The Rise of Experimental Physics

Electricity in the 17th and 18th Centuries. A Study of Early Modern Physics. J. L. HEILBRON. University of California Press, Berkeley, 1979. xiv, 606 pp., illus. $40.

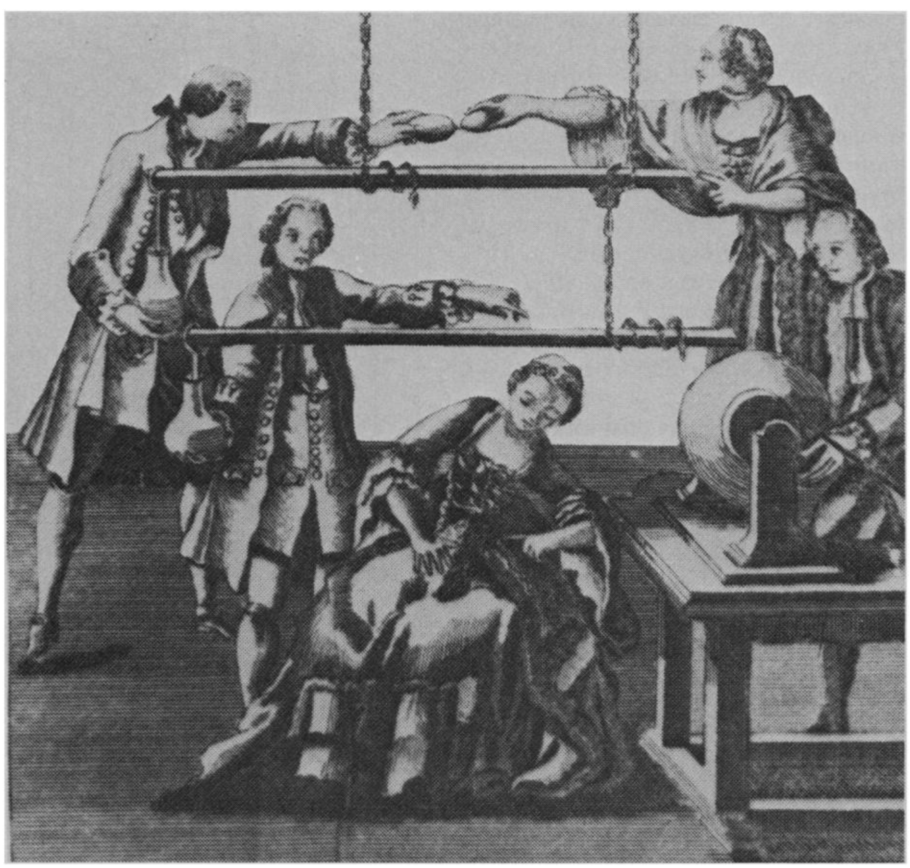
The science of physics has existed in name ever since Aristotle made it a separate discipline in his *Physica*; but for Aristotle, and for most of Western history, physics has meant something quite different from what it means today. For example, physicists and physicians were once both practitioners of the same science, as their names imply. It was not until the 18th century that medicine and the life sciences began to be placed in a category apart. Moreover physics, from the time of Aristotle until the 17th century, did not emphasize experiment and quantification. Experiment (what little of it there was) belonged to "natural magic," and anything measurable belonged to "mixed mathematics." Therefore physics as we know it is a relatively new area of science and one that has complicated origins.

In this book John Heilbron describes the rise of experimental physics by following its most characteristic and most dramatic subject—electricity. Electricity favored the creation of new and complex apparatus. It was ideal for demonstration experiments, which Heilbron believes did more than anything to define and narrow the scope of experimental physics. Its practitioners were academicians, university professors, and public lecturers, and it was among these three groups that experimental physics became established as a discipline. Heilbron identifies the members of each group and gives their salaries and the support available for their research. From the very beginning of experimental physics apparatus was expensive, and the physicist usually needed some institutional support to pay for his instruments. Heilbron judges the fortunes of the profession by the numbers of electricians working at different times during these two centuries. He also surveys the textbooks to show how the meaning of experimental physics changed. From this institutional setting he passes on to the history of electricity itself, which he carries through to 1800 and the voltaic pile.

The book represents an enormous amount of labor. Heilbron has read exhaustively in the primary and secondary literature, and because electricity was an international science his sources are in Latin, English, French, German, Italian, Swedish, and Dutch, all of which languages he appears to read without strain. The book is a valuable study if only for Heilbron's discussion of 18th-century academies, because he includes them all, not just those whose national languages are most widely known.

The great amount of detail that Heilbron includes has inevitably required a long book. It invites comparison with I. Bernard Cohen's equally long *Franklin and Newton* (1956), which for many years has been the standard work on 18th-century electricity. Although the two books are on the same subject, a comparison is not easy. The subtitle of Cohen's book is "An Inquiry into Speculative Newtonian Experimental Science and Franklin's Work in Electricity as an Example Thereof." As its title and subtitle indicate, that book identifies a current of experimental Newtonianism stemming from the *Opticks* and traces it through the 18th century in Britain and America. Heilbron, by contrast, has little use for Newtonianism or any other "ism." He believes that when it comes right down to the experiments all electricians did more or less the same thing. What was aether or electrical atmosphere for the Newtonians was subtle matter for the Cartesians, and although they squabbled over theory their experimental programs were very similar. He also makes little of Hermeticism as a stimulus to experimental physics, arguing that the rise of mixed mathematics, including architecture, fortification, navigation, astronomy, and optics, was much more important.

Heilbron prefers scientists who go

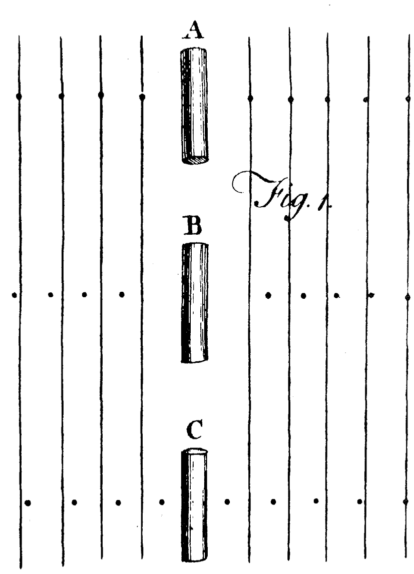


A one-person and a two-person discharge train, from Nollet's *Leçons de physique expérimentale*, vol. 6, 1748. "By [an] easy inference, electricians concluded that if one man . . . holds the jar and a second . . . touches the conductor, both will feel the shock when they bring their hands together. How many others . . . might be inserted between the first pair? Le Monnier tried 140 courtiers, in the presence of the King; Nollet shocked 180 gendarmes before the same fastidious company, and over 200 Carthusians at their monastery in Paris. 'It is singular [Nollet wrote in the *Mémoires de l'Académie des Sciences* (1746)] to see the multitude of different gestures, and to hear the instantaneous exclamation of those surprised by the shock.' " [From *Electricity in the 17th and 18th Centuries*] about their business without too much concern for philosophical matters. He believes that historians have allowed Galileo's ideological battle with the Church to dominate and distort our understanding of 17th-century science. As far as experimental physics is concerned, the Jesuits had the best instruments and were the best teachers. In the 17th century the greatest benefactor of experimental physics was the Catholic Church. If anything, the ideological conflict pushed the Jesuits in an advantageous direction, because it caused them to emphasize the less controversial subject of mathematics in their teaching. Heilbron does not approve of writing the history of science in terms of ideological conflict, or even conflicting theories, unless those theories directly affected laboratory practice. He may be taking too strong a position here, because theory and philosophical positions probably determined the course of electrical research more than he is willing to admit.

He also does not like heroes in science. Robert Boyle was capable of composing a "pious fraud" and Benjamin Franklin let his "intuition outrun his physics." The lightning experiments Franklin proposed, in addition to being ill-conceived (the first scientist to carry them out successfully was electrocuted), were not even original. Rather than credit one or two individuals with the major advances in electricity, Heilbron brings in all the lesser lights in order to reveal the actual complexity of the history. The story does not come out all that differently. The same major figures are still there, but with the detail Heilbron provides it is easier to understand the transitions between them.

There is one theme that comes out clearly in Heilbron's history. He shows that the major conceptual barrier to an adequate theory was the confusion between the *substance* of electricity and the attractive and repulsive *influence* of electricity. The "amber effect," from which the study of electricity began, seemed to indicate the existence of an effluvium agitating light objects and drawing them in. As new electrical phenomena were discovered, the effluvium had to be made more complex. The Abbé Nollet believed the effect was caused by two oppositely directed streams of material leaving and entering the electrified object; Franklin believed there was only a single static electrical "atmosphere." But neither theory differentiated adequately between the electrical substance and its "influence." How could one explain the fact that a damp cloth blocks the electrical influence and conducts the electrical fluid, whereas a pane of glass blocks the fluid and transmits the influence? No effluvial theory could do the job. The bitter battle between Nollet and the followers of Franklin over whether glass was impervious to the electrical "atmosphere" was a battle of words wasted, because neither Nollet nor Franklin was asking the question in the right way. Only in the works of Wilcke, Aepinus, and Volta did electricians finally forsake the atmospheres and separate the substance of electricity from its attractive and repulsive effects. What seems like an obvious step from our perspective required a century of experiment, until the results finally forced electricians in the direction of the "obvious" solution.

The history of electricity abounds in anecdotes. The stories are endless—from electrified boys suspended by silk cords from the ceiling to 200 electrified Carthusians. After Pieter van Musschenbroek's first shocking encounter with a Leyden jar, electricity was used to blast holes in cards, ignite spirits, drive pinwheels, and electrocute small animals. Electricity snapped and crackled to the amusement of an astonishingly wide audience. Heilbron shows, however, that although electricians usually had an eye out for the entertainment value of their experiments they were seldom content with theatrics alone. Even the most bizarre performances usually had a serious purpose.



John Canton's representation of the electric field, from Priestley's *History and Present State of Electricity*, vol. 1, 1767. Canton had informed Priestley "that electrical atmospheres 'are not made of Effluvia from excited or electrified Bodies, but are only Alterations of the State of the electrical Fluid contained in & belonging to the Air surrounding them . . . .' " In the figure "A, B, and C are neutral, positive, and negative, respectively. Since B pushes and C pulls the surrounding electrical matter, the air near B has less and near C more than its normal complement. . . . Priestley, who already had reasons to 'suspect the existence of electric atmospheres,' published Canton's theory. . . ." This approach (also expounded by Giambatista Beccaria), which "in effect assigned to the air some of the tasks Faraday later imposed upon the aether, seemed ratified by the perennial misleading failure to detect electrical motions in a vacuum. Many competent physicists therefore welcomed the approach." [From *Electricity in the 17th and 18th Centuries*]

John Symmer is a good example. In November 1758 he discovered that when he put both a black and a white sock on the same foot and then peeled them off one by one the socks ballooned out and cracked with electricity. When brought together they deflated and lost their electrical power, which was immediately restored when the socks were again separated. The phenomenon and the experimental apparatus involved amused many an amateur electrician, including the Prince of Wales, but it was not easily explained. In fact Symmer's socks brought about a revival of the two-fluid theory of electricity.

Some of the research programs at this time in the infancy of experimental physics sound very familiar. In 1784 van Marum commissioned the largest electrostatic machine in the world, because, as he wrote, "I took it as certain that, if one could acquire a much greater electrical force than hitherto in use, it could lead to new discoveries." The huge spark, two feet long and as thick as a quill pen, turned out to be of little value as a research tool, and for five years the machine stood idle. While van Marum was throwing money at the problems of electricity, Leonard Euler assaulted the same problems with "heady and irrelevant mathematics." His attempt to apply his newly discovered equations of hydrodynamics to electricity failed because the physical concepts were not yet there to be quantified. Heilbron's admiration is reserved for such painstaking experimenters as Henry Cavendish, who used his mathematics in one of the first careful calculations of experimental error. In his attempts to measure the relative resistivity of different materials Cavendish took the shocks through his own body and got the resistivity of iron correct to within 12 percent.

My major criticism of Heilbron's book is that it ends too abruptly. The first part of the book is about the beginnings of experimental physics, its institutional setting, and its practitioners. We are told that the history of electricity is the best illustration of this institutional and social setting, but Heilbron never goes back to tell us how the story that he has just given us illustrates the generalizations that he made in the beginning. Perhaps he believes the story speaks for itself, but more of his own interpretation would be helpful.

Electricity was not the only subject of experimental physics in the 17th and 18th centuries; heat, optics, and chemistry were equally important. Historians have tended to treat them as separate disciplines, and this is surely a mistake. There are signs of change, however. Historians of chemistry in particular have begun to emphasize the importance of theories of heat in the chemical revolution. We need to know how the sciences of electricity, heat, optics, and chemistry all grew out of the single subject of experimental physics, if indeed that is what happened. Heilbron's excellent book is an important beginning for this promising new investigation.

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Looking for Insights

A Retrospective Technology Assessment. Submarine Telegraphy: The Transatlantic Cable of 1866. VARY T. COATES and BERNARD FINN, with Thomas Jaras, Henry Hitchcock, and Robert Anthony. San Francisco Press, San Francisco, 1979. xvi, 264 pp., illus. Paper, $8.50.

The play-within-a-play or book-within-a-book, a literary device familiar to readers of *Hamlet* and *The World According to Garp*, has now been extended to social science. The history of the transatlantic cable has been embedded in a book whose main concern is helping to define a new discipline: retrospective technology assessment.

In the outer book, social scientist Vary Coates and historian Bernard Finn lead a multidisciplinary team seeking to link the past and the present by retrospectively carrying out a technology assessment (defined as "a systematic attempt to anticipate the potential impacts of technology on the economy, the environment, social institutions, and behavior"). In the inner book, businessman Cyrus Field leads a consortium of industrialists, engineers, and scientists seeking to link the Old World and the New by an undersea telegraph cable. Field's effort and its impacts make up the technology the outer book attempts to assess.

In the inner book, money is raised from businessmen and governments on two continents; naïve expectations are crushed as the initial straightforward attempts to lay the cable fail; an expert commission gets the project back on the right track; and, finally, with the aid of the world's mightiest steamship, the *Great Eastern*, and the world's most productive scientist-technologist, William Thomson (later Lord Kelvin), the cable team succeeds not only in connecting the continents but even in grappling from the depths and splicing a failed earlier cable.

In the outer book, money is raised from the National Science Foundation to pay for the study; naïve expectations persist; an expert commission meets at the George Washington University Library to eat a buffet supper and unconvincingly impersonate its 1861 predecessor; and rejecting two of the most productive tools in the historian's kit—archival research and imagination—the authors grapple in the depths for "productive insights and provocative hypotheses."

The conclusions that surface are unsurprising. Mankind ought to assess in advance those technologies that give entirely new capabilities—like instantaneous world communication, nuclear power, and genetic engineering. Networking technologies are especially worthy of assessment. The public is more interested in how technologies can be used than in how they work. Technology assessments can be biased by the assumptions and the interests of the assessors.

Unlike William Shakespeare and John Irving, the authors of this book fail to surround their inner plot with an outer story worthy of it. The play here is the only thing.

It features the impetuous Cyrus Field, whose energy made the cable project succeed at the same time as his impatience nearly doomed it. After the 1858 cable failed within a month of operation, businessmen learned to listen to their engineers' demands for quality standards. And those engineers, in turn, learned to listen to scientists' insistence that physical theory could be translated into guidance about power levels and detection methods. Governments learned to listen to technical experts: the 1861 Parliamentary Inquiry on Cables is a direct ancestor of the Kemeny Commission on Three Mile Island. The cable's direct impacts on the economics of shipping and futures markets, as well as its surprisingly damped and delayed impact on diplomacy, also make interesting reading.

But it is the outer book that carries the authors' real purpose. A retrospective technology assessment, we are told, is history not for its own sake but "in the hope of providing new insights into the relationship between technological change and social change."

The way the authors (particularly Coates and physicist Robert Anthony) seek this aim is through a positivist method of reaping a historical harvest already standing in the field, winnowing it according to mechanistic views of "impact," and grinding it in the mill of generalization. The tools of the technology assessor are employed: the Delphi method (here applied incorrectly); fully articulated impact trees; and the authors' own invention, the period profile approach.

The results totally lack the richness and the grace of recent books that rejected the armory of new methods and sought instead sympathetic yet critical involvement in the historical situation. Examples are Leslie Hannah's *Electricity before Nationalization*, an insightful administrative history of the impact of electricity in Britain; Anthony Wallace's *Rockdale*, an evocative account of the impact of the textile industry on 19th-century America; and even David McCullough's lively popular history of the Panama Canal, *The Path between the Seas*.

It would be unfortunate if the muse of history that inspired such works should find it necessary to disguise her virtues beneath the lab coat of positivist history for no better reason than to secure funding of studies in retrospective technology assessment from the hard-science-oriented funding officers of the National Science Foundation.

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A Memoir of Computing

From Dits to Bits. A Personal History of the Electronic Computer. HERMAN LUKOFF. Robotics Press, Portland, Ore., 1979 (distributor, International Scholarly Book Services, Forest Grove, Ore.). xvi, 220 pp., illus. $12.95.

Herman Lukoff's warm and human *From Dits to Bits* fills a void in the rapidly growing literature of computing. In the double introduction by John W. Mauchly and J. Presper Eckert, Mauchly writes,

> Until now, [the] history of the computer field has not been told in human terms by any of those who helped to create that history.