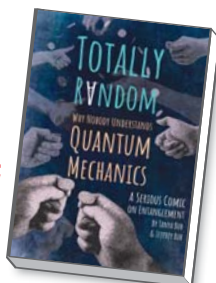


# The mysteries of quantum mechanics in graphic-novel form

**Totally Random**  
 Why Nobody  
 Understands  
 Quantum Mechanics;  
 A Serious Comic on  
 Entanglement

**Tanya Bub and  
 Jeffrey Bub**

Princeton U. Press, 2018. \$22.95 (paper)



Richard Feynman famously claimed in his 1964 Messenger lectures that nobody understands quantum mechanics. His statement was doubly ironic: Feynman was unquestionably a master of quantum mechanics, and he used the theory's predictions to describe how nature behaves while saying that no one knows how it can behave like that. We have yet to resolve that second irony. We understand how to use quantum mechanics successfully, but we still lack an agreed-on description of the quantum world. *Totally Random: Why Nobody Understands Quantum Mechanics; A Serious Comic on Entanglement* is a highly original attempt to give even nonphysicists a personal experiential appreciation of that peculiar situation.

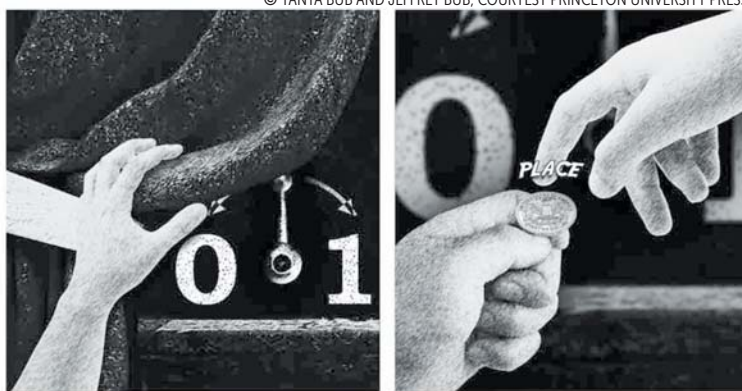
Jointly authored by graphic artist Tanya Bub and her father, philosopher of physics Jeffrey Bub, *Totally Random* is the result of the Bubs' intense intellectual discussions about quantum mechanics. Both Tanya and Jeff have alter egos who provide commentary throughout the book. But many other characters also contribute to the conversation. One is the reader, whose thoughts are channeled by a skeptical narrator. The founding fathers of quantum mechanics also appear; sources for their quotes are given in notes at the end of the book.

The first part of *Totally Random* ac-

quaints the reader with the most puzzling features of quantum mechanics. Feynman thought the two-slit experiment contains the only real mystery of the theory, but Erwin Schrödinger would have disagreed; he believed that entanglement was the most mysterious phenomenon in the new quantum world. The Bubs side with Schrödinger, and as an expository device, they "hand" the reader a pair of quoins, or superquantum coins. When tossed, each quoin is equally likely to land on heads or tails, just like a normal coin. But when two people each lay one quoin on their thumbs with the heads facing up and toss them simultaneously, the quoins always land with one on heads and the other on tails. If the quoin tossers lay the quoins on

their thumbs with faces oriented any other way, the quoins always land with the same face up. The quoins thus illustrate the scenario outlined by Sandu Popescu and Daniel Rohrlich in their 1994 paper introducing what is now called a PR box. That scheme explores the possibility of a theory even more nonlocal than quantum mechanics that still did not permit instantaneous distant signaling.

The Bubs show that those outcomes are puzzling because there is no way to rig each quoin in a pair to land the way it does without information about how the other quoin lands—information that would have to be transmitted arbitrarily fast if the quoins were tossed arbitrarily far apart. The quoin scenario is a nice metaphor



that brings home the significance of Bell inequalities and the subsequent experiments that verify the quantum-predicted correlations that violate them. It is only a metaphor, since the experimental correlations are not the superquantum correlations predicted by a PR box. As far as we physicists know, there are no quinos, no doubt to the disappointment of many young readers. But it is characteristic of comics to stretch what is possible to engage the reader's attention and imagination, and quinos are a significant improvement on the misleading metaphor of spooky action at a distance.

The "late great" physicists of the Copenhagen school—and their critics—appear in part two of *Totally Random*. Each group tries to convince the reader of how quantum mechanics describes—or fails to describe—our world. Their quoted views bring home the lack of consensus on quantum foundations that has by now persisted for nearly a century.

The quoin metaphor proves its worth in the final part of the book; it gives a real feeling for what quantum cryptography, computation, and teleportation are and how they are possible. I could quibble with some of the details here, but overall I have never seen such a simple and faithful account of the underlying principles.

Jeffrey Bub is a professor in both the philosophy department and the Joint Center for Quantum Information and Computer Science at the University of Maryland. He has published three scholarly books and numerous papers on the conceptual foundations of quantum mechanics. Unlike those works, *Totally Random* contains no mathematics. Its contents will be accessible to the interested reader who knows no quantum mechanics, and the authors thank six teenagers for their help in keeping it that way.

I would have loved this book as a teenager myself, and although it is unlikely to top the young adult reading charts, I expect it will inspire some to join the next generation of physicists and philosophers. As a reader of PHYSICS TODAY, you may want to buy copies for your family or friends. But don't part with the book without first reading it yourself, for it will surely give you a deeper appreciation of both the peculiarity and the power of quantum mechanics.

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Tucson



SCIENTIFIC MONTHLY (1920). PD-US

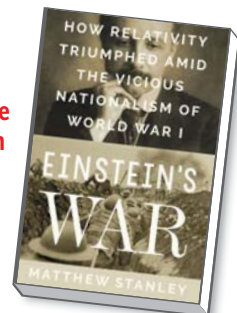
## Eddington and Einstein, scientists and wartime visionaries

On 29 May 1919, two British expeditions observed a solar eclipse to test a key prediction of Einstein's general theory of relativity: that the Sun's gravity would bend light from distant stars. The announcement of favorable results catapulted Albert Einstein to a level of worldwide fame that has fascinated and perplexed scientists and historians ever since. Matthew Stanley's *Einstein's War: How Relativity Triumphed Amid the Vicious Nationalism of World War I* is a welcome contribution to this year's centenary of the famous eclipse.

*Einstein's War* focuses on two protagonists: Einstein himself and British astronomer Arthur Eddington. Stanley, a historian of science at New York University, weaves the two biographies deftly, tracing their individual career paths and scientific achievements. He handles the science ably, but his treatment of the social and political context stands out. The devastating carnage of World War I and the extreme nationalism that engulfed the hostile nations provide the dra-

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Matthew Stanley  
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Random House,  
2019. \$28.00



matic backdrop to the author's narrative.

Stanley paints a vivid picture of both Eddington's wartime life as a Quaker pacifist in Cambridge, UK, and Einstein's isolation as a pacifist and internationalist in Berlin. One hundred years later, it is hard to imagine the brutality of the Great War and the vicious hatreds that it engendered among the citizens, including scientists, of the hostile nations. Stanley brings those realities to light and shows how Einstein and Eddington were two lonely beacons of sanity and humanity in a sea of vitriol and hatred.

The war had ended when British