camera obscura in the Middle Ages. To be sure, all the students of optics may have been pursuing the pleasures of intimate visual exchange with their mothers, but it is not apparent to me that the contention, if true, notably enhances our knowledge of the science of optics.

Once launched on this current, Manuel presses on under full sail. Where did Newton discover the law of universal gravitation? At Woolsthorpe, near his mother, of course. And was his longing for his mother not an attraction akin to that of gravity? You may be sure that it was. Although Manuel describes the idea as the wildest hypothesis, he notably does not refrain from feigning it. Attention to the details of the history of science could have spared him such a blunder. While Newton derived certain quantitative relationships in 1666, he did it without the concept of attraction, as his technical manuscripts reveal.

In passing, Manuel presumes to settle many of the basic questions of Newtonian science on similar terms, often with condescending asides to the historians of science who appear to think there is a logic internal to scientific thought. While scholars have searched for the origins of Newton's philosophy of nature in Gassendi and Henry More, his view of matter really stemmed from his dread of physical contact. Princess Caroline, with an insight into the psyches of Newton and Leibniz that was remarkably similar to Manuel's, grasped the secret meaning of the controversy better than scholars intent on a simplistic, rational verdict between the two. Learned accounts of Newton's ether with their fine distinctions of meaning are summarily swept aside and the issue is settled by recourse to the analyst's couch. As a historian of science, I find these passages balderdash. When Manuel does his thing, he does it very well indeed, and I know of no historian of science who can approach him. When he does our thing, however, it's another ball game. If scientists have psyches, as I certainly believe they do, science has a logic of inquiry and demonstration that is subject to other rules.

Lest anyone be in doubt, some of those learned accounts that Manuel brushes aside with ill-disguised disdain carry my name. Having worked off my spleen, I find that I am breathless in admiration of the total work. It is a virtuoso performance. I do not know any more about psychoanalysis than the average educated man, and I am unable to predict how psychoanalysts will receive the work. I flatter myself that I know a considerable amount about Newton, however, and as a Newtonian scholar I find it impossible to doubt that the book will be received as a masterpiece in its genre. It is a portrait of Newton such as no one has been able to produce before, not merely superior to others but vastly superior. So who cares if he doesn't like my learned articles?

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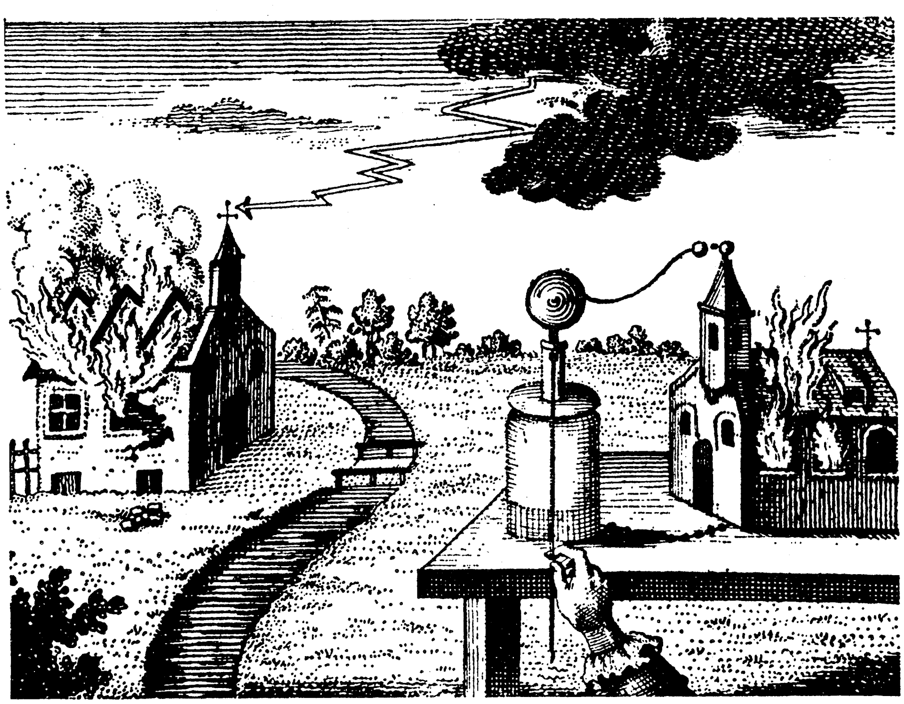
Antique Instruments

The Apparatus of Science at Harvard, 1765–1800. DAVID P. WHEATLAND, assisted by Barbara Carson. Harvard University Collection of Historical Scientific Instruments, Cambridge, Mass., 1968 (distributed by Harvard University Press). xii + 204 pp., illus. $20.

If the passage of time has separated the antique instruments of science from the living laboratory, its selective flow has helped to preserve some of the loveliest. And just such an occasion is at hand in this handsome, if casual (for few details of their operations are supplied), catalog of the collection of historical scientific instruments of Harvard University.

Ranging across the sciences, the collection contains telescopes and other astronomical instruments and models, surveying and drafting instruments, microscopes, clocks, vacuum pumps, chemical apparatus, and the equipment necessary to demonstrate and explain the common phenomena of physics—light, sound, electricity, magnetism, and the like. Excellent photographs of all the apparatus are given, with occasional plates in full color (of which perhaps the water pump in red mahogany and golden brass is the most attractive), and these are often accompanied by woodcuts drawn from related texts, though this association is sometimes forced, as in the juxtaposition of a cut from Chérubin's *La Dioptrique Oculaire* of 1671 with a Gilbert telescope of the late 18th century.

Although the book does not rival, in photography or text, such recent volumes as Henri Michel's *Les Instruments*



Equipment for demonstrating the virtues of lightning rods. In 1789 Harvard purchased from the Reverend John Prince a mahogany "thunder house" (similar to the model illustrated) 10 inches long and 8 high, with a lightning rod running up the gable. "Here was the lecturer's *tour de force!* When the circuit was complete, an electrical charge passed through the lightning rod without harm to the house. But a spark supplied to a broken circuit ignited a quantity of gun powder inside the house, blowing off the roof and flattening the four walls amid a cloud of black smoke, fire, and general approbation from the students." [Reproduced in *The Apparatus of Science at Harvard* from Beck's *Kurzer Entwurf der Lehre von der Elektrizität*, 1787] *des Sciences* (1966), with which it demands comparison, it is a work well done, simple and sober. Its failings are those of virtually all such publications to date; they are meant for the coffee table rather than the study.

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A Mathematical System

A History of Vector Analysis. The Evolution of the Idea of a Vectorial System. MICHAEL J. CROWE. University of Notre Dame Press, Notre Dame, Ind., 1967. xviii + 270 pp., illus. $12.95.

The evolution of the idea of a vectorial system is one of the most interesting and spirited segments of the history of mathematics. Few areas of mathematics have given rise to such ardent partisanships. The dialogues between advocates of one type of vector analysis over another often reached heated and vituperative levels. Even today the matter of vector notation is a quarrelsome subject among vector analysts. Since the story has not previously been fully or accurately told, students of the history of mathematics owe Michael Crowe a debt for his scholarly and painstaking narration. In following the tale the reader will encounter a long roster of great and not-so-great mathematicians and physicists, among whom are Leibniz, Wessel, Gauss, Argand, Buée, Mourey, Warren, Hamilton, Möbius, Bellavitis, Grassmann, Saint-Venant, O'Brien, Tait, Benjamin Peirce, Maxwell, Clifford, Schlegel, Cayley, Gibbs, Heaviside, Wilson, Burali-Forti, and others. In Crowe's book one finds much biographical material about these men, and the treatment of such principals as Hamilton, Grassmann, Tait, Gibbs, and Heaviside is really superb. The book is developed in strict chronological order, up to the year 1910, and each of the eight chapters concludes with a valuable collection of notes.

It was in 1830 that Hamilton began his search for a three-dimensional vectorial system, and in 1832 that Grassmann got his first ideas for his calculus of extension; in 1843 Hamilton discovered his quaternions, and in 1844 Grassmann published his *Ausdehnungslehre*. Crowe's story is largely about the fate and influence of these two great achievements. Because of similarities in the Hamilton and Grassmann systems, either one could have led to modern vector analysis through a process of simplification, but the "capital" of Hamilton's personal fame as opposed to the anonymity of Grassmann caused the quaternions to play the more influential role in the subsequent development of the Gibbs-Heaviside system. The quaternions, which were originally heralded as among the two or three truly great achievements in mathematics, are now largely regarded as a museum piece. But two worthy credits to quaternions still remain—they led ultimately to the highly versatile vector analysis of today, and they (along with Grassmann's calculus of extension) first opened the floodgates of modern abstract algebra. For the discoveries of Hamilton and Grassmann played a role in the history of algebra very much like that played by the discoveries of Lobachevski and Bolyai in geometry. Just as the latter led to the new non-Euclidean geometries, the former led to the new nontraditional algebras, and both, in turn, further led to the development of formal axiomatics.

Crowe's book purposefully concentrates on the more fundamental aspects of vector analysis, with the result that certain parts of the history of the subject receive little or no attention. Thus, though much is said of vector algebra, little is said of vector calculus; the del operator is scantily considered; and the history of notational squabbling is omitted. Closing the story at the year 1910 has led to the omission of the history of such allied subsequent developments as tensors, vector spaces, and linear algebra. But within his prescribed framework, Crowe tells his story completely, with scholarship, and magnificently—sometimes in almost majestically structured sentences.

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Memorial to a 20th-Century Figure

Oppenheimer. I. I. RABI, ROBERT SERBER, VICTOR F. WEISSKOPF, ABRAHAM PAIS, and GLENN T. SEABORG. Scribner, New York, 1969. x + 92 pp. + plates. $5.95.

In 1967 the American Physical Society devoted a special session of its spring meeting to a memorial for J. Robert Oppenheimer. At that session, four of Oppenheimer's colleagues reviewed his several careers and his contributions to science and society. Their speeches reflected their close personal connection with Oppenheimer, and so conveyed impressions of the man, as well as of his achievements. These talks have now been collected into a book, together with a brief introduction by I. I. Rabi. There is in addition a very good glossary of the scientific terms used by some of the speakers, which could serve as a model for books of this type.

Oppenheimer was a scientist, a teacher, the director of the atomic bomb project, an influential government adviser, and an expositor of science to nonscientists. The speeches printed here touch on all of these activities—most successfully, I think, on his work as scientist and teacher. Oppenheimer's greatest contribution to science in America was not in any of his papers, important as some of them were. It was rather the example of his dedication and the keenness of his critical insight, which, by inspiring his students and colleagues, raised theoretical physics in America to its present position of leadership. These aspects of Oppenheimer are movingly recalled in the speeches of Robert Serber, who deals with the prewar period, and Abraham Pais, who covers the postwar period in which Oppenheimer was director of the Institute for Advanced Study. It took Oppenheimer's special abilities to remain abreast of the many seemingly disparate developments in fundamental physics in the latter period and point the way to finding unexpected relationships among them. The speed and precision with which he was able to do this were apparent to anyone who ever attended a seminar at the Institute.

Oppenheimer's directorship at Los Alamos is recounted by Victor Weisskopf, who stresses how remarkable an institution that laboratory was. This may be seen not only from its inanimate products, but also in its effect on the lives of those who worked there. Again, it was Oppenheimer's genius for grasping all aspects of a complex problem and his ability to inspire the work of others that gave Los Alamos its special character.

Oppenheimer's advisory work for the government is described by Glenn Seaborg, who also mentions some of his efforts to promote a common under-