Vignette: Subsurface Geology

Is there a way of determining how hot Hell is, and how cold it would have to be for it to freeze over? It turns out that there is a venerable calculation for the climate of Hell. It is attributed to a mysterious Mr. Wensel of the U.S. National Bureau of Standards and was reputedly made more than a half-century ago.

He proposed that the searing statement in Revelation 21:8, "But the fearful, and unbelieving . . . shall have their part in the lake which burneth with fire and brimstone," provided a temperature touchstone. In order for a lake of molten brimstone to exist, the temperature in Hell would have to be below 444.6°C (832.3°F). For, if it were not, goes this argument, the brimstone and vapor would have become a gas and not a lake. . . .

It seems that every time someone gleefully trots out Mr. Wensel's numbers, some skeptic points out that an earthly assumption is at work—namely, that the pressure in Hell is the same as the pressure of the Earth's surface at sea level. And that surely is wrong, if for no other reason than Hades's placement in the area we euphemistically term "below." Under intense pressures, brimstone can stay liquid to 1,040°C (1,904°F) . . .

—*Stephen Strauss*, in *The Sizesaurus* (Kodansha)

Phases of Matter

Principles of Condensed Matter Physics. P. M. CHAIKIN and T. C. LUBENSKY. Cambridge University Press, New York, 1995. xx, 699 pp., illus. $49.95 or £35.

Readers' reactions to this book might hinge on their interpretation of the title. Those who view condensed matter physics as a generalization of solid state physics incorporating such diverse topics as superconductivity and phase separation in polymer melts will be disappointed; many topics of interest to them will not be found. Those who recognize the authors' traditional and more circumscribed reference to many-body processes not treated by solid state physics will find a rich and compelling work that fills a void in the library of physics.

Principles of Condensed Matter Physics focuses first and foremost on the phases matter can form into and on the transitions among them. In doing so it provides the first comprehensive overview for many of the forefront topics it covers. Its approach draws on the powerful concept of phases as the physical manifestations of broken continuous symmetries. Phase transitions then are the process by which these symmetries are broken and regained. In the process, materials acquire interesting properties such as shear rigidity, which can be calculated and compared with measurements. The authors also address phase transitions involving internal degrees of freedom rather than structural rearrangements, such as the onset of ferromagnetism. This is a remarkably broad and rich range of phenomena. In aiming for a unified presentation, the authors are confronted by the same challenge facing the entire condensed matter community: very few phase transitions have been explained completely. Tremendous progress in recent years, including important contributions by the authors, explains why this work can be written at all. The novelty of the results explains why it is virtually the only graduate-level textbook on the subject.

The solved systems range from the oft-described Ising transition to the more modern isotropic-nematic transition in liquid crystals. The most familiar phase transitions, such as melting and freezing, are treated approximately, by introducing the formalism of mean field theory. For cases where fluctuations are too important to average away, the authors provide a nice overview of the renormalization group, including the requisite discussions of scaling and universality. Since there is not yet a general theory for phase transitions, a sequence of increasingly complex examples, each of which highlights additional features of our still-evolving understanding, is provided. The authors include enough technical detail to provide a dedicated student with a foundation to start doing independent research. Indeed, some of the chapter-ending exercises only recently served as topics for doctoral theses.

Having established a set of theoretical tools for attacking even unsolved problems in the physics of phase transitions, the authors proceed into even more treacherous territory. More than half the book is dedicated to explaining materials' responses to external forces. These include dynamical responses such as elastic waves, the hydrodynamics of flowing fluids, and even the formation of topological defects during plastic deformation. Once broached, the subject of imperfections in otherwise uniform phases draws the work to its conclusion. The final chapters, dealing with defect-mediated melting, nucleation and growth of one phase in another, and fluctuations at interfaces, provide the reader with a taste of the ongoing research into the detailed mechanisms of phase transitions.

As with any pioneering effort, *Principles of Condensed Matter Physics* has some rough edges. The theoretical treatment is thorough and reflects nicely the authors' research interests in complex fluids. Less emphasis is placed on the experimental phenomenology that might invigorate the discussion. Lindemann's empirical melting criterion, for example, receives only a note in the glossary although it has provided a touchstone for experimental studies of melting for most of a century. Editorial gaffes such as the redating of two 19th-century references into modern times doubtless will be corrected in the next edition and meanwhile will divert students inquisitive enough to find them. Others, including at least one subtle sign error, might be more troublesome.

Even with these caveats, *Principles of Condensed Matter Physics* is an excellent introduction to the processes by which atoms and molecules become materials and how materials acquire their properties. It is beautifully organized to form the basis of a lecture course. The authors clearly have taken pains to complement traditional solid state textbooks and have avoided unnecessary overlap with classic texts such as Hansen and MacDonald's *Theory of Simple Liquids*. The amount of background required to get the most out of the many and varied examples suggests that *Principles of Condensed Matter Physics* would best be taken up immediately after a course in solid state physics. For the interested researcher, the self-contained chapters provide succinct overviews of the topics and more than enough information for going it alone into this exciting and evolving field.

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