books

Needed wherever magnetic experimentalists are playing

Ferromagnetic Materials: A Handbook on the Properties of Magnetically Ordered Substances, Vols. 1 and 2

E. P. Wohlfarth, ed.
643 pp, 610 pp. North-Holland, New York, 1980. \$102.50, \$102.50

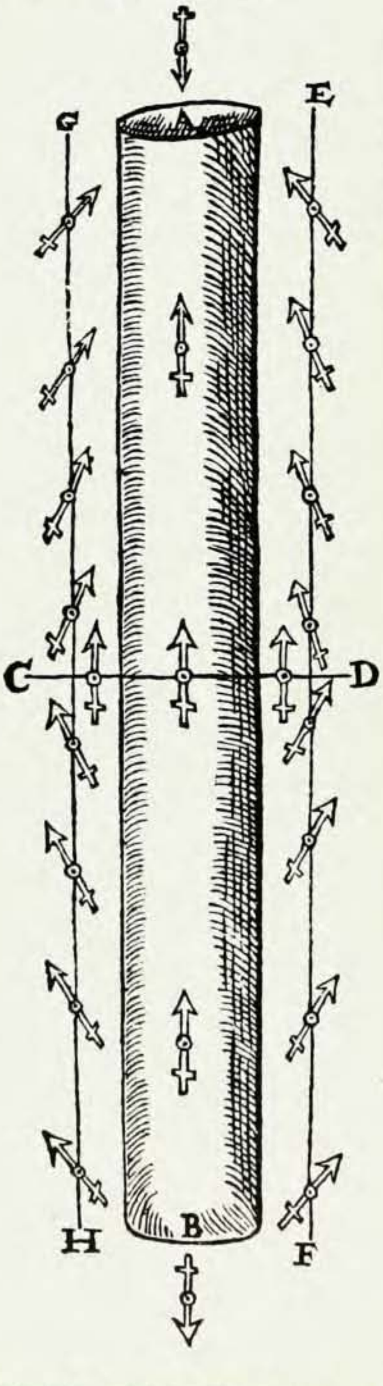
Reviewed by Anthony S. Arrott

The claim on the dust jacket—that these volumes will be the most comprehensive work to date on the subject of ferromagnetism—has the full support of this reviewer. A further claim, that it is a textbook as well as a reference, has yet to be tested, but it is likely that an advanced graduate course in special topics in magnetism could be based on these volumes. Each of the fifteen articles (a total of 32 are projected in four volumes) in the present two volumes can be read in an evening. Each provides the historical, phenomenological and theoretical background sufficient to tell a story about the properties of materials. The authors also give ample sources for the background information they assume of their readers.

The handbook provides comprehensive reporting of magnetic materials in tables, graphs and extensive bibliographies to make good another claim of the dust jacket, that the handbook is intended to replace R. M. Bozorth's monumental *Ferromagnetism* published some 30 years ago and used by a generation as a text for self-education. In particular, G. Y. Chin and J. H. Wernick refer primarily to Bozorth in their chapter on soft magnetic metallic materials. They have written a worthy sequel to Bozorth on this subject that dominated his book.

If you have ever wondered about that ad on the back of the city bus that spells out in large letters or chemical symbols the names chromium dioxide and gamma Fe_{203}, you will find the whole story of magnetic recording materials coherently presented by G. Bate in 125 pages. In describing this successful technology, Bate covers the physics, chemistry and metallurgy that went into its development. Part of the fascination of the subject is that "there is no universal relationship linking magnetic properties and recording performance." Although one may fully characterize the behavior of the individual particle on a magnetic tape, one cannot do so with the ensemble behavior of randomly packed strongly interacting particles. Bate weaves into the narative 600 or more references, including over 100 patents from more than ten countries.

The three ferromagnetic transition metals are treated by E. P. Wohlfarth, who also deserves to take a bow as editor. The magnetism of iron, cobalt and nickel remain a major challenge in the theory of metals. Wohlfarth reviews theory and experiment in separate sections in recognition of how little theory can quantitatively explain, let alone predict. In their treatment of dilute transition metal alloys, spin classes, J. A. Mydosh and G. J. Nieuwenhuys first make clear the variety of magnetic orderings to be encountered and then review the salient experimental features observed. They conclude with a survey of the random-molecular-field model, for which they show more enthusiasm than might be justified on the criterion of agreement with experiment. In return for bringing together the vast experimental literature of the last 25 years, they may be indulged a bit of propaganda. The reviews of more concentrated crystalline transition metal alloys apparently are to be covered in the later volumes. Volume 1 does contain the treatment by F. E. Luborsky of amorphous ferromagnets, which are a new class of materials competing for the market against the soft magnetic materials, described by Chin and Wernick, that have a century of development behind them. Luborsky's chapter might have been subtitled "everything you would



FROM WILLIAM GILBERT, ON THE MAGNET

have liked to have known before entering the competition." As a major contributor to the field, he remains cautiously optimistic about the future of amorphous ferromagnetic materials.

Rare-earth elements on their own have intriguing magnetic properties that have been systematically investigated in the last two decades. S. Legvold covers them and their alloys with one another. K. H. J. Buschow describes the properties of over 1000 intermetallic compounds that rare earths form with other metals. Many of these he and his colleagues at the Phillips Research Laboratories produced. In summarizing the ability of current theory to encompass the results on the compounds with nonmagnetic elements, Buschow says, "in a way all these results seem rather frustrating. Initially rare-earth intermetallics and their magnetic properties were believed to represent standard examples of the RKKY coupling scheme. From the discussion given above it would appear that the predictive value of the RKKY coupling scheme is actually rather limited and that for an *a priori* description of the magnetic properties in the rare-earth intermetallics a knowledge of details of their band structure would be required." Experimentalists are optimistic by nature, apparently.

When rare-earth elements are combined with Mn, Fe and Co, their Curie temperatures, in sharp contrast with those of all other compounds, are well above room temperature. Of all the compounds, perhaps the most likely to prove practical are the magnetostrictive rare-earth–Fe_2 compounds that A. E. Clark describes. Alloys that have been produced with magnetostrictions greater than 0.001, while maintaining high susceptibilities, yield the very high magneto-mechanical coupling coefficients suitable for transducer operation.

The mixed oxides of rare earths with transition metals, which crystallize in the garnet structure, find applications in microwave devices and thin films for magnetic bubbles. The late M. A. Gilleo presents the basic magnetic properties of the garnets. Their applications are given in chapters by J. Nicolas on microwave ferrites and by A. H. Eschenfelder on crystalline films for bubbles. P. J. Slick considers transition metal oxides of the spinel structure in a chapter on ferrites for nonmicrowave applications. Despite a lack of background in these applications of magnetic insulators, this reviewer found these articles interesting and easy to read. Eschenfelder has a second chapter devoted to amorphous films for bubbles. The typical example is a mixture of Gd, Co, and Mo.

As if there weren't enough magnetic materials already, nuclear technology has extended the actinide series, whose magnetic compounds W. Trzeviatowski covers. The magnetic properties are helpful in understanding the electronic structure of these materials.

The final chapter by S. W. Charles and J. Popplewell is on ferromagnetic liquids; these came out of the space program and have more recently been developed for use in rotating seals with impressive performance. The authors foresee many other applications for very fine ferromagnetic particles suspended in liquids. The secret is to prevent aggregation by coating the particles with a surfactant, typically a long organic molecule with a polar head. The authors neglect to point out that magnetic fluids make good toys, but everybody knows that about magnets in general.

Judging by the vast amount of information gathered from experiment and the small impact of theory on predicting magnetic behavior, one might conclude that magnetic materials are more fun to discover and experiment with than to try to understand quantitatively. Wherever the experimentalists are playing, they will find these volumes a must.

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Albert Einstein's Special Theory of Relativity: Emergence (1905) and Early Interpretation (1905–1911)

A. Miller

466 pp. Addison-Wesley, Reading, Mass., 1981. $39.50 cloth, $27.50 paper

The development of the special theory of relativity—one of the most significant episodes in the history of science—is invariably made to serve as an empirical basis for the discussion of fundamental concepts in the history and philosophy of science. Any attempt to characterize the nature of theory change in science must deal with this episode in some manner. For example, in *The Structure of Scientific Revolutions*, Thomas S. Kuhn uses the transition from Newtonian to Einsteinian physics to argue for the incommensurability of scientific theories and against the possibility of choosing, fully rationally, among competing theories. Karl Popper, whose views are opposite to those of Kuhn, uses this case instead to demonstrate that although scientific theories can never be verified, they can be falsified, in principle by a single experiment.

Surprisingly, Arthur Miller's new book is the only work extant that attempts to describe the detailed technical context, both experimental and theoretical, out of which Einstein's special theory of relativity emerged and to chronicle the arguments that led to its eventual acceptance. The book is long and difficult, but the story it tells is fascinating because it little resembles the tendentious descriptions of this era found in physics texts or philosophy journals.

The major contribution of the book is that is brings to light a feature of the development of special relativity that is not widely appreciated by philosophers, historians or physicists and that goes a long way toward explaining why physicists were so slow in accepting the theory itself and Einstein's contribution to it. The importance of Einstein's work went unrecognized initially because he was attempting to construct a *macroscopic* theory that would lead to the covariance of Maxwell's equations, while, in contrast, his contemporaries were working with atomic theories.

Miller places the development of special relativity in the context of the research program of electromagnetic theorists in the two decades preceding Einstein's 1905 "relativity" paper. This research program, greatly influenced by the recent discovery of the electron by J. J. Thomson and others, had two ambitious goals: to derive the Lorentz contraction and related effects, which were known to imply the invariance of Maxwell's equations for all inertial observers, from a microscopic theory of the interactions of the charged atomic constituents of matter with the ether, and to derive the mass of the electron, that is, its resistance to acceleration, from the energy stored in its self-electromagnetic field, which could achieve, in principle, the quite revolutionary step of reducing mechanics to electromagnetic theory. By 1905 Konrad Lorentz and Henri Poincaré had developed a theory of the electron that essentially satisfied the first of these goals but not the second; another group led by the German theorist Abraham, had formulated a theory that satisfied the second goal but not the first. The two theories made different predictions about the expected velocity dependence of the electron's mass, which was being tested experimentally.

It was in this intellectual climate that Einstein published his 1905 paper. There he showed that the Lorentz transformations and Lorentz's prediction for the velocity dependence of the electron's mass could be derived from two general macroscopic postulates, that the form of the laws of physics was