mechanics to a new level of rigor and completeness. But in developing his views he makes absolutely no concessions to any limitations on the part of his readers.

After an introductory survey he has a chapter summarizing Bohr's views. Though he never disagrees with him he finds it almost impossible to relate Bohr's informal empirical analysis to his own very formal reconstruction.

Axiomatization can follow one of two general methods. The first one, followed in the bulk of the book, selects physical concepts considered essential to a scientific theory and then maps concepts and propositions using them into an appropriate mathematical structure which then provides a unified vehicle for reasoning. For classical mechanics and classical statistical mechanics Scheibe uses a phase space of $2n$ dimensions to represent an object with n degrees of freedom and then establishes a one-to-one correspondence between the quantities that characterize the object and Borel functions in the phase space. To supply a comparative basis Scheibe shows in detail how states of an object, measurements of quantities, and probabilities are represented in phase space and how these representations are correlated with the corresponding propositions concerning state measurements and probabilities.

Quantum mechanics, following John von Neumann, requires a Hilbert space with rules peculiar to quantum mechanics regarding the way separate Hilbert spaces form a composite Hilbert space. Scheibe starts with the minimal basis necessary to describe measurements of quantities characterizing an object and systematically adds such further concepts as states of an object, time dependence, properties, and various types of probabilities. This mapping of physical propositions onto mathematical propositions serves to ground quantum logic in the sense that the logical connectives such as "and" and "or" coupling basic physical statements are governed by rules developed for the Hilbert space counterparts of these statements.

Within this general logical framework one can distinguish three different modes of interpreting quantum mechanics. The epistemic interpretation is concerned with states of knowledge, whereas the statistical interpretation expresses relative frequencies in statistical ensembles. An ontic interpretation is concerned with states of an individual object. While the first two are complete and complementary an ontic interpretation requires either an epistemic or a statistical extension to go from instantaneous states to time development.

The second way of axiomatizing a theory is to develop a direct axiomatization of the physical concepts rather than mapping them into an already established mathematical structure. This supplies a more precise basis for analysis in the sense that the mathematical and physical systems both have the same strength. Scheibe gives a concise and, when necessary, corrected summary of the limited aspects of quantum mechanics that have been subjected to such rigorous axiomatization by von Neumann, George Mackey and Gunther Ludwig.

After developing this general framework Scheibe gives a very formal treatment of some of the basic interpretative problems in quantum mechanics: indeterminacy, reduction of states, measurement, hidden variables and completeness. In each case he defends the orthodox Copenhagen interpretation as the only adequate and logically consistent position. He generally does this in a comparative way, analyzing any significant variations that can be given a precise formulation within his framework.

This book should become the successor to von Neumann's classical work (*Mathematical Foundation of Quantum Mechanics*, 1931) both in the positive sense of supplying a rigorous logical defense of quantum mechanical orthodoxy and also in the rather negative sense of being a source book respected by many but read by very few.

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The Sociology of Science: Theoretical and Empirical Investigation

R. K. Merton
605 pp. U. of Chicago Press, Chicago, 1973. $12.50

Robert Merton is a seminal figure in the sociology of science, and the reasons for his influence are apparent in this collection of twenty-two essays published between 1935 and 1972. Clarity of writing, wit and a truly impressive knowledge of science and its history all contribute to provide deep insight into the social structure of science. The editor of the volume, Norman Storer, has grouped the essays into five sections, ordering them within each section so as to bring out a logical rather than a chronological progression of ideas. In his introduction to the volume, Storer has provided an excellent overview of Merton's work and its evolution, relating it to the general context of sociological thought; he has also provided useful prefatory notes to each of the sections, summarizing the content of the essays in the section and

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relating them to other essays in the volume and to Merton's thought as a whole.

The first section provides the general framework on which Merton's sociological researches into the scientific community are based, and the second discusses general methodological questions regarding the sociology of science. But it is the final three sections, consisting of substantive researches into the sociology of science, that will be of most interest to readers of PHYSICS TODAY. In addition to an essay restating, with appropriate qualifications, Merton's well known views of the influence of the Puritan ethic on the development of science, section three includes his analysis of the "ethos" of science. "The ethos of science is that affectively toned complex of values and norms which is held to be binding on the man of science"; it consists of four sets of "institutional imperatives": "universalism" ("truth-claims, whatever their source, are to be subjected to preestablished impersonal criteria," "communism" ("the substantive findings of science are a product of social collaboration and are assigned to the community", "disinterestedness" (in a very broad sense), and "organized skepticism" ("the temporary suspension of judgment and the detached scrutiny of beliefs in terms of empirical and logical criteria"). These imperatives are embedded in the social structure of science, and Merton's analyses of them, and of their interrelations and conflicts with one another, provide penetrating insights into the behavior of scientists in a wide variety of historical instances. Section four extends this analysis of the social structure of science by examining the reward system of science, as embodied in the professional recognition of priority in scientific discovery. Conflicts of priority are argued to be "largely a consequence of the institutional norms of science itself," and by examining a multitude of cases, Merton demonstrates that multiple discoveries in science are more the rule than the exception. Within the framework developed in these two sections, section five examines ways in which work is evaluated in science—for example, the referee system (with the *Physical Review* as object of study), and the factor of age in evaluation and recognition. Throughout the book, empirical evidence is provided in abundance, although the essays included in this volume are not overburdened with masses of statistics.

As a sociologist, Merton is more interested in the fact *that* there are "preestablished impersonal criteria" in science than with the question of specifically *what* those criteria of acceptance and rejection are or with their detailed analysis and justification. And though Merton is well aware of this point, and even takes pains to insist on it, one can still argue that, for a full understanding of science (or, perhaps, of science *as science* rather than as a social institution), intensive study of its "internal logic" is also needed. But that Merton has not done everything toward an understanding of science does not detract from the immense value and interest of his work.

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Qualitative Theory of Second-Order Dynamic Systems

A. A. Andronov, E. A. Leontovich, I. I. Gordon, and A. G. Maier
524 pp. Halsted, New York, 1973.
$44.00

The study of dynamic systems started, of course, with celestial mechanics. The system, in this case, consists of the coordinates for a number of planets, their natural satellites, asteroids, comets and so forth. These coordinates change with time according to a well defined set of differential equations. For a long time, all the mathematical research in this area had the purpose of finding effective methods for solving these equations, in order to make precise numerical predictions. The well known *Treatise on the Analytical Dynamics of Particles and Rigid Bodies* by E. T. Whittaker, published in 1904, provides the best and most complete presentation of this whole approach, which still seems to dominate the teachings of classical mechanics.

It was realized, however, first by H. Poincaré, at about that time, that the intricacies of the three-body problem prevented any analytical treatment from giving the necessary (intuitive) understanding. Therefore, he started investigating its qualitative aspects, an alternative approach that was soon generalized and perfected by relatively few, but outstanding, mathematicians such as G. D. Birkhoff, M. Morse, E. Hopf, A. N. Kolmogorov of the previous generation, more currently by J. Moser, V. I. Arnold, S. Smale, and others.

The average physicist (at least in the West) is hardly aware of the incredible richness of this whole theory, and, indeed, there are only few monographs available. The recent books by Moser *(Stable and Random Motions in Dynamical Systems)* and by Arnold and A. Avez *(Ergodic Problems in Classical Mechanics)* are written in this vein, but emphasize the statistical aspects. These become important when the system has more than one degree of freedom, or when it is driven by an external time-dependent force. The book by A. A. Andronov and his coauthors, in contrast, considers only systems of one degree of freedom (such as one coordinate and one momentum or one current and one voltage) without a time-dependent driving force. These are the second-order autonomous systems that can have complicated nonlinear properties, including friction.

They can be graphically represented by trajectories in a two-dimensional surface (such as a plane, sphere and torus) and thus, completely visualized. The authors make thorough use of this tremendous asset. Their last figure has the number 349, but many figures have two sketches so that the total may amount to over 500. And it is a good thing, too, because this book emphasizes rigorous deductions, although they are given in a rather direct and informal language. The original version (by Andronov and Maier) dates from around 1950 when the recent tendency toward abstraction in mathematics had not as yet driven physics and mathematics so far apart.

The present book may well be the authoritative work on this topic for a long time. It arrives at a complete classification of the qualitative behavior for the second-order autonomous systems mentioned earlier. In that done as yet for the more complicated systems mentioned earlier. In that sense it has the character of a standard reference work, an exhaustive monograph, rather than a textbook, and it should prove invaluable to the working researcher who runs into a system of this kind.

The book is well organized into chapters, paragraphs, and sections so