

Modern field theory explained for experimenters too

Gauge Theories in Particle Physics

I. J. R. Aitchison, A. G. J. Hey
341 pp. Hilger (US dist. Heyden,
Philadelphia), 1982. \$36.00

Reviewed by Peter Higgs

It is now over ten years since the non-Abelian gauge theories that dominate the contemporary theoretical scene in particle physics acquired credibility as a result of Gerard 't Hooft's completion of the proof of their renormalizability. Shortly afterwards came the experimental discovery of weak neutral currents, in accordance with the Glashow-Salam-Weinberg electroweak theory, and the theoretical discovery of asymptotic freedom in gauge theories, which indicated that a gauge theory of quark interactions (quantum chromodynamics) might support an understanding of strong-interaction physics. Yet only in the last few years have a number of new books aimed to introduce graduate students to these developments rather than to present them in the context of weak interactions or quarks and partons.

There are two approaches open to authors of books on gauge theories. If they want to reach practical calculations quickly, starting from the relativistic quantum mechanics of particles, they may follow the approach of Richard Feynman, as did J. D. Bjorken and Sidney Drell in their classic text *Relativistic Quantum Mechanics* (1964). If, on the other hand, they want their readers to understand fully the principles underlying gauge theories and the subtleties of higher-order calculations, they may prefer to take the longer route via quantum field theory, as Bjorken and Drell did in their second volume. The authors of the book under review choose the former approach; by so doing they make the basic parts of the theory accessible to experimentalists, who tend to be put off by the complexities of the field-theoretic approach.

Apart from an introductory chapter,

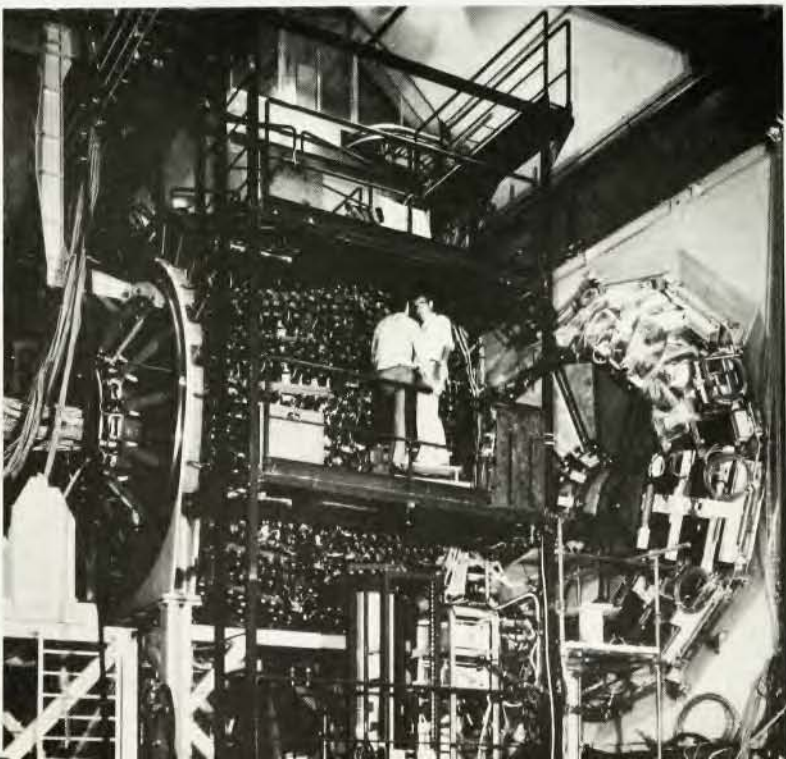
the book is divided into five parts. Part I presents the elements of the simplest gauge theory, quantum electrodynamics. Part II surveys the phenomenology of weak interactions. In Part III, the theoretical core of the book, "the gauge principle," is reached. After an account of the difficulties with unitarity bounds and non-renormalizability that occur in the Fermi and intermediate vector boson theories of weak interactions, the authors discuss the role of gauge invariance as a dynamical principle. (They are wrong in attributing to C. N. Yang and R. L. Mills the first derivation of a theory from a local symmetry requirement in 1954. Herman Weyl's unsuccessful unified theory of gravity and electromagnetism of 1918, in which the term "gauge invariance" first occurs, is the pioneering work.) A particularly welcome feature of Part III is a chapter, "Hidden Gauge

Invariance." It gives a careful account of how the theory of superconductivity describes the origin of the mechanism by which gauge particles become massive. Due recognition is given to the work of Philip W. Anderson, a contrast to the usual custom in the particle-physics literature.

Applications of the gauge principle to quantum chromodynamics and the standard electroweak theory follow in Part IV. There the reader is brought to readiness to perform tree-graph calculations in these theories. Finally in Part V, "Beyond the Trees," lurk the ghosts of L. D. Faddeev and V. N. Popov, waiting to patch up unitarity in the loop diagrams as they did when Feynman first conjured them up in 1962. At this point the limit of what can be understood without field theory is passed. The book ends with brief accounts of asymptotic freedom, grand

The UA2 detector at the CERN pp collider.

The discovery of vector boson events there brought electroweak gauge theory closer to confirmation last year.





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NEW ! STOCHASTIC QUANTUM MECHANICS AND QUANTUM SPACETIME

A consistent unification of relativity and quantum theory based on stochastic spaces

by Edward Prugovecki, University of Toronto

This monograph deals with the physical, mathematical and epistemological reasons behind the failure of past theoretical frameworks, including conventional relativistic quantum mechanics, to bring about a consistent unification of relativity with quantum theory. Its principle intent is to provide a systematic and self-contained introduction to an alternative unification based on stochastic phase spaces and stochastic geometries. This material is presented at a level accessible to graduate students in theoretical and mathematical physics, as well as to professional physicists and mathematicians.

The proposed framework for unification embraces classical as well as quantum theories by implementing an epistemic idea first put forth by M. Born, namely that all physical theories should be formulated in terms of stochastic rather than deterministic value for measurable quantities. The framework gives rise to a whole range of yet unresearched problems, whose solutions are bound to shed some light on the relationship between relativity and quantum theories at the most fundamental physical and mathematical levels.

1983 320 pp. Cloth
ISBN 90-277-1617-X \$48.50

NEW ! THE WAVE-PARTICLE DUALISM

A Tribute to Louis de Broglie on his 90th Birthday

Edited by I.S. Diner, D. Fargue, G. Lochak and F. Selleri, Foundation Louis de Broglie, Paris, France

Quantum Mechanics has reached maturity in its formalism and, although no experiment has yet challenged its predictions, the limits of its validity are still in question. In fact, this vision of the microphysical world remains the subject of endless debate, at the heart of which lies the 'foundational myth' of wave-particle dualism. Albert Einstein and Louis de Broglie considered this a deep physical reality rather than a phenomenological artifice. **The Wave-Particle Dualism** stems from the Proceedings of a Conference held in Perugia in April 1982 to honor Louis de Broglie on his 90th birthday. It gives a survey of essential experimental results in corpuscular and quantum optics and the most up-to-date theoretical aspects of microphysical phenomena: various interpretations of quantum mechanics, 'alternative theories' and hidden parameters theories, probabilistic and axiomatic questions and tentative crucial experiments.

1984 576 pp. Cloth
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NEW ! A DEVELOPMENT OF QUANTUM MECHANICS BASED ON SYMMETRY CONSIDERATIONS

by George H. Duffy, South Dakota State University

In this book, the treatment of the development of quantum mechanics is characterized by its use of simple symmetry considerations, and by its attention to detail otherwise often ignored. Emphasized from the beginning is how the particles making up matter act differently from common visible bodies. These differences enable symmetry to play a fundamental role in the construction of basic equations for particle motion.

Many review-discussion problems and solutions are presented, making this an ideal book for private study, or for use as an introductory textbook for physics majors and students of quantum mechanics. Its usefulness as a reference work is ensured by careful arrangement of subject matter and comprehensive indexing.

1983 352 pp. Cloth
ISBN 90-277-1587-4 \$60.00

GENERAL RELATIVITY AND MATTER A Spinor Field Theory from Fermi to Light-Years

by Mendel Sachs, Department of Physics and Astronomy, State University of New York at Buffalo

This monograph is unique in viewing general relativity as a fundamental theory of matter in all domains. After developing the mathematical background of Einstein's relativistic formalism and the spinor-quaternion calculus in a curved spacetime, Sachs relates the group structure of this theory and the geometry of curved spacetime to the existence of matter fields. The resulting generalization embraces both the inertial manifestations of matter (expressed as globally covariant field equations) and its force manifestations, in terms of a generalized spinor formalism which serves to unify them. Novel features of general relativity are shown to emerge, in elementary particle physics as well as astrophysics. The author's original approach also furnishes derivations not previously available, of several observed properties of inertial mass and gravitational force.

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unification and confinement.

Altogether, this is a very welcome addition to the *Graduate Student Series in Physics*, published by Hilger. It will surely achieve the authors' intention of providing a relatively painless approach to the understanding of gauge theories for many students, whether they be experimentalists or theorists!

Leptons and Quarks

L. B. Okun

361 pp. North-Holland, New York, 1982.
\$70.25

Weak-interaction physics has undergone a revolution: The theory is now unified with electromagnetism via the Weinberg-Salam model. The resulting electroweak theory has passed all experimental tests, including the crucial observation of weak neutral current effects in neutrino interactions, atomic parity violation, and electron-deuteron scattering. Of course, its crowning glory was the recent discovery of the $W^\pm$ and Z^0 intermediate vector bosons at CERN. Initial values for their masses and other properties, although still somewhat preliminary due to poor statistics, are in good agreement with theoretical expectations. Future precise measurements will test the electroweak model at the level of its quantum loop corrections.

In *Leptons and Quarks*, L. B. Okun, a recognized expert on weak interactions, has provided a nice primer for the new electroweak theory. This book grew out of lecture notes for graduate students in high-energy experimental physics. It emphasizes phenomenology and aims to develop basic calculational skills through concrete examples. Formal field theory techniques and subtleties such as quantization, path integrals, and renormalization are either omitted or only briefly mentioned. The author's goal (which is accomplished) is to provide an easily read, up-to-date overview of contemporary weak-interaction physics. The book consists of short sections devoted to numerous decay rates and scattering cross sections involving weak currents of leptons and quarks. Although details are scarce, the essentials are covered and well supplemented by an extensive set of references.

I liked Okun's choice of topics. Not only does he treat the traditional weak processes such as muon, beta, pion and kaon decays, but in addition, he discusses the more recent physics of tau lepton decays as well as b and t quark mixing effects and decays. He also presents in some detail other particularly relevant examples, such as neutrino scattering and electron-positron annihilation. These provide good exercises in relativistic kinematics for stu-

dents. Perhaps the best chapters are those devoted to K-mesons and CP violation. Okun's expertise and long involvement with that subject allow him to present an easy-to-follow discussion of what is often a confusing topic. It is up to date and complete.

Although this book was completed around 1980, well before the discovery of the $W^\pm$ and Z^0 , it is by no means obsolete. Okun discusses their anticipated production and basic properties. He clearly shows how they fit into the scheme of weak interactions. Students will better appreciate these recent discoveries after reading the introduction provided by this book. He also covers other contemporary topics, such as grand unification, proton decay and the Higgs scalar, albeit in an introductory manner.

A novel feature of this book is contained in its last 100 pages. There, besides including standard appendices, Okun categorizes research and review articles, monographs and conference proceedings according to topic. In some cases, their chronological ordering combined with his comments provide a nice historical perspective on the development of the field. In addition, he reproduces particle data tables there by handy reference.

For whom is this book suitable? Students familiar with advanced quantum mechanics should be able to follow and profit from the discussions in this book. An instructor teaching an introductory course on elementary-particle physics might use it as an outline for lectures. Supplemented by derivations, background and more details, it could make a very nice course text. Unfortunately, the cost is probably prohibitively high for students.

Overall this is a good introductory text. Translation from Russian does not impede the reading at all. Okun demonstrates not only his expertise in weak interactions, but also his rare ability to communicate that knowledge at a basic level.

WILLIAM J. MARCIANO
Brookhaven National Laboratory

Theory of Laser-Atom Interactions

M. H. Mittleman

Plenum, New York, 1982. \$35.00

How well are the compromises made? That is the question for the evaluation of a textbook. Is it authoritative and complete? That is the question for a research monograph. For books between textbooks and monographs there is no easy question, and no single answer is completely satisfactory. Nevertheless, when physicists become authors, they have a strong inclination to try the middle ground, to write books

accessible to students but at the same time containing all the most important results in their own fields.

This reviewer, as an author, is not an exception to this pattern, and the present book demonstrates that Marvin Mittleman is not either. Mittleman has aimed for a book that will explain, at the level of first-year graduate quantum mechanics, in one semester how atoms are modified by lasers.

It is an impossible task, of course, but an important one. Atomic physicists deserve to have what doesn't exist yet, an incisive analysis of the most important properties of atoms in laser fields. A book that provides it will be a feast for the reader. It will have to deal with fields largely kept, up to now, safely distinct: optical pumping, free-electron dressed states, photon statistics, multiphoton dynamics, ponderomotive effects, saturation spectroscopy, and atom-atom scattering, to name a few.

Mittleman's book does not attempt more than a few courses from such a feast. Probably it is all we should expect from any physicist with an active research program and classes to meet. The courses that he serves to the reader are determined by several limitations he has adopted. These define the book much more precisely than does the title, and can be described as follows:

Lasers modify atoms in many ways, some of them quite complex, and not all of them yet understood. Many different probes of laser-modified atoms have therefore been proposed and used in the last twenty years, each appropriate in its own domain: magnetic-optical double resonance, electron scattering, fluorescence, far-wing light scattering, multiphoton ionization, resonance Raman scattering, and many others. Mittleman achieves coherence in a short space by ignoring most of these, concentrating almost exclusively on probe interactions involving free charged particles. The major part of the book (Chapters 6-9) is devoted to this limited subject in several important manifestations: potential scattering in laser fields, ionization, electron-atom scattering and atom-atom scattering. These are also areas where Mittleman has concentrated his own research.

The focus provided by this concentration is the book's principal strength. Furthermore, the limitation to free charges as probes justifies another limitation, the neglect of dynamics in favor of scattering. That is, the interaction of an atom with a charged particle can be so brief that time-dependent electron rearrangement within the atom by the laser (sensitively probed by other methods) is safely neglected. Mittleman is able to treat the laser interaction as a static "dress-