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Book Review: *The Theory of Critical Phenomena*

The Theory of Critical Phenomena—An Introduction to the Renormalization Group. J. J. Binney, N. J. Dowrick, A. H. Fisher, and M. E. J. Newman, Clarendon Press, Oxford, 1992.

It is hard to believe that some 25–30 years ago phase transitions and critical phenomena were the most widely studied area of condensed matter physics. Because of intensive theoretical and experimental investigations this problem became one of the most extensively developed and one of the clearest fields of modern physics. Critical indexes have been calculated theoretically and measured experimentally with almost spectroscopic accuracy. A few good textbooks were written when interest in the subject was at its peak. The most detailed information about topics in critical phenomena is available in the Domb–Lebowitz (formerly Domb–Green) monographs, which have so far appeared in 15 volumes. Since then the theory of critical phenomena has held an honorable place in many courses in statistical mechanics, condensed matter physics, and field theory. Nevertheless, from time to time new textbooks appear covering the by now well-established field of phase transitions. The book under review is one of them. The best evidence of some delay in publishing such a book is the list of references. Only a few of them are dated as late as 1988–1989, while the remaining 100 or so appeared in the 1960s and 1970s.

The book is definitely a text rather than a monograph, with solved problems at the end of each chapter. The first six sections of the book consist of an introduction to the general area of critical phenomena, while the last eight chapters describe different aspects of the renormalization group approach to the Landau–Ginzburg (LG) model.

Chapter 1 contains a general introduction to physical aspects of critical phenomena and is completed by the scaling hypothesis and relations between critical indexes. Chapter 2 discusses the relation between statistical mechanics, thermodynamics, and the theory of phase transitions. Microscopic models are described in Chapter 3, which contains the general solution of the spherical model, solutions of the one–and-two dimensional Ising model, as well as the high-temperature expansions. Chapter 4 describes numerical methods, in particular simulation methods (algorithms of Metropolis, Swendsen–Wang, and Wolf) and molecular dynamics simulations that include velocity randomization at each time step (the Langevin

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method). Chapter 5 describes the general ideas that underly the renormalization procedure (block and site variables, renormalization of the Hamiltonian, calculations of critical indexes, and scaling laws). These are then illustrated by an application to two-dimensional bond percolation and the Ising model. Mean-field theory and corrections to it are considered in Section 6.

The second, main part of the book (Sections 7–14) consists of a detailed analysis of the LG model. After a general introduction and a solution in terms of the ideas of mean-field theory (Chapter 7), two field-theoretic methods, diagrammatic techniques and renormalization group theory, are introduced. Starting from the Gaussian version of the LG model, a perturbation scheme based on Feynman diagrams is used in Chapter 8 to calculate the partition function and the Helmholtz and Gibbs free energies. The consecutive renormalization of mass, field, and coupling constants is carried out in Chapter 9. Chapter 10 describes the calculation of the critical indexes η and γ by the renormalization technique and by the ε-expansion both above and below the critical dimension $d=4$. The renormalization group equations are then used to calculate all critical indexes for $T=T_c$ (Chapter 11) and $T \neq T_c$ (Chapter 12). Some interesting phenomena which occur in low dimensions, in particular the Kosterlitz–Thouless transition (without long-range order!), are considered in Chapter 13. The final Chapter 14 describes a number of generic properties of the LG model. Some, mainly mathematical, details important for understanding the main portion of the book are described in 14 appendices.

If one can ignore the anomaly implied by the appearance in 1992 of a textbook on phase transitions, this specific deserves a high rating. The book is written very clearly and simply, which makes it accessible to anyone who passed the principal undergraduate physics courses. One of course has to pay for this simplicity. Important problems such as those relating to phase transitions in liquid crystals, polymers, amorphous materials, and biological systems are not mentioned in this book. However, the main contemporary research that makes use of the ideas of phase transitions is principally focused on these modern fields!

Teachers and students either teaching or studying phase transitions —wherever they exist—should find this book very useful together with a number of additional sources. They might also find it helpful in the context of general statistical mechanics courses. And finally, young researchers working in the area of phase transitions will benefit from the detailed description of the renormalization group theory.

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Book Review: *Entropy Optimization Principles with Applications*

Entropy Optimization Principles with Applications. J. N. Kapur and H. K. Kesavan, Academic Press, San Diego, California, 1992.

This book undertakes an ambitious task, to present entropy optimization methods in the different disciplines of physics, statistics, and economics while at the same time endowing the diverse applications with a conceptual unity. To a surprising extent, the book succeeds.

The presentation is exceptionally well-organized. Each chapter examines some aspect of entropy optimization, with its introduction giving an overview of general principles. Specific applications in the chapter body then exemplify the principles. The Table of Contents is extremely thorough, which makes retrieving information easy and pleasant.

The four elements of any entropy optimization problem are the prior probability distribution, a set of moment constraints, the measure of entropy or cross-entropy that is to be optimized, and the probability distribution resulting from the optimization. The authors are able to fit many unusual problems into this paradigm. For example, many important statistical distributions, such as normal, gamma, etc., are entropy-optimizing distributions that have been specialized to certain types of intervals (finite, semi-infinite, or infinite) and subjected to certain moment constraints. Although this observation seems trivial, the authors (in typical style) use it to underscore an interesting point: Fisher and Pearson's historical controversy about their Method of Maximum Likelihood and Method of Moments is really a disagreement over the moment constraints relevant to an optimization problem.

Much of the book is predictable. For example, it is hardly surprising to be presented with the duality between Jaynes' Maximum Entropy Principle and the Kullback Minimum Cross-Entropy Principle, or to see another derivation of the Maxwell–Boltzmann, Bose–Einstein, or Fermi–Dirac distributions. On the other hand, however, much of the book displays entropy optimization in more exotic settings, such as population dynamics, economics, image reconstruction, and queueing theory and on a more

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general level, systematically permutes the four elements of entropy optimization given above into an exhaustive series of principles.

The book's biggest weakness (possibly due to a deliberate avoidance of controversy) is the absence of any explicit discussion about probability. The index, for example, does not contain the word "Bayes." The resulting imprecisions occasionally cause difficulties. The proof of Jaynes' Entropy Concentration Theorem, for example, purporting to show that most distributions are close to the maximum entropy distribution, seems to prove something entirely different, that empirical frequencies sampled from the maximum entropy distribution do not deviate much from it.

The book gives a practical, theoretically coherent view of many interesting problems, but at its end leaves its reader puzzling over more fundamental matters: what is probability and why does entropy optimization work so well? It is hard to ask for more from any book.

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