mathrm{G}}{dx}-\frac{d\mathrm{F}}{dy}$	(2)	Equivalent to Gauss' Law for magnetism
$\mathrm{P}=\mu\left(\gamma\frac{dy}{dt}-\beta\frac{dz}{dt}\right)-\frac{d\mathrm{F}}{dt}-\frac{d\Psi}{dx}$ $\mathrm{Q}=\mu\left(\alpha\frac{dz}{dt}-\gamma\frac{dx}{dt}\right)-\frac{d\mathrm{G}}{dt}-\frac{d\Psi}{dy}$ $\mathrm{R}=\mu\left(\beta\frac{dx}{dt}-\alpha\frac{dy}{dt}\right)-\frac{d\mathrm{H}}{dt}-\frac{d\Psi}{dz}$	(3)	Faraday's Law (with the Lorentz Force and Poisson's Law)
$\frac{d\gamma}{dy}-\frac{d\beta}{dz}=4\pi p'$ $\quad p'=p+\frac{df}{dt}$ $\frac{d\alpha}{dz}-\frac{d\gamma}{dx}=4\pi q'$ $\quad q'=q+\frac{dg}{dt}$ $\frac{d\beta}{dx}-\frac{d\alpha}{dy}=4\pi r'$ $\quad r'=r+\frac{dh}{dt}$	(4)	Ampère-Maxwell Law
$\mathrm{P}=-\xi p \quad \mathrm{Q}=-\xi q \quad \mathrm{R}=-\xi r$		Ohm's Law
$\mathrm{P}=kf \quad \mathrm{Q}=kg \quad \mathrm{R}=kh$		The electric elasticity equation ($\mathbf{E}=\mathbf{D}/\epsilon$)
$\frac{de}{dt}+\frac{dp}{dx}+\frac{dq}{dy}+\frac{dr}{dz}=0$		Continuity of charge

Original Form of Maxwell's Equations

$\nabla\cdot\mathbf{D}=\rho$	(1)	Gauss' Law
$\nabla\cdot\mathbf{B}=0$	(2)	Gauss' Law for magnetism
$\nabla\times\mathbf{E}=-\frac{\partial\mathbf{B}}{\partial t}$	(3)	Faraday's Law
$\nabla\times\mathbf{H}=\frac{\partial\mathbf{D}}{\partial t}+\mathbf{J}$	(4)	Ampère-Maxwell Law

Heaviside's Simplified Equations

Further Studies

- In 1883, Heaviside dug into the Treatise to find out how EM Energy moves
- After laborious transformations, he extracted a simple result: S=ExH, the flow of energy at a point in space. He concludes energy does not flow like water but rather passes through the surrounding field and enters the wire through its sides
- He gave his first account of his energy flow theorem in *The Electrician* in 1884 and continued a series on EM induction starting in January 1885
- He used his theorem and a new set of equations to clarify various propagation problems and explain such phenomena as “the skin effect”
- Due to limited access to scientific journals, he discovers that Cambridge-trained John Poynting had discovered the energy flow theorem shortly before him

Recognition

- In January 1889, William Thomas used much of his presidential address at a newly renamed IEE to praise Heaviside's propagation theory. Heaviside is named a Fellow of the Royal Society of London in 1891
- Heaviside moves with his aging parents to the seaside town of Paignton in Devonshire
- He publishes on EM theory, vector analysis, and his operator method of solving differential equations
- In 1893, he submits two installments of a paper covering operators in physical mathematics. Pure mathematicians object to his cavalier handling of divergent series
- His third installment is sent to a referee and rejected. Heaviside is incensed, he argues his method gives demonstrably right answers when handled properly.
- Despite of the objections, Heaviside operator methods later came into wide use, especially among engineers
- Oliver continued to work and publish until his death on February 3, 1925