The man who explained quantum mechanics FREE

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DAVID BOHM IN 1949, shortly after he had refused to testify before the House Un-American Activities Committee.

The man who explained quantum mechanics

David Bohm (1917–92) was a man of principle. He refused to denounce fellow members of the Communist Party in the US during the McCarthy era, and he insisted that physicists should search for an explanation of quantum phenomena when almost all physicists believed that none existed. Olival Freire Jr examines his life and work in a new biography, *David Bohm: A Life Dedicated to Understanding the Quantum World*.

David Bohm
A Life Dedicated to Understanding the Quantum World
Olival Freire Jr
Springer, 2019.
$84.99

Bohm's was an eventful life filled with significant scientific achievements. His 1943 doctoral dissertation on the scattering of protons was classified because of its potential military value for the Manhattan Project, and his subsequent work on plasma physics is renowned for its use of collective variables and for the discovery of what is now called Bohm diffusion. But Bohm is perhaps best known for his work on quantum mechanics. In 1951 he published a textbook on the topic in which he defended the orthodox Copenhagen interpretation. He gave a copy to Albert Einstein, and in the ensuing conversation, Einstein convinced him that there was something fundamentally wrong with the Copenhagen view.

So Bohm broke up with Copenhagen. He immediately went to work on an alternative approach and came up with what is still the simplest and most baffling solution of the paradoxes of quantum mechanics. He proposed that electrons had trajectories and suggested an equation of motion. From that proposal, he developed a full theory that he called the causal or ontological interpretation of quantum mechanics, now often called Bohmian mechanics.

At the time, almost all physicists believed that the paradoxes of quantum mechanics simply could not be solved. Most of Bohm's contemporaries opposed his theories and considered him a heretic. To make matters worse, Bohm also got into political trouble. After he refused to name other communists to the House Un-American Activities Committee, he was indicted for contempt of Congress, whereupon Princeton University terminated his contract. They refused to renew it even after Bohm was acquitted a few months later. As no other US university would hire him, he was effectively forced to leave the country. He moved first to Brazil, then a few years later to Israel, and from there to the UK.

Near the time of his move to the UK, he discovered the Aharonov–Bohm effect jointly with his student Yakir Aharonov; the effect demonstrates that the electromagnetic vector potential can influence the interference pattern of an electron's wavefunction even if the field strength vanishes. Also around that time, despite the personal price he had paid for his loyalty to the Communist Party, he abandoned Communism after learning of the crimes of the Soviet government under Joseph Stalin.

Freire, a physicist and historian of physics at the Federal University of Bahia in Brazil, has written about the history behind quantum mechanics before: In his previous book, *The Quantum Dissidents: Rebuilding the Foundations of Quantum Mechanics (1950–1990)*, published in 2015, he studied the growing interest in alternatives to the quantum orthodoxy, with chapters on Hugh Everett, Eugene Wigner, John Bell's nonlocality theorem, decoherence, and also Bohm.

In contrast to an earlier biography by F. David Peat, *Infinite Potential: The Life and Times of David Bohm* (1996), which focused more on Bohm's life, Freire is primarily interested in the content, development, and reception of Bohm's scientific ideas. As a physicist himself, Freire dives into the scientific details of Bohm's arguments with and reactions to his contemporaries, such as his responses to Bell's famous theorem and the experimental tests of Bell's inequality.

Freire meticulously works his way through a wealth of historical materials. The book includes quotations from letters and interviews and plots citation counts to help the reader visualize the impact of Bohm's papers over the years. Freire's declared goal is to depict his subject not as a hero or saint, but with all his contradictions, changes, and doubts. And that he does. For example, he describes how Bohm's enthusiasm for Bohmian mechanics waned over the years, how lackluster his defenses of it were by the 1960s, and how his interest returned to it in the 1980s. Freire avoids passing judgment on the value of Bohm's various ideas and approaches.

Readers will not learn Bohm's theories from this book. Those who want to understand Bohmian mechanics in its modern formulation and its status compared to the orthodox Copenhagen interpretation would do well to consult Detlef Dürr and Stefan Teufel's *Bohmian Mechanics: The Physics and Mathematics of Quantum Theory* (2009) or Jean Bricmont's *Making Sense of Quantum Mechanics* (2016). For those curious about the story behind the theory and the struggles and breakthroughs of its pioneer, *David Bohm* is a rich resource.

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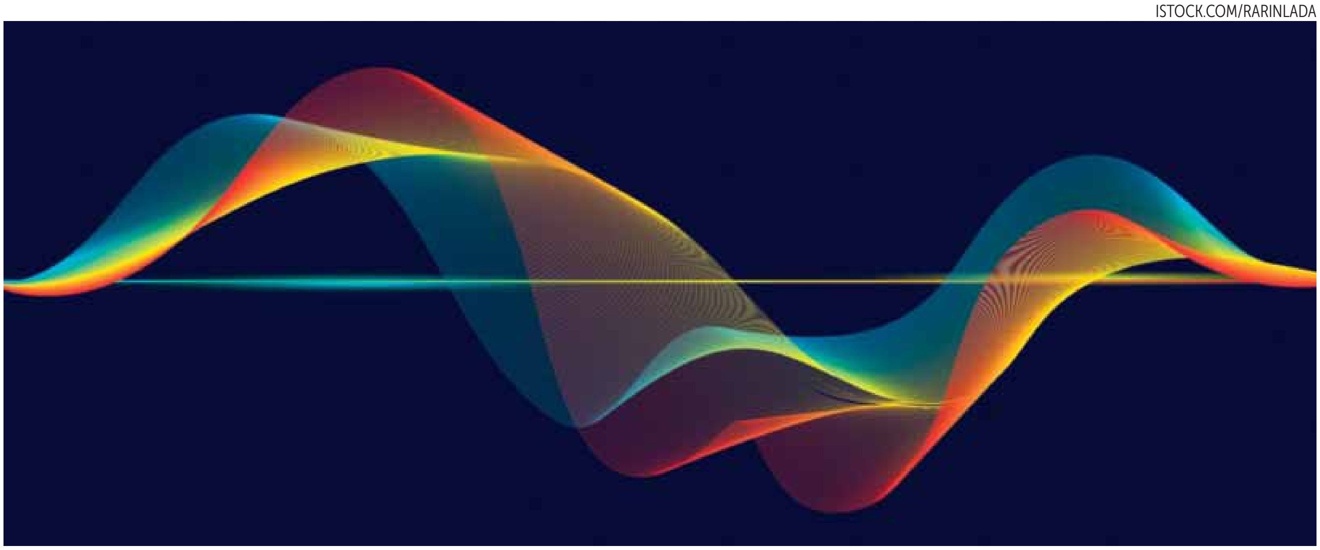
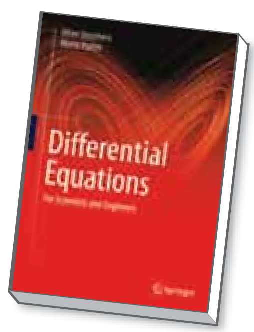


Testing the waters of differential equations

The textbook *Differential Equations: For Scientists and Engineers* by Allan Struthers and Merle Potter is an excellent starting point for undergraduates with a background in multivariable calculus who want to take the next step in their mathematical education. The book is framed as an ongoing discussion of the theory of differential equations. The authors frequently reference concepts and examples introduced earlier in the book to motivate further learning. That strategy makes the book feel like a continuing dialog between peers in which questions are asked and answers are proposed. The writing style is accessible to undergraduates, and students without much knowledge of differential equations will be able to jump right in.

Differential Equations
For Scientists and Engineers
Allan Struthers and Merle Potter
Springer, 2019 (2nd ed.). $59.99



Struthers and Potter choose not to prove the theorems they use throughout the book. Instead, they merely state them and then use them as tools to solve differential equations from physics, engineering, and biology. That practical approach makes *Differential Equations* an excellent resource for students who may not be mathematics majors. However, it also limits the scope of the book for advanced undergraduates, particularly mathematics majors who might have benefited from seeing more detailed proofs of some seminal theorems.

Chapter 1 is a detailed overview of concepts and techniques from linear algebra that are relevant to differential equations, and it includes plenty of explanations and examples. Much of its material is referenced and built on later in the book. As a probabilist, I was impressed by the way Markov chains were introduced as an example to motivate matrix–vector multiplication. Fundamental ideas from probability theory, including the Markov transition matrix and steady states of Markov chains, are explained effortlessly. The chapter concludes with an interesting, albeit short, discussion about how Google's algorithms determine page rankings for search results by solving an eigenvalue problem for a huge matrix.

Chapter 2 introduces simple methods for solving first-order differential equations. Most of the material will be a review for advanced undergraduate students, since they would have seen all the methods in one form or another in a calculus course. The last section discusses nonlinear first-order differential equations that are either separable or in exact form.

The authors point to chapter 3, titled "Linear Systems of Differential Equations," as the heart of the textbook. It be-