Preface

This book is meant to be a text for a first course in quantum physics. It is assumed that the student has had courses in Modern Physics and in mathematics through differential equations. The book is otherwise self-contained and does not rely on outside resources such as the internet to supplement the material. SI units are used throughout except for those topics for which atomic units are especially convenient.

It is our belief that for a physics major a quantum physics textbook should be more than a one- or two-semester acquaintance. Consequently, this book contains material that, while germane to the subject, the instructor might choose to omit because of time limitations. There are topics and examples included that are not normally covered in introductory textbooks. These topics are not necessarily too advanced, they are simply not usually covered. We have not, however, presumed to tell the instructor which topics must be included and which may be omitted. It is our intention that omitted subjects are available for future reference in a book that is already familiar to its owner. In short, it is our hope that the student will use the book as a reference after having completed the course.

We have included at the end of most chapters a "Retrospective" of the chapter. This is not meant to be merely a summary, but, rather, an overview of the importance of the material and its place in the context of previous and forthcoming chapters. For example, the Retrospective in Chapter 3 we feel is particularly important because, in our experience, students spend so much time learning about eigenstates that they get the impression that physical systems "live" in eigenstates.

We believe that students should, after a very brief review of salient experiments and concepts that led to contemporary quantum physics (Chapter 1), begin solving problems. That is, the formal aspects of quantum physics, operator formalism, should be introduced only after the student has seen quantum mechanics in action. This is certainly not a new approach, but we prefer it to the alternative of the formal mathematical introduction followed by problem solving. More importantly, we believe that the students benefit from this approach. To this end we begin with a derivation (read: rationalization) of the Schrödinger equation in Chapter 2. This chapter continues with a discussion of the nature of the solutions of the Schrödinger equation, particularly the wave function. We discuss at length both the utility of the wave function and its characteristics. It is our observation that the art of sketching wave functions has been neglected. We are led to this conclusion from discussions with graduate students who have had the undergraduate course, but are unable to sketch wave functions for an arbitrarily drawn potential energy function. We think that such a skill is crucial for understanding quantum mechanics at the introductory level and, thus, we spend a good deal of Chapter 2 discussing qualitative aspects of the wave function.

In Chapter 3 we solve the Schrödinger equation for two of the most important potential energy functions, the infinite square well and the harmonic oscillator. A point of contrast between the these potentials is penetration of oscillator wave functions into the classically forbidden region. We discuss this penetration at length because, in our experience, students have a great deal of difficulty with this concept. We then elaborate upon this concept by presenting the details of a problem not often seen in elementary texts, an infinite square well with a barrier in the middle. This affords the opportunity to see that, for energies less than the barrier height, the particle can be found on either side of the classically impenetrable barrier, thus making the particle's presence inside the barrier undeniable. This problem also sets the stage for solution of the more conventional barrier penetration problems in Chapter 5.

In Chapter 4 we discuss time-dependent states. We choose to do this at this point to contrast these states with those studied in the previous chapter. While we discuss the free particle wave packet (as does virtually every other text), we also present wave packets under the influence of a constant force and of a harmonic force. This discussion will, we believe, relate nicely to a later presentation of harmonic oscillator coherent states (Chapter 7).

Chapter 5 is an extension of Chapter 3 in that we solve the time-independent Schrödinger equation for several different one-dimensional potential energies. Included is one of the most successful analytic potential energy functions for characterizing diatomic molecular vibrations, the Morse potential. The chapter concludes with the WKB method for approximating solutions.

Chapter 6 presents the formalism of quantum physics, the mechanics of quantum mechanics, including a set of postulates. For completeness we also discuss the Schrödinger and Heisenberg pictures. Chapter 7 is devoted to the operator solution of the Schrödinger equation for the harmonic oscillator with emphasis on the properties of the ladder operators. Harmonic oscillator coherent states are also discussed. Chapter 8 introduces three-dimensional problems and is devoted to angular momentum. It is emphasized in this chapter that the concept of angular momentum in quantum mechanics transcends three-dimensional rotations (orbital angular momentum).

Chapters 9 and 10 are devoted to solving the radial Schrödinger equation for several different central potentials. In addition to the common central potentials, Chapter 9 includes a thorough discussion of the isotropic harmonic oscillator using the shell model of the nucleus as an example. The isotropic oscillator also permits introduction the concept of accidental degeneracy. Because they are constituents of oscillator eigenfunctions, an attempt is made to decrypt the different conventions that are used for Laguerre polynomials and associated Laguerre polynomials. In our experience, this is a source of confusion to many students. Also contained in this chapter is an elaboration on the Morse potential in which three-dimensional molecular motion is considered through rotation–vibration coupling. The discussion of the hydrogen atom, the sole content of Chapter 10, is standard, but, as for the isotropic oscillator, accidental degeneracy is stressed. Chapter 11 is included to demonstrate to the student that there are angular momenta in quantum mechanics other than orbital and spin angular momenta. It includes the introduction of the Lenz vector, its consequences and ramifications. This subject is not usually covered at the introductory level, but it is certainly not beyond the beginning student.

The material in the remaining four chapters depends heavily upon approximation methods. Chapter 12 presents time-independent approximation methods, while Chapter 13 illustrates the use of these methods to solve problems of physical interest. One problem that is included in Chapter 13, albeit superficially, is the effect of fine structure on the shell model of the nucleus. Chapter 14 treats the Stark and Zeeman effects. Particular attention is paid to the consequences of breaking the spherical symmetry of central potentials by application of an external field. Chapter 15 presents time-dependent approximation methods, followed by a discussion of atomic radiation including the Einstein coefficients.

There are more than two hundred problems. A detailed solutions manual is available. There are a number of appendixes to the book, including the answers to all problems for which one is required. Among the other appendixes is one listing the Greek alphabet with notations on common usage of these symbols in the book. There is also a short table of acronyms used in the book. The remaining appendixes contain material that is intended to be quick reference material and helpful with the core material in the book. A list of (the inevitable) corrections can be found at: http://users.stlcc.edu/cburkhardt/ and http://www.umsl.edu/∼jjl/homepage/.

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Charles E. Burkhardt
Jacob J. Leventhal

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