Faraday, Maxwell, and the Electromagnetic Field: How Two Men Revolutionized Physics

The story of two brilliant nineteenth-century scientists who discovered the electromagnetic field, laying the groundwork for the amazing technological and theoretical breakthroughs of the twentieth centuryTwo of the boldest and most creative scientists of all time were Michael Faraday (1791-1867) and James Clerk Maxwell (1831-1879). This is the story of how these two men - separated in age by forty years - discovered the existence of the electromagnetic field and devised a radically new theory which overturned the strictly mechanical view of the world that had prevailed since Newton's time.The authors, veteran science writers with special expertise in physics and engineering, have created a lively narrative that interweaves rich biographical detail from each man's life with clear explanations of their scientific accomplishments. Faraday was an autodidact, who overcame class prejudice and a lack of mathematical training to become renowned for his acute powers of experimental observation, technological skills, and prodigious scientific imagination. James Clerk Maxwell was highly regarded as one of the most brilliant mathematical physicists of the age. He made an enormous number of advances in his own right. But when he translated Faraday's ideas into mathematical language, thus creating field theory, this unified framework of electricity, magnetism and light became the basis for much of later, 20th-century physics.Faraday's and Maxwell's collaborative efforts gave rise to many of the technological innovations we take for granted today - from electric power generation to television, and much more. Told with panache, warmth, and clarity, this captivating story of their greatest work - in which each played an equal part - and their inspiring lives will bring new appreciation to these giants of science.
Nancy Forbes is an experienced science writer with over twenty-five publications in the area of science and technology including Imitation of Life: How Biology Is Inspiring Computing. She has also served as a contributing editor for The Industrial Physicist of the American Institute of Physics, and IEEE's Computing in Science and Engineering. Currently, she works for the US Department of Defense.

Basil Mahon is the author of The Man Who Changed Everything: The Life of James Clerk Maxwell and Oliver Heaviside: Maverick Mastermind of Electricity, among other publications. With degrees in engineering and statistics, Mahon was formerly an officer in the Corps of Royal Electrical and Mechanical Engineers and until his retirement worked for the British Government Statistical Service.Introduction

It is 1888. Picture a large, sparsely furnished room. It has stout wooden tables and workbenches - a laboratory of some kind - but there are no retorts, Bunsen burners, or flasks of brightly colored liquid. Instead, the room is stocked with curious metal devices that have strange names: Rh� mkorff coils, Knochenhauer spirals, Wheatstone bridges. Their purpose is to probe the ways of the mysterious invisible phenomenon - electricity.

The room has a single occupant, a young man, handsome, neatly suited, and dark-haired with a close-trimmed beard and moustache. He is deftly assembling some apparatus on one of the long wooden tables. At one end he has constructed a circuit that will produce electric sparks across a narrow air gap between two metal spheres connected to the ends of the wires in the circuit. Ordinarily air doesn't conduct electricity but, if the two spheres are close together and the voltage is high enough, a spark will appear to jump across the gap, although it is really a series of very rapid sparks that jump back and forth, or oscillate, between the spheres. To each sphere he has attached a metal rod connected to a rectangular metal plate - he has learned that this will alter the frequency of oscillation. He presses a key to activate the circuit, and vivid blue sparks crackle across the gap between the spheres.

So far, so good; his primary circuit works, as it had the day before and the day before that. He turns his attention to a separate part of the apparatus that he calls his detector - a simple loop of wire with a very small gap between its ends that he can adjust with a screw. He holds the detector close to the sparking primary circuit, and faint sparks appear across its own gap. This happens, he reasons, when waves of energy pass from the primary circuit to the detector.

All this is familiar ground to him, but the next steps are untried and will, he hopes, be decisive ones. Switching off the primary circuit for the moment, he props up a large zinc sheet in a vertical position at the far end of the table. Its purpose is to act as a reflector, like a mirror. He places the detector on the table between the primary circuit and the zinc reflecting sheet, closes the blinds, waits for his eyes to adjust to the darkness, and then switches on his primary circuit. Turning his back on the sparks scintillating between the spheres, he looks for tiny sparks between the terminals of his detector. They appear, faint but unmistakable. Now for the step that will, if successful, establish the result he is seeking. He looks to see if the brightness of the sparks varies as he moves the detector slowly away from the primary circuit toward the reflecting zinc sheet. Indeed, it does. The sparks diminish to nothing, then grow again to their brightest, and then the cycle repeats. He knows that when any kind of wave is reflected back toward its source, it forms a standing wave, which appears to vibrate in place, like a guitar string. Hence, waves are being produced by the primary circuit and reflected by the zinc sheet. This is exactly what he wanted to find. Heinrich Hertz, professor of experimental physics at the Technische Hochschule in Karlsruhe, has made one of the greatest experimental discoveries in the history of science: he has proved beyond doubt the existence of electromagnetic waves.

As Guglielmo Marconi and others were soon to show, the commercial value of Hertz's discovery was immense. But he had no notion of this, nor, indeed, of any practical application. What had captivated Hertz and set him on his quest was a beguiling but strange scientific idea - the brainchild of British experimentalist Michael Faraday in the 1830s that had been raised into a full mathematical theory by the young Scot James Clerk Maxwell three decades later. Their idea was so different from anything that had gone before that many of the leading men of the time dismissed it as a flight of fancy. Others were simply baffled; they did not know what to make of it. But to Hertz it was a beautiful idea that rang true. All it lacked was physical proof, and his quest was to supply experimental evidence that would put the matter beyond dispute.

From the time of Newton, leading scientists had believed that the universe was governed by mechanical laws: material objects held energy and inflicted forces. To them, the surrounding space was nothing more than a passive backdrop. The extraordinary idea put forward by Faraday and Maxwell was that space itself acted as a repository of energy and a transmitter of forces: it was home to something that pervades the physical world yet was inexplicable in Newtonian terms - the electromagnetic field.

Faraday's first notion of lines of force, much derided at the time, grew into Maxwell's sophisticated mathematical theory, which predicted that every time a magnet jiggled, or an electric current was turned on or off, a wave of electromagnetic energy would spread out into space like a ripple on a pond, changing the nature of space itself. Maxwell calculated the speed of the waves from the elementary properties of electricity and magnetism, and it turned out to be the very speed at which light had been measured. He surmised that visible light is just a small band in a vast spectrum of electromagnetic waves, all traveling at the same speed but with wavelengths that might range from nanometers to kilometers. All this remained just a theory with more skeptics than adherents until a quarter of a century later, when Hertz emphatically verified it by producing and detecting what we would now call shortwave radio waves in his laboratory. The door to previously unimaginable regions of scientific knowledge was opened.

It is almost impossible to overstate the scale of Faraday and Maxwell's achievement in bringing the concept of the electromagnetic field into human thought. It united electricity, magnetism, and light into a single, compact theory; changed our way of life by bringing us radio, television, radar, satellite navigation, and mobile phones; inspired Einstein's special theory of relativity; and introduced the idea of field equations, which became the standard form used by today's physicists to model what goes on in the vastness of space and inside atoms.

Faraday and Maxwell have attracted their share of biographers, and rightly so. Aside from their genius, both were admirable, generous-spirited men who conducted their science with infectious enthusiasm and exuded the kind of charm that made people feel better about themselves and the world in general. But perhaps even more compelling than their individual life stories is the way that the two men from totally different backgrounds - a self-taught son of a poor blacksmith and a Cambridge-educated son of a Scottish laird - were brought together by their curiosity about the physical world and their determination to find out how it works. Although they met only late in Faraday's life, they formed a tremendously strong bond - they were united by their willingness to challenge entrenched scientific customs and conventions. The theory of the electromagnetic field is their joint creation and has its own story, intertwined with theirs and with its own set of diverse supporting characters. There were, for example, the American rake Count Rumford, who was instrumental in founding the Royal Institution, which gave employment to the impecunious, young Faraday; the brilliant but vain Humphry Davy, who was Faraday's inspiring mentor; the maverick Oliver Heaviside, who summarized Maxwell's theory into the four famous "Maxwell's equations"; and the hardworking Oliver Lodge, who discovered waves along wires but found he had been comprehensively scooped by Hertz.

Welcome to the story of the electromagnetic field.
Other Books
Chirogenesis in Chemical Science,
□ □ □ □ □ . Forbes, N., and Mahan, B. (2014) Faraday , Maxwell, and the Electromagnetic Field: How Two Men Revolutionized Physics , Prometheus Books. 27. "Lepton," Wikipedia, last

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