if the reader desires. This approach works well, and Weinberg has succeeded in producing a fine book that should be both fascinating and accessible to the dedicated general reader. It should also be of interest to professional scientists and students who wish to learn more about the history of their field.

The opening chapter gives a brief overview of the book, an account of the early history of the Cavendish Laboratory (where so many of the important discoveries were made), and an introduction to scientific notation. The second chapter, on the discovery of the electron, is the longest and is the heart of the book. J. J. Thomson's experiments to determine the charge-to-mass ratio of cathode rays (electrons) are described in considerable detail, with flashback sections devoted to early ideas on electricity (including Benjamin Franklin's work), Newton's laws of motion, electric and magnetic forces, and heat and energy. It is emphasized that Thomson's achievement consisted not only in the charge-to-mass measurements but also in his willingness to interpret the cathode rays as the fundamental "atom" out of which the elements are constructed. (W. Kaufmann in Berlin had carried out similar measurements, but, under the influence of Mach, he did not claim to have discovered a fundamental particle.)

The chapter on the atomic scale is concerned with Millikan's measurement of the electron charge and its significance. In flashbacks on atomic weight, describing the work of Dalton, Gay-Lussac, Avogadro, and others and on electrolysis, dealing with Faraday's determination of the charge-to-mass ratio for ions, it is shown that following Thomson's work a single good measurement of the electron charge was all that was needed to determine not only the electron mass but also Avogadro's number and the masses and sizes of atoms. The early measurements by Townsend, Thomson, and Wilson of the charge-to-mass ratio of water droplets, with the average mass determined by their rate of fall through air, and Millikan's (and perhaps Fletcher's) important refinement of using oil drops are described in detail.

The chapter on the nucleus discusses the early history of radioactivity, the Geiger-Marsden discovery of large-angle scattering of alpha particles from a metal foil (which Rutherford described as being "almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you"), and Rutherford's interpretation that the alpha particles must be scattering from an atomic constituent (the nucleus) that is very much smaller than the atom itself. Moseley's measurement of atomic numbers using the Bohr formula, the subsequent atomic theory of the chemical elements, Chadwick's discovery of the neutron, and the evidence that the neutron is a fundamental particle and not a bound state of the proton and electron are then described.

The final chapter briefly describes photons, neutrinos, antiparticles, muons, pions, strange particles, and quarks. There are also 11 appendixes in which many of the topics of the book are reconsidered with the use of simple algebraic formulas.

The book is very well written and nicely produced. It is full of interesting photographs of people and apparatus. It succeeds not only in presenting many of the important results of modern and classical physics but also in giving a flavor of how physics was done in the 19th and early 20th centuries.

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Swirling Flows

Vortex Flow in Nature and Technology. HANS J. LUGT. Wiley-Interscience, New York, 1983. xviii, 297 pp., illus. $49.95. Translated from the German edition (Karlsruhe, 1979).

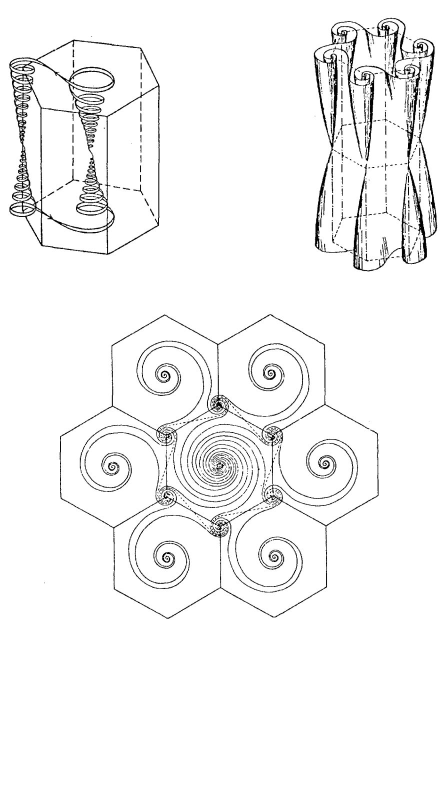
This handsome volume will delight anyone who sees beauty and order in the motion of a smoke ring or a dust devil. It is the work of a man in love with his subject, who spends his working hours computing the swirling flows around ships and aircraft and in his spare time observes their counterparts everywhere about him, from the leaves in his cup of tea to the Great Red Spot of Jupiter. He has surveyed the subject using virtually no equations (except in a mathematical supplement); he does use dozens of beautiful photographs from the laboratory and from nature and hundreds of sketches, graphs, and computer-generated pictures.

What is a vortex? It is, Lugt says, the rotating motion of material particles around a common center, also known as a whirl, an eddy, circulation, a cyclone, or a swirl; and almost every movement of matter may be considered vortical. In the first half of the book he deals with such flows on a human-sized scale and in the second half on a scale earth-sized or greater, where rotation and stratification are significant.

Examples are drawn from all of life: the bathtub vortex and the falling maple leaf, the flight of a boomerang and a wasp, the jet propulsion of a squid and the dangerous tip vortexes on the flight deck of an aircraft carrier. Then, as the scale expands, we learn the fascinating history of the development of the concept of the general circulation of our atmosphere and its watery images in the Sargasso Sea, the Gulf Stream, and El Niño. Still expanding, the book concludes with galactic vortexes, black holes, and the big bang.

This is a picture book, a book of history and philosophy, and an encyclopedia of natural and man-made phenomena; yet at the same time it is a textbook that can be recommended to any student of fluid mechanics. In particular, chapters 4 through 6 are intended as an unorthodox introduction, based on vorticity dynamics, to the theory of viscous fluids. Every reader will pick up useful tidbits: how to test whether an egg has been boiled, how a Frisbee flies, how pouring cold milk into hot coffee generates a spiral vortex. And even an expert on fluid mechanics on the human scale will find the second half of the book a pleasant introduction to the motion of the oceans and the atmosphere.

It is fun to read a technical book that



"Bénard cells in a rotating fluid. [*Top left*] Particle paths in a cell, perspective view; [*top right*] sketch of a cell which is distorted through rotation; [*bottom*] seven cells seen from above. The solid spiral lines represent particle paths, the dashed line is the border of the middle cell." [Reprinted in *Vortex Flow in Nature and Technology* from S. Chandrasekhar (1961)] has been written and edited with intelligence and love. The large-format pages are attractively designed. Seven hundred references are cited. And, as a rare final touch, the index is adequate.

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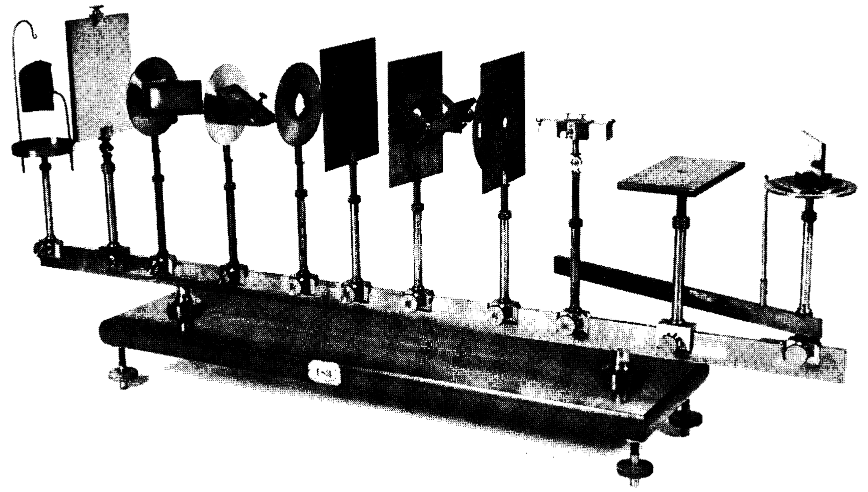
Apparatus of the Past

Nineteenth-Century Scientific Instruments. GERARD L.'E. TURNER. Sotheby Publications, London, and University of California Press, Berkeley, 1983. 320 pp., illus. $60.

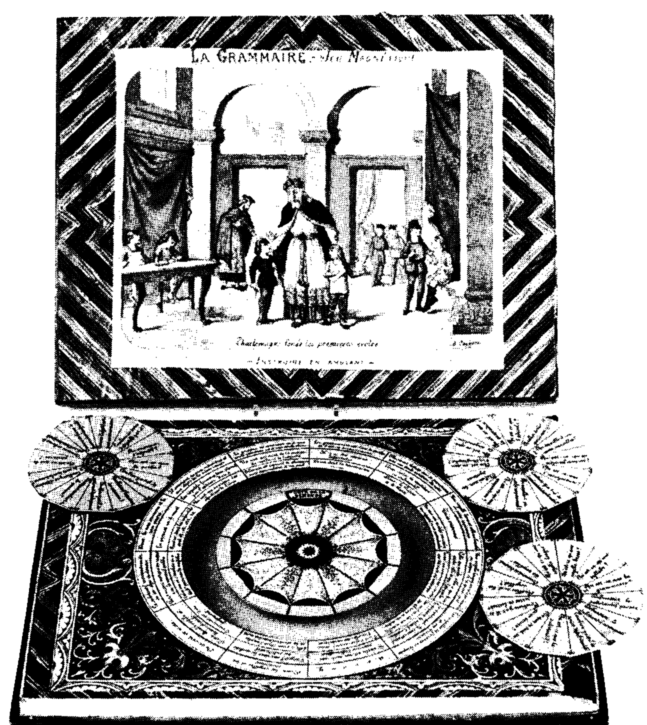


"An 'optical' bench for the study of the properties of radiant energy, signed: Ruhmkorff, rue des Orfèvres 6, Paris. The accessories are: heat source, bright brass screen, two prismatic cells, mica disk, black glass, aperture and mica sheet tiltable, aperture disk, thermopile, mahogany table, reflector on divided plate. The metre bar is divided to half-centimetres. . . . Base 680 × 88 mm; bar 1012 mm. 1845. *Teyler's Museum (183).*" [From *Nineteenth-Century Scientific Instruments*]

The publication of a major book on 19th-century scientific apparatus is welcome. There is an obvious antiquarian as well as historical interest in these handsome examples of fine design and construction, hand made of brass and polished wood. In addition they are of practical interest to the teaching physicist. Despite natural breakage, the desire to replace old apparatus with state-of-the-art equipment, the temptation to use old apparatus as sources of parts for new research apparatus, and "leakage" from equipment storage rooms, a surprisingly large amount of 19th-century apparatus survives in colleges and universities. In my lectures I regularly use wave machines, a guinea and feather tube, electrostatic demonstration apparatus, and acoustical apparatus from the second half of the century because it does a better job of showing the phenomena than anything available today.

Turner's book is a series of well-executed compromises. He points out at the beginning that the subject of 19th-century scientific apparatus is a large one and he can, in the compass of a single volume, give primarily an overview and introduction to the subject. The apparatus Turner discusses and illustrates is drawn from the physical sciences (there is essentially nothing relating to what we would today call biology). Focusing still more narrowly, the bulk of the apparatus was used for physics or for closely related fields. After an introductory chapter and chapters on time and weights and measures, there is a series of eight chapters describing physics apparatus. Anyone who has looked at an older physics book will immediately recognize the familiar order of topics, starting with mechanics, hydrostatics, and pneumatics, going on to heat, sound, and light, and finishing with magnetism and electricity. Chemistry is given a relatively short treatment, which is perhaps a reflection of the fact that chemists use breakable glassware and so leave relatively few artifacts behind them, in contrast to physicists, who build in brass. The remaining chapters deal with various aspects of applied science such as surveying, navigation, calculation, and meteorology. The very last chapter, on recreational science, shows examples of scientific apparatus likely to be found in the 19th-century home.

The book is designed to be reasonably self-contained. The text that accompanies the more than 400 photographs and engravings gives enough background to place the apparatus in its proper historical and scientific contexts. There are useful short biographies of important scientists and instrument makers. Occasional misstatements do creep in: in the discussion of the work of Ångström on the measurement of the wavelengths of spectral lines, the statement is made that



"Game for teaching French grammar, employing a secret magnetic needle, and strips of iron embedded in three question disks. The magnetic needle points to the correct answer. Inscribed: la grammaire jeu magnétique—instruire en amusant. Box 295 × 230 × 35 mm. c. 1900. *Private collection.*" [From *Nineteenth-Century Scientific Instruments*]