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astrometry and refrains from criticizing the subjects he treats. Some of what has come down to us through many centuries could surely be improved. Is it really still appropriate to reckon angles in a hexagesimal system, with two different units (hours and degrees), no less? Has the concept of the ecliptic—such as it is—not outlived its usefulness? On the other hand, he has indeed introduced new concepts (proper direction, natural direction) where there was a need for them.

No worker in the field will be able to ignore this book without risking damage to the quality of his or her own work. It is also indispensable for the serious student. It may well show some seasoned astrometrist that the time has passed when one can engage in much modern astrometry without knowing (or at least knowing how to use) relativity. The beginner, especially the undergraduate student, will do well to study relativity and, for example, Laurence Taff's excellent *Computational Spherical Astronomy* before attempting to read Murray's volume. No library of any astronomical research institute will be complete without this important work.

HEINRICH EICHHORN
University of Florida

Manifolds, Tensor Analysis, and Applications

R. Abraham, J. E. Marsden, T. Ratiu
 582 pp. Addison-Wesley, Reading, Mass.,
 1983. \$34.95

This book is the first basic text in a series of books on global analysis, pure and applied, which is planned by Ralph Abraham, Philip J. Holmes and Jerrold E. Marsden and comprises both advanced and basic texts. The series aims at giving the keys of global analysis to a wide audience of scientists and engineers. One of the advanced texts has already appeared: *Gauge Theory and Variational Principles* by David Bleeker (1981). A second basic text, on Riemannian geometry and Lie groups, is on the drawing board.

Two of the authors of this text have previously written an advanced classic on the subject, *Foundations of Mechanics* (Abraham and Marsden, 1978), and one is currently writing a popular series *The Visual Mathematics Library* (Abraham with Christopher Shaw). The present text is a good book. It offers some of the essence of the first with the quality of presentation of the second.

What does this text cover? Basics in topology, calculus on Banach spaces, vector bundles, vector fields and dynamical systems, tensors and differential forms, integration on manifolds, applications to Hamiltonian mechanics, flu-

id mechanics, Maxwell's equations, thermodynamics and five delightful appendices. Lie groups are not mentioned. Not everyone needs Lie groups, but the stage (and the titles of the series and the books) is so well set up for them that their absence is a pity. More important, the absence limits the definitions of other concepts. For instance, the basic definition of Killing-vector fields requires the concept of group action on a manifold. In this book Killing-vectors are defined in the limited context of Riemannian geometry (that is, isometries) as the vector fields X satisfying $L_X g = 0$. A later example tells us that the flow of X consists of isometries, and isometries are defined in a later exercise. The information is there, but the picture is broken up into three pieces. Similar remarks apply to other concepts. The usual definition of vector bundles includes a statement on the group action of the structural group on the typical fiber. Without it, the key notions of structural group and transition functions, the distinction between fibers at a point and typical fibers, between trivialisable and trivialisations, are either absent or obscured.

Lie groups will, I believe, be an important part of the second basic text, and in this sense the present book is only half a book. Comments on the choice of topics, and their division between the two books will be more pertinent after the second book is published. Depending on the audience, the first book alone—or the two books combined—could serve as a basis for an excellent course in mathematical physics.

CECILE DEWITT-MORETTE
University of Texas, Austin

Relativity and Its Roots

B. Hoffmann
 176 pp. Freeman, New York, 1983. \$9.95

The greatest strength of this short and very readable book, written by an award-winning Einstein biographer, lies in its thorough treatment of the "roots," the history of ideas about the relativity of motion. Though its tone suits a lay audience, even a working physicist may find some surprises in this narrative.

Relativity, Banesh Hoffmann reminds us, is as old as Western philosophy itself. Most of us know of Aristarchus of Samos, but he begins from Philolaus, whose moving-Earth (but not heliocentric!) cosmology came two centuries earlier. He touches briefly on the contributions of Nicolaus Copernicus, Johannes Kepler, Galileo Galilei and René Descartes on the way to the most "interesting" case, that of Isaac Newton. Here he dwells on the curious fact that the very thinker who en-

shrined relativity at the core of physical thought had grave misgivings about the principle and desperately defended his "absolute" space in the face of the very cogent criticisms of George Berkeley and Gottfried Wilhelm von Leibnitz.

Hoffmann gives Immanuel Kant and Ernst Mach their due but realizes that it was the development of modern optics that posed the greatest challenge to relativity. On this part of the story he lavishes his most careful attention.

The problem arose from James Bradley's discovery, in 1728, of stellar aberration. In its time, it posed no conceptual difficulties, and in fact led to the best available estimate for the speed of light. But a century later, in the context of the wave theory of light and the ether hypothesis, stellar aberration pointed to a "stationary" medium and spawned the ill-fated attempts to measure the absolute velocity of the Earth optically.

François Arago made the first of these tries. In 1818 he sought the first-order effect on the index of refraction of glass as it turned in the ether "wind." It was the failure to observe this effect that gave rise to Augustin Fresnel's hypothesis of a "partial drag" of the ether, dependent on the index of refraction. This notion seems hopelessly contrived now, and it did even then. But after it was apparently "confirmed" by Armand Fizeau's ingenious moving-stream experiment of 1851, what was a natural philosopher to believe?

We must remember that in that era the wave theory of light, though widely accepted, had not yet silenced all of the skeptics. In the heat of this debate, it was hard for most scientists to regard light waves and the ether as separable hypotheses, regardless of how awkward the latter might sometimes appear. That is why Albert Einstein's more graceful analysis of the Fizeau result would become a strong selling point for special relativity.

When he deals with James Clerk Maxwell's *mechanical* ether, with its vortices and idle-wheels, Hoffmann's otherwise faithful historical account falters somewhat. It is not quite correct to represent Maxwell as discarding the model once it had served its purpose of guiding him to his equations. Physicists who would like to get this tangled story straight would do well to choose Daniel Siegel as their guide (in *Conceptions of the Aether*, edited by G. N. Cantor and M. J. S. Hodge).

Like most good popularizers of Einstein's theories, when he comes to special and general relativity Hoffmann seeks a balance between formal rigor and intuitive clarity. In his initial discussions of each, he succeeds. For example, he explicitly shuns the

common trap of confusing what is actually *seen* with the picture reconstructed after correcting for time-lags of light signals. But his transitions to formalism are sometimes a bit abrupt. He resolves the "twin paradox" with the aid of Minkowski diagrams, which may satisfy physicists but have little appeal to others. And his introduction to the metric tensor will probably lose most lay readers. The text is too brief to do much more than display the bare

bones of the formalisms, without sufficient applications to demonstrate their power.

When we strive to convey the meaning of relativity to the general public, physicists must never forget that however natural it may seem to *us* to regard the world as "a function of x, y, z and t ," it rarely seems so to *them*.

Relativity and its Roots could be of some value as a supplementary text in an undergraduate relativity course or

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