Warps: Einstein's Outrageous Legacy (Norton, 1994), with its rich historical insight and entertaining anecdotes by another renowned expert in the field, could provide a useful supplement.

An ambitious instructor might wish to use these books to design an upper-level physics or astronomy course in which the text is supplemented everywhere by simple, back-of-the-envelope mathematical derivations of the key ideas. Designing such a course might pose a challenge, but it is my hunch that it would be very well received.

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Broken Symmetry: Selected Papers of Y. Nambu

Edited by T. Eguchi and K. Nishijima
World Scientific, River Edge, N.J., 1995. 467 pp. $86.00 hc ISBN 981-02-2356-0; $35.00 pb ISBN 981-02-2420-6

From the revolutions of relativity and quantum mechanics in the first quarter of our century, physicists attained both a more refined description of nature and an appreciation that events can be influenced by unexpected, novel and sometimes paradoxical processes having no analogue in the earlier, classical physics. Examples include the mixing of time and space, mass–energy transmutation, tunneling and modification of dynamics in force-free regions.

In the years that followed the invention of relativity and quantum theory, these two disciplines were combined into relativistic quantum field theory, which has been successful at energy and distance scales far removed from the original solar and atomic applications. Although much technical development accompanied this expansion, very few new physical principles emerged, beyond those already present in the initial formulations of relativity and quantum mechanics. One notable instance of new physics that accompanied the development of quantum field theory concerns the absence of observed symmetry in natural phenomena, even though the equations that govern our theories possess a high degree of symmetry. Yoichiro Nambu is a principal contributor to this subject, and in his recently published selected papers, aptly titled *Broken Symmetry*, one can follow very nicely the fascinating, if winding, flow of these ideas.

Physicists widely agree that the ultimate laws of nature enjoy a high degree of symmetry, that the formulation of these laws is unchanged when various transformations are performed. However, it must also be recognized that actual physical phenomena rarely exhibit overwhelming regularity. Therefore, at the very same time that we construct a physical theory with intrinsic symmetry, we must find a way to break the symmetry in the physical consequences of the model. Progress in physics can frequently be seen as the resolution of this tension.

In classical physics, the principal mechanism for symmetry breaking, already realized within Newtonian mechanics, is through boundary and initial conditions on dynamical equations of motion. But for quantum theory, which does not need initial conditions to make physical predictions, other mechanisms of symmetry breaking must be found.

The mechanism of spontaneous symmetry breaking presents itself as one resolution to our problem: Equations of motion are symmetric, but if the ground (lowest energy) state is degenerate, with copies related by a symmetry transformation, a solution necessarily selects one ground state, thereby breaking the symmetry. (A double-well potential, with left–right symmetry, illustrates the mechanism: In the ground state, a particle must be at the bottom of one of the two wells, and left–right symmetry is broken.) Spontaneous symmetry breaking evidently occurs in classical mechanics (as the previous example illustrates); it does not occur in quantum mechanics, with its finite number of degrees of freedom, because tunneling lifts the ground-state degeneracy. However, in the infinite volume limit—the thermodynamic limit with the infinite number of degrees of freedom that is appropriate for relativistic quantum field theory—tunneling disappears and spontaneous symmetry breaking can occur.

It was Werner Heisenberg who realized that, for a many-body system like a ferromagnet, the large number of degrees of freedom suppresses tunneling, and spontaneous symmetry breaking ideas are applicable. Moreover, he proposed in 1959 to use them in particle physics but did not construct a phenomenologically viable model. Heisenberg's work inspired Nambu, who had earlier understood the Bardeen–Cooper–Schrieffer theory of superconductivity in these terms (1960 paper **28**), to suggest a "superconductor" model of elementary particles (1960 paper **33**) and to elaborate the idea with collaborators (1961–62 papers **34–38**). This resulted in the accepted theory for pions: With the approximation that their small mass is neglected, they are viewed as the massless particles that accompany spontaneous symmetry breaking. Ironically, even though Nambu's analysis of BCS theory was complete, when it came to particle physics he did not appreciate the generality of a gapless mode—massless particle—accompanying infinite vacuum degeneracy; when Jeffrey Goldstone produced a simple example suggesting this generality, Nambu, according to the collection's introduction, "felt as if a prize catch had been stolen from under [his] nose." (Nevertheless, Nambu did receive several other distinguished prizes, which are listed in a useful *curriculum vitae* included in the book.)

By researching the Heisenberg-type model rather than one containing a gauge field, as in the BCS theory, Nambu could "not know whether a finite observed [gauge-field] mass can be compatible with [gauge] invariance" (1960 paper **33**). (That it can be was argued for particle physics by Julian Schwinger and Philip Anderson in 1962 and 1963, but the physics community did not respond until these results reappeared—when many people introduced gauge fields into Goldstone's example, thereby making possible the present-day standard model for elementary particles.)

Nambu has contributed significantly to physics in other areas as well, and this is reflected by the other papers in the collection. There is his three-triplet model of hadrons, which gave us an early suggestion for the "color" degree of freedom (1965 paper **54**). The semiclassical expansion for quantum field theory is derived (1968 paper **71**). String theory—touted by some as the new paradigm for particle physics—owes its action formulation to Nambu (1970 paper **78**). The remainder of the book comprises interesting papers that deal with subjects that did not blossom (infinite component wave equations), or were superseded (dispersion relations), or have not yet found a wide audience (generalized Hamiltonian–Nambu dynamics, field theories defined on finite sets of integers, nonparticle physics applications of supersymmetry).

While I regret that the publishers did not reset the papers in a uniform typeface, the modest price ($35 for the paperback) makes up for the sometimes illegible reproduction. The book benefits from the inclusion of previously unpublished material, informal lectures and conference-summary talks that are not widely available. These, together with the selected research papers, provide an excellent scientific biography of Nambu and of the Japanese physics tradition, which he describes in several places.

In a foreword, the editors joke that Nambu's work is ten years ahead of us, because it takes ten years to understand him. The clear and well-written research papers belie this exaggeration. But it is in the less formal presentations that the motivation for Nambu's ideas, as well as his charming modesty, become evident and make reading this collection the pleasure that it is.

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Introduction to Superconductivity

Michael Tinkham
McGraw-Hill, New York, 1996.
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It is fashionable to declare that various branches of science are dead, or at least no longer likely to produce genuinely new conceptual developments. This has been said of superconductivity, although not as often as of physics itself. The last time was in the mid-1980s, just in time to be confounded by the revolution in high-temperature superconductivity sparked by Georg Bednorz and Alex Müller. One of the happy products of the ensuing expansion of the field is a second and enlarged edition of Michael Tinkham's *Introduction to Superconductivity*, which surely is one of the most useful texts for those engaged in this extensively developed area of research.

This book, like the first edition, published in 1975 and by now familiar to several generations of students and researchers, covers the middle ground between applications and detailed microscopic theory. Drawing on the author's many outstanding contributions to our understanding of the phenomena of superconductivity, it gives a clear account of the experimental foundations of the subject, together with an uncluttered interpretation in terms of the order parameter theory of Vitaly Ginzburg and Lev Landau and the microscopic theory of John Bardeen, Leon Cooper and J. Robert Schrieffer.

The new edition is a testament to the fact that neither the field nor the author has been inactive over the past 20 years. Tinkham has taken advantage of his experience in teaching with the first edition to rearrange or expand the original material to make it more accessible for beginners. He has also added a substantial discussion of recent important developments and active research areas, notably high-temperature, nonequilibrium and mesoscopic superconductivity.

A new chapter on the high-temperature superconductors largely eschews the microscopic theory to focus on the elegant ideas introduced to describe the behavior of magnetic flux lines in the superconducting state. This was a wise choice, even though it meant excluding recent developments on the theory of strongly correlated electron systems, which will undoubtedly find their place in future texts. The phenomenology of the superconducting state is less controversial and lends itself to a rather compact exposition based on a more-or-less conventional Ginzburg–Landau model of layered superconductors.

The new chapters on nonequilibrium superconductivity and on the properties of small, low-capacitance junctions produced by modern nanofabrication techniques include discussions of the Coulomb blockade, the single-electron tunneling transistor, macroscopic quantum tunneling and the consequences of the uncertainty relation between phase and number. In the past, much of this material could be found only in conference articles or in the original literature.

The modifications for this edition of *Introduction to Superconductivity* have made a good book even better. It should continue to serve as a reference for researchers and a source of inspiration for teachers for many years to come.

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Introduction to Molecular Dynamics and Chemical Kinetics

G. D. Billing and K. V. Mikkelsen
Wiley, New York, 1996. 183 pp.
$49.95 hc ISBN 0-471-12739-6

We can divide the possible areas of coverage for a book like this into either kinetics and dynamics or experiment and theory. In this context, kinetics refers to chemical reaction rates in thermal ensembles, whereas dynamics also includes molecular-beam studies, laser-assisted processes, ultrafast events and energy transfer. *Introduction to Molecular Dynamics and Chemical Kinetics* by G. D. Billing and K. V. Mikkelsen is essentially all kinetics. As far as theory versus experiment, it is essentially all theory. Thus a better name might be "Introduction to Theoretical Chemical Kinetics." Within this corner of the kinetics-dynamics universe, though, the coverage is rather broad, including reactions in the gas phase, at gas–solid interfaces and in solution. The references are primarily to classic and pedagogical sources; there are 15 references to other books, 27 references to journal articles from the years 1918–42, 23 to articles from the 1949–79 period and only 11 from 1980–95. There are 16 chapters and 7 appendices, and the chapters tend to be very short; excluding exercises and references, the average chapter length is seven pages.

One feature contributing to the conciseness of the chapters is that some of the algebra is relegated to the exercises, which are answered in a 16-page section at the back of the book. But some subjects are simply insufficiently developed. For example, the chapter on generalized transition-state theory consists of algebraic manipulations that could be useful for introducing variational transition-state theory or vibrationally adiabatic models. But then the chapter ends, and the subject is abandoned. I found the chapters on classical trajectories and electronically nonadiabatic collisions frustratingly short as well.

The authors of this book are both widely respected research scientists in the areas they cover. The pedagogical quality of their book is a compromise between brevity and clarity. For example, the transition state is defined first in chapter 6 as "an activated complex" and then specified to be a point along the reaction path where the energy gradient is zero and the Hessian has one negative eigenvalue. Then the fundamental assumption of transition-state theory is stated to be that once a system has crossed the transition state it does not return. A novice to the theory might find it hard to appreciate the beauty and rigor of the transition-state theory from this discussion. For example, what if the system reacts without passing through this "point" along the reaction path? Modern treatments, following Wigner's approach from the 1930s, define the transition state as a hypersurface or, based on modern scattering theory, define it as a metastable quantum state, either of which allows a better appreciation of the fundamental dynamical assumption.

The best part of the book is its treatment of chemical reactions in solution. Unfortunately, this section makes little connection to the gas-phase part of the book. For example, in chapter 14 transition-state theory is derived from scratch—more clearly than it was in chapter 6, but also with no reference to chapter 6. A section I found especially interesting is the treatment of the electrostatic energy of the dielectric polarization of the sol-