

Einstein's relatively large contribution to quantum theory

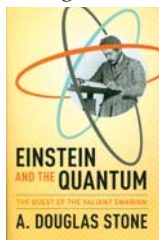
Einstein and the Quantum

The Quest of the Valiant Swabian

A. Douglas Stone
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Reviewed by Daniel Kleppner

The pantheon of quantum mechanics includes Max Planck, Albert Einstein, Niels Bohr, Louis de Broglie, Werner Heisenberg, Erwin Schrödinger, Paul Dirac, and Max Born. All those personalities appear in *Einstein and the Quantum: The Quest of the Valiant Swabian*, Douglas Stone's audacious recounting of the subject's genesis. Stone, however, argues that the creation saga, as commonly narrated, seriously understates the immense breadth and depth of Einstein's contributions.



In the book, Stone shows how Einstein's ideas animated the development of quantum mechanics from its infancy through its first quarter century. He argues that the full extent of Einstein's impact is not appreciated because his iconic status in the world of physics, and also for the greater public, was due primarily to his creation of general relativity. Furthermore, Einstein himself sabotaged (my word, not Stone's) the history of his role: Rather than taking pride in the edifice he helped create, Einstein balked at quantum mechanics' "spooky action at a distance" and effectively disowned the theory. His scientific memoir is devoted to general relativity and makes only scant mention of quantum mechanics. Einstein is better known for denouncing quantum theory than for creating it.

Stone narrates the hectic circumstances that induced Planck to announce his quantum hypothesis in a speech on 14 December 1900. Planck viewed his proposal as a mathematical

trick and a physical absurdity—an act of desperation, as he later called it. In contrast, the quantum hypothesis that Einstein presented in his paper on the photoelectric effect at the beginning of 1905, his annus mirabilis, was an act of deliberation and logical necessity.

Stone shows how Einstein recognized that the success of Maxwell's electromagnetic theory spelled the downfall of Newtonian physics. The error was deeper than the problem of the ether that Einstein had handily resolved with his special theory of relativity. The error lay in the statistical mechanics of radiation. Einstein was driven to conclude that radiation fields could exchange energy with matter only in discrete packages. Rather than accept Planck's hypothesis that the energy of matter is quantized, Einstein proved that for statistical mechanics to be consistent, the energy of radiation must be quantized. Unlike Planck's proposal, Einstein's paper had physical consequences with experimental ramifications.

Furthermore, Einstein recognized—again using statistical arguments—that if radiation fields are quantized, the energy content of matter must also be quantized. Lacking any theory for the structure of atoms, he turned to thermodynamics and focused on the specific heat of solids to show how vibrational quantization could explain the mysterious temperature variation of some materials. Stone describes a deep irony in the specific-heat paper: For the specific heat of diamond, Einstein used data taken by Zürich Polytechnic professor Heinrich Weber, who, irritated by Einstein's brashness, had blocked his academic career. That led to Einstein's employment in the Zürich patent office and the period of thinking and writing that culminated in the magical year.

As Stone points out, years before Bohr invoked the correspondence principle, Einstein had fully appreciated the significance of wave-particle duality; in 1909 he had discovered that the fluctuations of thermal radiation simultaneously display both wave-like and particle-like behavior. However, Einstein's attempts to build on that understanding and develop a full quantum theory of matter were unsuccessful, and

so he turned to the problem of gravity. He later told Otto Stern that in his career he spent much more time thinking about quantum theory than about gravity. Einstein returned to quantum mechanics with his 1917 paper on radiation, in which he introduced the concept of spontaneous emission and laid the foundations for all future radiation theory. To his distress, probability played an essential role.

In the summer of 1924, Einstein unscrambled de Broglie's PhD thesis and recognized the significance of its seminal hypothesis. He explained it to Schrödinger, who thus was inspired to set out on the quest that led to the creation of wave mechanics as we know it today. That same year Einstein presented his theory of the quantum gas, which included the phenomenon that became known as Bose-Einstein condensation. In his 1935 paper with Boris Podolsky and Nathan Rosen, Einstein focused his attention on entanglement and its ensuing paradoxes. At that point he became estranged from the scientific community, much to the sadness of many of his colleagues.

Einstein and the Quantum is delightful to read, with numerous historical details that were new to me and charming vignettes of Einstein and his colleagues. By avoiding mathematics, Stone makes his book accessible to general readers, but even physicists who are well versed in Einstein and his physics are likely to find new insights into the most remarkable mind of the modern era. As for the book's enigmatic subtitle, "Valiant Swabian" was Einstein's signature to Mileva Marić in the early days of their courtship, before fate propelled his career upward and their marriage fell apart.

Command and Control

Nuclear Weapons, the Damascus Accident, and the Illusion of Safety

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Because journalists often make poor historians, I had my suspicions when I