Preface to the Third Edition

The preparation of another edition of a text on quantum mechanics is always a challenge. On the one hand, one may decide to cover some previously omitted topics, after gauging again their relevance. On the other hand, the fast evolution of the subject implies the need to incorporate not only new experimental facts and theoretical developments but also new concepts in the description of nature. Therefore, self-imposed constraints about the overall length of the book become strained. This is a good motivation for a revision. As a consequence, few items have been omitted and many more included, even some which are usually not discussed in introductory texts (like the breakdown of symmetries).

The book consists of two main parts. The first one displays the following organization:

- As in the previous editions, the basic principles of quantum mechanics are introduced within the framework of Hilbert spaces. Their empirical consequences (both thought and real experiments) and theoretical implications (uncertainty relations, no-cloning theorem) are discussed.
- The Heisenberg matrix realization of the basic principles allows us to solve the two-state system, the harmonic oscillator and a combination of the two, the Jaynes–Cummings model. The Schrödinger realization covers conventional subjects, including both bound and scattering examples. The contrast between these two realizations underscores the appearance of the most important quantum observable, the spin.
- The description of many-body systems requires the distinction between fermions and bosons and the indistinguishability among each of the two types of particles. As a consequence of these two features, there appears another formulation of quantum mechanics, the so-called second quantization.

  Most of the many-body examples that are presented – in fact, most of the many-body systems existing in nature – are treated within the framework of independent degrees of freedom. This is true both for fermion cases (atoms, nuclei, molecules, metals, band structures in crystals, etc.) and for boson systems

(Bose–Einstein condensates). One explicit exception is outlined (fractional Hall effect).

- Perturbation theory makes it possible to improve over-simplified approximations. Hartree–Fock procedures allow us to optimize these zero-order descriptions. The Born–Oppenheimer approximation is an essential tool in the treatment of molecules.
- *The time principle*. Time evolutions are calculated both exactly (spin systems) and perturbatively. The main motivation for the creation of quantum mechanics was to explain the stability of electron orbits in atomic hydrogen. Therefore, a brief introduction to Quantum Electrodynamics is presented so that this formalism can then be used to verify the extent to which this explanation has been accomplished by the formalism.
- Symmetry properties under transformations (translations, rotations, parity, exchange, etc.) are essential tools to obtain solutions to problems displaying such symmetries. However, the descriptions of many relevant systems involve the breaking of some symmetries, as exemplified by the BCS theory of superconductivity. The restoration of such symmetries is made through the introduction of collective variables.
- Our everyday life has been altered in an essential way through technologies based on quantum properties, the most conspicuous cases being the transistor and the laser. Quantum dots, scanning tunneling microscope, magnetic resonance imaging and Josephson junctions are also described in the corresponding chapters.
- Eigenstates of the position operators are normalized through the introduction of the Dirac delta function. They lead to the notion of propagators and to the path-integral formulation of quantum mechanics.

The second part of the text is based on the concept of entanglement, which is the superposition principle applied to two or more systems. The following items are included:

- Even more counterintuitive consequences of quantum mechanics appear in experiments involving the entanglement of two particles. Technological improvements have allowed the experimental verifications of such consequences.
- The EPR paper (1935) pointed at inconsistencies between experiments involving two entangled particles separated by superluminal distances, the locality principle and the predictions of quantum mechanics. These inconsistencies lead to the introduction of additional hidden mechanisms. In 1964, J. Bell proved that any local mechanism implied correlations that were violated by quantum mechanics. Experiments verified the quantum predictions. Nature is non-local.
- Quantum information theory concerns the possible use of quantum superpositions inherent to quantum bits (qubits), which carry much more information than classical bits. This program has succeeded in problems concerning cryptography and teleportation. However, it is presently stalling on problems of quantum computation, due to the inherent fragility of superposed states, which are destroyed through interactions with the environment (decoherence).

- Decoherence also allows us to explain the coexistence of microsystems described by quantum mechanics and macrosystems obeying Newton's laws. In fact, macrosystems emerge from the quantum substrate as a consequence of interactions with the environment. A new interpretation of quantum measurements appears within a consistent scheme.

Finally, a brief history of quantum mechanics is presented. Quantum mechanics emerges as an animated subject under permanent, albeit discontinuous, evolution.

Buenos Aires *Daniel R. Bes*

Springer

http://www.springer.com/978-3-642-20555-2

Quantum Mechanics
A Modern and Concise Introductory Course
Bes, D.
2012, XXII, 298 p., Hardcover
ISBN: 978-3-642-20555-2