Preface

Quantum mechanics pervades many branches of science, from physics, material science, informatics, to chemistry and molecular biology. Many products of everyday life derive from discoveries based on quantum physics, like silicon chips, magnetic storage devices, lasers, medical imaging devices, as well as chemicals and biochemicals. Therefore, scientists and engineers in many fields need a good understanding of quantum theory, but often they are overwhelmed by the sheer volume of most standard textbooks on quantum physics.

Our approach is to first limit discussion to the smallest systems in nature that still display the basic features of quantum theory. Hence this tutorial at first deals with systems in which only two quantum states are involved, subject to external perturbations. Such effective spin one-half systems are a valuable training ground to elucidate the subtleties of quantum theory and, indeed, the essence of quantum mechanics lies in the two-level system. We present basic quantum calculations step by step in a simple notation and in sufficient detail because the practitioner usually has no time to lose when proceeding from one equation to the next.

As a starting point we assume the reader to have taken introductory courses in quantum mechanics and linear algebra, and to be familiar with the Schrödinger equation and the essentials of angular momentum, which we recapitulate in Part I of the book. Part II covers essential topics of quantum physics based on the two-state approach, including subjects of high contemporary interest as quantum entanglement, quantum chaos, or geometric phases. In Part III, the results then are applied to various topics from atomic, condensed matter, and nuclear physics, and from quantum informatics.

We then proceed to the more general concepts of quantum theory. To this end, Part IV of this treatise restarts from first principles to develop the theory of angular momentum, spherical tensors, and irreducible representations. We derive a generalized spin precession equation that covers the higher multipole interactions, and apply the results to various topics in atomic and condensed matter physics. Chapters on multiple quantum transitions, dressed atom effects, spin relaxation and decoherence conclude the tutorial.

The text is based on various lectures given by the authors on the two-state system, irreducible tensors, and quantum chaos, and is complemented with an illustrative set of basic experiments, many of them done in the authors' respective laboratories. In short, the aim of this tutorial is to provide the bachelor student as well as the practitioner with a compact text that lets them understand a wealth of quantum physics.

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