Preface

This text was prepared and used in a two-quarter course for graduate electrical-engineering and materials-science students at Stanford University. The aim of the course was to teach those parts of quantum mechanics which an engineer might need or find useful in his profession. To my surprise this made the course almost orthogonal to traditional physics quantum courses, which provide those parts which most physicists feel every student should go through. The analytical solution of the harmonic oscillator states is rarely useful after the course is over. I believe that it is also rare that a solution of Schroedinger's equation is what is needed in engineering activities. For most questions concerning electronic structure of molecules or solids a tight-binding formulation is much more to the point, along with a knowledge of how to obtain the parameters which are needed, and how to calculate properties in terms of them. We have not seen these in other quantum texts. It is also important to have a feeling for when one can use a one-electron approximation and how to include many-particle effects when they are needed. One needs familiarity with perturbation theory and with the variational method, and confidence in the use of Fermi's Golden Rule. One needs the elements of quantum statistical mechanics and I believe also the many other topics one may see from scanning the Table of Contents, including even the elements of the shell model of the nucleus. It is not easy for a student to absorb such a variety of material in a short period, but the more modern approach of learning only that piece of a subject which one needs at the moment is not a viable approach for the fundamental laws which govern physics. Nearly fifty exercises, listed by chapter, are directed at using quantum mechanics for every-day problems, rather than to illustrate features of quantum theory. Solutions are available as a teachers' guide from the publisher. I have found it rather easy to generate problems when the material under discussion really has such wide use.

Graduate students in mechanical engineering, chemistry and chemical engineering, in addition to the electrical engineers and materials scientists, took this course. Most of these had taken no physics nor mathematics courses beyond their sophomore year as undergraduates. For that reason it was essential to include Lagrangian and Hamiltonian mechanics, Chapter 3, and such mathematical techniques as Lagrange multipliers, which physics majors learn only in their third or fourth years. I assumed that a third- or fourth-year undergraduate engineer would also be qualified to take the course, since their physics and mathematics background was the same, but none survived to the end. It appears to me that the graduate engineers have grown in sophistication, partly through other technical courses, to the point that they can deal effectively with such an abstract subject. They of course do it with varying success, but I believe it is so very essential for modern engineers to have a systematic presentation of quantum theory that it was an important experience for all of them. One wonders in particular how a modern materials scientist can obtain a Ph. D. without ever studying the fundamental rules which govern the behavior of materials. Similarly if any engineer needs to work with very small systems, as is increasingly common, he certainly should be able to recognize and deal with quantum effects. Having a "Schroedinger-solving code" on his computer is beside the point.

Although the text is designed for engineers, and engineering backgrounds, it has seemed to me that it might also be useful for physics graduate students who have completed a traditional, more sophisticated, course in quantum mechanics. If that course was light on the approximations which have proven successful for applications, or in dealing with systems which involve many electrons, this text might provide what is needed for that physics student to use the knowledge of quantum theory he has obtained.

We generally use equations which can be evaluated in MKS units, but in the end the energies in atomic systems will be of the order of electron-volts and atomic dimensions are of order Angstroms. Thus it is easiest in all regards to use the composite constants $\hbar^2/m = 7.62$ eV-Å^2, with m the electron mass, and $e^2 = 14.4$ eV-Å, with e the electronic charge, so that results are obtained immediately in convenient terms. This is in keeping with almost all treatments of quantum mechanics so that results here can be matched with those in other texts. Then the interaction energy between two electrons a distance r apart is written e^2/r. The main place where the customary units become problematical to one educated with MKS comes with the use of magnetic fields, given here in gauss. Then the parameters needed for evaluation are given explicitly at the beginning of Chapter 22.

There is a central, and hopefully appealing, feature to the text which is not essential to its real goal. That is the assertion that quantum theory follows from a single absolute truth, the wave-particle duality, stated on the first page. The full generality of the statement is only developed as we proceed, and Planck's constant which makes the connection between the two descriptions is obtained from experiment, but no further postulates are required. We do not deduce all of the consequences with elegance and rigor, but believe the basic derivations are all essentially correct. Then if a student is puzzled by some question, such as Schroedinger's cat, he may recognize that if he cannot understand something which follows from the wave-particle duality, it is that duality which he does not understand. He should perhaps address his concern at the source of problem and may not be likely to resolve it by thinking about some remote consequence. Our focus is not on the deep philosophical questions which quantum theory inevitably raises, but it may provide a basis for dealing with them which is appealing to the mind of an engineer.

This view of a single postulate is not apparent in more historical developments where the Pauli Principle, or the Uncertainly Principle, can appear to be independent postulates. This is partly because they initially were, and partly because the teaching of quantum mechanics may be mixed with teaching about the unfinished theory of fundamental particles, which evolved simultaneously. In our view quantum mechanics does not tell us what nature will provide, but does tell us the behavior of anything we can define and specify, either as a particle or as a wave. Similarly the questions of the "true" meaning of measurement and the collapse of wavefunctions do not arise with the pragmatic approach of asking only questions which can be tested experimentally. We see how to ask such questions, and how to answer them. Quantum mechanics cannot do more, nor can any other theory. This reliance on a single postulate can be a comfort to a student who is taken rapidly through an extraordinary range of systems and phenomena in a brief period. Hopefully the net effect is to allow him to recognize when he needs quantum theory, and to know how to proceed when he does.

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