example, is presented as an artifact of the low masses of the three lightest quarks and as a convenient bridge to the more fundamental color SU(3). His treatment is tight and leaves few loose ends; not many writers on this subject offer the reader a physical feeling for the Cabbibo angle. The book contains a useful appendix on natural units as well as an excellent glossary and an ample bibliography.

One of the strongest sections takes the reader through the transition from a perturbation description of the fleeting interactions of quarks and gluons to the quasiclassical realm of quark confinement, all by means of simple intuitive arguments that an undergraduate could easily grasp.

In particle physics, experimenters usually have to wrestle with epiphenomena far removed from the fundamental processes that, after much toil and confusion, their labors have uncovered. Okun has much to say about the interaction of experiment and theory in these difficult circumstances.

In his preface Okun reveals that this work traces its origins to a summary talk prepared for—but not delivered at—the 1980 Rochester Conference in Madison, Wisconsin. Those who suffered the disappointment of that canceled appearance may now find recompense in this much-expanded version. It is a measure of both the depth of the author's insight and of the maturity of particle physics that with the simple addition of a brief summary of recent experiments, that six-year-old perspective remains fresh and valid.

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The Nature of Irreversibility

Henry B. Hollinger and Michael J. Zenzen
340 pp. Reidel, Boston, 1985. $39.50

Microphysics is deterministic and reversible; macrophysics is statistical and irreversible. The mathematical process of averaging cannot introduce a distinction between the two directions of time. Where, then, does irreversibility creep in?

Ludwig Boltzmann's theory of dilute gases gave the first answer to this question and furnished the starting point for all subsequent theories of irreversiblity. Boltzmann's famous equation expresses the rate of change of the density of molecules in position–velocity space in terms of the rates of two-body molecular collisions. Unlike the equations that govern individual two-body collisions—Newton's equations of motion—Boltzmann's equation is irreversible. Its irreversibility arises from one of the postulates needed to derive the equation—that of molecular chaos, according to which the *initial* velocities of colliding molecules are at all times statistically uncorrelated. Time-symmetric equations of motion combined with an asymmetric auxiliary condition yield an asymmetric statistical description.

But Boltzmann's postulate is too strong for an isolated gas. Even if the initial velocities of colliding molecules are uncorrelated at an initial moment when the gas is far from equilibrium, they will not remain uncorrelated. There are two ways to overcome this difficulty. If we wish to keep Boltzmann's equation we must assume that interactions between the gas and its environment destroy two-particle correlations before they have a chance to build up. Alternatively, if we wish to consider isolated systems, we must choose a weaker assumption than molecular chaos. For example, we may assume that two-particle correlations (or, in quantal systems, the off-diagonal elements of a density matrix) are absent at some initial moment. Most modern kinetic theories proceed from an assumption of this kind.

In *The Nature of Irreversibility* Henry Hollinger, a chemist, and Michael Zenzen, a philosopher, reexamine the question of "what ingredient [needs] to be added to particle mechanics, classical or quantum, to lead the mechanics through statistics to a prediction of fluid mechanics." They confine their attention to isolated systems and conclude that the necessary ingredient is "the assumption of recent equilibrium." If an isolated gas is "forcibly withdrawn" from equilibrium, it will relax to an "equilibrium plateau." Eventually (after a time comparable to the Poincaré recurrence time) it will undergo a "spontaneous withdrawal" from the new equilibrium—unless another "forced withdrawal" intervenes. In systems that exhibit irreversible behavior, Hollinger and Zenzen argue, the characteristic time interval between forced withdrawals is short compared with the characteristic interval between spontaneous withdrawals: "Irreversibility is a consequence of a simple relation between an intrinsic time t_i and an environmental time t_e." To support this conclusion, they show in some detail how kinetic and hydrodynamic equations can be deduced from the Liouville equation (for which they give an incorrect proof) under the assumption of "recent equilibrium."

Their derivations of kinetic and hydrodynamic equations implicitly assume that the nonequilibrium state is at most a few collision times old. This assumption is far stronger than those underlying modern kinetic theories of isolated gases (which the authors criticize for being excessively formal) and it is less realistic than the assumption that external perturbations keep two-particle correlations from building up. It appears that the authors have mistaken a sufficient condition for irreversibility—recent equilibrium—for a necessary one. I found this surprising in a book that claims to resolve "the paradox of irreversibility . . . in a simple, logically clear, and aesthetically pleasing manner."

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Introduction to Gauge Field Theories

Masud Chaichian and Nikolai F. Nelipa
332 pp. Springer-Verlag, New York, 1984. $46.70

There are now a half-dozen or so books available whose main purpose is to present and discuss the standard model of elementary-particle interactions. This is entirely appropriate as there is now a broad consensus that the standard model provides us with an essentially correct description of high-energy physics. The modifications that are seriously considered these days are confined to adding more particles (such as an extra family of quarks and leptons, or supersymmetric partners of known particles), while the basic, underlying ideas of gauge invariance, spontaneous symmetry breaking and renormalization seem secure. Nonetheless anyone setting out to write a book on the standard model is faced with the problem of deciding which aspects to discuss. After all, the standard model is able to account for (or at least does not blatantly contradict) the results of all high-energy experiments. Furthermore, the mathematical basis of the standard model, quantum field theory, is itself a vast subject with many subtleties.

In *Introduction to Gauge Field Theories*, Masud Chaichian and Nikolai F. Nelipa tackle this problem, with mixed results. This text, intended for advanced graduate students and workers in the field, presupposes some familiarity with quantum field theory and the basic properties of elementary particles. Even readers with adequate preparation, though, will find some vexing deficiencies. There is almost no meaningful comparison of theory and experiment and hence no real discussion of how the standard model came to be the standard model. For example, after presenting an alternative model in which quarks have integer charge, Chaichian and Nelipa say that "nowadays one considers mostly models with fractional charges," but they do not say why. In a number of places they make statements that could easily mislead the unwary reader. For example, in one paragraph of the introduction we are told that the strong nuclear interaction is short range (true), that short-range interactions are mediated by massive particles (true) and that gauge particles can be either massive or massless (true). However, the obvious inference—that the strong interaction is mediated by massive gauge particles—is not true. The theory of the strong interaction, quantum chromodynamics, is fully explained later, but a clearer presentation in the introduction would have been welcome. This may partly be the fault of the translation by Juri Estrin, which does not always fall easily on the ear. But the translation cannot be blamed for figure 10.2, which depicts beta functions that do not vanish at zero coupling (as they must), or the discussion of the origin of the up-quark mass in the SU(5) grand unified theory, which is simply wrong.

On the plus side, there are thorough and clear treatments of quantum mechanics for constrained systems (gauge fields are an example), of the renormalization group for a generic quantum field theory and of applications of quantum chromodynamics to strong-interaction phenomena at high energies. This last topic is the book's strongest point; here Chaichian and Nelipa do present and discuss experimental data as well as theoretical calculations.

If this were the only book of its type available, I would recommend it in spite of its flaws. However, it has stiff competition. I particularly like *Gauge Theory of Elementary Particle Physics* by Ta-Pei Cheng and Ling-Fong Li (Oxford U.P., New York, 1984; for a review see PHYSICS TODAY, December, page 78), which is better written and more complete. Anyone planning to read or own just one book on the standard model of elementary particles would do well to investigate the alternatives.

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Elements of Modern Optical Design

Donald C. O'Shea
402 pp. Wiley, New York, 1985. $39.95

The usual, somewhat limited concept of optical design deals with ray tracing through optical systems. Donald C. O'Shea definitely stresses ray tracing in this text, introducing it gradually—first for thin lenses, then for paraxial rays and finally as the exact ray tracing. He makes it amply clear, however, that one must consider other topics: modulation, scanning, spectrometers, detectors and the shape of the laser beam. Separate chapters are devoted to these topics, and anyone who knows some optics will have an easy time reading them. The book also