The Value of Einstein's Mistakes

Steven Weinberg's love for and knowledge of history inform his instructive sampling of Albert Einstein's mistakes (PHYSICS TODAY, November 2005, page 31). One mistake, or at least one tantalizing omission, seems worth adding to the collection. In a May 1905 letter to Conrad Habicht, Einstein wrote that he thought his revolutionary contribution was the hypothesis that light consists of particles.[1]

Consider his lifelong passion for unification, as in his resolution of the clash between Isaac Newton's mechanics and James Clerk Maxwell's electrodynamics (with the special theory of relativity modifying the former). It is hard to believe that Einstein did not worry about reconciling the well-established wave aspects of light with his new particle hypothesis. If he had pursued that connection, he could have developed one-photon quantum mechanics in 1905 or shortly afterward, by combining the Poynting-vector expression for the power intensity of light with his own relation between frequency and energy of a particle to obtain the photon-number intensity of a light beam. The wave equation is the Maxwell equations, and the probability interpretation pops up immediately.

Many observers have said that general relativity was one advance that would have taken a very long time without Einstein, but we have no direct test for that statement. However, if you accept my argument that Einstein could have developed the first true quantum mechanics, then we can say exactly how long it took the physics community to catch up—20 years for Heisenberg's matrix mechanics and Schrödinger's mathematically equivalent wave mechanics.

Reference

1. A. Einstein, *The Collected Papers of Albert Einstein*, vol. 5, English translation, Princeton U. Press, Princeton, NJ (1995), p. 20.

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As Steven Weinberg points out, it's a good thing for people to understand that even the greatest scientists make mistakes. However, I think Weinberg grossly understates the issue. Maybe his article should have been titled "Einstein's Published Mistakes."

The practice of science, as PHYSICS TODAY readers surely know, involves making mistakes, realizations, corrections, and more mistakes. Trial and error is a fundamental part of the process. I think that point deserves emphasizing. Too many of our schoolchildren learn to avoid invention and new thinking because they have been convinced that making mistakes is shameful.

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In his thoughtful and timely article, Steven Weinberg analyzes some of Einstein's mistakes and notes some others. Another fundamental conceptual mistake is hidden in Einstein's celebrated 1905 paper on relativity.

In a lengthy discussion in the first part of that paper, Einstein showed that the speed of light can be made constant by adopting a clock synchronization based on two-way light signals. With that synchronization, measurements of the one-way speed of light become logically circular, and Einstein later declared that the constancy of the speed of light was "neither *a supposition nor a hypothesis* about the physical nature of light, but a *stipulation* which I can make at my free discretion to arrive at a definition of simultaneity."[1]

However, Einstein overlooked that the validity of Newton's laws at low speeds in each reference frame permits the use of simple mechanical methods of synchronization, such as slow clock transport or sound signals. Einstein's synchronization procedure with light signals is thus superfluous—it plays no fundamental role and is merely the most convenient of several possible synchronization procedures. Furthermore, if clocks are synchronized by slow clock transport or by some other mechanical procedure, then measurements of the one-way speed of light are not logically circular, and those measurements provide an unambiguous experimental test of the constancy of this speed. In fact, clock transport has been used in such experimental tests.[2,3] Einstein should have considered the implications of alternative synchronization procedures for the conceptual foundations of relativity, and he should have recognized that the constancy of the speed of light had to be established by experiment, not by stipulation.

References

1. A. Einstein, *The Collected Papers of Albert Einstein*, vol. 6, English translation, Princeton U. Press, Princeton, NJ (1996), p. 439.
2. T. P. Krisher et al., *Phys. Rev. D* **42**, 731 (1990).
3. P. Wolf, G. Petit, *Phys. Rev. A* **56**, 4405 (1997).

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Steven Weinberg writes, "Einstein rejected the notion that the laws of physics could deal with probabilities, famously decreeing that God does not play dice with the cosmos. But history gave its verdict against Einstein—quantum mechanics went on from success to success, leaving Einstein on the sidelines."

Einstein did not reject quantum theory merely because it is probabilistic. He wrote: "There is no doubt that quantum mechanics has seized hold of a beautiful element of truth, and that it will be a test stone for any future theoretical basis."[1] Nor was Einstein unilaterally opposed to God playing dice. He expected God to either play dice all the way or not at all. If individual events were totally undetermined, then the overall events should also be undetermined, and not display remarkable regularity. "In for the penny, in for the pound," he wrote. Thus, a more accurate quote from Einstein about God and dice playing is the following:

"That the Lord should play with dice, all right; but that He should gamble according to definite rules, that is beyond me."[1]

Reference

1. A. Einstein, quoted in J. Wheeler, W. Zurek, *Quantum Theory and Measurement*, Princeton U. Press, Princeton, NJ (1983), p. 8.

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I enjoyed Steven Weinberg's article except for the not-so-subtle knock on religion at the beginning, where he refers to "other supposed paths to truth," and the subhead, "Science sets itself apart from other paths to truth by recognizing that even its greatest practitioners sometimes err." If the point of the article is to show the superiority of science over other "supposed paths," Weinberg confuses the issue by ending with the claim that Einstein "made no mistakes" in his decisions about "great public issues," including his opposition to militarism, his refusal to support the Stalinist Soviet Union, and his enthusiastic Zionism. Since none of those public issues are ones in which science alone can provide answers, how did Einstein achieve such infallible knowledge about them without relying on paths to truth other than science? With all due respect for his undoubted genius in science, I think Weinberg's hostility to religion is blinding him to errors in elementary logic.

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How unfortunate that Steven Weinberg chose to insert a criticism of religion—"other supposed paths to truth"—in his article. That Einstein was not infallible seems to have little relevance to the question of whether the prophets of various religions are infallible, and the latter question seems to have little place in a piece about Einstein.

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While I very much enjoyed Steven Weinberg's article "Einstein's Mistakes," I am puzzled by the author's statement about quantum mechanics: "The difficulty is not that quantum mechanics is probabilistic—that is something we apparently have to live with. The real difficulty is that it is also deterministic, or more precisely, that it combines a probabilistic interpretation with deterministic dynamics."

Quantum mechanics is an acausal deterministic theory in the sense that a physical system's state (mathematically described by a state vector) at a given initial time determines its state at a specified later time, but its state is not in one-to-one correspondence with sharp values of all its dynamical variables; that correspondence is probabilistic. Therefore events, identified by sharp values of those variables at one spacetime point, are not causally connected with other events. That is something we have to live with.

Why does the combination of these two attributes—acausality and determinism—constitute a special difficulty? Weinberg asks, "So where do the probabilistic rules of the Copenhagen interpretation come from?" Why do they have to come from anywhere other than from human brains? Nature exists out there, independent of human thought, but its mathematical description surely is a human construction rather than an immutable law given to us on a stone tablet.

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Einstein should be allowed his mistakes, like the rest of us, and Steven Weinberg understandably points out only the most newsworthy. I write to point out another misunderstanding—mistake, if you will—in Einstein's work only because it is often found in the literature today.

Einstein described diffusion as the motion of neutral particles on atomic (Brownian) length and time scales. He used a stochastic differential equation—a Langevin equation—in the high-friction limit to describe diffusive trajectories. Einstein did not discuss how his treatment could accommodate macroscopic boundary conditions or produce macroscopic flow, which is, after all, what Fick's law of diffusion is all about.

Langevin equations, in the spirit of Einstein's work, are widely used today to describe the motion and fluctuations of density of charged