STATISTICAL PHYSICS AND ITS PHILOSOPHY

Gerard Emch and Chuang Liu, *The Logic of Thermo-Statistical Physics*. Heidelberg: Springer-Verlag, 2002. Pp. xiv + 703. US$89.95 HB.

By Lawrence Sklar

This book is the joint product of a philosopher of science (Liu) and a mathematical physicist with a long and distinguished career in the foundational aspects of physical theories, especially on the algebraic approach to quantum theories (Emch).

The bulk of the book is taken up with an extensive review of some of the formal approaches to foundational issues in statistical mechanics. These are presented in their full technical version with its requisite mathematical apparatus. There are three chapters devoted to the mathematical theory of probability and its interpretations. Two chapters present historical preliminaries to the technical expositions of physics. Two chapters and an appendix are devoted to issues in the philosophy of science, and there are also shorter philosophical and interpretive passages embedded in the chapters devoted to the exposition of the foundational physics.

The chapters devoted to expounding the mathematical physics will be of great value to those interested in foundational questions in statistical mechanics. A number of the mathematical treatments of fundamental issues are treated with great clarity and precision. For this reason the book provides a very useful resource, presenting much difficult material in a transparent way and in some detail, and providing abundant directions to further source material in the literature. These chapters will, of course, only be of use to a reader with some substantial background in analysis and topology since mathematical apparatus is used without hesitation.

Chapters 2 and 3 discuss the development and formalisation of thermodynamics (here called by the more appropriate name of thermostatics), and the discovery and early development of the kinetic theory of gases.

Chapters 7 through 9 explore ergodic theory and its generalisations from its beginnings in Boltzmann and Maxwell through the modern treatments. The ergodic approach attempts to model both equilibrium

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and non-equilibrium phenomena by studying the evolution of whole sets of possible dynamical trajectories for the microscopic components of a system in phase space. The approach uses primarily measure theoretic methods. Fundamental to obtaining the desired results are results on the instability of trajectories for plausible models of real systems. For some idealised systems, say hard spheres in a box, such instability results can be obtained. But other results, especially the Kolmogorov–Arnold–Moser theorem, show that for more realistic systems the dynamics in phase space cannot fully obey the demands required for the ergodic type results to be obtained. The hierarchy of ergodic properties, the problem of demonstrating sufficient conditions for having these properties for realistic idealised systems and the role of such results as the KAM Theorem in casting doubt on the universality of the ergodic features are all discussed here. Chapter 10 goes on to describe the method of Gibbs' ensembles and is very helpful in understanding how the notion of an equilibrium ensemble is extended to the quantum domain via the characterisation of the equilibrium state given by Kubo, Martin, and Schwinger (the so-called KMS condition).

Chapters 11 through 14 take up the issue of phase change, which represents one of the most characteristic macroscopic features of matter. The most well-known examples are the gas–liquid, gas–solid and liquid–solid transitions but further examples involving macroscopic magnetic states and other situations describable thermodynamically are also important. First of all the historical background is presented. Then the Ising and other rigorous models are explained. In the former, one considers a two-dimensional lattice of spinning particles interacting by their magnetic moments. Although the example seems simple, Onsager's classic calculation of the relevant thermodynamic functions for this model represents a major achievement for equilibrium theory. Next the methods of scaling and the renormalisation group are explored. The methods have provided significant insight into the nature of the solid phase through the exploration of the form of correlational order demonstrated by small and large arrays. Crucially, renormalisation theory can explain why dissimilar systems can show phase transitions to the solid state that are similar with regard to their macroscopic characteristics. A further chapter is devoted to the issue of treating phase change in the quantum context. A final chapter of exposition, Chapter 15, takes up the approach to equilibrium. Here the two central topics treated are the role of master equations and possible methods for treating the approach to equilibrium in quantum statistical mechanics.

Not every important topic is taken up even in this quite long book. For example in the theory of approach to equilibrium, the Lanford "rigorous derivation of the Boltzmann equation" is only mentioned, and 'BBGKY' (Bogolyubov, Born, Green, Kirkwood, and Yvon) methods are not treated at all. The latter yields the Boltzmann equation but on the basis of dubious posits, whereas the former demonstrates rigorously that, given more plausible assumptions, the evolution of an ensemble will be such that it will be highly probable that systems will behave in a Boltzmannian way, but applies only to one highly idealised system and for very short time periods. Nor is there any discussion of the alleged role played by cosmological considerations in getting time-asymmetry into the statistical mechanical model or to any other treatment of the asymmetry problem. But the treatment of the topics that are covered is extensive, rigorous and exceedingly clear even for the most difficult material.

The three chapters on probability theory are, first, historical, second, a discussion of the formal mathematical theory of probability, and, third, a discussion of interpretive issues. The frequentist model of von Mises and the subjectivist model of de Finetti are discussed and there is a treatment of the problem of offering a formal model of randomness suitable for interpreting probability. There is also a clear exposition of Shannon's information theoretic concept of entropy.

The bulk of the philosophy of science is found in Chapters 1 and 16. Here there is an exposition of the semantic conception of theories and its contrast with the syntactic view. According to the latter, theories are characterised in logico-linguistic terms, whereas on the former view they are characterised in terms of families of set-theoretical models. There is a discussion of how testing of theories looks from the semantic view and some discussion of inter-theoretic reduction from that perspective. An interesting suggestion is that one should look at the theoretical situation in physics as multi-leveled, with a structural theory giving rise to a theory that models dynamical trajectories, these trajectories then being held to be isomorphic, or approximately so, to actual dynamical evolutions of real systems.

Much is said about the difficulties that occur due to the fact that the idealised systems described in theories are, indeed, idealisations of real systems. There are a number of well-taken remarks to the effect that the real role of idealisation in theory is not that of dealing with the 'messiness' of reality but with the problem of 'carving nature at its joints', that is, with finding appropriate explanatory structures that reveal the real way in which the world works. But there is surprisingly little in these chapters, or elsewhere in the book, about the details of the real issues that this problem of idealisation gives rise to in the specific context of statistical mechanics.

There is a condensed, but trenchant and subtle, discussion of the legitimacy of the models developed by ergodic theory and its generalisations in Section 9.5, "Conclusions and Remaining Issues", of the final chapter on ergodicity. Here some issues of controllability of idealisation by limits, the set of measure zero problem, the problem of the isolation of systems as an idealisation and related familiar philosophical issues from ergodic theory are taken up. The discussion here is learned and stimulating, but quite brief (fourteen pages in all). There is a much briefer discussion of a philosophical sort in Section 15.3, where the idealisations used in the book's derivation of the master equation approach to non-equilibrium problems are very briefly noted and commented upon.

For very extended discussions of such issues as contrasting and contending idealisations in the non-equilibrium problem, for example, or the way in which renormalisation methods provide explanatory structures in physical theories, the reader will have to turn to the existing treatments of these topics in the literature to which they are directed in the text of this book.

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