The Founders of Electromagnetic Theory

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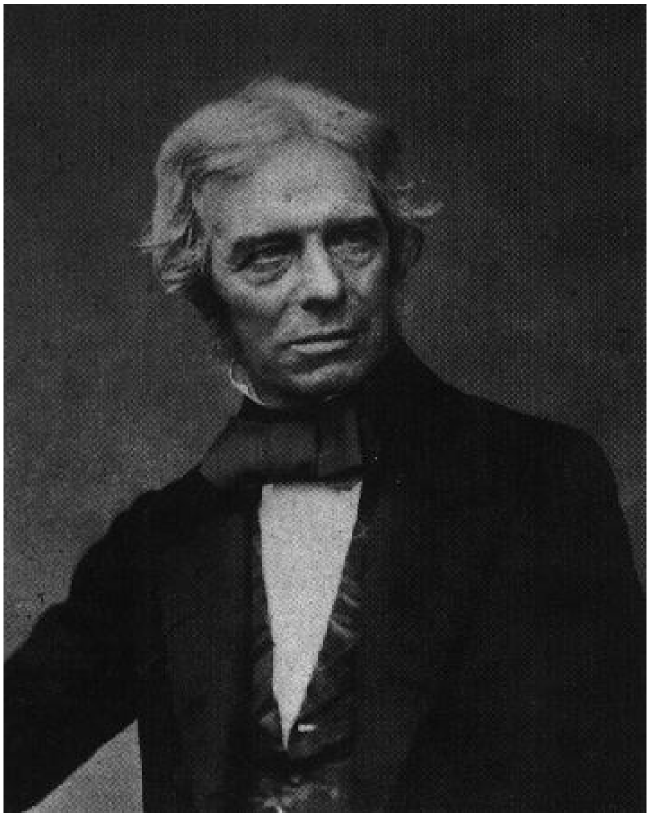
Introduction:

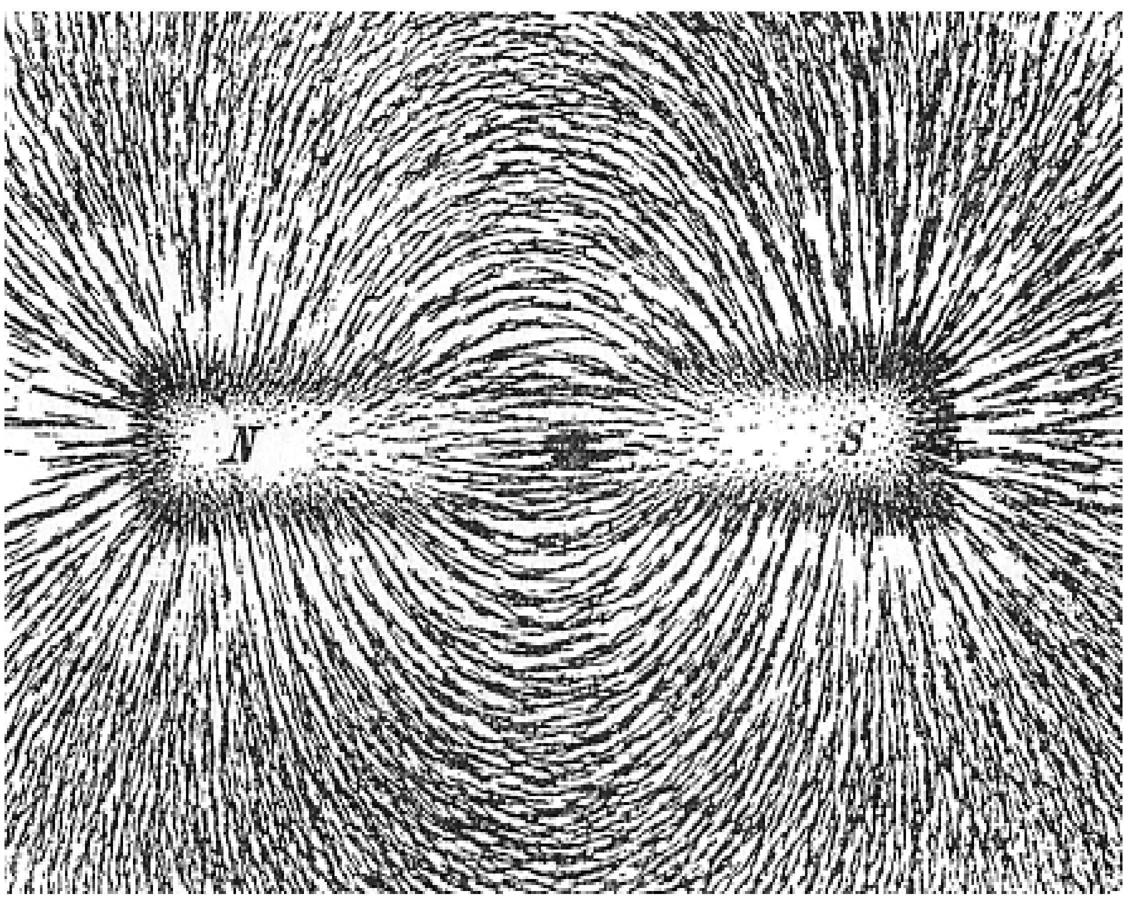
The founders of electromagnetic theory were trying to understand simple phenomena and determine relationships that cause these phenomena to occur. How iron filings on paper react when a magnet is brought near, is just one of the many experiments that led to the discovery of self-inductance, electromagnetic force, and electromagnetic fields. Although many theorist and experimentalist had thought on electromagnetism, there was no clear theory that united all of the theories or experiments to one coherent thought, until James Maxwell wrote his dynamic theory of electromagnetism, then Leigh Page proved Maxwell by re-deriving Maxwell's equations using Michael Faraday and André-Marie Ampère, justifying James Maxwell's theory of electromagnetism.

Michael Faraday:



Michael Faraday conducted many chemical experiments before experimenting in electromagnetism in 1821. Faraday discovered Magnet-Electric induction, by using two wires in sliding contact with a copper disk and rotating the disk between the poles of a horseshoe magnet, he created the first generator. Faraday's device is impractical to use, but enhanced the understanding of electricity and magnetism. (Institution 2011)

Philosophers had always observed magnetic power by strewing iron filings on a sheet of paper and observing the curves in which they dispose themselves when a magnet is brought underneath. Faraday believed that the lines generated in that representation represented lines of magnetic force; curves whose direction coincides with the direction of the magnetic intensity at each and every point.



"Faraday found that a current is induced in a circuit either when the strength of an adjacent current is altered, or when a magnet is brought near to the circuit, or when the circuit itself is moved about in presence of another current a magnet. He saw from the first that in all cases the induction depends on the relative motion of the circuit and the lines of magnetic force in its vicinity. The precise nature of this dependence was the subject of long-continued further experiments. In 1832 he found that the currents produced by the induction under the same circumstances in different wires are proportional to the conduction powers of the wires—a result which showed that the induction consists in the production of a definite electromotive force, independent of the nature of the wire, and dependent only on the intersections of the wire, and dependent only on the intersections of the wire and the magnetic curves. This electromotive force is produced whether the wire forms a closed circuit (so that a current flows) or is open (so that electric tension results).

All that now remained was to inquire in what way the electromotive force depends on the relative motion of the wire and the lines of force. The answer to this inquiry is, in Faraday's own words, that 'whether the wire moves directly or obliquely across the lines of force, in one direction or another, it sums up the amount of the forces represented by the lines it has crossed,' so that 'the quantity of electricity thrown into a current is directly or obliquely across the lines of force, in one direction or another, it sums up the amount of the forces represented by the lines it has crossed,' so that 'the quantity of electricity thrown into a current is directly as the number of curves intersected.' The induced *electromotive force is in fact, simply proportional to the number of the unit lines of magnetic force intersected by the wire per second.*

This is the fundamental principle of the induction of currents."(Whittaker Vol. I, 1987)

Although Faraday is entitled to this principle's discovery, it was not fully familiar or clear to his contemporaries. Since Faraday was not a mathematical physicist, he could not talk in their language, so he representation his "lines of force" repelled many. The idea of electromotive force was still unclear and many viewed it in obscurity and misapprehension. (Whittaker Vol. I, 1987)

André-Marie Ampère

Hans Christian Oersted's first discovered electromagnetism in 1820. This discovery disagreed with Coulomb's work in the 1780's, where electricity had nothing to do with magnetism. Ampere used two wires, rolled into a helix, each conducting current to prove Oersted's findings. One week after starting the experiment he stated that the two helices either attracted or repelled each other, thus supporting electromagnetism. Ampere went on to try to understand the "why" to this phenomena. He hypothesized that two currents attract each other when moving parallel to each other in the same direction, and repelled each other when moving parallel to each other in opposite directions. Although Ampere did not discover electromagnetism, he discovered many relationships in the field, even though he did not fully understand the theory that made it possible. (Book Rags, 2011)

James Clerk Maxwell:

James Maxwell, a Scottish physicist and mathmetician, is most well known for his electromagnetic theory. Maxwell combined many experiments and theories into one, consistent theory uniting Electricity, Magnetism, and Optics; all part of phenomenon, the electromagnetic field. (Cambell and Garnet, 1882)

Maxwell in 1864 wrote a dynamical theory of the electromagnetic field, opening by showing the difference between his method and other strictly mathematical theorists. Maxwell calls this the "first sight" into the explanation of electricity and magnetism, which at the time was the majority of theories dealing with the subject. The "first sight" dealt with the mutual movement of bodies with certain electrical or magnetic states by strictly treating the force acting on the two bodies in reference only, without any express consideration to the surrounding medium. The more prominent theory was developed by MM. W. Weber and C. Neumann, although they had to assume the relative velocity and distance between the two particles affect the force acting on the particles. That assumption caused Maxwell to not think of that theorem as the ultimate and instead deemed it useful, "in leading to the coordination of phenomena." (Simpson, 1997; p.254)

Maxwell calls his theory a "Dynamical Theory" because he assumed that in space there is matter in motion, producing electromagnetic phenomena.

> *The electromagnetic field is that part of space which contains and surrounds bodies in electric or magnetic conditions.*
>
> *It may be filled with any matter, or we may endeavor to render it empty of all gross matter, as in the case of Geissler's tubes and other so-called vacua.*
>
> *There is always, however, enough of matter left to receive and transmit the undulations of light and heat, and it is because the transmission of these*

radiations is not greatly altered when transparent bodies of measurable density are substituted for the so-called vacuum, that we are obliged to admit that the undulations are those of an aethereal substance, and not of the gross matter, the presence of which merely modifies in some way the motion of the other. (Simpson, 1997; p. 255)

Maxwell believed that the electromagnetic field consisted of more than the "objects in consideration"; he believed that the composition of particles, as well as the composition of the field were very important in understanding the results. Maxwell went on to discuss Faraday's "lines of force" in more detail.

We may now consider another phenomenon observed in the electromagnetic field. When a body is moved across the lines of magnetic force it experiences what is called and electromotive force; the two extremeties of the body tend to become oppositely electrified, and an electric current telnds to flow through the ody. When the electromotive force is sufficiently powerful, and is made to act on certain compound bodies, it decomposes them, and causes one of their components to pass towards one extremity of the body, nad the other in the opposite direction.

Here we have evidence of a force causing and electric current in spite of resistance; electrifying the extremities of a body in opposite ways, a condition which is sustained only by the action of the electromotive force, and which, as soon as that force is removed, tends, with an equal and opposite force, to produce a counter current through the body and to restore the original electrical state of the body; and finally, if strong enough, tearing to pieces chemical compounds and *carrying their components in opposite directions, while their natural tendency is to combine, and to combine with a force which can generate an electromotive force in the reverse direction.*

This, then, is a force acting on a body caused by its motion though the electromagnetic field, or by changes occurring in that field itself; and the effect of the force is either to produce a current and heat the body, or to decompose the body, or, when it can do neither, to put the body in a state of electric polarization, - a state of constraint in which opposite extremities are oppositely electrified, and from which the body tens to relieve itself as soon as the disturbing force is removed. (Simpson, 1997; p.257-258)

Faraday's "lines of force" were not well understood before Maxwell's theory explained how they affected to system of particles, thus creating induced currents in systems. Maxwell was able to take Faraday's "lines of force" and apply them to understand electromagnetic field in more detail. Maxwell developed a "second view" from other scientists' findings and going into more depth in his own experiments. In Maxwell's theory the "electromotive force" causes the motion of one part of the medium to another, and that force is the reason the motion of one part causes motion in another part. Since Maxwell was a very accomplished theorist which helped him be just as well of an experimentalist. Maxwell had a better understanding of his experiments because he understood how they were supposed to work theoretically. (Simpson, 1997; p347)

Maxwell also deemed that light is made of electricity and magnetism, to prove this Maxwell used a spinning-coil apparatus. The apparatus was designed to determine the British Association Ohm, but Maxwell used it to test his proposal.

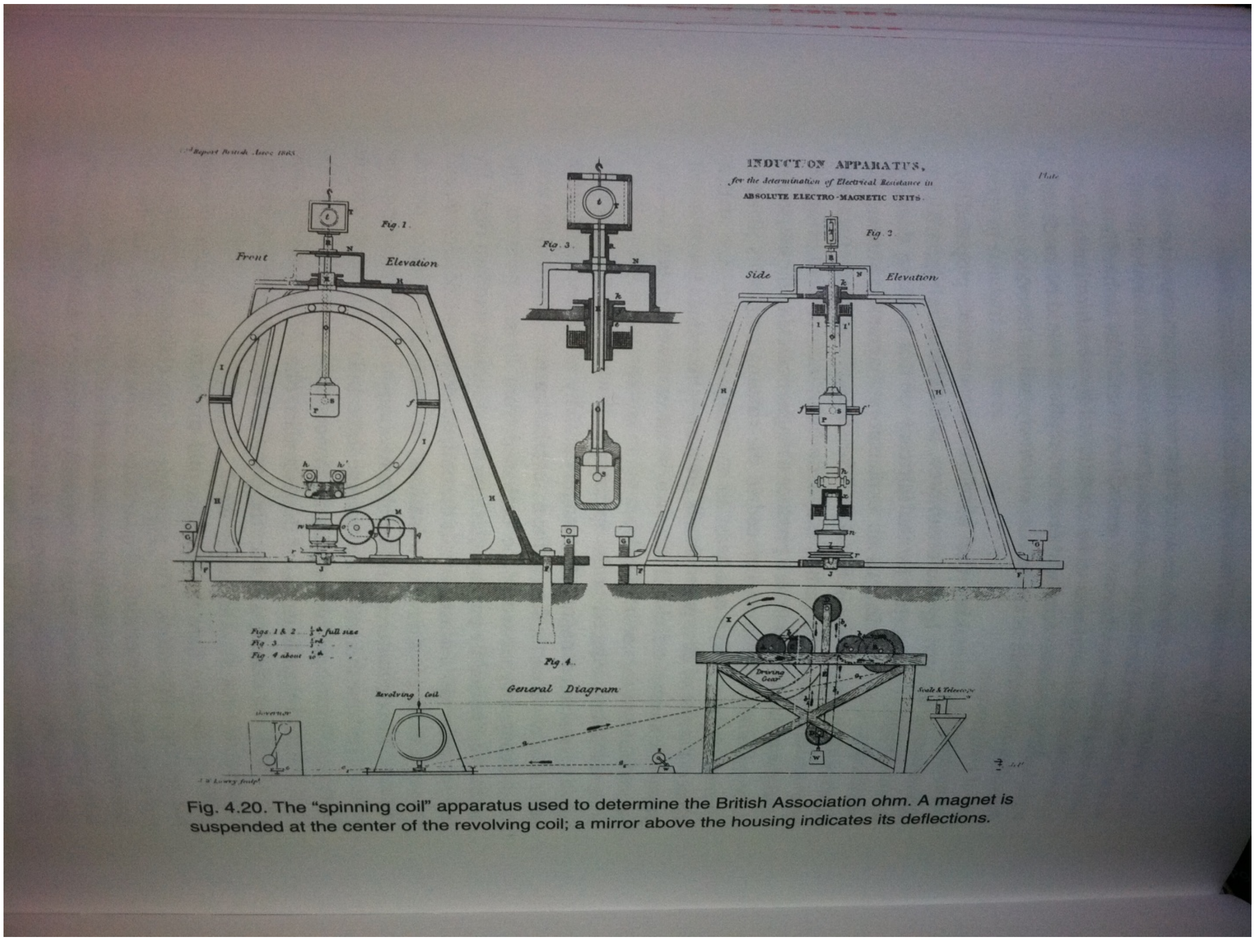


Fig. 4.20. The "spinning coil" apparatus used to determine the British Association ohm. A magnet is suspended at the center of the revolving coil; a mirror above the housing indicates its deflections.

The first results in the experiment were too preliminary for critical analysis, but Maxwell went into depth in the immense *Treatise on electricity and Magnetism*. Maxwell died at the age of 49 while in the height of his powers, one can only wonder how much more he would have accomplished had he lived longer.(Simpson, 1997 p.353-360)

Leigh Page:

Leigh Page attended Yale University and later taught mathematical physics there. He conducted many experiments and wrote many textbooks. Page also derived the complete electromagnetic theory, including Maxwell, using Coulomb's law and the Lorentz Transformation. (Wikipedia, 2011)

Leigh Page showed that if you understand the relativity theory of Poincaré and Lorentz, “the effect of electric charges in motion can be deduced from a knowledge of their behavior when at rest, and thus the existence of magnetic force may be inferred from electro-statics: magnetic force is in fact merely a name introduced in order to describe those terms in the ponderomotive force on an electron which depends on its velocity.” In this proof Page shows that Ampere’s law for the force between current-elements, Faraday’s law of the induction of currents and the whole of the Maxwellian electro-magnetic theory, can be derived from the assertion that there are no electric effects within a charged closed hollow conductor. (Whittaker Vol. II, 1987)

Conclusion

Faraday’s limited education hindered his ability to theorize in electromagnetic, but his experiments brought new ideas to light for other, more educated theorists to use. Maxwell by far was the most prominent figure in the electromagnetic theorems, with his vast knowledge and ability to experiment knowledgeably, was able to carry the most weight in his theorems. Page combined other theorist works and proved the validity of Maxwell, Faraday and Ampere.

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