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Book Review: *Beyond Equilibrium Thermodynamics*

Beyond Equilibrium Thermodynamics. Hans Christian Ottinger, John Wiley, New Jersey, 2005.

The title of this book is carefully chosen since it intends to imply the study of linear and nonlinear deviations from equilibrium. This study is intended to be more general than the thermodynamics of irreversible processes as discussed by de Groot and Mazur in their classic text.

The book is divided into two parts. Part I: The Phenomenological Approach contains an introduction and chapters on hydrodynamics, linear irreversible thermodynamics, complex fluids and relativistic hydrodynamics. Part II: The Statistical Approach contains chapters on the projection-operator method, kinetic theory of gases, and simulations. There are several appendices on equilibrium thermodynamics, mechanics and geometry, functional derivatives, quantum systems, and applications of beyond-equilibrium thermodynamics.

It is difficult to decide whether the book is intended to be a monograph or a text for advanced students. There are a large number of exercises throughout with solutions to those exercises in an appendix. On the other hand, the book starts with a daunting 12 pages of symbols and notation and a somewhat turgid text.

Equilibrium thermodynamics is nicely discussed and is based on the presentation of Callen. The aim of the book is to provide a foundation for nonequilibrium thermodynamics which is as close as possible to the foundation of equilibrium thermodynamics given by Gibbs. The acronym for this foundation is GENERIC, which stands for the General Equation for the Non Equilibrium Reversible Irreversible Coupling. This formalism was introduced by Grmela and Ottinger in 1997. The basic equation is given symbolically by

$$\frac{dx}{dt} = L(x) \cdot \frac{\delta E(x)}{\delta x} + M(x) \cdot \frac{\delta S(x)}{\delta x}$$

where x is a set of independent variables needed for a complete description of a nonequilibrium system. $E(x)$ and $S(x)$ are, respectively, the total energy and entropy, and $L(x)$ and $M(x)$ are matrices representing geometric structures (Poisson) and dissipation (friction) properties. The term involving E is the reversible contribution. The matrix L is Poissonian and is antisymmetric while M is the friction matrix and is symmetric. It is hard to disagree with this equation, but the major difficulty is determining the form of S out of equilibrium.

In the chapter on hydrodynamics, there is an adequate discussion of the usual treatment and the GENERIC formulation. There is an interesting section entitled Something is Missing concerning the hydrodynamic velocity field which makes contact with some recent work of Brenner. In the chapter on linear irreversible thermodynamics, there is a section entitled Paralyzing Criticism, which implies that there is little new in the usual development except for the Onsager reciprocal relations, which are also questioned. Similar presentations occur in the next two chapters.

In part II, the Poisson and friction matrices are obtained using the projection operator method. In the chapter on the kinetic theory of gases, the Poisson and friction matrices are also obtained and used for an alternative derivation of the Boltzmann equation. There is no discussion of the range of validity of the nonlinear Boltzmann equation.

One of the most interesting chapters is that on simulations. The distinction is made between brute-force simulations and thermodynamically guided simulations, which are based on GENERIC. This is the most convincing indication of the utility of the GENERIC scheme.

I now have a much better understanding of the formulation of GENERIC and its applicability. This is the most positive feature of the book.

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