



WHAT'S WRONG WITH THIS PILLOW?

N. David Mermin

Attitudes toward quantum mechanics differ interestingly from one generation of physicists to the next. The first generation are the founding fathers, who struggled through the welter of confusing and self-contradictory constructions to emerge with the modern theory of the atomic world and supply it with the "Copenhagen interpretation." On the whole they seem to have taken the view that while the theory is extraordinarily strange (Bohr is said to have remarked that if it didn't make you dizzy then you didn't really understand it), the strangeness arises out of some deeply ingrained but invalid modes of thought. Once these are recognized and abandoned the theory makes sense in a perfectly straightforward way. The word "irrational," which appears frequently in Bohr's early writings about the quantum theory, is almost entirely absent from his later essays.

The second generation, those who were students of the founding fathers in the early postrevolutionary period, seem firmly—at times even ferociously—committed to the position that there is really nothing peculiar about the quantum world at all. Far from making *bons mots* about dizziness, or the opposite of deep truths being deep truths, they appear to go out of their way to make quantum mechanics sound as boringly ordinary as possible.

The third generation—mine—were born a decade or so after the revolution and learned about the quantum as kids from popular books like George Gamow's. We seem to be much more relaxed about it than the

other two. Few of us brood about what it all means, any more than we worry about how to define mass or time when we use classical mechanics. In contemplative moments some of us think the theory is wonderfully strange and others think it isn't; but we don't hold these views with great passion. Most of us, in fact, feel irritated, bored or downright uncomfortable when asked to articulate what we *really* think about quantum mechanics.

I'm one of the uncomfortable ones. If I were forced to sum up in one sentence what the Copenhagen interpretation says to me, it would be "Shut up and calculate!" But I won't shut up. I would rather celebrate the strangeness of quantum theory than deny it, because I believe it still has interesting things to teach us about how certain powerful but flawed verbal and mental tools we once took for granted continue to infect our thinking in subtly hidden ways. I don't think anybody, even Bohr, has done an adequate job of extracting these lessons. From this point of view the problem with the second generation's ironfistedly soothing attitude is that by striving to make quantum mechanics appear so ordinary, so sedately practical, so benignly humdrum, they deprive us of the stimulus for exploring some very intriguing questions about the limitations in how we think and how we are capable of apprehending the world.

I would guess that an unvoiced reason for such efforts to render quantum mechanics uninterestingly bland is the desire to counter the kind of dumb postquantum anti-intellectualism that says that even the physicists now know that everything is uncertain, leading to the disastrous corollary: Anything goes. It is indeed important to emphasize to those who would go from quantum mechanics to know-nothingism that the quantum theory, far from filling us with paralyzing (or liberating) uncertainty,

now permits us to make the most accurate quantitative calculations in the history of science. We must certainly speak up against "the general antirationalist atmosphere which has become a major menace of our time, and which to combat is the duty of every thinker who cares for the traditions of our civilization."

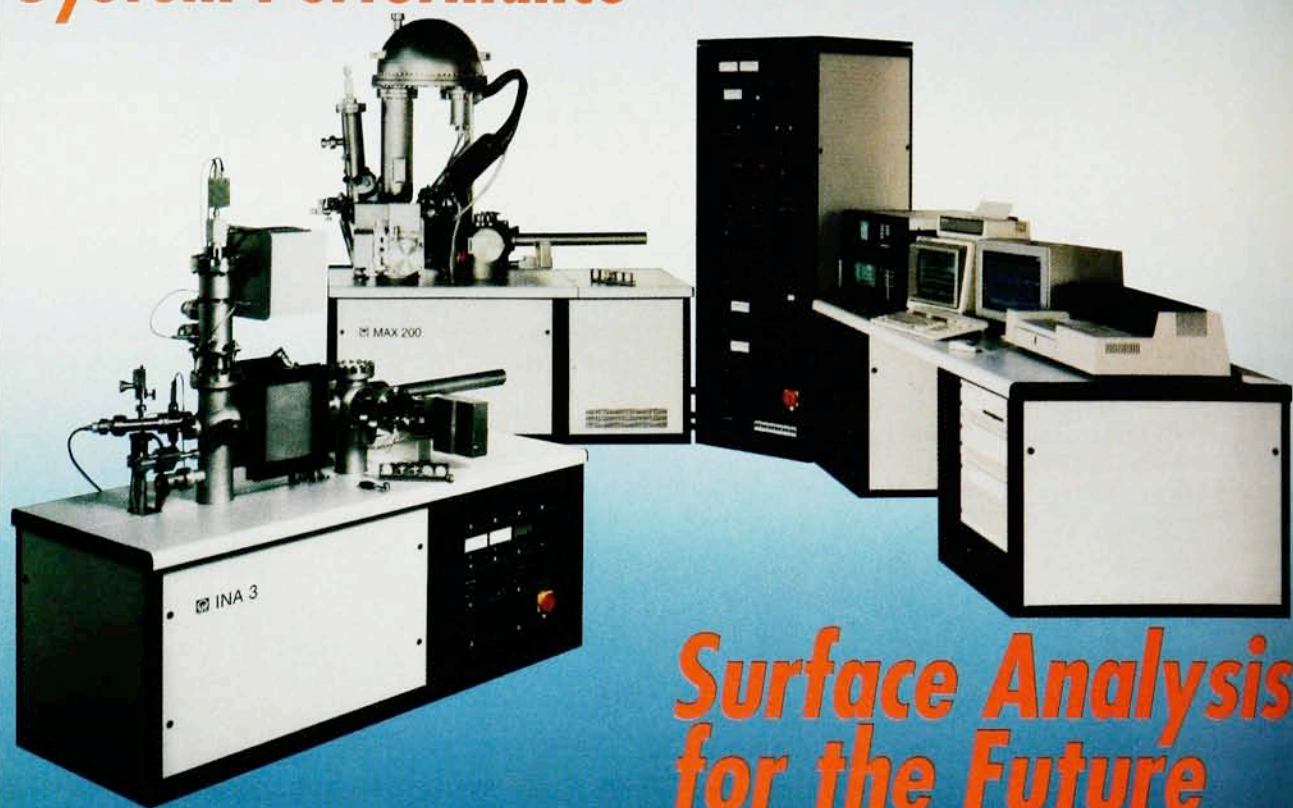
On the other hand it's important in combat to shoot at the right target. The above quotation is from Karl Popper and is directed against the writings of Heisenberg and Bohr. Physicists in the second generation certainly have a much better sense of where to direct their fire; but in sanitizing the quantum theory to the point that nothing remarkable sticks out above the surface you run the risk that if you go inside and look around you won't find anything left to make it hang together anymore.

Thus although it is a fact about the quantum theory of paramount importance that it permits us to calculate measurable quantities with unprecedented precision, it does not follow from this that statements that the quantum theory is not deterministic but acausal are vast exaggerations—that the theory has little to do with whether or not nature is a game of probability. Yet it has been argued in this context¹ that even radioactive decay—the very paradigm of acausal discontinuous quantum behavior—appears as probabilistic and abrupt only when an inappropriate question is asked: If a particle is in a state of very well-defined energy, then it is inappropriate to ask for the exact time of its decay, and the answer is probabilistic only because the question is not appropriate to the experimental situation.

Now to be sure I can, at least in principle, produce at noon a particle that will decay as the clock is striking midnight, provided I make it in some tricky superposition of energy eigenstates for which asking when the particle decays is the appropriate

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question. But that does not mean that the acausality and discontinuity I associate with the beta decay of a free neutron are somehow my fault, stemming from my having asked the wrong question. The argument that the decay is causal and smooth relies on the fact that the quantum state—which incorporates all there is to know about the neutron—changes continuously, without any jumps, and indeed deterministically, according to Schrödinger's equation. That's fine. Nevertheless, if I put the neutron into a spherical cavity lined with counters, there will be a rather well-defined "ping!" at a rather well-defined but unpredictable moment. "All there is to know about the neutron" may well be evolving continuously and deterministically, but that little guy in the cavity goes off discontinuously and probabilistically.

Something interestingly puzzling gets lost by insisting that we are confronted with discontinuity and probability only when we ask a foolish question. The puzzle has to do with the nature of the quantum state, and whether it should be viewed as describing the system, or as describing our knowledge of the system, or as some combination of both, or as none of the above because the quantum state is actually nothing more than an ingredient in a mathematical algorithm for computing the results of a well-defined experiment. Using the continuous and deterministic evolution of the quantum state to argue against discontinuity and indeterminism in the atomic world makes more or less sense depending on which of these positions you adopt. If indeed it is nothing more than "all there is to know about the system" that changes continuously and deterministically, then this says nothing about whether the world itself can change discontinuously and probabilistically, unless one takes the position that physics is not about the world but only about "all there is to know" about the world, to which I would say: "Ping! Thus do I refute you."

If, however, the state describes the system and not just our knowledge of the system, then I somehow have to think of a neutron as continuously and deterministically leaking electron, albeit in a six-dimensional configuration space (nine, if you count the antineutrino too). This introduces continuity and determinism. But the "ping!" is still there, now being induced by the interaction with the surrounding counters. Are the counters asking the wrong question?

Another thing frequently declared by members of the second generation

to be resolved by refraining from asking foolish questions is the puzzlement engendered in some by contemplating the Einstein-Podolsky-Rosen experiment.² Usually what is offered in support of this claim is the observation that there is nothing mysterious in the measurement of the spin of one particle being correlated with the probability distribution of the spin of the other, even if the two are far apart, since the two particles originate from a common source. Nobody would quarrel with that, but what many people find mysterious is not the existence of such correlations but their particular character, which turns out to be utterly inconsistent with some extremely simple and apparently very reasonable ideas about the kinds of correlations it is possible to have between far-apart noninteracting systems exclusively as the result of their having once been together in the same place. It may well be that to ask for any explanation of this "unreasonable" character of the correlations is to ask a foolish question. But the question cannot fairly be dismissed as foolish without saying what it is and making explicit the simple and apparently reasonable ideas that have to be thrown out with it.

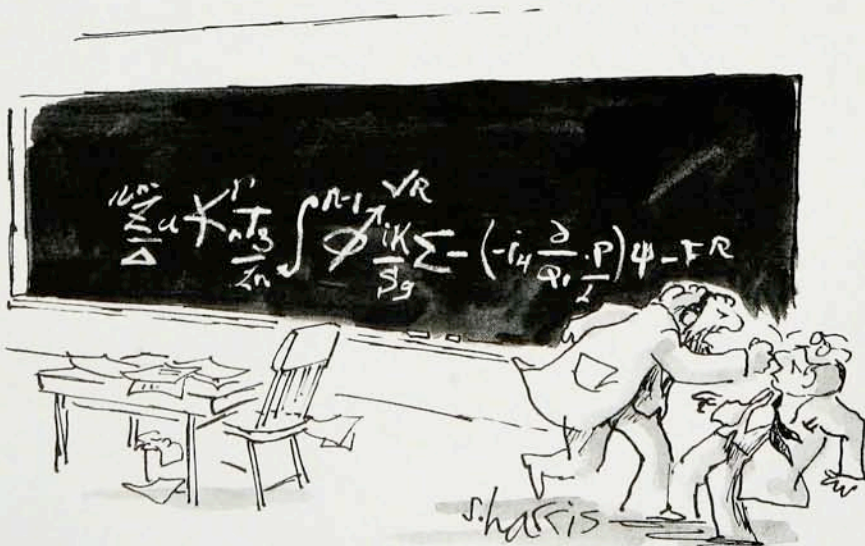
My own view of EPR, which keeps changing—I offer this month's version—is that barring some unexpected and entirely revolutionary new developments, it is indeed a foolish question to demand an explanation for the correlations beyond that offered by the quantum theory. This explanation states that they are the

way they are because that's what the calculation gives. Some explanations may sound more profound than this—saying, for example, that the correlations are a simple consequence of angular momentum conservation—but that is only because they go into a little more detail about what goes into the calculation. There is, however, an interesting nonfoolish question: Why do many knowledgeable and thoughtful people feel so strongly impelled to ask the foolish one?

My current version of the answer, not very well developed, is that it has something to do with certain deterministic presuppositions that are built into our thought and language at some deep and not very accessible level, and that have somehow infected even the way we think about probability distributions. Being of this frame of mind, I am therefore unwilling to be told both that the importance of indeterminism in quantum mechanics has been grossly exaggerated and that there is nothing peculiar about the EPR correlations. Einstein once wrote to Schrödinger that "the Heisenberg-Bohr tranquilizing philosophy—or religion?—is so delicately contrived that, for the time being, it provides a gentle pillow for the true believer." When I rest my head on a quantum pillow I would like it to be fat and firm; the recently available pillows have been a little too lumpy to soothe me back to sleep.

References

1. H. Feshbach, V. F. Weisskopf, *PHYSICS TODAY*, October 1988, p. 9.
2. See, for example, reference 1 or F. Rohrlich, *Science* **221**, 1251 (1983). ■



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