Relativistic Quantum Mechanics

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Book review

Relativistic Quantum Mechanics
H M Pilkuhn
2003 Heidelberg: Springer-Verlag
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The aim of relativistic quantum mechanics is to describe the finer details of the structure of atoms and molecules, where relativistic effects become nonnegligible. It is a sort of intermediate realm, between the familiar nonrelativistic quantum mechanics and fully relativistic quantum field theory, and thus it lacks the simplicity and elegance of both. Yet it is a necessary tool, mostly for quantum chemists. Pilkuhn's book offers to this audience an up-to-date survey of these methods, which is quite welcome since most previous textbooks are at least ten years old.

The point of view of the author is to start immediately in the relativistic domain, following the lead of Maxwell's equations rather than classical mechanics, and thus to treat the nonrelativistic version as an approximation. Thus Chapter 1 takes off from Maxwell's equations (in the noncovariant Coulomb gauge) and gradually derives the basic aspects of Quantum Mechanics in a rather pedestrian way (states and observables, Hilbert space, operators, quantum measurement, scattering,...). Chapter 2 starts with the Lorentz transformations, then continues with the Pauli spin equation and the Dirac equation and some of their applications (notably the hydrogen atom). Chapter 3 is entitled 'Quantum fields and particles', but falls short of treating quantum field theory properly: only creation/annihilation operators are considered, for a particle in a box. The emphasis is on two-electron states (the Pauli principle, the Foldy–Wouthuysen elimination of small components of Dirac spinors, Breit projection operators,...). Chapter 4 is devoted to scattering theory and the description of relativistic bound states. Chapter 5, finally, covers hyperfine interactions and radiative corrections.

As we said above, relativistic quantum mechanics is by nature limited in scope and rather inelegant and Pilkuhn's book is no exception. The notation is often heavy (mostly noncovariant) and the mathematical level rather low. The central topic is the description of atoms and molecules, including relativistic effects. The author fulfils this program in a reasonable way and offers a valuable tool to the targeted audience. I am not overly enthusiastic about the end result, but I might be prejudiced. Clearly, going further would require the full power of quantum field theory, but this is clearly beyond the scope of the book.

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