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Book Review: *Statistical Physics II: Nonequilibrium Statistical Mechanics*

Statistical Physics II: Nonequilibrium Statistical Mechanics. R. Kubo, M. Toda, and N. Hashitsume. Springer Series in Solid-State Science, Vol. 31, Springer-Verlag, Berlin, 1985, 279 pp., $29.50.

This book, by three well-known statistical mechanicians, is the nonequilibrium companion to *Statistical Physics I, Equilibrium Statistical Mechanics*, by Toda, Kubo, and Saito published in 1982 (Springer Series in Solid-State Science, Vol. 30). The original publication in Japanese in 1973, second edition in 1978, contained both parts in a single volume. This information comes from a preface by Kubo, dated February 1985, where it is also stated that a considerable part of Chapter 4, Statistical Mechanics of Linear Response, was rewritten and parts of other chapters were revised for the present edition.

The present volume is a useful addition to advanced textbooks on nonequilibrium statistical mechanics of which there are not many. It is in some ways complementary to van Kampen's book, *Stochastic Processes in Physics and Chemistry* (North-Holland, 1981). Both books cover the same background material on Brownian motion and stochastic processes but then their choice of topics is quite different. van Kampen's book emphasizes random walks, chemical reaction kinetics, and the transition from a master equation to a deterministic law plus fluctuations, the famous Ω^{-1} expansion. It does not therefore require a working knowledge of quantum mechanics. Major parts of this book, on the other hand, deal with relaxation and resonance phenomena in which quantum mechanics plays a central role. In fact Chapter 5, which makes up about half of the book, is titled Quantum Field Theory Methods in Statistical Mechanics and contains extensive discussions of diagrammatic techniques for Green's Functions, material covered in many solid-state books.

I found the style and organization of this book quite nice, as is van Kampen's. A graduate student or researcher going through both books will get a solid background in the subject. He will also realize (and this is

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something useful) that many of the hot new things in the current literature are rediscoveries of forgotten works (sometimes forgotten for very good reasons).

There is an interesting section in the book, Sec. 4.7, where the authors discuss some of the conceptual and mathematical difficulties associated with linear response theory—to which Kubo, of course, has made fundamental contributions. The section begins with the flat statement "Statistical mechanics is indeed a very difficult theory. Treating a dynamical system with an enormously large number of degrees of freedom, it must transform the dynamic evolution into a stochastic one by some sort of coarse graining. This we call in the following stochastization." It then goes on to respond to "van Kampen's objection" to linear response theory. This objection, well known to the cognoscente, concerns "the use of simplistic perturbations calculations...(when) dynamical trajectories in phase space are essentially unstable and are very sensitive to perturbation. Therefore a perturbational calculation of microscopic dynamics has only an extremely small range of validity. Thus he claims that microscopic linearity and macroscopic linearity are totally different. The latter can be understood only by a kinetic approach such as the use of a Boltzmann–Bloch equation for electrons in an applied external field."

Kubo's response to this criticism is "that the linear-response theory does not use a perturbational calculation for phase trajectories. Instead, it uses it for a limited class of phase distribution functions which are sufficiently smooth since we are considering near equilibrium states."... "Secondly, as was already discussed, the difference between the kinetic method and the linear-response theory is the interchange of the order of stochastization and linearization. Although it is difficult to prove it rigorously, this interchange is legitimate. The linearity considered in the linear-response theory is indeed macroscopic and not microscopic when it is applied to a macroscopic system."

It is my belief that Kubo's response is essentially correct *when it works* and this may involve some subtleties not discussed here. As an example, consider the motion of a charged test particle in a fluid subject to a small constant external field E. Then, if the collision cross-section decreases with velocity (something to be expected on general grounds), there is probably no true stationary state with a constant drift (even if the fluid is infinite so that generation of heat is no problem). There is, however, likely to be a "metastable state" which would be normally observed over experimental times where the linear-response theory would work [see, for example, Ferrari, Goldstein, and Lebowitz, Diffusion, Mobility, and the Einstein Relation, *Statistical Physics and Dynamical Systems: Rigorous Results*, J. Fritz, A. Jaffe, and D. Szasz, eds. (Birkhauser, Boston, 1985)].

A nice feature of this book is the authors' ability to convey the fact that the subject is an exciting one and that this is not the final word on the physics or mathematics of nonequilibrium phenomena. This makes the book interesting to the reader who feels encouraged to supply missing links. Some of these in fact exist in the mathematical literature and it would have been nice if they were at least referred to. For example, Section 2.2 discusses at some length how to go from the Ornstein–Uhlenbeck process for the velocity, $v(t)$, of a particle satisfying the standard Langevin equation to the Wiener process of Brownian motion for the position, $x(t)$, of that particle. It is explained there that this has to be done by some coarse graining in the temporal and spatial scale on which the position of the particle is measured. It would have been useful to mention there the "well-known fact" that with the appropriate scalings of space and time one has the precise, sharp, desired result,

$$X_\varepsilon(t) \equiv \varepsilon x(t/\varepsilon^2) \xrightarrow[\varepsilon \to 0]{} W_D(t)$$

the Wiener process with the diffusion constant D. This is easy to derive and goes under the general name of Donsker's invariance principle in the mathematical literature. [See for example, Durr, Goldstein, and Lebowitz, *J. Stat. Phys.* **30**:519 (1983) and also A. DeMasi N. Ianiro, A. Pellegrinotti, and E. Presutti. A Survey of the Hydrodynamical Behavior of Many-Particle Systems, in *Nonequilibrium Phenomena II, from Stochastic to Hydrodynamics*, J. L. Lebowitz and E. W. Montroll, eds. (1984) and references there].

I have also a small complaint, of a different nature, about Sec. 2.7 which is entitled Brownian Motion of a Quantum System. What is done in this section is a derivation via more or less standard perturbation theory of a master equation for a general system *weakly coupled* to a heat reservoir. This, while interesting and useful, is not what the words Brownian motion convey in the usual context, where weak coupling in *not* a general requirement.

Despite these caveats, which are almost unavoidable in a general textbook covering a wide variety of topics, the book is indeed a very useful one and highly recommended.

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