Elegant spin on journey to the very heart of the matter

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Title: Quantum Mechanics: Symbolism of Atomic Measurements
Author: Julian Schwinger
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Who needs another book on quantum mechanics? There are dozens of excellent textbooks on the market. But this one really *is* different.

Julian Schwinger's famous lectures on quantum mechanics evolved over many years, first at Harvard University and then the University of California at Los Angeles. He always planned to write them up as a book, but hesitated because he "had not yet found the perfect way to do quantum mechanics". He did publish the notes of lectures he gave at a summer school in Les Houches in 1955, and the book was reissued in revised form in 1991.

The intention was that these notes would form the basis of a definitive textbook, incorporating many more applications, but the writing was cut short by Schwinger's untimely death in 1994. His erstwhile associate, Berthold-Georg Englert, has done a great service to the physics community in producing what is now the closest approximation we can have to the book he would have written, using mainly notes of lectures at UCLA.

Though some editing has been needed, Englert has clearly stuck closely to the original: Schwinger's unique style shines through. I heard him lecture only once or twice, but it was an unforgettable experience. He spoke as he wrote, with meticulous planning and - remarkably for a physicist - in elegant, complete, grammatical sentences!

Most quantum mechanics textbooks start with Schrodinger's wave mechanics, and go through the standard problems of potential wells, the harmonic oscillator and the hydrogen atom before reaching spin as a kind of puzzling afterthought. But from a fundamental point of view, this is illogical: an electron spin is the simplest of all quantum-mechanical systems, where measurements have only two possible outcomes. So that is where Schwinger starts, gradually constructing the algebraic formalism from a discussion of Stern-Gerlach-type experiments. Even before this, there is a carefully argued historical and philosophical prologue that sets the scene, centred on the two key features of quantum physics - atomicity and its probabilistic character; this alone would make the book worthwhile. The emphasis on discrete variables is a very modern approach, which will surely become more popular with the rising importance of quantum computing - though quantum computers are not specifically mentioned here. Continuous variables such as position and momentum appear only much later, as limits of variables with a large but finite number n of values, as n tends to infinity.

The importance Schwinger ascribed to choosing the right symbolism is emphasised in the subtitle. The only other book with a similar emphasis, and the obvious comparison, is Dirac's classic, *The Principles of Quantum Mechanics* . Indeed, some of Schwinger's notation comes straight from Dirac, for example primes to denote eigenvalues. Schwinger has a beautifully concise notation for quantum measurements (though it is probably unlikely to catch on), from which he develops - almost by sleight of hand - the Dirac bra-ket notation. The whole of the first third of the book, entitled "quantum kinematics" and representing lectures from the fall quarter, is devoted to the logical development of this symbolism and algebra.

The structure of the book is meticulously logical: all of the basic formalism is developed before the author turns to applications in the winter and spring quarters. This is an elegant, but uncompromising approach. It will enthral some students, but may leave others mystified. Every step follows logically, but it is not always easy to see the motivation - which often emerges much later. More signposts would be welcome; but students who do stay the course will be amply rewarded.

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Schwinger's other great innovation, the action principle that now bears his name, forms the basis of the second section, the winter's lectures on "quantum dynamics". This is an undervalued and very powerful approach, that should be more widely known and used. It can be regarded as the differential equivalent of Feynman's path-integral formalism, but it has many advantages: it is conceptually simpler and often easier to use.

Once the formal structure is in place, its power and conciseness rapidly become clear. Schwinger deals in short order with a wide range of applications in a clear, unified and logically satisfying way. Many details that usually come from messy solutions of complicated differential equations seem to fall out, for example the energy eigenfunctions of the harmonic oscillator. Unusually, he treats the hydrogen atom first by demonstrating its formal mathematical equivalence to the harmonic oscillator. There is an excellent treatment of the WKB and Rayleigh-Ritz methods, using linear potentials as an example.

The final section, the spring lectures, is on the dynamics of interacting particles, including scattering problems, identical particles, and an introduction to "second quantization" - a term Schwinger rightly labels misleading.

The treatment of identical particles is elegant and persuasive, leading to a simple derivation, for example of the Mott scattering cross-section. There is a very interesting chapter on approximation methods, in particular the Hartree-Fock and Thomas-Fermi approximations. The final chapter, on electromagnetic radiation, is an introduction to (non-relativistic) quantum electrodynamics.

To a theoretical physicist, this book is a delight and a wonderful resource. But does it succeed as an undergraduate textbook? It would be hard to recommend it as a first introduction to the subject, but that is not its purpose. Schwinger starts by saying: "I presume that all of you have been exposed to some undergraduate course in quantum mechanics, one that leans heavily on de Broglie waves and the Schrodinger equation."

He goes on to state his aim: "I have never thought that this simple approach was acceptable as a general basis for the whole subject, and I intend to move immediately to replace it in your minds by a foundation that is perfectly general." In this aim the book succeeds admirably, though it does require a considerable degree of dedication from the student.

This is a book I shall treasure, but there is surely scope for another that uses a similar approach at a less demanding level and with more emphasis on early applications.

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