became manifest to the physics community at large, and an appointment at the University of Chicago ensued. Subsequently Gell-Mann received an invitation from Caltech, and he stayed there until his retirement in 1993. Johnson describes incisively Gell-Mann's collaborations at Caltech with Richard Feynman—and their rivalry.

Much of the book is devoted to a comprehensive and perceptive account of Gell-Mann's important and varied contributions to particle physics, both as an innovator and as a critic: strangeness, K_0-K_0 regeneration, renormalization group methods, dispersion relations, the σ model, the eightfold way, current algebra, quarks, quantum chromodynamics—work done by himself and with collaborators. One of the very valuable features of the book is Johnson's even-handed and fair exposition of George Sudarshan and Robert Marshak's (earlier) formulation of the V-A hypothesis in the weak interactions, of Yuval Ne'eman's independent framing of the SU(3) classification scheme and the eightfold way, and of George Zweig's independent invention of the quark model. Johnson has also carefully recorded Gell-Mann's views regarding the reality of quarks, from his first suggestion of the model to his later reinterpretations of his initial views.

Strange Beauty gives a sympathetic description of Gell-Mann's personal life—of his courtship of Margaret Dow, his first wife, and of their marriage and travels. Johnson does not shy away from discussing the price paid by Gell-Mann's children for his success. Similarly, his marriage with Marcia Southwick, whom he married some ten years after Margaret died, is forthrightly and sensitively described. Johnson also relates Gell-Mann's passion for birdwatching, for linguistics, for collecting primitive art, and for one-up-manship. But other aspects of Gell-Mann's life—his involvement with Los Alamos, with the Rand Corporation, with the Institute for Defense Analysis (IDA) as a "Jasonite," and more generally with the military-industrial complex, are probed less thoroughly. Johnson's concluding chapters deal with Gell-Mann's affiliation with the Santa Fe Institute, his involvement with the description of complex systems, and the writing of *The Quark and the Jaguar* (Freeman, 1994).

All in all, *Strange Beauty* is an elegant biography of one of the outstanding theorists of the twentieth century.

Thermal Physics

Ralph Baierlein
Cambridge U. P., New York, 1999. 442 pp. $95.00 hc ($42.95 pb) ISBN 0-521-59082-5 hc (0-521-65838-1 pb)

An Introduction to Thermal Physics

Daniel V. Schroeder
Addison-Wesley, San Francisco, 2000. 422 pp. $44.00 hc ISBN 0-201-38027-7

The teaching of undergraduate thermal and statistical physics has been dominated for the past twenty-five years in the United States by two textbooks: *Fundamentals of Statistical and Thermal Physics* by Frederick Reif (McGraw-Hill, 1965) and *Thermal Physics* (Second Edition) by Charles Kittel and Herbert Kroemer (Freeman, 1980). However, during this period there have been many developments that are not reflected in these and other texts. Fortunately, two recently published texts, Ralph Baierlein's *Thermal Physics* and Daniel V. Schroeder's *An Introduction to Thermal Physics*, at least partially address the need for up-to-date material in this important field.

Thermal physics is a difficult subject to teach, partly because of the subtleness of its concepts, the lack of an organizing mathematical statement analogous to Newton's equation of motion in mechanics, and the paucity of models, other than the ideal gas, that can be solved by simple techniques. As a result, few physics undergraduates appreciate the arguments of classical thermodynamics in the context of heat engines, and many find statistical mechanics to be a grab bag of tricks that can be applied only to relatively uninteresting problems. By contrast, research in statistical physics is a rapidly growing area with many diverse applications.

One of the major decisions that instructors have to face when teaching a one-semester course in thermal physics is the relative weight to give to thermodynamics and statistical mechanics. A good argument can be made for adopting the approach taken by Reif and by Kittel and Kroemer, which is to introduce heat and thermodynamics using the students' knowledge of the atomic structure of matter rather than from a macroscopic point of view. However, the limitation of this approach is that students will probably not appreciate the reasoning of classical thermodynamics.

Both Baierlein and Schroeder have faced these challenges by discussing new developments, by stressing conceptual understanding, and by motivating the second law of thermodynamics by considering the multiplicity of a macrostate.

Baierlein's text emphasizes the development of statistical mechanics and is organized around the themes of entropy and the second law of thermodynamics, the canonical probability distribution, the partition function, and the chemical potential. Critical phenomena in the context of mean-field theory and the renormalization group for the one-dimensional Ising model are the major recent developments that are discussed. There are also many interesting tidbits, such as discussions of recent experiments on Bose–Einstein condensation, entropy and evolution, the history of the third law of thermodynamics, and negative temperatures. However, Baierlein uses the ideal gas model too exclusively, and I would have preferred more discussion by him of other models and applications. His emphasis on noninteracting systems makes it difficult for students to attain a sense of how statistical physics can be used in general.

Schroeder's text also combines the macroscopic and microscopic approaches but takes a more balanced approach. Part I introduces the first and second laws, using both microscopic and macroscopic viewpoints, but Part II includes chapters on engines and refrigerators and on free energy and chemical thermodynamics. Part III discusses further applications of statistical mechanics. In general, Schroeder's text has more applications, problems, and references to the literature. For example, the text includes a table of thermodynamic free-energy data, and the student is asked to use these data to discuss such problems as the phase transition between diamond and graphite and the power provided by a lead–acid cell. Schroeder's arguments are generally less sophisticated than Baierlein's, but they would be easier to follow for most undergraduate students. It is also refreshing that Schroeder suggests problems that require the use of a computer (or a programmable calculator) to do some numerical calculations. These problems enable the instructor to assign questions more complex than those that can be answered in terms of simple analytical formulae. Schroeder also has included a chapter on weakly interacting gases and the Ising model, and he discusses Monte Carlo simulations in the context of the latter. However, his treatment of the virial expansion is unnecessarily abstruse.

Schroeder is co-author with Michael E. Peskin of *An Introduction to Quantum Field Theory* (Addison-Wesley,

1995) and clearly enjoys writing and teaching. His text clearly fits into the standard undergraduate curriculum and can be used by students as early as their second-year.

Baierlein is an experienced teacher and author, who has written the innovative texts, *Atoms and Information Theory* (Freeman, 1971), *Newtonian Dynamics* (McGraw-Hill, 1983), and *Newton to Einstein: The Trail of Light* (Cambridge, 1992). So it is no surprise that his *Thermal Physics* is very well written and a pleasure to read. What makes this text stand out is the quality, clarity, and conciseness of the writing. However, many of the arguments are rather abstract and would be best appreciated by students who are already familiar with the subject or who are very bright and well prepared. To some extent, Baierlein's *Thermal Physics* is similar in style to his *Newtonian Dynamics*, and to *The Feynman Lectures* (Addison-Wesley, 1991)—great texts for those who are already familiar with the subject. The book is advertised as suitable for both undergraduates and graduates in physics and astronomy, but I suspect that it will fall into a crack between the two levels, being too difficult for most undergraduates and not sufficiently sophisticated for most graduate courses.

I strongly recommend that instructors adopt one of these two texts for their undergraduate courses on thermal physics. I would choose Schroeder's text because it is written at a lower level and hence easier to supplement. However, I would refer frequently to Baierlein's text for supplementary material for my class discussions. Both texts belong in the library of anyone teaching thermal and statistical physics. They are beautifully written and convey the feeling that physics is a discipline to be studied with devotion and love.

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ITEP Lectures on Particle Physics and Field Theory, Vols. 1 and 2

M. A. Shifman
World Scientific, River Edge, N.J., 1999. 875 pp. $141.00 (set) hc ISBN 981-02-2639-X; $84.00 (set) pb ISBN 981-02-2640-3

Mikhail A. Shifman's two-volume *ITEP Lectures* . . . are of great interest as more than presentations of theoretical physics: They are a monument to a remarkable community of creative physicists who managed to flourish intellectually, under conditions that were materially difficult and cognitively surreal, during the declining years of the Soviet Union. Shifman was at the center of the ITEP group, intellectual descendants of Lev Landau and Isaac Pomeranchuk, which made major contributions to high energy theory. (This was recognized, for example, by the APS's 1999 Sakurai Prize, which was awarded jointly to Shifman, Arkady Vainshtein, and Valentine Zakharov). In a charming introduction, Shifman describes some aspects of the way the group functioned. He gives a sense of the joy the members managed to find in their work—and in each other—in an often sinister and sometimes hostile environment.

The bulk of the book is a series of short monographs that grew out of research-oriented courses given as part of a regular tradition at ITEP. The range of topics, within high energy theory, is quite diverse. It includes heavy quark physics, quantum chromodynamics sum rules (also called ITEP or SVZ—for Shifman, Vainshtein, Zakharov—sum rules), instantons, conformal field theory, supersymmetric quantum mechanics, and supersymmetric quantum field theory. There is also a final course on a fascinating but comparatively sparsely studied (and at present rather isolated) chapter of mathematical physics—what Shifman calls quasi-exactly solvable models. In these models some, but not all, of the low-energy states and their wavefunctions can be found algebraically.

The treatment of each topic is clear and rigorous, expounded in vigorous prose and leavened from time to time with strong opinions frankly expressed. They put me in mind of Sidney Coleman's legendary series of Erice lectures, *Aspects of Symmetry* (Cambridge, 1988). Exalted company, indeed!

The common thread that ties most of these courses together is Shifman's expressed desire to do justice to "quantum chromodynamics, *the* theory of our world." The first two courses, on heavy quarks and sum rules, present approximation techniques that are firmly rooted in the microscopic theory and can be applied to describe specific experimental situations in a detailed quantitative fashion, as Shifman discusses. The third, on instantons (in the QCD context), discusses an aspect of QCD that is quite fundamental—without its instantons, QCD would possess symmetries that are not observed in nature—but not part of any controlled approximation. In the later courses, the emphasis shifts from approximate results in real QCD to exact results for (one would hope) instructive models.

Shifman expresses his philosophy in a striking passage (one of many):

> As time passes, the hope that the full analytic solution of QCD will be found, fades away. . . . theorists whose philosophy is 'all or nothing' abandoned the field. [The 'all or nothing' philosophy is widespread and, unfortunately, not only in theoretical physics. This is a favorite child of the so-called revolutionaries in all times and in all countries. The misfortunes it brought to our world are innumerable.] (In the original, the material in brackets is a footnote.)

In light of this comment, it is somewhat ironic that he puts so much emphasis on exact results for unrealistic models featuring supersymmetry and/or conformal symmetry. For these have made, in practice, extremely little impact on the application of QCD to the physical world. As Shifman concludes, somewhat ruefully: "It remains to be seen whether the remarkable discoveries and the elegant, powerful methods . . . will prove to be helpful in solving the messy problems of real-life particle physics."

However, woefully underplayed here are such tangibly significant developments as:

- ▷ Ever more sophisticated factorization methods, better algorithms, and gritty calculations that have sculpted perturbative QCD into a versatile and indispensable tool for the analysis and design of accelerator experiments;
- ▷ Numerical work using lattice QCD that has proved the fundamental nonperturbative results (confinement, chiral symmetry breaking) directly, given good quantitative results for the low-energy spectrum, and produced many impressive results for heavy-quark systems;
- ▷ Weak-coupling but nonperturbative methods that have been used to describe the high-density phase in a controlled approximation, with confinement and chiral symmetry breaking as demonstrable, analytic consequences; and
- ▷ The high-temperature frontier (also partially accessible to weak coupling methods) now being explored in heavy ion collisions.

The material Shifman presents on