

cussion Poincaré seems to come out on top, for it is clear that the author believes his conventionalism is the only reasonable attitude (so does the reviewer!). The same trend of thought continues in the examination of the nature of geometry and the extent to which we can specify it through physical theory and experimentation.

The 160 pages of the part on topology are devoted almost exclusively to time. There is an elaborate examination of the causal theory of time, in accordance with which time is inextricably connected with the succession of cause and effect. This will probably make little impact on physicists, who have long since abandoned the notions of cause and effect in favor of a concept of causality of their own. The section on the attempts to demonstrate the anisotropy of time by physical means, for example by statistical thermodynamics, are of decidedly greater interest. The author concludes that the usual attempts to prove anisotropy from statistics are illusory but believes he can save the idea by the introduction of the notion of "branch not interfere with overall entropy producers for limited time periods, but do not interfere with overall entropy production in the larger systems of which they are a part. Grünbaum has a strong belief that in any case the anisotropy of time cannot provide definite knowledge that time flows one way, and he bolsters his view by an ingenious set of arguments.

In the final part of the book the author pays his respects to philosophical problems involved in the theory of relativity, particularly with reference to the assumption of the constancy of the velocity of light (in free space) in all inertial systems and the role of the velocity of light as the maximal velocity at which energy can be transferred in our universe.

Grünbaum's volume contains a great deal that should be of value to any physicist interested in the foundations of his science, though it must be confessed that it is not by any means easy reading. The author could have materially assisted the reader by providing a brief summary of his main conclusions at the end of each section. Another drawback to the book is the almost negligible index.

Coming now to the book by S. A. Basri, a member of the physics staff of Colorado State University, we note that the author's expressed aim has been to provide a foundation for a *sin-*

gle deductive theory on which all of physics could be built. The present volume is essentially the first part of his program since he agrees that any physical theory must have as its basis an adequate way of handling space and time. He begins by making clear what he means by a deductive theory, and this is in consonance with the usual interpretation. He has chosen to cast his subsequent development in the terminology of symbolic logic with only brief summaries of what his results mean in ordinary language. The author's principal achievement is the construction of a space-time geometry based on general relativity but differ-

ing from the latter in certain important respects. For example, no method is given for the calculation of the metric coefficients, which in general relativity is carried out by means of the field equations and the energy-momentum tensor. The book contains an appendix devoted to a brief and elementary presentation of the terminology of symbolic logic and set theory. Further development of the author's ideas will be looked for with interest by philosophers of physics.

* * *

The reviewer is Hazard Professor of Physics at Brown University.

Orbits: theory and practice

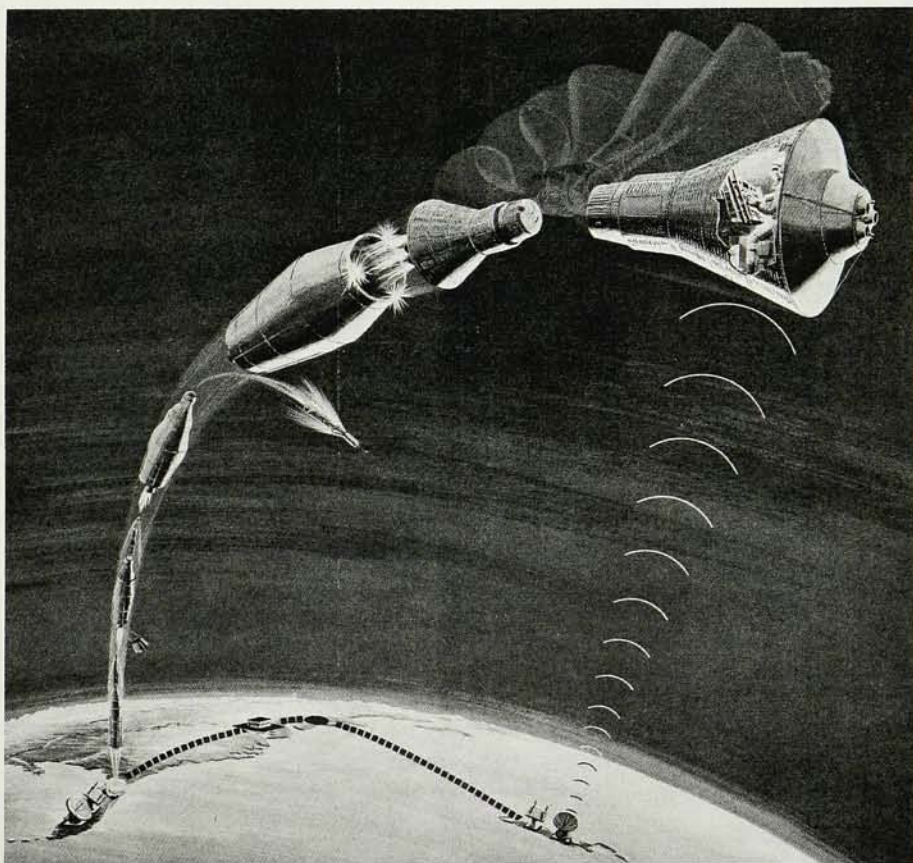
AN INTRODUCTION TO ASTRODYNAMICS. (2nd edition) By Robert M. L. Baker Jr, Maude W. Makemson. 439 pp. Academic Press, New York, 1967. \$11.75

ASTRODYNAMICS: APPLICATIONS AND ADVANCED TOPICS. By Robert M. L. Baker. 539 pp. Academic Press, New York, 1967. \$16.50

by Robert E. Street

Astrodynamics is defined as the application of celestial mechanics to the de-

termination of the trajectories of space vehicles, either by precomputation of the desired path or by determination of the orbit after the vehicle is launched. When the first edition of this *Introduction* was published in 1960, courses in astronautics were just beginning to be organized in this country. Most instructors were basing their courses upon notes taken from the classical texts in celestial mechanics together with relevant material from aerodynamics, geophysics, navi-





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gation, propulsion and optimization theory. Most of these topics were included in the first edition but the treatment was so sketchy that this reviewer, for instance, did not find this book a very satisfactory text.

Apparently the authors learned the same, for after using the first edition in their courses at the University of California at Los Angeles for the past seven years, they proceeded to revise and expand it until now it has become the present two volumes. The first five chapters of the first edition, together with the chapter on "Observation Theory," now comprise the "Introduction," while the remaining chapters now greatly expanded, become the advanced volume. All of the "Introduction" and the first chapter of the advanced volume are confined to the two-body problem. This material, according to the authors, makes up a full year undergraduate course. The remaining chapters of the second volume are then the basis for a graduate course.

Unfortunately both volumes still give many references to a nonexistent book on astrodynamics by Samuel Herrick, which apparently will not be published. Also, there are too many references to unpublished company documents. These do not belong in a text that is expected to be widely used.

Except for this minor criticism, the books are indeed welcome. They are well written, the proper points are emphasized, difficulties pointed out, many numerical examples are worked out in detail, and useful tables as well as many exercises are included. There is an extensive glossary of symbols and terms in both volumes. As in most engineering texts today, the student is expected to have had a first course in physics and calculus. He should also have some familiarity with vector notation since the summary given in the "Appendix" is very brief. The other appendixes give many of the mathematical derivations.

The "Introduction" can be used independent of the advanced volume for an introductory course. It features interesting historical notes and a discussion of the minor planets (because they are closer in interest to astrodynamics than the major planets) as well as the moon, comets and meteorites. There is a more thorough treatment of the astrodynamical constants than is usually found in textbooks. The other chapters consider coordinate systems

and observation theory. Interspersed throughout is the usual two-body orbit theory based on Kepler's and Newton's laws.

The second volume is an even greater extension of the advanced sections of the earlier edition. The first chapter is a long discussion of orbit determination and improvement, albeit still restricted to the two-body problem, with many numerical examples. The methods considered are those of Laplace, Lagrange, Gauss, Gibbs, Herrick and Herget. The next three chapters consider the various perturbations. These are not only the perturbations due to other bodies; included are the effect of the earth's asphericity, atmospheric drag and lift, electromagnetic and low-thrust forces and radiation and relativistic effects. Encke's method and the variation-of-parameters method are emphasized under special perturbations; general perturbations include a wide variety of techniques, with the example of a geocentric satellite to illustrate the effects that may be included. The last two chapters are on applications to lunar trajectories and interplanetary orbits. Throughout the author assumes a thorough knowledge of the first volume.

In both volumes, there is a carefree approach to some of the derivations. This is not unusual in engineering texts and can be rectified by the instructor. From his own experience in teaching astrodynamics to engineering students, this reviewer can only agree with Baker and Makemson that they have settled upon the best approach to the subject for beginning students.

Both authors are well known in the field of astrodynamics and have published other books and numerous papers.

* * *

The reviewer is professor of aeronautics and astronautics at the University of Washington, where he has been primarily concerned with the development of the astronautics program.

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