A vast treatise on general relativity

Gravitation

C. W. Misner, K. S. Thorne, J. A. Wheeler
1278 pp. W. H. Freeman, San Francisco, 1973. $39.50 hardcover, $19.95 paperback

Reviewed by S. Chandrasekhar

The growth of interest in general relativity during the 1960's has been spectacular. One may perhaps associate the beginnings of this growth with Hermann Bondi's elucidation and clarification of the reality of gravitational waves in 1962 and the remarkable group of young men, including Roger Penrose, Andrzej Trautman, Ray Sachs and Felix Pirani who were associated with him at that time. And the three great landmarks in this development of general relativity are Penrose's announcement of the first of his theorems on the inevitable occurrence of singularities in spacetime under certain general conditions, the discovery of Kerr's solution (which must be included among the great astronomical discoveries of the 1960's), and Stephen Hawking's theorems on black holes.

A further remarkable aspect of this growth of general relativity during the 1960's is that most of the important contributions were made by young men in their twenties and thirties. Two of the authors (Kip Thorne and Charles Misner) of this vast treatise on general relativity are distinguished members of that group of young men; and the third author, John Wheeler, is, of course, well known as an ardent evangelist of general relativity for two decades and more.

That this rapid development of various aspects of general relativity will result in books attempting to consolidate these advances is to be expected. *Gravitation* is the last and the most ambitious of the recent books; two other noteworthy books are those by Steven Weinberg (*Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*, Wiley, 1972) and by Stephen Hawking and George Ellis (*The Large Scale Structure of Space-time*, Cambridge U.P., 1973). Indeed, *Gravitation* is three books written in parallel. There is a "track 1" (appropriately distinguished), which, in the authors' words, focuses on the "key physical ideas . . . and is suitable for a one-semester course at the junior or senior level . . . and constitutes the indispensable core of gravitation theory that every advanced student of physics should learn." And there is "track 2," which "is designed for a rigorous full year course at the graduate level . . . intended to give competence in gravitational physics." And finally, there are the 137 illustrations with extensive legends and the 163 "Boxes" in which the larger part of the material covered in the text is reamplified and can mostly be read independently of it. This attempt by the authors to write effectively three books in one makes it already a most unusual one in current scientific literature. (We shall return later to the question as to how successful the authors have been in their attempt.)

The present treatise is the only general one that is extant that attempts to present the theory from the point of view of Cartan's calculus and differential forms. And it is also the only one in which one finds extensive treatments of relativistic stellar structure (Part 5), gravitational collapse and black holes (Part 7), the propagation, generation, and detection of gravitational waves (Part 8) and a discussion of the possible experimental tests of general relativity carried out in terms of the parametrized post-Newtonian approximation (developed principally by Thorne, Will, and Nordtvedt; Part 9).

The treatment of relativistic stellar structure is particularly noteworthy for its complete and full account of the radial pulsations of spherical stars and clusters, and of the role of dynamical instability of relativistic origin (which sets in at a radius substantially larger than the Schwarzschild radius); this instability is important for our understanding of neutron stars and dense star-clusters. There is, however, no treatment of rotating stars—to which one of the authors (Thorne) has made basic contributions; and neither is there an account of Thorne's beautiful work of the nonradial pulsations (with attendant gravitational radiation) of fully relativistic stars.

In many ways, the most successful

part of the book is the 100 pages that deal with gravitational collapse and black holes. The character of the geodesics of photons and of test particles both in the Schwarzschild and the Kerr geometries are delineated with detail and clarity. The separation of the Hamilton–Jacobi equation appropriate for the Kerr metric (by making use of Carter's third integral) is explicit and clear. And the same thing is true of the account of the Penrose process. The three-track method of the authors shows itself to its best advantage in this part.

The part on gravitational waves is a most useful one, particularly in the enumeration of the astronomical sources of gravitational waves and the means of detection that are available.

The general framework of testing general relativity in terms of the parametrized post-Newtonian approximation, which deals at one stroke all possible metric theories of gravity, will clearly play a central role in various experiments (classical and new) that are currently being refined and undertaken.

Anyone who even casually turns the 1200 and more pages of *Gravitation* cannot fail to be impressed by the incredible amount of effort that must have gone into its preparation. And all the greater pity because in my judgment the attempt to write three books in one is not a complete success. There is needless repetition (indeed, almost everything is stated at least three times) and the style fluctuates from precise mathematical rigor to evangelical rhetoric (which often obscures and confuses the issues). It must also be admitted (even if the distinguished authors wince at this remark) that a discriminating reader can discern where the style of one leaves off and of another takes charge. The internal evidence, in fact, suggests (?) that the burden of compiling this enormous book has been on the shoulders of one of the authors, and perhaps the repetitiveness and the amorphous character of the book could have been avoided if all three had not tried to integrate their separate but noble efforts. This repetitiveness becomes clear if one asks oneself what a student who has mastered the 150 pages devoted to general relativity in the *Classical Fields* of Landau and Lifshitz will learn from this book and how large a book will be needed to provide that additional knowledge.

One of the distinguishing marks of the book is the large amount of rhetorical prose, which invades whole sections, and there is appropriate canonization of some of the contributors to general relativity, old and young. (While selecting individuals for canonization is a matter of judgment and attitude, one wonders why neither Karl Schwarzschild nor Roy Kerr find a place in their pantheon.)

There is one overriding impression this book leaves. "It is written with the zeal of a missionary preaching to cannibals" (as J. E. Littlewood, in referring to another book, has said). But I (probably for historical reasons) have always been allergic to missionaries.

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The Quantum Theory of Light

Rodney Loudon
338 pp. Clarendon, Oxford, 1973. £7.50

Quantum optics is a relatively new and rapidly expanding field. As such, many of its more subtle aspects, such as the statistical properties of light, have not yet found their way into beginning graduate-level courses.

The present text is a milestone toward making such material available to students at this level. Rodney Loudon, a recognized authority in the field, succeeds in bringing such advanced topics as the quantum theory of laser behavior, light scattering and the photon statistical aspects of nonlinear optics to these students.

The first six chapters dealing with simple optical processes could be read with profit by senior and first-year graduate students. The next three chapters treat the quantization of the field and various optical experiments that require the quantum theory of light for their interpretation. In the latter effort, as the author points out, "the existence of the quantization leads to the possibility of a new type of experiment in which the distributions of photons in beams of light are measured. Such experiments form the observational basis of *quantum optics*." In the final third of the book, Loudon develops laser theory, light scattering and nonlinear optics in a pedagogically appealing fashion without sacrificing depth.

The only negative aspects that I came across were minor: The utility of the book as a textbook would perhaps have been enhanced with the inclusion of more problems, and secondly, the student interested in tracking down the original papers will find the bibliography a bit skimpy.

In general Loudon's text is a very fine presentation of the material and deserves a place on the shelf of every student of modern optics. In fact, my copy has already been stolen.

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Across the Frontiers

Werner Heisenberg
229 pp. Harper & Row, New York, 1974. $7.95

Werner Heisenberg is known through out the world of science as one of the creators of quantum-mechanics—both of its mathematical formalism and of its conceptual implications, and also as a man who stayed at the forefront of physics during his whole career. A collection of essays and addresses written or delivered by him during the last 15 years (only one short paper dates from 1948) is therefore certain to command the interest of many readers, and for a variety of reasons. Some may look for an authoritative description of the main lines of development of modern physics, and they will not be disappointed: in several of the chapters and especially in the one "Planck's Discovery and the Philosophical Problems of Atomic Theory," the second one in this collection, such a survey is painted with broad, yet certain strokes.

Other readers, more interested in the history of physicists than in physics and its history, may regard this book as a valuable source of information about Heisenberg himself; they will appreciate his erudition, which embodies the best traditions of German scholarship, and admire the skill with which he adapts his style to the occasion and the subject. (Compare for instance the Festival Oration for the 800th Anniversary Celebrations of the City of Munich, chapter 5, with his lecture on Abstraction in Modern Science, chapter 8.)

But the main interest of this book lies elsewhere. Through nearly all the chapters there runs a consistent philosophical attitude: Quantitative physics became only possible by a severe limitation of the range of phenomena studied. Within this limited field it has been extremely successful and it has also led to the spectacular development of modern technology. But this type of physics cannot deal with other forms of human experience that are equally important or, perhaps, more important. And science-based technology, for all its successes, holds serious threats to human society, human culture and even to human life. How-

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