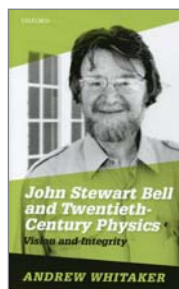


John Stewart Bell and Twentieth-Century Physics

Vision and Integrity

Andrew Whitaker

Oxford U. Press, 2016. \$44.95 (460 pp.). ISBN 978-0-19-874299-9



John Stewart Bell, best known for his groundbreaking contributions to the foundations of quantum mechanics, was one of the most esteemed physicists of the 20th century. It was only a matter of time before he received a full biography, and historians and physicists interested in his life and work will welcome *John Stewart Bell and Twentieth-Century Physics: Vision and Integrity*.

After his undergraduate studies at Queen's University Belfast, Bell moved to Harwell National Laboratory and the University of Birmingham, where he worked with Rudolf Peierls and later earned his PhD. He went on to work in the theoretical division at CERN, where he stayed for the rest of his career and became known for his work on accelerator design and on particles and fields.

In the mid 1960s Bell brought a major innovation to another field, foundations of quantum mechanics. After exposing flaws in John von Neumann's proof against the possibility of modifying quantum mechanics via the introduction of additional "hidden" variables, Bell reexamined the famous Einstein-Podolsky-Rosen thought experiment suggested by Albert Einstein and his collaborators in 1935. Bell was able to prove that no theory complying with the assumptions of realism and locality could reproduce all quantum mechanics results—a proof that we now call Bell's theorem.

John Clauser and Abner Shimony were among the first to explore Bell's theorem experimentally, and experiments with the theorem continue to this day. The most recent ones involve massive particles, detectors separated by 140 km or so, and photons coming from distant stars in the galaxy. So far the experiments have confirmed quantum predictions, led to the establishment of entanglement as a quantum signature, and contributed to the blossoming of quantum information research.

Although Bell's current prominence

derives mostly from his work on quantum foundations, biographer Andrew Whitaker rightly notes that during his lifetime, Bell's reputation arose largely from his more conventional work on particles, fields, and accelerators. When Bell was elected as a Fellow of the Royal Society of London in 1972, the citation was almost entirely dedicated to nuclear and elementary-particle physics.

John Stewart Bell and Twentieth-Century Physics presents a vivid description of Bell's life and covers his diverse scientific accomplishments in detail. Occasionally, there is too much detail—certain passages risk overwhelming the reader. Despite that flaw, the book is invaluable for readers seeking a better understanding of quantum mechanics. It is also useful for readers interested in the history of 20th-century physics, particularly those who want to know more about particle physics and the history of CERN.

Whitaker was well placed to write this book. A physicist himself, he works on foundational issues of quantum mechanics, has interests in the history of science, and has already published books presenting the conceptual subtleties of quantum mechanics. He also currently teaches at Bell's alma mater, Queen's University Belfast. Thus he is very familiar with Bell's work and background.

Although thoroughly researched, the book would have benefitted from a deeper plunge into the literature about the stigma that haunted research in foundations of quantum mechanics throughout most of the second half of the 20th century. Bell was keenly aware of that professional bias, as Whitaker notes, and it could have been more thoroughly presented. Talented physicists such as Clauser, Heinz-Dieter Zeh, and Klaus Tausk found their careers obstructed because of their interest in foundations. For example, when Clauser was looking for a job in the summer of 1972, the chair of the physics department at San Jose

State University asked physicist Bernard d'Espagnat if Clauser's work was "real physics."

Bell himself received a letter from Léon Rosenfeld in December 1966 just after the publication of the paper deriving the theorem that now carries his name. Rosenfeld told Bell that he considered "hunting hidden parameters as a waste of your talent," adding: "I don't know, either, whether you should be glad or sorry for that." Nowadays the prejudice against foundational research is a thing of the past; quantum information theory is a blossoming field that draws directly from once-maligned work. However, for the sake of the current and future good health of physics, the full history should not be forgotten.

Bell's biography reminds us of the obstacles encountered in the making of physics. Whitaker's book, with its vivid biographical depiction and wealth of technical detail, fills a lacuna felt by many historians, philosophers, and physicists.

Olival Freire Jr

Federal University of Bahia
Salvador, Brazil

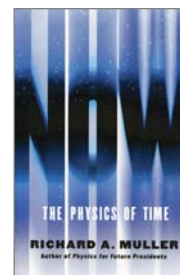
Now

The Physics of Time

Richard A. Muller

W. W. Norton, 2016. \$27.95 (368 pp.).
ISBN 978-0393285239

Richard Muller's *Now: The Physics of Time* is an ambitious undertaking that begins much like a popular account of relativity and quantum physics, but culminates by proposing a new theory of time. As in his acclaimed *Physics for Future Presidents: The Science Behind the Headlines* (Norton, 2007), based on a course he offers for nonscience majors at the University of California, Berkeley, the writing is entertaining and at times refreshingly idiosyncratic. Muller has a way of keeping a reader's attention with provocative ideas or claims. Examples include sections entitled "Actually, There Are No Black Holes" and "Feynman Reverses Time" and an extended discussion on the entropic arrow of time. Skeptical



readers can be assured that he wraps up his mysteries with sober resolutions, but intriguing lessons remain.

Other popular accounts have already covered much of what *Now* discusses, but the book stands apart because Muller, a professor at the University of California, Berkeley, is a leading experimental cosmologist. Although Muller's lucid discussions of the behind-the-scenes difficulties of cosmological experiments make up only a small fraction of the text, they present important new insights to a general audience. It would not hurt if the Antaeus parable, which warns of the perils of losing touch with the ground, were declared required reading for any theoretical physicist.

The first parts of the book aim to introduce the basic physics of spacetime. Some crucial passages, however, may be hard to follow for a novice, as the treatment of relativity relies perhaps too much on difficult discussions of frames. For instance, someone not already familiar with local inertial frames is not likely to get much out of the statement, "If you are accelerating, handle the equations by imagining that your acceleration is essentially a continuous jumping of your proper frame from one reference frame to another one that is moving slightly faster." It is also unfortunate that the book eschews spacetime diagrams on the grounds that they could undermine Muller's new view of time by giving the impression of a spacetime without a dynamical flow.

Muller advises readers to be clear about frames of reference, but he does not always follow that important counsel. When he asks, "How far is it from the outside to the surface of the black hole?" he replies, "The answer is infinite." He seems to be integrating the line element at fixed time, varying only the radial Schwarzschild coordinate, but that trajectory is not the worldline followed by the "falling surface" alluded to in his statement.

The main purpose of these introductory discussions is to set the stage for a new theory of time. In an attempt to avoid spoilers, I'll let the brief quote "the explosion of the universe continually creates not only new space but also new time" suffice to indicate the main idea. Muller is open about the proposal's weaknesses, such as the possibility of violations of general covariance. As the

quote suggests, his proposal incorporates an incremental progress of time, which has been envisioned in some discrete theories of quantum gravity. Proponents of such theories are still struggling with the immense difficulties of making their proposals consistent with covariance.

Muller's proposal is original and intriguing, and it has implications beyond physics. He dares to think in broad categories, connecting a physical theory about the universe with climate change and such unwieldy topics as free will. Potential observational tests of Muller's new theory, however, receive rather short treatment. Some statements might be held against the theory if taken as specific predictions; for example, in chapter 22, Muller draws connections between entropy, empathy, and the electorate, and asserts that "the US voter does not

want to elect a sociopath." In addition, it sometimes seems that Muller is too quick to push aside competing theories. For instance, he argues that the immense entropy contained in black holes cannot matter for Arthur Eddington's explanation regarding the arrow of time, because black holes are so far away from us. There may be much to criticize about Eddington's proposal, but such quick dismissal is not entirely persuasive.

Nevertheless, Richard Muller's new theory deserves a serious look, and his book presents important lessons in physics and beyond. Most readers will find intriguing new insights in *Now: The Physics of Time*. The book might even be useful to the future presidents in the title of Muller's previous opus.

Martin Bojowald

*Pennsylvania State University
University Park*

Cavity Optomechanics Nano- and Micromechanical Resonators Interacting with Light

Edited by Markus Aspelmeyer, Tobias J. Kippenberg, and Florian Marquardt

Springer, 2014. \$179.00 (357 pp.). ISBN 978-3-642-55311-0

Quantum Optomechanics

Warwick P. Bowen and Gerard J. Milburn

CRC Press, 2016. \$99.95 (358 pp.). ISBN 978-1-4822-5915-5

Optomechanics, the study of the mechanical effects of light on massive objects, has a long and distinguished history. It took off nearly 50 years ago, when Arthur Ashkin demonstrated that small dielectric balls can be accelerated and trapped using the radiation-pressure forces associated with focused laser beams. That led to the development of optical tweezers, a tool with wide-ranging applications in biological science.

A parallel development, investigations into the strong enhancement of mechanical effects created by resonant light scattering, led to the laser cooling of ions and neutral atoms. That was followed by the realization of atomic Bose-Einstein condensates in 1995 and the subsequent explosion in the study of quantum degenerate atomic systems. Critical break-

throughs can also be traced back to work on optical gravitational-wave antennas that started in the 1970s and 1980s. It is in that context that researchers understood the role of fundamental quantum optical effects in mechanical position measurements and the resulting standard quantum limit and advanced the idea of back-action evading measurements.

Quantum optomechanics, the field that evolved from those developments, promises to provide motion and force detection near the fundamental limits imposed by quantum mechanics. The field provides the basis for the quantum state control of truly macroscopic objects and for experiments that may lead to a more profound understanding of quantum mechanics.

Light can interact with matter either resonantly or nonresonantly, and both interactions

