A model monograph for plasma physics

Methods in Nonlinear Plasma Theory

Ronald C. Davidson
356 pp. Academic, New York, 1972. $18.50

Reviewed by David Montgomery

Most interesting problems in continuum mechanics are nonlinear. Plasma problems are perhaps the most nonlinear of all, involving classical mechanics and electromagnetism on an approximately equal footing. This guarantees an abundance of intriguing effects to work on, but also means that solutions are often limited to rather specific situations, involving less generality than modern physicists are trained to expect.

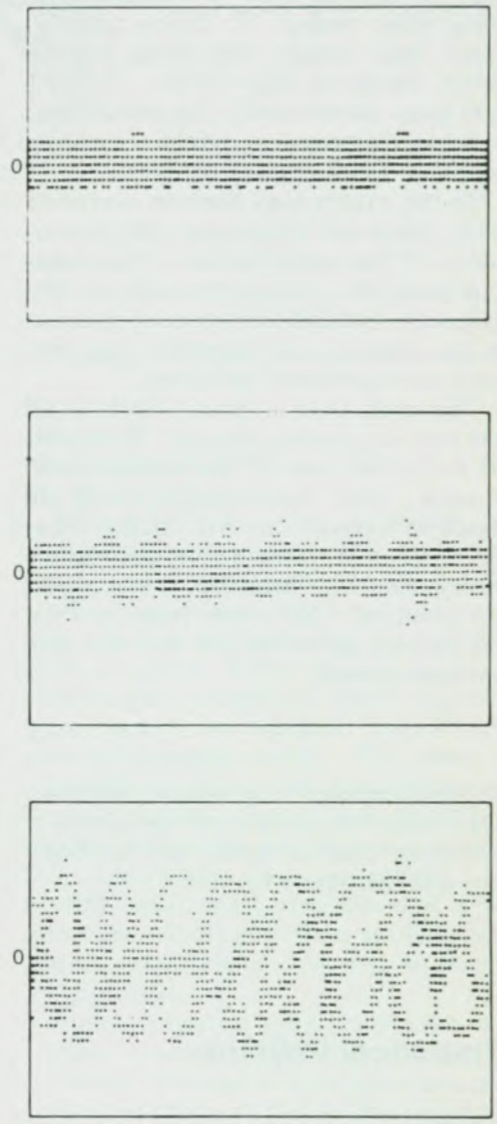
R. C. Davidson's monograph is a professional's guided tour through the essentials of a variety of nonlinear plasma calculations of the last decade. It is a specialist's book, full of details and over a thousand equations (almost all of them worth including). It assumes familiarity with plasma physics at the level of a serious two-semester graduate course. It treats nonlinear wave processes in their cleanest form—in plasmas that are usually uniform, unbounded, fully ionized, isotropic, and so forth. Little stress is laid on such topics as stability in bounded geometrics, or attempts to relate the results to specific devices. It is not a handbook from which to design fusion reactors, or to use in writing press releases for *The New York Times*. It is an honest book.

The first half deals with "coherent" phenomena, the second with "turbulent" ones. The distinction is that in "coherent" phenomena, one considers only a single plasma, with sufficiently smooth variations in the field quantities that analytically representable solutions may be imagined to exist, while in "turbulent" cases one considers an ensemble of similar plasmas in which the details of the excitations differ among members of the ensemble. Ensemble averaging then sometimes leads to more tractable dynamical equations for the expectation values than the individual systems possess, and to smoother solutions.

The "coherent" half of the book is, in my opinion, an unqualified success. Dealing primarily with electrostatic effects in the absence of a magnetic field, it treats, in a lucid manner, nonlinear electron plasma oscillations and ion acoustic waves, their amplitude limitations, their interactions with single particles and with each other, and plasma echoes. I found the chapter on the Korteweg–de Vries equation extraordinarily good. The presentation of the multiple-time-scale perturbation theory is a reasonable compromise between brevity and rigor. Some omissions in the area of collisionless electrostatic shocks might well be remedied in any future edition, and I would like to see some coherent magnetohydrodynamic phenomena touched upon; but limitations of space must inevitably dictate a few such omissions.

The "turbulent" half of the book is also a success, but a slightly qualified one. The main emphasis is on Vlasov plasma processes in the *weak turbulence* limit. By this one means that the ensemble contains only plasmas that can be expected to keep their fluctuating electrostatic or electromagnetic energy densities small compared to their kinetic energy densities. This was possibly the most exciting area of plasma theory in the 1960's, because it appeared that, for the first time in the history of continuous media, one had an example that admitted the possibility of tractable calculations of turbulent spectral densities in closed form. Literally hundreds of papers poured out, applying the techniques to every imaginable situation from electron tubes to the galaxy—usually, however, with no hard-nosed, detailed confrontation with any kind of data and with little attention to the mathematical content of the formalism. Now the time has come to cool off, and inquire in just what sense the theory may in fact be true. Yet Davidson brushed off what are to me very fundamental questions about the foundations of the theory as being obvious and trivial, when they may be neither.

For example, considerable work has been invested in efforts to include damped waves in formalism. The earliest one-dimensional version could be formulated consistently in terms of undamped waves, but I. B. Bernstein and F. Englemann showed the logical



Computer simulations. Here the finite-size particle method is employed to show electron–ion beam instability. This simulation involved 10^4 electrons and 10^4 ions with symmetric initial conditions. The four plots show, from top to bottom, the particle distribution at 0, 3, 7 and 11 time units. The horizontal axes show position, and the verticle axes, velocity. (From *Methods in Nonlinear Plasma Physics.*)

necessity of including damped waves in two and three dimensions. Many good physicists have run aground trying to do this in a way that would, simultaneously, preserve the various conservation laws, keep the perturbed distribution functions continuous as the growth rates pass through zero, avoid ill-posed diffusion equations, lead to estimates for the accuracy of the solutions, and, lastly, predict final states. In my opinion, no one has yet succeeded in doing this, though T. Burns and G. Knorr have come closer than anyone (*Phys. Fluids* **15**, 610 (1972)). Yet if I read page 164 correctly, the whole issue is being dismissed as trivial—without, however, indicating any details!

To the extent that one can overcome such occasional misgivings, the presentation of the applications is then clear and energetic. Applications to electromagnetic instabilities and to plasmas in an external dc magnetic field are given an impressive treatment.

The book is of a genre which is all too rare in plasma physics. If attended to by the rest of the physics community, such monographs could do much to improve the still slightly sleazy reputation plasma physics suffers among the older branches of the physical sciences. No other book now on the market does the job this one sets out to do so well.

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Statistical Physics

F. Mandl
379 pp. Wiley, New York, 1971. $10.00

Statistical physics is a subtle subject. Its foundations yield a rich harvest of delicate questions. Yet a great many of the essential techniques require no elaborate mathematical preparation, and the material can be introduced into the curriculum at a fairly early stage. The problem of presentation is largely one of achieving a balance between methods and understanding. This is made especially challenging when both thermodynamics and statistical techniques are brought together under the rubric "Statistical Physics"; for then it becomes necessary to insure that the student grasps the scope of traditional thermodynamic reasoning so as not to short-change its power and validity for the apparent insight offered by those examples simple enough to be dealt with in detail by statistical methods.

My impression of this volume by F. Mandl is that it meets very well the objectives suggested above, and in a straightforward manner makes the material accessible for all students at some point in their undergraduate careers while maintaining a level that insures suitability for good students as early as the second year. By contrast, the recent splendid book of J. Kestin and J. R. Dorfman, *A Course in Statistical Thermodynamics* (Academic, 1971), is more detailed, more sophisticated, more demanding and is ideally suited for a course given in the senior year. An earlier work by Mandl on quantum mechanics is well known to physicists and is distinguished by its rigor, formality and elegance. I was anxious, therefore, to find how the author would treat a different subject for a different audience.

The flavor of this book is evident in the very first chapter where the First Law is introduced by macroscopic and microscopic arguments developed together. There is an easy exchange between them, and the result is pedagogically sound. Clarity characterizes the presentation and becomes especially helpful for such unfamiliar topics as, for example, adiabatic cooling, negative temperatures or the Bose–Einstein condensation.

All the essential material is here as well as a significant number of marked sections that could be omitted if a simpler or somewhat reduced course were desirable. The author also offers a "flow chart" on the inside cover, which is intended to assist in selecting alternative, simplified paths through the material. It is never obvious what ought to be omitted, however, and some might reasonably argue that black-body radiation or the Debye theory of specific heats, for instance, are essential to any presentation, however elementary. The point is, that Mandl's book is usable in reduced form and gains considerably from this flexibility.

The volume (which although written for an English university course and a part of the Manchester Physics Series, is entirely suitable for American students) is divided into 12 chapters ranging from the First and Second Laws to fluctuations in the grand ensemble, and includes a good discussion of problems dealt with only by quantum statistics. The examples chosen are current whenever possible and generally informative. In addition there are Appendices covering some useful mathematical formulas, a discussion of the density of states and "hints" to the solution of the problems that close each chapter. There is a decent bibliography and a useful index.

Students should find the reading direct and unambiguous and the problems of help in understanding the text. The numerous figures, graphs and illustrations are all well chosen and reproduced with clarity. They ought to be of particular help to anyone whose first exposure to the subject comes from this book, and it is for just such an audience that "Statistical Physics" can be recommended with confidence.

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Principles of Surface Chemistry

G. A. Somorjai
283 pp. Prentice-Hall, Englewood Cliffs, N.J., 1972. $10.95

Surface phenomena have been around for a very long time. Willard Gibbs laid the foundations of the thermodynamics of interfaces in the 19th century and Irving Langmuir discovered chemisorption in the 1920's. It is only quite recently, however, that surface studies have become fashionable in physics. The reasons are at least partly connected with the development of a number of new techniques, the ready availability of ultrahigh vacuum, and undoubtedly also with the fact that surfaces and the processes occurring on them represent one of the few frontiers left in the electron-volt domain. Whatever the reasons, the current interest in surfaces makes welcome any book that may serve as a general introduction to the field, summarizes the current state of knowledge, discusses the principal methods of attack and points out the major unsolved problems.

Principles of Surface Chemistry by Gabor A. Somorjai tries to fulfill the first three of these objectives, but does not address itself particularly to the fourth. The book was written as part of an undergraduate physical-chemistry series, and its level is elementary throughout. It covers a fairly wide range of topics from surface structure and diffraction to physi- and chemisorption with chapters on thermodynamics, electronic properties, and the dynamics of surface atoms in between. Perhaps the range has made superficiality inevitable, but one wishes for considerably more depth in almost every chapter, as well as for better balance. Somorjai is an expert in low-energy electron diffraction, and it is understandable that this subject receives considerable emphasis, that is, more than one chapter, while field emission, for instance, receives only