Quantum Field Theory

Gauge Fields. Introduction to Quantum Theory. L. D. FADDEEV and A. A. SLAVNOV. Translated from the Russian edition (Moscow, 1978) by D. B. Pontecorvo. Benjamin/Cummings Advanced Book Program, Reading, Mass., 1980. xvi, 232 pp. $28.50.

The quantum field theory of elementary particles has been revolutionized in recent years by the introduction of "gauge fields." The electromagnetic field is an example of a gauge field. It is now generally believed that the weak interaction and the strong interaction are also mediated by particles described by gauge field theories. The success of these theories is even renewing the hope that we may find one gauge theory that unifies all the forces.

Most books on quantum field theory approach the problem of quantization by using the traditional operator formalism in which commutators are put in correspondence with Poisson brackets. The quantization of a gauge theory is particularly unpleasant by this method because one must first separate out the gauge degrees of freedom and there is no "natural" way of doing this. The authors of the book under review use the path integral formalism of Feynman and incorporate ideas of Schwinger.

Path integrals are as ill defined as anything else in quantum field theory, and the authors are aware of this. Their viewpoint is that the only part of a renormalizable quantum field theory that is not ambiguous is perturbation theory and that the path integral should be viewed as a "generating function" for the perturbation theory. As a generating function, the path integral has immense advantages over other formulations. The treatment of the hitherto deadly combination of relativistic invariance and the presence of nonphysical gauge degrees of freedom is attractive and natural. The authors develop the path integral formalism for the S matrix from scratch for a system with one degree of freedom and then show how to apply it to a system with constraints such as a gauge field. They also discuss how fermions, matter fields in general, and broken symmetries are incorporated.

The perturbation theory that they so derive still has to be renormalized, of course. Renormalization can be a bit of a morass, and the authors are obviously anxious not to sink into it, so they discuss a few low-order diagrams in detail and, after giving the motivation for the general strategy and the results of renormalization theory, refer the reader elsewhere. I think they struck a good compromise here.

The standard criteria of renormalization theory are sufficient to show that gauge theories are renormalizable if the "gauge" is specially chosen. Without further argument there is no guarantee that different gauges will remain physically equivalent after renormalization. This is important because one needs one gauge for renormalization and another to verify that transition probabilities are always positive (that is, that the inner product in the associated Hilbert space is positive definite). Consideration of this point leads into a discussion of "generalized" Ward identities, which I found a little terse. The authors also give examples of theories in which renormalization and gauge invariance are not compatible (Adler, Bell, and Jackiw anomalies).

The book concludes with a brief chapter on physical applications, notably the Weinberg-Salam model of weak interactions and asymptotic freedom. The applications are chosen to illustrate features that are now thought to be definitive without getting embroiled in all the latest "fine tuning."

This will be a most valuable book for people who already know some quantum field theory and wish to be introduced to the perturbation theory of gauge theories.

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A Public Health Issue

A Safe Cigarette? Proceedings of a conference, Cold Spring Harbor, N.Y., Oct. 1979. GIO B. GORI and FRED G. BOCK, Eds. Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y., 1980. xii, 364 pp., illus. $45. Banbury Report 3.

This volume contains a wealth of information on activities, accomplishments, and problems related to the development, acceptability, use, and evaluation of less hazardous cigarettes. The facts of "tobacco science," as one contributor terms it, are presented in considerable but variable detail. The book is divided into sections, on epidemiological trends (five papers), toxicological dimensions (ten papers), cigarette engineering (eight papers), behavioral and economic issues (seven papers), and achievements and future directions in risk reduction (general discussion). The contributors are physicians, statisticians, chemists, toxicologists, behavioral scientists, and others from government agencies, universities, private research institutions, voluntary health agencies, and the tobacco industry here and in Europe.

The health consequences of smoking cigarettes of various types were assessed in epidemiological and autopsy studies reported in the book, which indicate that death rates for lung cancer and coronary heart disease were lower and abnormalities in bronchial epithelial cells were less frequent in smokers of cigarettes with less tar and nicotine. Smokers who used filter cigarettes had lower rates of certain cancers and of coronary heart disease than smokers who did not. In toxicological studies, certain constituents of smoke, such as tar, known carcinogens, oxides of nitrogen, nicotine, and carbon monoxide, have been identified as hazardous and linked with cancers of lung and skin, abnormalities of the cardiovascular system, impaired fetal development, and abnormalities of structure or function in various animal tissues or cells. But, despite much research, the characterization of the thousands of constituents of cigarette smoke is incomplete, and the mechanisms by which the wide range of harmful effects are produced are inadequately understood. Nevertheless, studies of human populations and animal models provide strong support for the belief that the hazards of cigarettes decrease as the dose of smoke declines.

Substantial changes in smoking habits and in the composition of cigarettes and the quantity and character of the smoke they produce are described. Cigarettes yield less tar and nicotine now than they used to, and there has been a phenomenal growth in the use of filters. The energy and ingenuity of the tobacco industry and others concerned with the production of cigarettes are apparent in the section of the book on cigarette engineering. Cigarettes have been or could be modified through the selection of different tobacco plants, the use of different parts of the plant or of the whole plant, and the use of different cultivation and curing processes as well as through changes in manufacturing processes. Opportunities for modifying the chemical composition of cigarette smoke include the use of reconstituted tobacco sheet, the selective removal of certain substances, and the use of natural or artificial additives or substitutes. Natural or synthetic flavors are used to make the newer cigarettes more palatable. Physical methods for reducing delivery of cigarette smoke, including filtration and dilution, are described.