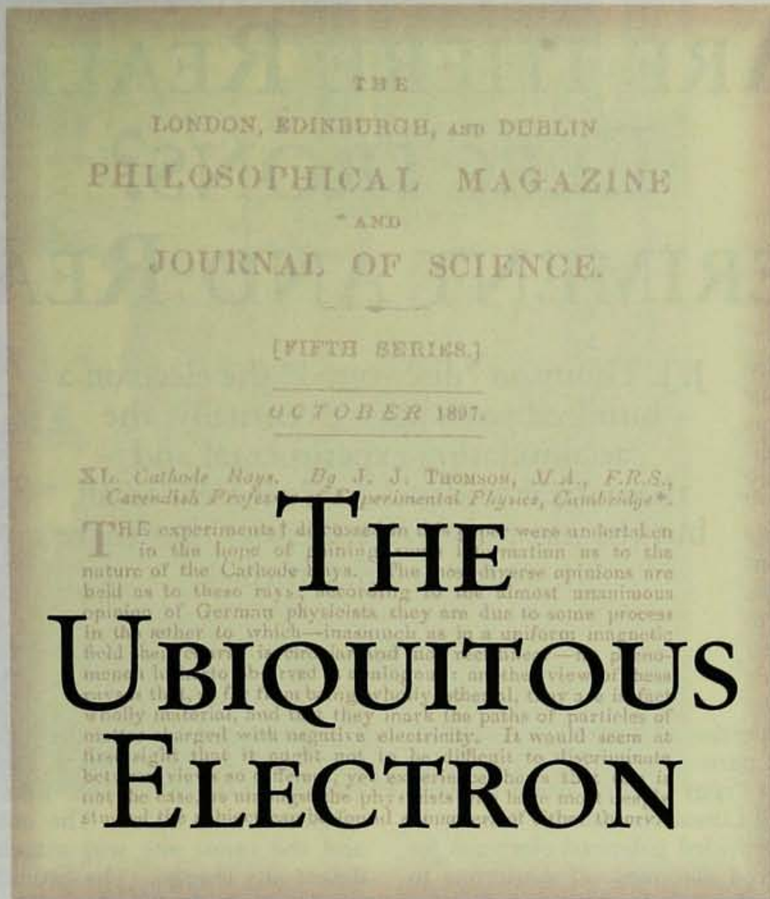
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XL. *Cathode Rays.* By J. J. Thomson, M.A., F.R.S., Cavendish Professor of Experimental Physics, Cambridge*.

The Ubiquitous Electron

As early as about 1830 electrical discharges in gases were intriguing a number of experimental physicists in Europe. In 1881, at the Cavendish Laboratory at the University of Cambridge, J. J. Thomson began experimenting with gaseous discharges, and continued to do so for the next 50 years.

When Thomson started his research, cathode rays had already been known for about 50 years, but their nature was controversial. As Thomson later wrote in the paper reporting his discovery of the electron, "The most diverse opinions are held as to these rays; according to the almost unanimous opinion of German physicists they are due to some process in the aether to which . . . no phenomenon hitherto observed is analogous; another view of these rays is that, so far from being wholly aethereal, they are in fact wholly material, and that they mark the paths of particles of matter charged with negative electricity."

In the paper published in *Philosophical Magazine* 100 years ago this month, Thomson reported that cathode rays were charged particles, which he called "corpuscles." It's hard to recall any discovery since then that has had more impact on not only physics but science, technology and our daily lives. To encompass the total impact of the electron in the late 20th century is daunting, but the articles that follow do provide fascinating glimpses of its influence on today's physics research and applications.

Allan Franklin explores the gradual acceptance of the particle nature of the electron in his article, "Are There Really Electrons? Experiment and Reality" (beginning on page 26). Thomson found that cathode rays have a negative charge, are deflected by an electrostatic force as if they had a negative charge and are acted on by a magnetic force as if there were a negatively charged body moving in the path of the cathode rays. Franklin observes that Thomson then used the famous argument: "If it looks like a duck, quacks like a duck and waddles like a duck, it's probably a duck." Of course 30 years later Thomson's son, George P. Thomson (as well as Clinton Davisson and Lester Germer), used experiments on electron diffraction to demonstrate that electrons behaved like waves.

Thomson's electron was the first elementary particle discovered, and indeed the first evidence of the existence of an elementary particle. Martin Perl's article, "The Leptons after 100 Years" (which begins on page 34), asks what is the intrinsic difference between the electron, the muon and the tau. Perl notes that each new lepton was discovered using a different technology—the electron with the cathode-ray tube, the muon with cosmic-ray detectors and so on.

"It is ironic that, a century after Thomson discovered that cathode rays were made up of integral charged particles, the most exciting developments in the theory of electrons in solids have to do with the 'fractionalization' of the electron," writes Philip Anderson in his article, "When the Electron Falls Apart" (which begins on page 42). Some of these electron fragments behave as though the electron had broken apart into three or five or more pieces. Others—spinons and holons—act like chargeless spins or spinless charges.

Alan Fowler, in his article "On Some Modern Uses of the Electron in Logic and Memory" (which begins on page 50), explains how silicon technology came to dominate logic and memory devices. But how much further can this technology go? "Like most phenomena with exponential growth rates, it cannot be expected to expand forever," writes Fowler. Although he sees difficulties with all the alternative technologies he discusses, "If there is no attempt to find alternatives, they will never be found."

Electron microscopy and lithography is the subject of J. Murray Gibson's article, "Reading and Writing with Electron Beams" (which begins on page 56). Electron microscopy is now capable of visualizing the structure of materials on the atomic level. Electron lithography plays an important role in custom patterning of semiconductor chips, enabling chips with as many as 90 million transistors per cm^2 to be produced. In the 21st century, Gibson writes, electron lithography may take over from optical lithography.

What surprises does the ubiquitous electron have in store for us in the century that lies ahead?

Gloria B. Lubkin