books

The principals behind quantum physics

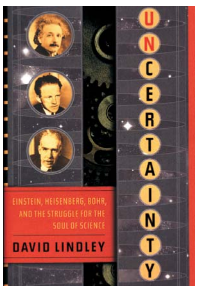
Uncertainty

Einstein, Heisenberg, Bohr, and the Struggle for the Soul of Science

David Lindley
Doubleday, New York, 2007. $26.00 (257 pp.). ISBN 978-0-385-51506-1

Reviewed by Pedro G. Ferreira

If I were to pick one idea from modern physics that has seeped into popular culture, it would be the Heisenberg uncertainty principle. More than Albert Einstein's theory of relativity, it pops up in the most unexpected places. David Lindley rolls out a few choice examples toward the end of his new book, *Uncertainty: Einstein, Heisenberg, Bohr, and the Struggle for the Soul of Science*. One involves a news editor commenting on embedded news reporting in Iraq, claiming that "the more precisely the media measures individual events in a war, the more blurry the warfare appears to the observer." Another is Claudia Jean "C. J." Cregg, the press officer in the television series *The West Wing*, who is being followed by a "fly on the wall" filmmaker and is asked if it has been a typical day at the White House: "I don't have to tell you about the Heisenberg principle," she responds knowingly.



Of course, I should have thrown the book across the room in anger, but I didn't. Because Lindley has done a pretty good job in sorting out the tangled ideas of quantum physics, his book just might lead the general public to understand what the principle is all about.

In his earlier book, *Boltzmann's Atom: The Great Debate That Launched a Revolution in Physics* (Free Press, 2001), Lindley tackles a similarly ubiquitous concept: entropy. He tells a compelling narrative of Ludwig Boltzmann and how the troubled physicist slowly came up with his view of statistical physics. *Boltzmann's Atom* portrays a complex man caught up in the fight between the atomists and the phenomenologists. His erratic career path in physics and his untimely death were a result of his lifelong battle with depression. The definition of entropy, the idea of irreversibility, and the birth of the quantum emerge from a life steeped in irrationality. The mix of emotion and high concept worked incredibly well.

In *Uncertainty*, Lindley tries the same approach, albeit on a grander scale. To faithfully narrate the development of quantum physics, he had to weave together the stories of numerous characters. There is, of course, Werner Heisenberg, an ascetic young man whom Niels Bohr described as "a little peasant boy, . . . very quiet, friendly and shy." Espousing the approach of Max Born, his mentor, that a proper theory must be expressed in terms of formal mathematics, Heisenberg came up with the matrix formulation of quantum mechanics. It was, he claimed, an attempt "to obtain foundations of quantum mechanics based exclusively on relationships between quantities that are in principle observable." One of those relationships is the inability to simultaneously observe the position and momentum of a particle: the uncertainty principle.

Bohr plays a lead role. Lindley gives readers an insight into Bohr's ability to come up with groundbreaking ideas based on broad concepts and assumptions that lead to hard numbers. Yet, as Lindley tells us, "for a man counted among the great theorists of physics, Bohr had remarkably little ability in the higher realms of mathematics." It was when he joined forces with the mathematically inclined Arnold Sommerfeld that the full explanatory power of Bohr's hydrogen atom was unleashed. Bohr comes across in the book as the godfather of the quantum, always alert to developments, sometimes confused by the different formulations, but a guiding light to Heisenberg, Erwin Schrödinger, Wolfgang Pauli, and the great young physicists who follow.

Einstein comes across as the cantankerous old uncle, overtaken by events and skeptical of the path modern physics is taking. He writes of Heisenberg's seminal paper: "Heisenberg has laid a large quantum egg. In Göttingen they believe it (I don't)." Although, over the years, Einstein was a source of many disparaging remarks about the new theory, he did at some point engage with it. For example, with Boris Podolsky and Nathan Rosen, he came up with a thought experiment that neatly showed some of the strange and, to him, unacceptable consequences of quantum mechanics: correlations of physical properties at spacelike separations.

Uncertainty is a mess of ideas and characters, a compelling read. Lindley has successfully created an arc and has been careful not to overly systematize the events that flesh it out. He has been able to profitably give us a real sense of the process of discovery in the early 20th century, as Europe hurtled toward war and the repression of intellectual life. Chaos was the essential background to the emergence of the quantum, the gem of modern physics. Editors, journalists, and scriptwriters should read the book before they cherry pick any more quantum concepts. They will enjoy it and will look less foolish.

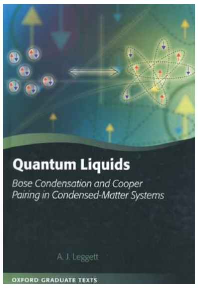
Pedro G. Ferreira is a reader in physics at the University of Oxford in the UK. His interests are in cosmology, the early universe, the cosmic microwave background, and astroparticle physics. He is the author of *The State of the Universe: A Primer in Modern Cosmology* (Weidenfeld and Nicholson, 2006).

Quantum Liquids

Bose Condensation and Cooper Pairing in Condensed-Matter Systems

A. J. Leggett
Oxford U. Press, New York, 2006. $70.00 (388 pp.). ISBN 978-0-19-8526438

In *Quantum Liquids: Bose Condensation and Cooper Pairing in Condensed-Matter Systems*, Anthony Leggett has attempted to produce a graduate textbook for the Oxford University Press series on the various examples of macroscopic quantum-coherent states in condensed-matter physics. Chapters are devoted to liquid helium-4, Bose–Einstein condensation (BEC) in cold atoms, classical superconductivity, liquid helium-3, and cuprate superconductivity; a final, eighth chapter covers assorted exotic systems.



Not that Leggett, a 2003 Nobel laureate in physics and MacArthur Professor at the University of Illinois at Urbana-Champaign, would ever use the words "macroscopic quantum coherence": He devotes much of the first two introductory chapters to explaining why he rejects the now-classic description in terms of coherent states and favors instead the narrower idea of off-diagonal long-range order. In so doing, he explicitly rejects the connection of coherence with broken gauge symmetry that eventually led to the electroweak theory; but more seriously, the words "Goldstone boson" do not appear in reference to the phonons and collective modes in helium, nor does the question of why they do not appear in superconductors. Because the Bardeen-Cooper-Schrieffer (BCS) theory has always been viewed as the poster child for the concept of broken symmetry, Leggett's refusal to look in those directions warrants questioning—and all the more in a work of reference.

The early chapters of the book also divagate on a number of questions that seem out of place in a text at this level. For instance, is it at all relevant that "there is no proof of the existence of Bose–Einstein condensation in any physical system" (page 46). If there were "proof" of nonexistence, it would be the premises of the proof that would be questioned, not the physics of liquid helium.

For graduate students who want a thorough grounding in some of the most fundamental aspects of quantum fluids—such as statistical mechanics in a rotating container, the Landau–Silin approach to metals, the dynamical theory of the dielectric constant of metals, and the theory of Feshbach resonances in dilute gases—*Quantum Liquids* would be very useful. And for those of us who have specialized in a particular branch of the field and need updating on the marvelous things that have been done with cold atoms or on the beautiful details of the liquid ^{3}He story, the book is a wonderfully informative source. Each of the four chapters on the classic, well-understood cases of liquid ^{4}He, Bose alkali gases, superconductivity, and liquid ^{3}He is full of small gems of insight, typical of Leggett's finical style.

But from time to time it seems as if the author has distorted or ignored history. One wonders if Henry Hall and Joe Vinen would have been happy being dropped from the history of quantized vorticity in superfluid ^{4}He. In the chapter on classical superconductivity, John Rowell is not mentioned in connection with the Josephson effect. And perhaps I might have earned some credit for the formalism in section 5.8, the one using time-reverse pairing. In addition, the entire and crucially important subject of flux lattices, flux pinning, and creep and flow is postponed to a cursory inclusion in the chapter on cuprates. The omission of the flux lattice and flow properties constitutes a serious incompleteness in a learning tool.

For my specialty, the cuprates, I had hoped to see a thoughtful, if idiosyncratic, treatment like those in the previous chapters; instead, the coverage in chapter 7 does not actually reflect the modern state of the subject. Again, Leggett's characteristic viewpoint comes into play: He says, in effect, that some may believe that the Hubbard model is useful—but he doesn't, offering no explanation (page 332). Yet Leggett is not finicky about the mathematically questionable basis of the antiferromagnetic spin-fluctuation theory. Another example: A long-ago paper by one of his close colleagues, Myron Salomon, shows that the transition is always of *x*–*y* character—that is, into a fluctuating paired liquid—which invalidates the naive Jeff Tallon phase diagrams that Leggett uses.

In a few paragraphs in chapter 8, Leggett dismisses the large field of organic superconductors. He does not mention established data that demonstrate the coincidence of a Mott transition in an organic material with that in an antiferromagnetic superconductor, nor does he mention the demonstrations of triplet superconductivity in organics. Instead, the subject is dismissed as "probably phonon-motivated" (page 352) despite the myriad evidences for Mott–Hubbard physics. Leggett at least admits that the heavy-fermion superconductors are likely to have exotic order parameters and an electronic mechanism, but his long-term love affair with antiferromagnetic spin fluctuations continues. Superconductivity in Sr_2RuO_4, whose order parameter so closely resembles that of his favorite ^{3}He, is given a brief mention. Except for a final note on the BCS–BEC crossover, all of chapter 8 is cursory and out of date.

In summary, *Quantum Liquids* is a book that many condensed-matter theorists can read with profit. But because the text is so selective and occasionally misleading in parts, I would question its use as a comprehensive textbook for graduate students.

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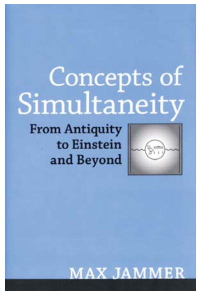
Concepts of Simultaneity

From Antiquity to Einstein and Beyond

Max Jammer
Johns Hopkins U. Press, Baltimore, MD, 2006. $49.95 (308 pp.).
ISBN 978-0-8018-8422-1

All physicists know that something important happened to the concept of simultaneity in 1905. But most are unaware that in the past 100 years a feud has developed over whether the simultaneity of distant events in a given reference frame is fact or convention. Max Jammer, a professor emeritus of physics and former president at Bar-Ilan University in Israel, has written various books, including three classics published by Harvard University Press: *Concepts of Space: The History of Theories of Space in Physics* (1954), *Concepts of Force: A Study in Foundations of Dynamics* (1957), and *Concepts of Mass in Classical and Modern Physics* (1961). Since the last of the three was first published more than 40 years ago, one might be curious as to whether his new book, *Concepts of Simultaneity: From Antiquity to Einstein and Beyond*, is as good as the rest.



Jammer discusses notions of simultaneity in various contexts, including Egyptian hieroglyphs, Aristotle's works, and the tenseless Hopi language. Early philosophers criticized astrology by addressing the simultaneity of distant events. For example, Sextus Empiricus challenged the Chaldean method of casting horoscopes at birth: An astrologer on high ground waited to hear a gong when a woman gave birth, but because of the sound delay, the astrologer did not note the position of the stars at exactly the moment of birth. St. Augustine of Hippo denounced astrology by arguing that even though two women at distant places were known to have given birth at the same time because messengers dispatched from each birthplace met midway between the two, the children still had distinct lives.

Coincidentally, Albert Einstein's