

Mermin habitually answers opinions, real and abstract

In his Reference Frame “What’s Bad About This Habit” (PHYSICS TODAY, May 2009, page 8), N. David Mermin discusses what is real and what is abstract in physics—but without first defining what he means by those terms. The lack of definition is another bad habit that diminishes his otherwise interesting comments. In physics, we can give a concrete definition of “real”: phenomena or events that can be recorded by a device. The process of recording involves an irreversible transition that generally requires an interaction with a macroscopic device. The device can be our brains, but with some reservations, because sometimes we see or remember imaginary events that never happened. But “acquisition of knowledge or information,” *pace* Werner Heisenberg, although it occurs, is not relevant. Or as Richard Feynman remarked, “Nature . . . behaves the way she is going to behave whether you bother to take down the data or not.”¹

By the above definition of reality, Mermin is correct to point out that operators in Hilbert space and quantum wavefunctions are abstractions. I also believe that one should not lose any more sleep over the collapse of a wavefunction than over the change of any probability function after one of the possible outcomes has been recorded. But it does not follow, for example, that because electromagnetic fields are operators in Hilbert space, the manifestations of those fields are also abstractions or that the spacetime continuum where those fields are

located is devoid of reality. Ironically, Mermin’s article appears in an issue of PHYSICS TODAY whose cover and associated article show photographs of the spectacular magnetic field lines located in space (the Sun’s corona) and recorded in time in a UV image taken by a NASA spacecraft. The fields are made visible by the radiation of charged particles, in a similar way that planets and their orbits are observed by the reflection of solar radiation or that subatomic particles are seen by tracks left in a cloud or a spark chamber. Likewise, in the two-slit experiment, the effect of quantum interference with single photons can be recorded; consequently, the manifestations of the associated quantum wavefunction that predicts the interference are also real.

Mermin claims that “spacetime is an abstract four-dimensional mathematical continuum of points that approximately represent phenomena,” and that it “is nothing more than an extremely effective way to represent relations between distinct events.” But spacetime points do not represent phenomena; instead, they represent the locations of phenomena, which are determined by measurements of the relative distances and the time intervals between events. Mermin remarks that his point of view “may also be easiest to see in quantum physics, where time and space refer ultimately to the time and place at which information is acquired or, if you prefer, at which a measurement is made.” But in both quantum and classical mechanics, the location in spacetime is also obtained by measurements, as are other characteristics of the event. Hence, in accordance with our concrete definition of reality, spacetime is real, although special relativity tells us that our measurements of position and time are frame dependent.

Mermin is also concerned with the habit of attaching reality to “spooky actions at a distance” associated with the Einstein-Podolsky-Rosen effect. But what is measured in the associated experiments are correlations that are predicted by quantum theory to occur at any distance of separation for the entangled particle states. That includes the

case in which the distance becomes vanishingly small, and then such concerns as “nonlocality” and “faster-than-light influences” are not relevant. What would be really spooky is if those correlations depended on distance, because it would show that quantum mechanics is flawed. However, measurements demonstrate that the correlations do not depend on distance; thus they confirm again that the manifestations of quantum entanglement are not abstractions.

Bad habits in the interpretation of such quantum phenomena usually originate from attempts to impose on the microscopic world views of reality learned from classical physics.

Reference

1. R. P. Feynman, R. B. Leighton, M. Sands, *The Feynman Lectures on Physics*, vol. 3, Addison-Wesley, Reading, MA (1965), p. 3–7.

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I thoroughly enjoyed David Mermin’s May 2009 Reference Frame. However, definitions of the terms “abstraction” and “reality” are necessary. Unfortunately, that is an extraordinarily difficult task. I offer here the admittedly naive concepts I employed in attempting to understand his essay.

Reality is that which can be observed; this is, presumably, what Bertrand Russell meant when he stated that the proof of a concept lies in its comparison with reality. Observations, though, don’t always lead to unique interpretations: Entanglement can be fancifully interpreted as action at a distance, when it is really the result of two particles being produced by a single quantum state that requires that they obey the conservation laws applicable to the particular state.

If anything is ever detected, or is prevented from passing between two entangled particles, action at a distance would be confirmed. In the absence of such evidence, I prefer the less exotic explanations.

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We humans are attracted to fanciful models that are often more exciting than reality; so I agree with Mermin's basic premise. But I cannot always be confident of distinguishing a real property from a fanciful abstraction. In fact, if pushed, I would have to admit I'm not sure what a real property really is. Possibly Mermin can enlighten me.

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David Mermin tells us that our "bad habit" of reifying the quantum state "induces people to write books and organize conferences about 'the quantum measurement problem.' " However, a quantum measurement problem does not arise only from an unfortunate perspective on quantum theory.

A quantum measurement problem, as close to magic as anything in science, is displayed in quantum-theory-neutral experimental observations that assume only the free choice of the experimenters. In the two-slit experiment, one can choose to demonstrate each object concentrated at a single slit or perform the contradictory demonstration, that each object spread over both slits. Facing this dilemma, George Greenstein and Arthur Zajonc note that "even had quantum theory never been invented, these [two-slit] experiments could have been performed, and we would still find ourselves unable to understand them."¹

Quantum weirdness is increasingly misappropriated as a way to buttress pseudoscience. It is a responsibility of physicists to combat such misappropriation. (See our letter in *PHYSICS TODAY*, November 2006, page 14.)

Presenting the intriguing strangeness of quantum mechanics honestly and interestingly by the use of books Mermin might seem to deplore can effectively combat the misuse of the quantum mysteries. Dismissing the measurement problem as merely a bad way of viewing quantum theory abandons a fascinating mystery in physics to the purveyors of pseudoscience.

Reference

1. G. Greenstein, A. Zajonc, *The Quantum Challenge: Modern Research on the Foundations of Quantum Mechanics*, 2nd ed., Jones and Bartlett, Sudbury, MA (2006), p. 124.

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I am that friend of David Mermin's "who was enchanted by the revelation that quantum fields were the real stuff that makes up the world." I plead guilty to reification and offer the following defense.

I started out, as I think we all did, with the notion that there is a reality out there and that space and time are part of it—not just "an extremely effective way to represent relations between distinct events." When I read Arthur Eddington's *The Nature of the Physical World* (J. M. Dent & Sons, 1942) in high school, I learned that reality was not what it seemed—that Eddington's solid writing desk, for example, was mostly empty space. The next step in my understanding of reality came in college when I found that the electromagnetic field offered a more satisfying picture of the world than action at a distance, which even Isaac Newton derided.¹

When I encountered quantum mechanics, of course, everything became confusion. However, along with David, I was fortunate to attend Julian Schwinger's courses at Harvard University just after he had perfected his treatment of quantum field theory.² I sat enthralled throughout the three-year series (1956–59), in which Schwinger developed QFT as a seemingly inevitable consequence of the most basic assumptions.

However, I came away with a different understanding of QFT than David's. I understood that the fields are physical properties of space that are described by field strengths—just as in classical physics, except that in QFT the state of the field at each point is represented by a vector in Hilbert space rather than by a pure number. That use of Hilbert space, which followed naturally from Schwinger's "measurement algebra," allows superpositions of values. The operators in Hilbert space, as I understood it, are mathematical tools that describe the evolution of the state vectors, and they are not to be reified.

When I saw how QFT resolves the paradoxes of modern physics, it became irresistible. The special relativity paradoxes—for example, Lorentz contraction and time dilation—are a natural result of the way fields behave.³ The spacetime curvature of general relativity, which I could never really visualize, does not exist in QFT; the gravitational field equations are equivalent to spacetime curvature for those who can visualize it, but equivalent is not the same as identical.⁴ Finally, the mysterious wave-particle duality of quantum mechanics vanishes; in QFT, reality consists of fields and only fields.