Journal of Statistical Physics, Vol. 112, Nos. 1/2, July 2003 (© 2003)

Book Review: *Phase Transition Dynamics*

Phase Transition Dynamics. Akira Onuki, 714 pp., Cambridge University Press, 2002.

This book, written by A. Onuki qualifies as being a magnum opus. One cannot but be impressed by the breadth of the author's interests and his mastery of various topics ranging from standard solid state physics to soft matter typified by fluids, polymers and gels. It is certainly a veritable tour de force in its scope and depth of presentation. There is no doubt in my mind that Onuki's ponderous volume will serve as a standard reference on dynamics of phase transitions for years to come.

However, I must warn the potential reader that the level throughout the volume is quite advanced and the book cannot be characterized as an introduction to the different topics discussed in it. Fortunately there are other books able to fill this niche. Not only is the level of Onuki's volume advanced, but the author in analyzing different problems, regularly invokes results from more specialized literature. This certainly disqualifies this book as an easy read. Nevertheless an advanced graduate student or specialist working on any of the topics dealt with in this book will find a wealth of information, a quick reference to fundamental results, and a useful list of references as of the time of publication. The plan of the book is not to proceed from the simple to the complex, but rather to present all of the subjects on an advanced level from the start. Basing my judgement on the few topics that I am familiar with, the exposition seems excellent and clear, if at times reduced to a bare bones description. The entire volume is theoretically oriented, the fundamental experimental results being described in a more cursory manner, but in enough detail to give the theoretical developments ample backing. More formal,or mathematically intensive, derivations are relegated to the 47 appendices interspersed in the main text.

In presenting this book to a general physical audience one is faced with the problem of simply listing the topics involved. At 714 pages and 57 chapters this ponderous volume defies simple classification. The closest to this would be as an encyclopedia of phase transition dynamics. In my

0022-4715/03/0700-0429/0 © 2003 Plenum Publishing Corporation

cursory description of the subject matter, I will only describe those topics which I deem essential or that, in some manner, are relevant to my research interest. There is much more subject matter and detail in this book that cannot be described in this limited space.

Part 1 of a total of three parts, is a selection of topics in equilibrium statistical mechanics. First of all the author sets the stage by introducing fundamental notions of spin systems and fluids. A thermodynamic and hydrodynamic description of both systems is introduced at an advanced level. A fair amount of space is devoted to a detailed treatment of the thermodynamic fluctuations of microscopic operators in both systems. What I found awkward in this and subsequent chapters is that some of the fundamental relations are simply lifted from the literature without derivation or comment, thus rendering the book quite difficult to follow when it discusses topics with which one is not already familiar. When the stage is set the book proceeds to deal with critical phenomena and scaling. It gives a very detailed introduction to the thermodynamic scaling in the critical regime based on critical exponents, fractal dimensions and the scaling ansatz. The equation of state in the critical domain is treated for Ising systems, fluids and fluid mixtures. Fluctuations of various thermodynamic variables in the critical domain are thoroughly discussed, the case of ^{4}He being treated in detail.

We next move to the chapter on mean-field theories, which I deem to be the best section in Part 1. It treats exhaustively the mean-field ansatz in a number of contexts starting with a general description of the Landau theory, following which the Bragg–Williams approximation is applied to ferromagnetic Ising spin systems, alloys, and the van der Waals theory of fluids and fluid mixtures. A fair amount of space is dedicated also to mean-field theories of polymers and gels. The Flory theory of polymer solutions and polymer blends is treated thoroughly and the elasticity of isotropically swollen polymer gels, gels subject to a uniaxial stretching force and one-dimensional constrained gels, are described at the mean-field level. Again, I note that many of the fundamental results are simply lifted from the literature and then used as a basis for further developments. The concluding section of Part 1 consists of a discussion of advanced theories in equilibrium statistical mechanics. The epsilon-expansion of the Ginzburg–Landau–Wilson Hamiltonian precedes the treatment of the Feynman-diagram expansion together with its applications to fluids, fluid mixtures, ^{4}He near the superfluid transition, polymer solutions, and polymer blends. A major part of this chapter is however devoted to a thorough and advanced treatment of renormalization group theory and some of its ramifications, concluding with an exposition of two-phase coexistence and surface tension. The topic of the interfacial profile and surface tension are discussed for systems near the critical point. Applications are made to symmetrical tricritical systems and to polymer systems, as well as to thermal and quantum mechanical fluctuations in the interfacial profile. Part 1 of the book concludes with a discussion of vortices in systems with a complex order parameter.

The second part of the book contains a selection of topics in dynamics of fluids and polymers. It is based on the Langevin equation applied to critical dynamics as well as general linear response theory. The first chapter of this part begins with a formal discussion of one variable (single particle) and multivariate Langevin equations. The general theory is then developed further by introducing the A, B, and C models of the time-dependent Landau–Ginzburg equation and the framework of the linear response theory for thermal disturbances and for transport coefficients in fluids. The chapter on the dynamics of fluids is the best and most exhaustive chapter in this part of the book. It focuses on the behavior of one and two-component fluids close to a critical point and the behavior of ^{3}He and ^{4}He close to a superfluid transition. The theoretical framework in this context is provided by the dynamic equations of non-linear Langevin type analyzed by means of dynamic renormalization group theory. As in Part 1, polymers and gels feature prominently also in Part 2 of the book. The third chapter of Part 2 deals exhaustively with viscoelastic dynamics in polymer systems, entangled polymer solutions, and gels. The discussion of polymer dynamics is based on the introduction of stress-diffusion coupling. Results from the Part 1 of the book, on the static thermodynamic properties of polymer solutions and gels, form the basis for the discussion of polymer dynamics. Dynamical coupling between stress and diffusion, based on the relative motion of different solution components in case of unbalanced stress, is analyzed in semidilute polymer solutions, gels, and polymer blends. Static properties of gels are first considered by constructing the appropriate Ginzburg–Landau–Wilson Hamiltonian in the harmonic and third-order elastic interaction approximation for neutral and charged gels. This is the basis for a derivation of the dynamical equations for gels and macroscopic instabilities of swollen gels. Part 2 of the book concludes with an analysis of quenched randomness in network structures, and describes the frozen disorder inherent in the formation of gels.

The third and last part of this volume is dedicated to phase-ordering and defect dynamics. The emergence and growth of order, especially as occurs by spinodal decomposition, and the dynamics of interfaces and vortices, makes up the bulk of Part 3 of the book. Primary emphasis is placed on various aspects of spinodal decomposition. The first chapter starts with phase ordering in nonconserved systems, described by model A dynamics under the influence of different types of external quenching.

Dynamical equations for the motion of the interface in nonconserved and conserved systems are derived with, and in the absence of, a noise contribution. In addition their relation to the more general Stefan problem is given more than cursory attention. Effects of hydrodynamics in the phase-separation dynamics are treated next, leading to an exposition of spinodal decomposition and boiling of single component fluids where density variations after the temperature quench lead to the emergence of thermal plumes. Spinodal decomposition is clearly the focus of this chapter and is treated in detail also in the case of adiabatic spinodal decomposition, periodic spinodal decomposition, and viscoelastic spinodal decomposition in polymers and gels. Vortex motion and defect turbulence of quantized vortices in superfluids are examined at the end of the chapter. This is followed by a chapter dealing with various aspects of nucleation. The free energies of droplets, as described by various models of phase transition, and their size distribution are derived to develop evolution equations for droplet growth and their nucleation rate. Lifshitz–Slyozov and related theories of droplet growth are discussed in detail. Nucleation in single-component systems and nucleation at very low temperatures are also analyzed. The quantization of the Rayleigh–Plesset equation is treated in detail, and its consequences when applied to the quantum nucleation rate. Nucleation problems in polymers and the effect of viscoelastic stresses are discussed at the end of the chapter. Chapters on phase transition dynamics of solids and of fluids in shear flows conclude this part of the book. Coupling of the dynamics of order parameter change to the elastic displacement field variables of various lattices and to the shear stresses in fluids are essential in this context.

I stress again that Onuki's volume contains much more than alluded to above. Due to its size alone it would be extremely difficult to give it an appropriate and fair description. It is however an excellent and exhaustive advanced text in various aspects of phase transition dynamics that I highly recommend to advanced graduate students and specialists.

Rudi Podgornik
National Institutes of Health
Bldg. 9, Room 1E116
Bethesda, Maryland 20892-0924
e-mail: rudi@helix.nih.gov