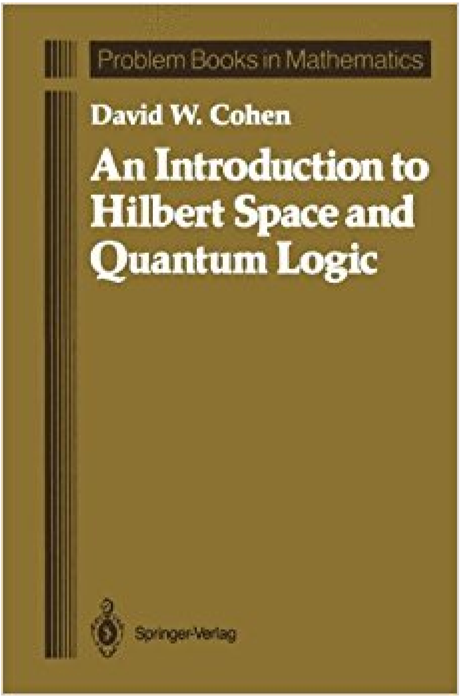
An Introduction To Hilbert Space And Quantum Logic (Problem Books In Mathematics)



Synopsis

Historically, nonclassical physics developed in three stages. First came a collection of ad hoc assumptions and then a cookbook of equations known as "quantum mechanics". The equations and their philosophical underpinnings were then collected into a model based on the mathematics of Hilbert space. From the Hilbert space model came the abstaction of "quantum logics". This book explores all three stages, but not in historical order. Instead, in an effort to illustrate how physics and abstract mathematics influence each other we hop back and forth between a purely mathematical development of Hilbert space, and a physically motivated definition of a logic, partially linking the two throughout, and then bringing them together at the deepest level in the last two chapters. This book should be accessible to undergraduate and beginning graduate students in both mathematics and physics. The only strict prerequisites are calculus and linear algebra, but the level of mathematical sophistication assumes at least one or two intermediate courses, for example in mathematical analysis or advanced calculus. No background in physics is assumed.

Book Information

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Customer Reviews

This book gives a nice introduction to the mathematical formalism behind quantum physics and the logic of measurement. The first chapter gives an introduction to measure theory with emphasis on probabilities of measurement outcomes. The author is careful to point out that the calculation of the Lebesgue integral presents more difficulties than in the Riemann integral case, since the fundamental theorem of calculus does not apply to Lebesgue integrals. This is followed by an elementary introduction to Hilbert space in Chapter 2. This is standard material and most of the proofs of the main results are omitted and left to the reader as projects. Chapter 3 is more controversial, and attempts to formulate a logic of experimentation for "non-classical" systems. This is done by use of what the author calls a "manual", which is viewed as an abstraction of the experimenters knowledge about a physical system. A manual is a collection of experiments, and an "event" is a subset of an experiment. Orthogonality of events is defined, along with the notion of a collection of events being "compatible", meaning that there is an experiment that contains all of these events. A manual is called "classical" if every pair of events is compatible. The author then exhibits systems that are not classical via the double-slit and Stern-Gerlach experiments. A logic of events is then developed in the next section, where quantum logic is defined explicitly. The author defines a pure state that is not dispersion-free as a state of ontological uncertainty as opposed to "epistemic" uncertainty. Quantum systems have states that are ontologically uncertain according to the author. The author chooses not to engage in the debate about the actual existence of these states and, accordingly, no real-world experiments are given to illustrate the relevance of the concepts and definitions. The next chapter covers the geometry of infinite-dimensional Hilbert spaces. The structure of the collection of these subspaces is defined in terms of the quantum logic defined earlier. This is followed by a discussion of maps on Hilbert spaces, as preparation for defining observables in quantum systems. The important Riesz representation theorem is stated but the proof left to the reader. Projection operators are defined also with the eventual goal of relating them to the compatibility of two propositions. Gleason’s theorem is discussed in Chapter 6, along with a discussion of the geometry of state space. The proof of Gleason’s theorem is omitted, the author emphasizing its difficulty. The proof in the literature is non-constructive and thus the theorem is suspect according to some schools of thought. The spectral theorem, so important in quantum physics, is discussed in the next chapter. Once again the proofs are left to the reader for most of the results. The spectral theorem allows the author to define another notion of compatibility in terms of the commutativity of two Hermitian operators. The books ends with a overview of the EPR dilemna and is naturally more controversial than the rest of the book. This topic has provoked much philosophical debate, and the author gives the reader a small taste of this in this chapter. The book does serve its purpose well, and regardless of one’s philosophical position on quantum physics, the mathematical formulations of quantum physics and measurement theory are nicely expounded in this book.

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