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Preface

It has been known for more than fifty years that Quantum Field Theory is necessary for describing precision experiments involving electromagnetic interactions. Within the last few decades of the twentieth century it has also become clear that the weak and the strong interactions are well described by interacting quantum fields. Although it is quite possible that at even smaller length scales some other kind of theory may be operative, it is clear today that quantum fields provides the appropriate framework to describe a wide class of phenomena in the energy range covered by all experiments to date.

In this book, we wanted to introduce the subject as a beautiful but essentially simple piece of machinery with a wide range of applications. This book is meant as a textbook for advanced undergraduate or beginning post-graduate students. For this reason, we employ canonical quantization throughout the book. The name of the book is an echo of various children's texts that were popular a long time ago, not a claim to primacy or originality.

Our approach differs from many otherwise excellent textbooks at the introductory level which set up the description of electrons and photons as their goal. For example, decays are rarely discussed, since the electron and the photon are both stable particles. However, decay processes are in some sense simpler than scattering processes, since the former has only one particle in the initial state whereas the latter has two.

We felt that the basic machinery of Feynman diagrams could be introduced through decay processes even before talking about the quantization of spin-1 fields. With that in mind, we start with some introductory material in Chapters 1 and 2 and discuss the quantization of scalar fields in Chapter 3 and of spin-$\frac{1}{2}$ fields in Chapter 4. Unlike many other texts at this level, we use a fermion normalization that should be applicable to massless as well as massive fermions. After that we discuss the generalities of the S-matrix theory in Chapter 5, and the methods of calculating Feynman diagrams, decay rates, scattering cross sections etc. with spin-0 and spin-$\frac{1}{2}$ fields, in Chapters 6 and 7.

The quantization of the spin-1 fields, with special reference to the photon, is taken up next in Chapter 8. After this, we have a detailed introduction to quantum electrodynamics in Chapter 9, where we introduce the crucial concept of gauge invariance and give detailed derivations of important scattering processes at their lowest orders in perturbation theory.

Discrete symmetries can serve as a good guide in calculating higher order corrections. With this in mind, we discuss parity, time reversal, charge conjugation, and their combinations, in Chapter 10. Unlike most other textbooks on the subject which describe the $\mathcal{P}$, $\mathcal{T}$, $\mathcal{C}$ transformations only in the Pauli-Dirac representation of the Dirac matrices, we present them in a completely representation-independent way. Since other representations such as the Majorana or the chiral representations are very useful in some contexts, we hope that the general formulation will be of use to students and researchers.

We calculate loop diagrams in Chapter 11, showing how to use symmetries of a problem to parametrize quantum corrections. In this chapter, we restrict ourselves to finite contributions only. Some basic concepts of renormalization are then described, with detailed calculations, in Chapter 12. Only the electromagnetic gauge symmetry is used in these two chapters for illustrative purpose. But this leads to a more general discussion of symmetries, which is done in Chapter 13. This chapter also discusses the general ideas of symmetry breaking, and the related physics of Nambu-Goldstone theorem as well as its evasion through the Higgs mechanism. This is followed by an introduction to the Yang-Mills (or non-Abelian) gauge theories in Chapter 14. Finally, a basic introduction to standard electroweak theory and electroweak processes is given in Chapter 15. In keeping with our overall viewpoint, we discuss decays as well as scattering processes in this chapter.

We have tried to keep the book at the elementary level. In other words, this is a book for someone with no prior knowledge of the subject, and only a reasonable familiarity with special relativity and quantum mechanics. To set the stage as well as to help the reader, we visit briefly the relevant parts of classical field theory in Chapter 2. A short but comprehensive introduction to group theory also appears in Chapter 13, since we did not want to assume any background in group theory for the reader.

The most important tools to help the reader are the exercise problems in the book. These problems are not collected at the ends of chapters. Instead, any problem appears in the place of the text where we felt it would be most beneficial for the reader to have it worked out. Working it out at that stage should also prepare the reader for the ensuing parts of the chapter. Even if for some reason the reader does not want to work out a problem at that stage, we suggest strongly to at least read carefully the statement of the problem before proceeding further. Some of the problems come with notes or hints, some come with a relation that might be useful later. A few of the problems are marked with a $\star$ sign, implying that they might be a little hard at that stage of the book, and the reader can leave it at that point to visit it later. A few have actually been worked out later in the book, but we have not marked them.

The book was submitted in a camera-ready form to the publishers. This means that we are responsible for all the mistakes in the book, including typographical ones. We have spared no effort to avoid errors, but if any has crept in, we would like to hear about it from the reader. We have set up a web site at

`http://tnp.saha.ernet.in/~pbpal/qftbk.html`

containing errata for the book, and a way of contacting us.

The book grew out of courses that both of us have taught at several universities and research institutes in India and abroad. We have benefited from the enquiries and criticisms of our students and colleagues. Indrajit Mitra went through the entire manuscript carefully and offered numerous suggestions. Many other friends and colleagues also read parts of the manuscript and made useful comments, in particular Kaushik Bhattacharya, Ed Copeland, A. Harindranath, H. S. Mani, José Nieves, Saurabh Rindani. Those who have taught and influenced us through their lectures, books and papers are too numerous to name separately. We thank them all.

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