THE HISTORY OF ELECTROMAGNETICS AS HERTZ WOULD HAVE KNOWN IT

R. S. Elliott, Fellow

University of California
Los Angeles, California

SUMMARY

Highlights of the separate developments of the sciences of electrostatics and magnetostatics are traced through the end of the seventeenth century. These include Gilbert's cataloging of materials which, when rubbed, attracted light bodies, a phenomenon he labeled electric; Peregrinus' discovery that a lodestone, shaped to be spherical, behaved as though it possessed north and south magnetic poles, which prompted Gilbert to appreciate that the earth itself is a giant spherical magnet; and Kirchner's demonstration that the two poles of a magnet have equal strength.

As the eighteenth century opened, Gray discovered that certain materials could be used to convey electricity from one place to another. The inverse square law of electrostatics was established, first by suggestive work of Franklin and Priestley, then by the unpublicized experiments of Robinson, then by the brilliant but unpublished research of Cavendish, and finally by the widely-disseminated results of Coulomb, using a torsion balance of his own invention. Magnetostatics also entered the quantitative stage, as Michell established that the inverse square law applied as well for magnetic poles.

The first quarter of the nineteenth century saw an explosion in discoveries. Volta announced the invention of the first chemical battery, thereby providing a source for continuous electric current. Poisson developed a firm and elegant mathematical basis for electrostatic and magnetostatic theory, including a model to explain the behavior of magnetic materials. Oersted discovered that an electric current could deflect a compass needle; shortly thereafter Biot and Savart announced that they had determined a law of force which governed the effect. Ampère found that two current-carrying conductors exerted forces on each other, and developed a law to describe the effect. He also clarified the concepts of voltage and current, at the same time introducing the revolutionary idea that magnetism is basically an electrical phenomenon. Faraday's interest was piqued; he mused that the inverse of Oersted's discovery should also be true, namely that a magnet should exert a force on an electric current. His verification of this idea led to his invention of the first electric motor.

In 1826 Ohm established the law that bears his name, connecting the voltage, current, and resistance of a circuit. Joule added to this in 1841 by demonstrating that the heat loss in a wire is given by I^2R.

But the middle of the nineteenth century was principally illuminated by the experimental discoveries of Faraday and the theoretical developments of Maxwell. Always searching for converses, Faraday reasoned that, if an electric current can produce magnetic effects, shouldn't it also be true that a magnetic field can induce an electric current? Six years of fruitless trying were crowned in 1831 by his discovery that a moving magnet inside a coil of wire caused a current to flow in the wire. In short order he invented the first electric generator and the first transformer.

Faraday, lacking in formal education, and unable to express his ideas in mathematical terms, fathered one of the richest concepts in physics, the idea of a field. He proposed that a permanent field of force surrounded a magnet and interacted with an electric current in its presence, ultimately extending this idea to electric fields as well. This concept collided head on with action-at-a-distance theories whose adherents attacked Faraday mercilessly. Maxwell came to his rescue by developing a mathematical theory of electrostatics and magnetostatics in terms of fields, extending it to include Faraday's emf law. This launched Maxwell into a quest for a theory that would cover all electromagnetic phenomena. Trained as a hydrodynamicist, and comfortable with mechanical models, Maxwell imagined a fluid medium whose vortices represented a magnetic field, and whose particles constituted the matter of electricity. The famous Maxwell's equations which bear his name, originally described the behavior of disturbances in this hypothetical medium. With the scaffolding removed, they have become the governing laws of all macroscopic electromagnetic phenomena. A key conclusion of these equations is the theoretical prediction of the existence of electromagnetic waves, a prediction that would await the brilliant experiments of Hertz.

0149-645X/88/0000-0191$01.00 © 1988 IEEE