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Linda E. Reichl: A Modern Course in Statistical Physics

Wiley-VCH, 3rd revised and updated edition, 2009, 411 pages

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Some twenty-five years ago, I began my journey in statistical physics in earnest by taking a course on critical phenomena at the TU Munich, having just gone through an introductory statistical mechanics and thermodynamics class as part of the standard theoretical physics sequence. As students, we were then facing the notorious gap separating course texts that cover the standard material and current review articles or even original research publications, naturally written on a much advanced level. Fortunately for us, Linda E. Reichl had just published *A Modern Course in Statistical Physics* which quickly became our text of choice, aiding us to find and insert the numerous missing links between our elementary course knowledge and recent research. We were enthralled by the clarity and conciseness of Reichl's exposition; consequently many of our required seminar presentations in this course listed her book as a premier reference.

I was thus delighted to see Reichl's text re-emerge in its third incarnation, considerably revised and updated. In her preface, the author promises a "greater emphasis on fluctuations", partly motivated by current research in nanoscale materials and biological or other complex systems. Reichl certainly delivers, providing her readers with a "thorough grounding in thermodynamics, hydrodynamics, and statistical physics". I reckon the material presented in this volume easily sufficient for two full semesters of a standard graduate-level lecture course.

Following introductory remarks that lucidly lay out the conceptual foundations of statistical physics, Reichl begins with an exposition of the microcanonical approach, including a careful discussion of fluctuations about the equilibrium averages of thermodynamic quantities, and treats the usual suspects of standard examples (spin systems, harmonic oscillators, and the classical ideal gas). She then switches gears and gives a very clear introduction to phenomenological thermodynamics, the various thermodynamic potentials, and applications that encompass heat engines, gas liquefaction, osmotic pressure, and chemical reactions.

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Conditions for thermodynamic stability are stressed, and through analysis of fluctuations a link with the statistical description of macrosystems is established. However, a detailed explanation of the fundamental connection between statistical physics and thermodynamics must have fallen victim to the two revisions of this otherwise quite self-contained text: When microcanonical entropy and derived concepts such as temperature are introduced in Chap. 2, recourse is made to thermodynamic relations, but the basic equivalence (in the thermodynamic limit) of the Gibbs statistical and thermodynamic entropy concepts are never truly established. While this logical gap should not pose an obstacle for students who have already been exposed to elementary statistical physics before, it will unfortunately limit this text's value for complete newcomers.

Chapter 4 contains a beautiful treatment of phase transitions on purely thermodynamical grounds. In addition to general Landau theory and the van-der-Waals and Weiss mean-field approaches to liquid-vapor and magnetic systems, the superfluid phases of He^4 and He^3, their mixtures, and superconductors are covered. The subsequent chapter returns to statistical mechanics, utilizing the canonical ensemble. Aside from standard topics such as the classical ideal gas and Debye model of phonons in crystalline solids, the reader will find intriguing material on correlations in interacting classical fluids, the Ising model in various dimensions, as well as scaling theory and a glimpse into the renormalization group approach for critical phenomena. Reichl concludes her discussion of equilibrium statistical mechanics with the grand-canonical ensemble in Chap. 6. This approach is naturally employed to derive the virial expansion for classical fluids, and to study the low-temperature properties of ideal quantum gases, including Bose–Einstein condensation in optical traps and the Bardeen–Cooper–Schrieffer model of superconductivity.

The remaining four chapters of this remarkably rich text address nonequilibrium statistical physics and transport theory. Chapter 7 treats the theoretical description of Brownian motion by means of Langevin and Fokker–Planck stochastic equations of motion, and derives Onsager's reciprocity relations, along with the Wiener–Khintchine and fluctuation-dissipation theorems. It also covers linear response theory, first in a classical setting, and then through a microscopic quantum-mechanical approach. The following Chap. 8 is devoted to phenomenological hydrodynamics and the Navier–Stokes equations. Characteristic of Reichl's text, intricate applications are incorporated, such as thermoelectric effects and the hydrodynamics of mixtures and superfluids. The following chapter is devoted to the computation of transport coefficients, beginning with elementary mean-free-path models, but in the bulk based on the (linearized) Boltzmann equation. Parts of this section will likely pose the most demanding challenges to students. The final Chap. 10 is concerned with an introduction to nonequilibrium phase transitions, with the Brusselator model for chemical oscillations and traveling waves and the Rayleigh–Benard convection instability serving as the prime examples.

Almost all chapters are interspersed with insightful "Exercises" that apply the general theoretical framework to specific applications; I would however like to question the page editors for placing some of these intermissions at rather peculiar locations in the text. In addition, a large variety of very useful problems are provided at the end of each chapter, some quite challenging (fortunately, free solution manuals are available for instructors). Many theoretical results are supported through actual experimental data, a rare find in statistical mechanics textbooks. The volume also lists many references, often to original research papers. A set of appendices provides background on elementary probability theory, differentials, ergodicity, second quantization, scattering theory, and series expansions and integrals.

In summary, I enthusiastically recommend Reichl's third edition of *A Modern Course in Statistical Physics* for the advanced student and active researcher. (Novices should probably first consult a more elementary text.) It is rewarding to see how this book has grown and matured over the years, hopefully mirroring our own development since our student days. I will most definitely keep Reichl's *Modern Course* in close reach, and expect to be frequently consulting this volume, not only when preparing graduate-level courses, but occasionally also for the sake of my group's research activities.