History of Electromagnetism Maxwell's Laws

Group 5 and Group 6

History of Electromagnetism

Introduction/Brief Theory Review

Originally, electricity and magnetism were considered to be two separate forces. This view changed with the publication of James Clerk Maxwell's 1873 A Treatise on Electricity and Magnetism in which the interactions of positive and negative charges were shown to be mediated by one force. There are four main effects resulting from these interactions, all of which have been clearly demonstrated by experiments: Electric charges attract or repel one another with a force inversely proportional to the square of the distance between them: unlike charges attract, like ones repel. Magnetic poles (or states of polarization at individual points) attract or repel one another in a manner similar to positive and negative charges and always exist as pairs: every north pole is yoked to a south pole. An electric current inside a wire creates a corresponding circumferential magnetic field outside the wire. Its direction (clockwise or counter-clockwise) depends on the direction of the current in the wire. A current is induced in a loop of wire when it is moved toward or away from a magnetic field, or a magnet is moved towards or away from it; the direction of current depends on that of the movement. In April 1820, Hans Christian Ørsted observed that an electrical current in a wire caused a nearby compass needle to move. At the time of discovery, Ørsted did not suggest any satisfactory explanation of the phenomenon, nor did he try to represent the phenomenon in a mathematical framework. However, three months later he began more intensive investigations.Soon thereafter he published his findings, proving that an electric current produces a magnetic field as it flows through a wire. The CGS unit of magnetic induction (oersted) is named in honor of his contributions to the field of electromagnetism. His findings resulted in intensive research throughout the scientific community in electrodynamics. They influenced French physicist André-Marie Ampère's developments of a single mathematical form to represent the magnetic forces between current-carrying conductors. Ørsted's discovery also represented a major step toward a unified concept of energy.

This unification, which was observed by Michael Faraday, extended by James Clerk Maxwell, and partially reformulated by Oliver Heaviside and Heinrich Hertz, is one of the key accomplishments of 19th-century mathematical physics.It has had far-reaching consequences, one of which was the understanding of the nature of light. Unlike what was proposed by the electromagnetic theory of that time, light and other electromagnetic waves are at present seen as taking the form of quantized, self-propagating oscillatory electromagnetic field disturbances called photons. Different frequencies of oscillation give rise to the different forms of electromagnetic radiation, from radio waves at the lowest frequencies, to visible light at intermediate frequencies, to gamma rays at the highest frequencies.

Ørsted was not the only person to examine the relationship between electricity and magnetism. In 1802, Gian Domenico Romagnosi, an Italian legal scholar, deflected a magnetic needle using a Voltaic pile. The factual setup of the experiment is not completely clear, nor if current flowed across the needle or not. An account of the discovery was published in 1802 in an Italian newspaper, but it was largely overlooked by the contemporary scientific community, because Romagnosi seemingly did not belong to this community. An earlier (1735), and often neglected, connection between electricity and magnetism was reported by a Dr. Cookson. The account stated: A tradesman at Wakefield in Yorkshire, having put up a great number of knives and forks in a large box ... and having placed the box in the corner of a large room, there happened a sudden storm of thunder, lightning, c. ... The owner emptying the box on a counter where some nails lay, the persons who took up the knives, that lay on the nails, observed that the knives took up the nails. On this the whole number was tried, and found to do the same, and that, to such a degree as to take up large nails, packing needles, and other iron things of considerable weight.

Maxwell's Laws

Maxwell's equations, or Maxwell–Heaviside equations, are a set of coupled partial differential equations that, together with the Lorentz force law, form the foundation of classical electromagnetism, classical optics, and electric circuits. The equations provide a mathematical model for electric, optical, and radio technologies, such as power generation, electric motors, wireless communication, lenses, radar etc. They describe how electric and magnetic fields are generated by charges, currents, and changes of the fields. The equations are named after the physicist and mathematician James Clerk Maxwell, who, in 1861 and 1862, published an early form of the equations that included the Lorentz force law. Maxwell first used the equations to propose that light is an electromagnetic phenomenon. The modern form of the equations in their most common formulation is credited to Oliver Heaviside. Maxwell's equations may be combined to demonstrate how fluctuations in electromagnetic fields (waves) propagate at a constant speed in vacuum, c (299792458 m/s). Known as electromagnetic radiation, these waves occur at various wavelengths to produce a spectrum of radiation from radio waves to gamma rays.

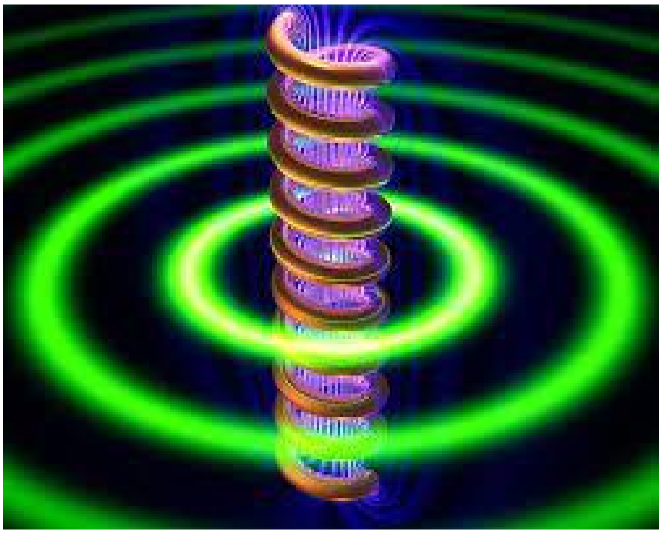

Figure 1: *Electromagnetism*

Figure 2: *Electromagnetism wave*

Gauss's law

Gauss's law describes the relationship between a static electric field and electric charges: a static electric field points away from positive charges and towards negative charges, and the net outflow of the electric field through a closed surface is proportional to the enclosed charge, including bound charge due to polarization of material. The coefficient of the proportion is the permittivity of free space.Gauss law describes the nature of the electric field around electric charges. The law is expressed in terms of electric charge density and electric charge density.

Gauss's law for magnetism

Gauss's law for magnetism states that electric charges have no magnetic analogues, called magnetic monopoles; no north or south magnetic poles exist in isolation.Instead, the magnetic field of a material is attributed to a dipole, and the net outflow of the magnetic field through a closed surface is zero. Magnetic dipoles may be represented as loops of current or inseparable pairs of equal and opposite "magnetic charges". Precisely, the total magnetic flux through a Gaussian surface is zero, and the magnetic field is a solenoidal vector field

Faraday's law

The Maxwell–Faraday version of Faraday's law of induction describes how a time-varying magnetic field corresponds to curl of an electric field.In integral form, it states that the work per unit charge required to move a charge around a closed loop equals the rate of change of the magnetic flux through the enclosed surface. The electromagnetic induction is the operating principle behind many electric generators: for example, a rotating bar magnet creates a changing magnetic field and generates an electric field in a nearby wire. Faraday was a scientist whose experiment setup led to Faraday's Law.The experiment is not very complex. When a battery is disconnected, no electricity flows through the wire. Hence, no magnetic flux is induced in the iron (Magnetic Core). The iron acts like a magnetic field that flows easily in a magnetic material. The purpose of the core is to form a path for the flow of magnetic flux.

Ampere's law with Maxwell's addition

The original law of Ampère states that magnetic fields relate to electric current. Maxwell's addition states that they also relate to changing electric fields, which Maxwell called displacement current. The integral form states that electric and displacement currents are associated with a proportional magnetic field along any enclosing curve.

Maxwell's addition to Ampère's law is important because the laws of Ampère and Gauss must otherwise be adjusted for static fields.[clarification needed] As a consequence, it predicts that a rotating magnetic field occurs with a changing electric field.A further consequence is the existence of self-sustaining electromagnetic waves which travel through empty space. The speed calculated for electromagnetic waves, which could be predicted from experiments on charges and currents,matches the speed of light; indeed, light is one form of electromagnetic radiation (as are X-rays, radio waves, and others). Maxwell understood the connection between electromagnetic waves and light in 1861, thereby unifying the theories of electromagnetism and optics.

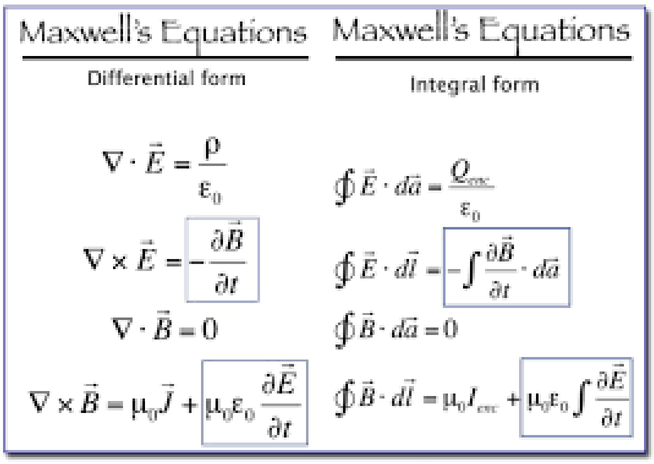

Figure 3: *Maxwell's Equations*

Conclusion

Maxwell's Equations. Maxwell was the first person to calculate the speed of propagation of electromagnetic waves, which was the same as the speed of light and came to the conclusion that EM waves and visible light are similar.Maxwell's equations are a set of four equations that describe the behavior of electric and magnetic fields and how they relate to each other. Ultimately they demonstrate that electric and magnetic fields are two manifestations of the same phenomenon. In fact, Maxwell concluded that light is an electromagnetic wave having such wavelengths that it can be detected by the eye. Other wavelengths should exist—it remained to be seen if they did. If so, Maxwell's theory and remarkable predictions would be verified, the greatest triumph of physics since Newton.

References

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