Thinking outside the Copenhagen box FREE

Foundations of Quantum Mechanics: An Exploration of the Physical Meaning of Quantum Theory. , TravisNorsen, Springer, 2017, $59.99 (paper)

Jean Bricmont

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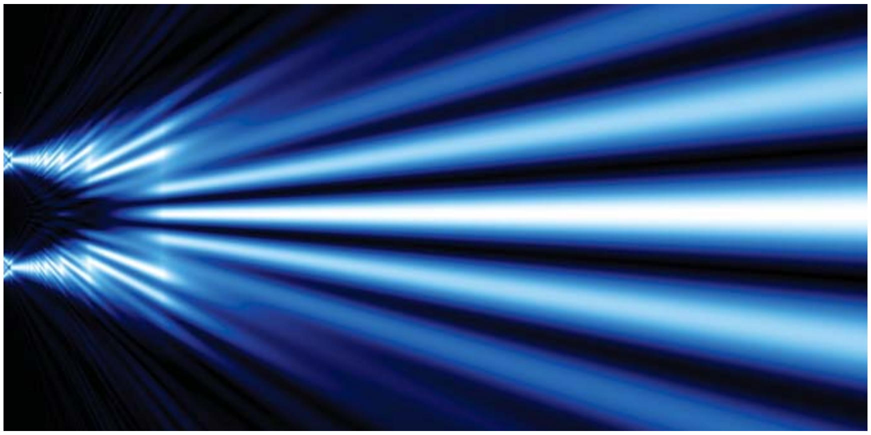

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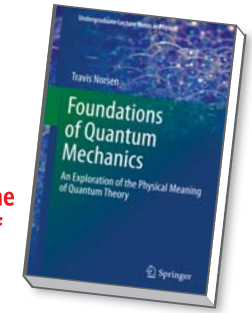

Foundations of Quantum Mechanics
An Exploration of the Physical Meaning of Quantum Theory
Travis Norsen
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Most books about the mysteries of quantum mechanics are popularizations rather than serious physics texts, assume considerable technical background, or are wrong-headed in their approach. Travis Norsen's new book, *Foundations of Quantum Mechanics: An Exploration of the Physical Meaning of Quantum Theory*, is an exception. It is clearly written, accessible to undergraduate students, and thorough in covering the important issues surrounding physical interpretations of quantum theory. The book is intended as the main text for an undergraduate course on the foundations of quantum mechanics, but it would also serve well as a supplemental text in a regular undergraduate quantum mechanics course.

Every physicist knows how to use quantum mechanics to predict the results of measurements; the extraordinary accuracy of those predictions is not in dispute. But the textbook quantum formalism is remarkably silent about what the theory says outside the laboratory. Most physicists, of course, do believe that there is a reality beyond the laboratory, but what quantum mechanics says about that reality is not clear at all.

If a physicist is asked what it means for an electron to have a given quantum state, there is only one orthodox answer: If we measure a property of an electron in a laboratory, we will obtain one of several possible results, with a well-defined probability attached to each. But that answer says nothing about the property of the electron before it is introduced to the laboratory or about the properties of the overwhelming majority of electrons that are never introduced to any laboratory. And if those poor unmeasured electrons have no properties of their own—no position, momentum, energy, or angular momentum—what does it mean to say that they exist?

Such conundrums have led some physicists to suggest that physics is fundamentally about observations or human perceptions. A main goal of Norsen's book is to offer several compelling alternatives to that perspective. The spontaneous collapse theory, Hugh Everett's many-worlds theory, and the pilot-wave theories of Louis de Broglie and David Bohm each receive detailed, chapter-length treatments.

Of those alternatives, Norsen finds pilot-wave theory the most compelling. The basic concept can be summarized in two words: Particles move! More precisely, their motion is guided by the wavefunction, a bit like the way classical particles are guided by the Hamiltonian. In pilot-wave theory, particles have positions—and thus trajectories—at all times.

Through pedagogical examples, Norsen explains how the pilot-wave theory works. He shows how it accounts for the results of the famous double-slit experiment and, most importantly, what the act of measuring is in the context of the theory. All measurements of physical quantities other than positions are contextual in pilot-wave theory, which means that their results are not determined solely by the quantum state and the exact position of the particle, but rather by a combination of those properties and the precise way the measuring apparatus is set up. "Measurements," therefore, do not measure any preexisting property of a particle, but depend on the way the quantum particle interacts with the apparatus.

Pilot-wave theory's understanding of measurements as interactions should be good news for Niels Bohr's followers, since it vindicates Bohr's intuition about, as he put it in 1949, "the impossibility of any sharp distinction between the behavior of atomic objects and the interaction with the measuring instruments." Because the act of measuring does not reveal any preexisting property of a particle, pilot-wave theory is not refuted by the various "no hidden variables theorems," as Norsen explains.

Norsen carefully discusses the issue of nonlocality and what John Bell really proved. He also devotes one chapter to dissecting what the Copenhagen interpretation has meant to a cross section of physicists. Norsen's attitude toward that interpretation is summarized by the following passage: "One thing is for sure: to whatever extent the Copenhagen philosophy insists that it is not merely wrong, but impossible, to provide a uniform, coherent, realistic description of the world, which is nevertheless consistent with all known experimental facts, the Copenhagen philosophy is in that regard simply wrong."

Foundations of Quantum Mechanics shows that there are ways to escape from the Copenhagen box, and Norsen explains with both clarity and patience the issues and concepts at stake. Reading this book should be a priority for all physicists who want to deepen their understanding of their most fundamental theory.

Jean Bricmont
Catholic University of Louvain
Louvain-la-Neuve, Belgium