A Modern Introduction to Quantum Field Theory

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Book reviews

A Modern Introduction to Quantum Field Theory
M Maggiore
2004 Oxford: Oxford University Press
308pp £47.95 (hardback) 0-19-852073-5

This book gives a clear exposition of quantum field theory at the graduate level and the contents could be covered in a two semester course or, with some effort, in a one semester course.

The book is well organized, and subtle issues are clearly explained. The margin notes are very useful, and the problems given at the end of each chapter are relevant and help the student gain an insight into the subject. The solutions to these problems are given in chapter 12. Care is taken to keep the numerical factors and notation very clear.

Chapter 1 gives a clear overview and typical scales in high energy physics. Chapter 2 presents an excellent account of the Lorentz group and its representation. The decomposition of Lorentz tensors under $SO(3)$ and the subsequent spinorial representations are introduced with clarity. After giving the field representation for scalar, Weyl, Dirac, Majorana and vector fields, the Poincaré group is introduced. Representations of 1-particle states using m^2 and the Pauli–Lubanski vector, although standard, are treated lucidly.

Classical field theory is introduced in chapter 3 and a careful treatment of the Noether theorem and the energy momentum tensor are given. After covering real and complex scalar fields, the author impressively introduces the Dirac spinor via the Weyl spinor; Abelian gauge theory is also introduced. Chapter 4 contains the essentials of free field quantization of real and complex scalar fields, Dirac fields and massless Weyl fields. After a brief discussion of the CPT theorem, the quantization of electromagnetic field is carried out both in radiation gauge *and* Lorentz gauge. The presentation of the Gupta–Bleuler method is particularly impressive; the margin notes on pages 85, 100 and 101 invaluable.

Chapter 5 considers the essentials of perturbation theory. The derivation of the LSZ reduction formula for scalar field theory is clearly expressed. Feynman rules are obtained for the $\lambda\phi^4$ theory in detail and those of QED briefly. The basic idea of renormalization is explained using the $\lambda\phi^4$ theory as an example. There is a very lucid discussion on the 'running coupling' constant in section 5.9. Chapter 6 explains the use of the matrix elements, formally given in the previous chapter, to compute decay rates and cross sections. The exposition is such that the reader will have no difficulty in following the steps. However, bearing in mind the continuity of the other chapters, this material could have been consigned to an appendix.

In the short chapter 7, the QED Lagrangian is shown to respect P, C and T invariance. One-loop divergences are described. Dimensional and Pauli–Villars regularization are introduced and explained, although there is no account of their use in evaluating a typical one-loop divergent integral.

Chapter 8 describes the low energy limit of the Weinberg–Salam theory. Examples for $\mu^- \rightarrow e^-\bar{\nu}_e\nu_\mu$, $\pi^+ \rightarrow \ell^+\nu_\ell$ and $K^0 \rightarrow \pi^-\ell^+\nu_\ell$ are *explicitly* solved, although the serious reader should work them out independently. On page 197 the 'V-A structure of the currents proposed by Feynman and Gell-Mann' is stated; the first such proposal was by E C G Sudarshan and R E Marshak.

In chapter 9 the path integral quantization method is developed. After deriving the transition amplitude as the sum over all paths, in quantum mechanics, a demonstration that the integration of *functions* in the path integral gives the expectation value of the time ordered product of the *corresponding operators* is given and applied to real scalar free field theory to get the Feynman propagator. Then the Euclidean formulation is introduced and its 'tailor made' role in critical phenomena is illustrated with the 2-d Ising model as an example, including the RG equation.

Chapter 10 introduces Yang–Mills theory. After writing down the typical gauge invariant Lagrangian and outlining the ingredients of QCD, the adjoint representation for fields is given. It could have been made complete by giving the Feynman rules for the cubic and quartic vertices for non-Abelian gauge fields, although the reader can obtain them from the last term in equation 10.27. In chapter 11, spontaneous symmetry breaking in quantum field theory is described. The difference in quantum mechanics and QFT with respect to the degenerate vacua is clearly brought out by considering the tunnelling amplitude between degenerate vacua. This is very good, as this aspect is mostly overlooked in many textbooks. The Goldstone theorem is then illustrated by an example. The Higgs mechanism is explained in Abelian and non-Abelian ($SU(2)$) gauge theories and the situation in $SU(2)\times U(1)$ gauge theory is discussed.

This book certainly covers most of the modern developments in quantum field theory. The reader will be able to follow the content and apply it to specific problems. The bibliography is certainly useful. It will be an asset to libraries in teaching and research institutions.

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Hamiltonian Chaos and Fractional Dynamics

G Zaslavsky
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This book provides an introduction and discussion of the main issues in the current understanding of classical Hamiltonian chaos, and of its fractional space-time structure. It also develops the most complex and open problems in this context, and provides a set of possible applications of these notions to some fundamental questions of dynamics: complexity and entropy of systems, foundation of classical statistical physics on the basis of chaos theory, and so on.

Starting with an introduction of the basic principles of the Hamiltonian theory of chaos, the book covers many topics that can be found elsewhere in the literature, but which are collected here for the readers' convenience. In the last three parts, the author develops topics which are not typically included in the standard textbooks; among them are:

- the failure of the traditional description of chaotic dynamics in terms of diffusion equations;
- the fractional kinematics, its foundation and renormalization group analysis;
- 'pseudo-chaos', i.e. kinetics of systems with weak mixing and zero Lyapunov exponents;
- directional complexity and entropy.

The purpose of this book is to provide reearchers and students in physics, mathematics and engeenering with an overview of many aspects of chaos and fractality in Hamiltonian dynamical systems. In my opinion it achieves this aim, at least provided researchers and students (mainly those involved in mathematical physics) can complement this reading with comprehensive material from more specialized sources which are provided as references and 'further reading'.

Each section contains introductory pedagogical material, often illustrated by figures coming from several numerical simulations which give the feeling of what's going on, and thus is very useful to the reader who is not very familiar with the topics presented. Some problems are included at the end of most sections to help the reader to go deeper into the subject.

My one regret is that the book does not mention the famous 'Shadowing Lemma' of Anosov and Bowen for hyperbolic systems.

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Path Integrals in Quantum Mechanics

J Zinn-Justin
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By treating path integrals the author, in this book, places at the disposal of the reader a modern tool for the comprehension of standard quantum mechanics. Thus the most important applications, such as the tunnel effect, the diffusion matrix, etc, are presented from an original point of view on the action S of classical mechanics while having it play a central role in quantum mechanics.

What also emerges is that the path integral describes these applications more richly than are described traditionally by differential equations, and consequently explains them more fully.

The book is certainly of high quality in all aspects: original in presentation, rigorous in the demonstrations, judicious in the choice of exercises and, finally, modern, for example in the treatment of the tunnel effect by the method of instantons. Moreover, the correspondence that exists between classical and quantum mechanics is well underlined. I thus highly recommend this book (the French version being already available) to those who wish to familiarize themselves with formulation by path integrals. They will find, in addition, interesting topics suitable for exploring further.

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