Book Reviews

Modern View of General Relativity

Gravitation. CHARLES W. MISNER, KIP S. THORNE, and JOHN ARCHIBALD WHEELER. Freeman, San Francisco, 1973. xxx, 1380 pp., illus. Cloth, $39.50; paper, $19.95.

In July 1955 there was held in Berne a meeting to celebrate the 50th anniversary of special relativity. By sad mischance Einstein died shortly before the meeting began, and its president, Wolfgang Pauli, commented in his opening remarks, "By this unforeseen event this important moment is a turning point in the history of the theory of relativity and therefore of physics."

By one of the ironies of history, the meeting was a turning point in another sense also. The renaissance of general relativity which we are now enjoying can be dated from that meeting in Berne. For the first time isolated relativists were brought together from all over the world, and by their interaction they gained the strength to intensify their efforts, to train brilliant young research students, and to introduce new mathematical methods which have revolutionized our understanding of general relativity and therefore of physics. As a result, even before the discovery of quasars, pulsars, x-ray sources, and the microwave background the number of people working in the field increased dramatically. The sad irony is that Einstein himself never knew of this change in the standing of his great theory.

The year 1955 was memorable for relativists for another reason also. In that year a well-known nuclear physicist published his first paper on general relativity. The paper showed boldness of imagination and a deeply intuitive but very individual approach. Its author was John Archibald Wheeler, who now, together with his one-time students Charles Misner and Kip Thorne, has presented in a massive book his view of general relativity, as based on a 20-year love affair with it. Much of the book is written in the well-known Wheeler style, with its combination of physical insight, vigorous use of analogy, elaborate diagrams and tables, and a prose style varying from the unusually colloquial to the unusually lyrical, ending with an eschatological vision of the theory of the future. Interspersed with this one can recognize the more sober style of the junior authors when they deal with their own specialty.

In my opinion this approach pays off handsomely, and the result is a pedagogic masterpiece that will teach any alert student both insight and technique, and, starting from the foundations of the theory, will prepare him to face most of the rigors of the current research literature. The first sign of attention to pedagogic detail is the division of the book into two tracks. Track 1 is intended to provide "a one-semester course at junior or senior level or in graduate school." When combined with track 2 it becomes a "rigorous full-year course at the graduate level." Each page is labeled track 1 or track 2, and is marked so that the track 1 pages are easily picked out by the eye. The treatment is so designed that "with a few exceptions any track 2 chapter can be understood by readers who have studied only the earlier track 1 material."

This attention to pedagogic detail is by no means restricted to the general design of the book. The writing throughout is passionately concerned with communicating ideas, methods, and techniques, and since the authors do this so well, and are also so obviously enjoying themselves, this book immediately establishes itself as the best introduction to its subject. In addition it is a mine of information, especially for recent developments.

The treatment throughout is modern in spirit, both in its basic mathematics and in its physics, but pedagogic requirements are always kept to the forefront. For instance, the definition of a tangent vector as a directional derivative is carefully explained and frequently used. In the process the reader comes both to understand the definition and to appreciate its power. The same is true for the treatment of the calculus of forms and other mathematical techniques that are not usually described in books on general relativity. However, the discussion only glances at the most powerful mathematical methods that are needed, for instance, in proving singularity theorems. For those the reader must turn to Hawking and Ellis's recent book *The Large Scale Structure of Space-Time* (reviewed in *Science* **182**, 705 [1973]).

Of course there is much more to general relativity than mathematical technique, important though that undoubtedly is. Relativity is part of physics, and it is this physics that motivates the mathematical technique and, in the end, justifies the great interest the theory is now enjoying. In my opinion this book gives an outstanding account of general relativity as a physical theory. The main emphasis is placed on topics to which the authors have themselves made significant contributions. In view of the width of their interests this is not too serious a restriction, although I would have preferred to see a more detailed discussion of the equations of motion, of the algebraic structure of exact solutions, of the asymptotic properties of gravitational radiation, and of the Newman-Penrose spin coefficients.

By contrast, the authors are in their element when they discuss the initial value problem, relativistic stars, cosmology, black holes, the emission and detection of gravitational waves, and experimental tests of general relativity. These topics receive authoritative and modern treatment.

In this era of intense interest in gravitation we may be grateful to Misner, Thorne, and Wheeler for guiding us through its intricacies with such insight.

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Earth Dynamics

Gravity and Tectonics. KEES A. DE JONG and ROBERT SCHOLTEN, Eds. Wiley-Interscience, New York, 1973. xxxii, 502 pp., illus. $24.95.

This volume honors R. van Bemmelen, distinguished author of many papers on the relationship between gravity and tectonics, including some thoughtful papers on global tectonics written in the 1930's, long before this

subject became as fashionable as it is today. It consists of 31 papers divided into three groups: general, on the orogenic systems in the Mediterranean region, and on orogenic systems in North America.

The general section begins with three papers on the global aspects of tectonics by Press, Jacoby, and Schuiling. Press advocates gravitational instability arising from the lower density that may be associated with partial melting in the low-velocity zone as the cause of plate motion; Jacoby favors the gravitational instability that causes sliding of the plates away from the midocean ridges toward the trenches; Schuiling too favors gravitational sliding and sees the thermal blanketing effect of a continental mass as resulting in uplift of the continent, which starts the drift cycle. There is, of course, a fundamental difference between the type of convection advocated in these three papers and the mantle-wide convection currents suggested by many as the driving mechanism for continental drift. In mantle-wide convection it is the viscous drag on the bottom of the lithospheric plates that produces the movement. In the convection postulated by Press, Jacoby, and Schuiling the viscous drag impedes the motion of the plates. I find the gravitational instability hypotheses more plausible than mantle-wide convection, but I think we still have much to learn about the mechanics of plate tectonic processes.

The remainder of the general section is concerned with processes on a smaller scale: Ramberg's beautifully illustrated description of his elegant scale-model experiments using centrifuge techniques, Durney and Ramsay's account of observations of the evidence for strain and deformation in the rocks themselves, and Voight's analysis of a major slide during the Alaskan earthquake and comparison of it with the Heart Mountain overthrust in Wyoming. One of the more intriguing of Ramberg's model experiments is that for the midocean ridges. The experiment implies a much higher viscosity for the spreading lens below the ridge than that which would correspond to a silicate melt. This suggests that the melt occupies only a small portion of the spreading lens zone.

In the second and longest section of the book, gravity tectonics concepts are applied to structures in the Mediterranean region ranging from the Pyrenees to the islands of the Aegean, with, of course, several discussions on the Alps. Almost all the authors agree that gravity plays some part in the tectonic process, for example, diverticulation in the pre-Alps, but some, in particular Lemoine and Laubscher, emphasize the paradoxes.

The section on the orogenic systems of North America ranges across almost the entire continent, from Newfoundland (Kay) to the California Coast Ranges (Hsü) and from the southern Canadian Rockies (Price) to the Ouachitas (Viele). In many of these papers, gravity sliding plays a prominent role. As Hsü remarks, "The pendulum has begun to move in an opposite direction. Theoreticians speculating on the motor of the plate motion are leading us back to gravity tectonics."

This is, of course, a book with a definite point of view, the importance of gravity in tectonic processes, and most of the contributors share that point of view. Nevertheless, the evidence for the effect of gravity in tectonics at all scales is impressive and the analyses reasonably critical, so the book provides excellent material for seminars and courses in structural geology and tectonics.

The book lacks an index.

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Localizing Big Problems

Our Environment. The Outlook for 1980. ALFRED J. VAN TASSEL, Ed. Lexington (Heath), Lexington, Mass., 1973. x, 590 pp., illus. $20.

What an excellent idea. Design a graduate seminar around a necessary and novel project and assign each student a portion of the report to write. Then not only will the students experience a sense of working and thinking together, but the results can be published to be read by the public at large, rather than only the archivists. A. J. Van Tassel did this once before, in *Environmental Side Effects of Rising Industrial Output* (Heath, Lexington, 1970). Now he tries again. His goal in this latest effort is to predict "the state of the environment in the United States in 1980. Is there any way in which we [can obtain] a quantified answer to that question?" Van Tassel's approach is to assign each of his students a specific water or air basin. The students attempt to ascertain the environmental conditions of these various areas in 1970 and then, on the basis of the population and industrial growth of the preceding decade, to project environmental improvement and deterioration into the coming decade. Such an approach focuses on the factors unique to each particular region rather than on some homogenized national norm.

Both the potentialities and the pitfalls of the scheme show up in this monograph. Approximately 20 students, all candidates for a master's degree in business administration, contribute chapters. An academic exercise of this sort demands a strong, if not ruthless, guiding hand. The editor must insist that each author provide certain basic information, which in some instances may amount to no more than filling in blanks with statistics. Each author must describe his procedures, and these of course tend to be repetitive from chapter to chapter. For the reader this treatment becomes monotonous after a while, and there are times when he wishes the book had been reduced by as much as a quarter. The more resourceful authors in the class, such as Martin in his chapter on the Hudson, Matern on San Francisco Bay, French on the Savannah River, Carmichael on recycling, and Seaman on solid waste disposal in four eastern cities, manage to say something novel and interesting that goes beyond the standard form. Others have apparently been unable to find the required data; chapters 7 (on Lake Erie) and 24 (waste disposal in five midwestern cities) are weak and the statistical work in them far inferior to that of the other chapters.

Some of the procedures described may leave the reader uneasy. For example, the main measure the group uses for environmental stress in water pollution is BOD (biological oxygen demand). As some of the authors point out, this omits the nonorganic impact of industrial pollution. The general discussions of the effects of mercury, DDT, and oil from the water bodies and the environment by some of the authors do not fill the gap.

There are also some errors. Thus in a summary the editor remarks that "water pollution is of little concern to Atlanta since it has no major waterways." If anything, the absence of major waterways near a large city is almost inevitably a signal that the city will have a sewage disposal problem. Indeed Atlanta, along with Cleveland