Preface

Although there are many textbooks that deal with the formal apparatus of quantum mechanics and its application to standard problems, before the first edition of this book (Prentice–Hall, 1990) none took into account the developments in the foundations of the subject which have taken place in the last few decades. There are specialized treatises on various aspects of the foundations of quantum mechanics, but they do not integrate those topics into the standard pedagogical material. I hope to remove that unfortunate dichotomy, which has divorced the practical aspects of the subject from the interpretation and broader implications of the theory. This book is intended primarily as a graduate level textbook, but it will also be of interest to physicists and philosophers who study the foundations of quantum mechanics. Parts of the book could be used by senior undergraduates.

The first edition introduced several major topics that had previously been found in few, if any, textbooks. They included:

- A review of *probability theory* and its relation to the quantum theory.
- Discussions about *state preparation* and *state determination.*
- The Aharonov–Bohm effect.
- Some firmly established results in the theory of *measurement*, which are useful in clarifying the interpretation of quantum mechanics.
- A more complete account of the *classical limit.*
- Introduction of *rigged Hilbert space* as a generalization of the more familiar Hilbert space. It allows vectors of infinite norm to be accommodated within the formalism, and eliminates the vagueness that often surrounds the question whether the operators that represent observables possess a complete set of eigenvectors.
- The *space–time symmetries* of displacement, rotation, and Galilei transformations are exploited to derive the fundamental operators for momentum, angular momentum, and the Hamiltonian.
- A charged particle in a magnetic field (Landau levels).

- Basic concepts of *quantum optics.*
- Discussion of modern experiments that test or illustrate the fundamental aspects of quantum mechanics, such as: the direct measurement of the momentum distribution in the hydrogen atom; experiments using the single crystal neutron interferometer; quantum beats; photon bunching and antibunching.
- Bell's theorem and its implications.

This edition contains a considerable amount of new material. Some of the newly added topics are:

- An introduction describing the range of phenomena that quantum theory seeks to explain.
- Feynman's *path integrals.*
- The adiabatic approximation and Berry's phase.
- Expanded treatment of state preparation and determination, including the *no-cloning theorem* and *entangled states.*
- A new treatment of the *energy–time* uncertainty relations.
- A discussion about the influence of a measurement apparatus on the environment, and vice versa.
- A section on the quantum mechanics of rigid bodies.
- A revised and expanded chapter on the *classical limit.*
- The *phase space* formulation of quantum mechanics.
- Expanded treatment of the many new interference experiments that are being performed.
- Optical homodyne tomography as a method of measuring the quantum state of a field mode.
- Bell's theorem without inequalities and probability.

The material in this book is suitable for a two-semester course. Chapter 1 consists of mathematical topics (vector spaces, operators, and probability), which may be skimmed by mathematically sophisticated readers. These topics have been placed at the beginning, rather than in an appendix, because one needs not only the results but also a coherent overview of their theory, since they form the mathematical language in which quantum theory is expressed. The amount of time that a student or a class spends on this chapter may vary widely, depending upon the degree of mathematical preparation. A mathematically sophisticated reader could proceed directly from the Introduction to Chapter 2, although such a strategy is not recommended.

The *space–time symmetries* of displacement, rotation, and Galilei transformations are exploited in Chapter 3 in order to derive the fundamental operators for momentum, angular momentum, and the Hamiltonian. This approach replaces the heuristic but inconclusive arguments based upon analogy and wave–particle duality, which so frustrate the serious student. It also introduces *symmetry* concepts and techniques at an early stage, so that they are immediately available for practical applications. This is done without requiring any prior knowledge of group theory. Indeed, a hypothetical reader who does not know the technical meaning of the word "group", and who interprets the references to "groups" of transformations and operators as meaning sets of related transformations and operators, will lose none of the essential meaning.

A purely pedagogical change in this edition is the dissolution of the old chapter on approximation methods. Instead, stationary state perturbation theory and the variational method are included in Chapter 10 ("Formation of Bound States"), while time-dependent perturbation theory and its applications are part of Chapter 12 ("Time-Dependent Phenomena"). I have found this to be a more natural order in my teaching. Finally, this new edition contains some additional problems, and an updated bibliography.

Solutions to some problems are given in Appendix D. The solved problems are those that are particularly novel, and those for which the answer or the method of solution is important for its own sake (rather than merely being an exercise).

At various places throughout the book I have segregated in double brackets, [[$\cdots$]], comments of a historical comparative, or critical nature. Those remarks would not be needed by a hypothetical reader with no previous exposure to quantum mechanics. They are used to relate my approach, by way of comparison or contrast, to that of earlier writers, and sometimes to show, by means of criticism, the reason for my departure from the older approaches.

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