

Classical mechanics: three treatments

Foundations of Mechanics (Second Edition)

R. Abraham, J. E. Marsden
806 pp. Benjamin/Cummings Adv. Books,
Reading, Mass., 1978. \$46.50

**Mathematical Methods of
Classical Mechanics**

V. I. Arnold
462 pp. Springer, New York, 1978. \$24.80

Classical Dynamical Systems

W. Thirring
258 pp. Springer, New York, 1978. \$20.80

Reviewed by Barry Simon

Physics has traditionally sloughed off those areas where it is felt (whether correctly or not) that the fundamentals are well-understood. Thus, one typically finds fluid dynamics or circuit theory taught these days in engineering or applied mathematics departments. Of course, we like to comfort ourselves that we still present the core subjects like mechanics, but even here, there has been noticeable slippage in recent years. Schools that used to make undergraduates sit through mechanics three times have often reduced that to two (a trend I applaud) and graduate-level mechanics courses are being given and taken less seriously. At Princeton, for example, I would guess that no more than one in five recent *theoretical* PhD's knows the Hamiltonian-Jacobi theory.

It is unfortunate that the formal mechanics of the nineteenth century has fallen into disrepute but it is much more serious that the mechanics of the twentieth century has never been in repute; my putative Princeton theorist certainly knows the subject dealt with in the Hamiltonian-Jacobi theory but he probably thinks that a homoclinic point has something to do with crystal classification! This is particularly strange because the advances of William Rowan Hamilton and Karl Jacobi are primarily formalistic and are therefore themselves devoid of physics (although they are often exceedingly useful tools in the understanding of



Henri Poincaré, whose far-reaching insights led to modern concepts about the stability of classical dynamical systems. (Photograph courtesy of the AIP Niels Bohr Library).

physics). On the other hand, the phenomena discovered by Henri Poincaré—and more recently by those developing his extraordinarily profound vision—are rich in interesting and subtle physics often already present in systems of two oscillators coupled in a non-separable non-linear way.

I think it is not unlikely that we will see a reversal in the current lack of interest in classical mechanics due precisely to the importance of those stability questions which characterized the modern approach. Indeed, there is already considerable pressure in this direction: Poincaré was interested in the stability of the Newtonian solar system—a rather academic topic not only because of the long times involved, but because physical and astrophysical effects not included within the Newtonian model become significant in that time scale; but stability in plasmas is hardly “only of academic interest.” Moreover, molecular dynamicists, who have long realized that nuclear motion in molecules takes place at a quasi-classical limit, have realized more re-

cently that interesting phenomena occur when the classical limit is one with extremely unstable classical orbits. In fact, one theoretical chemist I know shows slides in his talks of “the KAM laundry” in honor of the celebrated theory of Andrei Kolmogorov, Vladimir Arnold and Jürgen Moser (considering the critical earlier contributions of Carl Ludwig Siegel, should perhaps be called “SKAM”). Finally given the fact that KAM is a theory of systems that are nearly integrable and given the popularity of soliton concepts in modern quantum field theory, one does not need too vivid an imagination to predict that some kind of formal infinite-component KAM theory could soon be the rage in high-energy theory. In addition the success of Yang-Mills theory is likely to give new impetus to the study of those geometric concepts critical to modern mechanics.

In this sense, the three books I review here are most timely. They represent the first *comprehensive* introductions to the modern mathematical approach to classical mechanics though one should emphasize excellent books on more advanced specialized topics like celestial mechanics¹ and other areas² as well as two earlier briefer introductions.³ Although Abraham-Marsden is officially a “second edition,” it contains about 500 pages more than the first edition's 296.

The authors (and, for that matter, the translators, who have done superb jobs of translating into idiomatic, readable English) are a distinguished lot. Arnold, who is the A of KAM, is among the most celebrated of living Russian mathematicians, Thirring is undoubtedly Austria's most famous physicist and both Abraham and Marsden have high reputations within the field of mathematical mechanics.

My own rating of the books and I suspect that of most others is clear. Arnold's book is a masterpiece about which I will shortly wax rhapsodic. Thirring really is an excellent book which would come out on top in most company but not in the present one. Even Abraham-Marsden, which I did not like so much, has redeeming values.

Arnold's book consists of four parts:

Principles of MAGNETIC RESONANCE

C.P. Slichter,

University of Illinois at Urbana-Champaign
Second corrected and revised printing of
the second edition

the book remains one of the best expositions of the quantum theory of resonance in existence. It has my highest recommendation.

—*Journal of the Optical Society of America*

this is an excellent updating of what was already an established standard

—*Applied Spectroscopy*

This essential graduate textbook now includes additional references as well as a conversion table to assist in transforming expressions in the text into SI units.

(Springer Series in Solid-State Sciences, Vol. 1). 1980/416 p./115 illus./Cloth \$24.80
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Newtonian, Lagrangian and Hamiltonian mechanics and then thirteen "Appendices" on advanced topics. The level of exposition is uniformly high and throughout there are little gems, for example, a pretty set of problems (Section 8.D) showing that only two central force fields have all orbits closed, or a simple application of homotopy concepts to the existence of periodic motions (Section 45). His presentation of parametric resonance (Section 25) is especially good. I would not hesitate to use the first two parts as a basic text in an advanced undergraduate course. I am not so happy with Arnold's appendices: there is too much "pop science" about them and no real coherence. One wished he had said twice as much about half the subjects; it is especially sad that he says so little about KAM.

Thirring's book is not only the shortest but he deals with several important subjects (scattering and relativistic mechanics, including a discussion of particle motion in the Schwarzschild solution) not discussed in the other books. He does this by omitting the treatment of several other basic topics like rigid bodies and constrained systems and by not carrying the mathematical formalism very far. It should be mentioned that this is the first volume of a four volume set which is sort of a mathematical physicist's Landau-Lifschitz. Like the first volume, they are all well-written, but unlike the first, the later volumes have no real competition and the last two on quantum mechanics are likely to become classics.

My biggest complaint about the Abraham-Marsden volume is summarized in the term "overkill": too much notation, too many reformulations of the same result, too many extra things added that really shouldn't concern their audience. In spite of this, if one penetrates their notation (particularly difficult if someone with some mathematical background takes their advice and skips the first 160 pages of "Preliminaries"), one finds clear writing. Moreover, their Part III, "An Outline of Qualitative Dynamics" is absolutely unique. It is clear that someone who's appetite is whetted by Arnold would probably have to be sent to this part.

Finally a word about these books as an introduction to the mathematical language of manifolds. I prefer Arnold's policy of introducing the concepts as needed over that of the other authors who begin with preliminary chapters full of mathematics. I also find this discussion in Abraham-Marsden too abstract and that Thirring has too much of a tendency to immediately introduce coordinates; again, I prefer Arnold's balanced presentation. But here I am not sure that a reader who was not already familiar with the lan-

guage of manifolds might not find Thirring preferable.

In summary, I think every aspiring physicist should get a copy of Arnold. Someone interested in some of the topics only treated in Thirring or who wants somewhat more elementary introduction to manifolds should consider also getting that book. Abraham-Marsden, their own description notwithstanding, is not really an introductory text. It shouldn't be attempted until the reader has mastered one of the other books but I welcome it as a useful addition to the more advanced literature.

References

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Black Holes and Warped Spacetime

W. J. Kaufmann, III

221 pp. Freeman, San Francisco, Cal., 1979.
\$7.95

The study of black holes is a subject much written about these days. Unlike so many other popular versions, William Kaufmann's book provides a clear, thorough treatment of the new astrophysics without resorting to a "gee-whiz" narrative style. He has written several other books on astronomy and some of the material in *Black Holes and Warped Spacetime* can also be found in his *Galaxies and Quasars*.

Kaufmann patiently lays out the details needed for an understanding of the current black hole theories: how stars evolve through their thermonuclear fuel cycles; how they expire into gravitational collapse; the different categories of compact objects—white dwarfs, neutron stars, and black holes; various techniques for determining the