

LETTERS TO THE EDITOR

Letters are selected for their expected interest for our readers. Some letters are sent to reviewers for advice; some are accepted or declined by the editor without review. Letters must be brief and may be edited, subject to the author's approval of significant changes. Although some comments on published articles and notes may be appropriate as letters, most such comments are reviewed according to a special procedure and appear, if accepted, in the Notes and Discussions section. (See the "Statement of Editorial Policy" at <http://www.kzoo.edu/ajp/docs/edpolicy.html>.) Running controversies among letter writers will not be published.

THE REAL SCANDAL OF QUANTUM MECHANICS

The *real* scandal of quantum mechanics is that so many physicists still insist on thinking about quantum phenomena with classical ideas. Hobson¹ advised us that the universe "is made of" quantized fields, preferring that to "manifestations of a wave function," used by Kampen² in his letter. The wave function is merely an intellectual tool used by physicists, and the notion that anything is "manifestations of wave functions" is just as incorrect as the notion that electrons are particles. The trouble with the terms "particle" and "wave function" is that each of these has a well-defined meaning, and experiment shows that nothing is made of either of them. In contrast, Hobson's "quantized field" has no meaning at all and hence is invulnerable to criticism. But, Hobson claimed that he has found what the universe "is made of!"

It seems that almost everyone feels that the universe must be "made of" *something* and wants to know *what*. Another outstanding example of this urge of the human mind is the paper³ by President Bush's OSTP Director, John H. Marburger III, which I have referenced in my essay,⁴ "The mental universe." It is fine how marvelously Marburger disposes of both "waves" and "particles."

"The wave is not in the underlying stuff, it is in the spatial pattern of detector clicks. We do not—cannot—measure waves in the underlying stuff. We can only measure detector clicks. But when we hear the click we

say "there's an electron!" We cannot help but think of the clicks as caused by little localized pieces of stuff that we might as well call particles. This is where the particle language comes from. It does not come from the underlying stuff, but from our psychological predisposition to associate localized phenomena with particles."

Excellent! However, you will have noticed that, just like Hobson, Marburger demanded that the universe be "made of" *something*: in Marburger's case, "underlying stuff." (I was present for Jack's talk, and he even pronounced it as German "Stoff.") But, we are also quite aware that Marburger did *not* advise President Bush to institute a National Science Foundation program to characterize the "underlying stuff" even though this is supposed to be fundamentally what the universe is made of!

Sorry folks—*stuff and nonsense!* We know for a fact that the universe is not "made of" anything. Get it through your heads, physicists! It is sometimes said that the only thing that is real are the observations, but even *that* is not true: observations are not real either. They, and everything else, are purely mental.

You *are making* observations *right now*. But let us get more sophisticated about it and carefully make some observations of a certain kind. We find in certain selected circumstances that we typically *only* measure values $\hbar/2$ and \hbar . We understand these results completely since we have quantum mechanics! It is true that we also have in our minds the notion of a three-

dimensional object or "thing," and that we know from quantum mechanics that any such *thing*, should it exist, cannot⁵ have spin angular momentum less than \hbar , so we know *for sure* that our observations of *half* of that value cannot possibly be of things. And, while the observed values that are \hbar in principle could be of "things" (photons totally flattened in the direction of motion by special relativity), Occam's razor tells us that, since such a notion adds nothing, and is *ruled out* for our *other observations* (the $\hbar/2$ measurements), we should not even consider the notion, which is valueless or rather worse than valueless.

Now, let us make some more observations, but in a different way. We find now that we often get values 9.1×10^{-28} g. Again, because we have quantum mechanics, we are quite justifiably certain that we are observing one eigenvalue of some operator. In fact, the current central task of physics is to find that operator! It is curious that the job is completely done for angular momentum but is *not yet* done for mass energy.

Why have we made *these two particular* sets of observations and not others? It is because Emmy Noether taught us that symmetries lead to conservation laws, and our universe (the set of all of our observations—hey, THAT is all we know about the universe) turns out to have various symmetries (for unknown reasons) that result in conserved quantities.

It is no fun to make measurements of quantities that are *not* conserved because they are evanescent. But it seems to be very dangerous to make observations of quantities that *are* conserved

because they stay the same, and so they start us thinking, again, about “things” (which by definition also stay the same).

Gröblacher *et al.*⁶ put the final end to reality: I quote the first and final sentences of their abstract: “Most working scientists hold fast to the concept of ‘realism’—a viewpoint according to which an external reality exists independent of observations.” How true! But, then... “Our result suggests that giving up the concept of locality is not sufficient to be consistent with quantum experiments, unless certain intuitive features of realism are abandoned.” Aspect⁷ captured this as “... it implies renouncing the kind of realism I would have liked.” *Finis!*

Let us review all of our candidates for “what the universe is made of:”

“Particle, wave, and wave function” are wrong by experiment.

“Quantized fields and underlying stuff” are wrong simply because they are meaningless.

“Mental” is correct, which you verify with complete certainty automatically through the very process of thinking about it.

RESPONSE TO “THE REAL SCANDAL OF QUANTUM MECHANICS,” BY RICHARD CONN HENRY [AM. J. PHYS. 77 (10), 869–870 (2009)]

It is remarkable what interpretive extremes physicists will go to in order to make sense of quantum physics. But, as Van Kampen and I argue in our letters, quantum physics needs no interpretation. Once one views electrons, photons, and so forth as fields rather than particles, the pieces fall into place. Those quantum pieces include some surprising and nonintuitive concepts such as uncertainty, nonlocality, and cats that can (in idealized thought experiments) be simultaneously alive and dead, but these are not inconsistencies that need to be rectified by a Copenhagen, many worlds, hidden variables, mental, or mystical interpretation; they are simply phenomena that physicists need to get used to.

If, as Henry asserts, observations and everything else are “purely mental” and “not real,” then this desk I am sitting at is not real. Henry apparently takes David Mermin’s question “Is the moon there when nobody looks?”¹ quite seriously, and answers, “No, and furthermore it is not there even when you do look.” Such a view reduces to its ultimate absurdity the notion that quantum physics needs an interpretation.

Eugene Wigner’s interpretation of quantum physics invokes mental phenomena in a way that is similar to, but less extreme than, Henry’s interpretation. Wigner argued 50 years ago that the consistency of quantum physics requires human consciousness to ultimately “collapse the wave packet,” i.e., to select one from the many possible outcomes of an unpredictable microscopic experiment. A recent book by Rosenblum and Kuttner touts this view.² But do wave packets then not collapse on planetary systems where there are no humans? Can a low-IQ

human collapse a wave packet? Can a monkey, or a cat, do it? Decoherence theory explains perfectly well how wave packets are collapsed by the interaction of quantum fields (wave functions) with macroscopic systems.

With great confidence but no stated justification, Henry makes assertions such as “quantized fields have no meaning at all,...the wave function is merely an intellectual tool used by physicists,...we know for a fact that the universe is not made of anything,” and “observations are not real” but “are purely mental.”

As Faraday, Maxwell, Einstein, and most physicists who have thought about it, knew, spatially continuous fields such as the electromagnetic field are physically real. If not, then electromagnetic radiation violates conservation of energy. Furthermore, the quantized electromagnetic field is an elementary variation on the classical field: the energy of the quantized field does not vary over a continuous range but must instead be a whole-number multiple of hf (plus the vacuum energy). Thus a quantized electromagnetic field is continuous in space and time but comes in discrete bundles having energy hf , $2hf$, etc. Such a bundle is called a “field quantum.” It is not a difficult concept. For an authoritative nontechnical discussion of photons and material particles as field quanta, see Robert Mills’ *Space, Time and Quanta*.³

Henry asserts that “the wave function is merely an intellectual tool used by physicists.” But the wave function for an electron is the nonrelativistic limit of a real physical entity, the quantized electron-positron field. As stated by Weinberg and quoted in my previous letter, such “quantum fields are the basic ingredients of the universe.” The views of Weinberg and Mills surely deserve more than Henry’s quick brush off.

Henry quotes the paper of Gröblacher *et al.*, and Aspect’s response to it, as though this ended all discussion and proved the nonreality of every-

¹A. Hobson, “Response to ‘Comment on The scandal of quantum mechanics [Am. J. Phys. 76, 989–990 (2008)],” Am. J. Phys. 77, 293 (2009).

²N. G. van Kampen, “The scandal of quantum mechanics,” Am. J. Phys. 76, 989–990 (2008).

³J. Marburger, “On the Copenhagen interpretation of quantum mechanics,” in *Symposium on The Copenhagen Interpretation: Science and History on Stage*, National Museum of Natural History of the Smithsonian Institution, 2 March (2002); Marburger’s excellent paper is no longer available at the OSTP website, so I made it available at <<http://henry.pha.jhu.edu/Marburger.pdf>>.

⁴R. C. Henry, “The mental universe,” Nature (London) 436, 29 (2005).

⁵R. Shankar, *Principles of Quantum Mechanics*. 2nd ed. (Plenum, New York, 1994), p. 324.

⁶S. Gröblacher *et al.*, “An experimental test of non-local realism,” Nature (London) 446, 871 (2007).

⁷A. Aspect, “To be or not to be local,” Nature (London) 446, 866 (2007).

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thing. But the paper of Groeblacher *et al.* is full of reservations and claims to only “suggest” that “giving up the concept of locality is not sufficient...unless certain intuitive features of realism are abandoned.” And Aspect’s comment on the paper of Groeblacher *et al.* is that “they conclude by questioning realism rather than locality.... Interesting as this conclusion is, it remains a matter of personal preference not of logical deduction.”

I agree with Henry that the universe is not made of things. But that does not mean it is mental; in fact, it is made of real quantum fields. In an argument similar to Henry’s point about spin $\frac{1}{2}$, Redhead⁴ used the physical reality of vacuum fields to make precisely this point, namely, that any consistent view of quantum physics must be a field, not a particle, view. Fields are not things and fields are not made of things. It is the other way around: things are made of fields.

¹N. D. Mermin, “Is the moon there when nobody looks? Reality and the quantum theory,” *Phys. Today* **38**, 38–47 (April 1985).

²B. Rosenblum and F. Kuttner, *Quantum Enigma: Physics Encounters Consciousness* (Oxford U.P., Oxford, 2006).

³R. Mills, *Space, Time and Quanta* (W. H. Freeman, New York, 1994), Chap. 16.

⁴M. Redhead, in *Philosophical Foundations of Quantum Field Theory*, edited by B. H. R. Brown and R. Harre (Oxford U.P., Oxford, 1988), pp. 9–23.

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If you would like to see my *reaction* to Art Hobson's various comments, please scroll down to the next page!

Added note: if you happen to like my response to Art's third paragraph (see below), then you will also like the following quote from Chapter XIII of Arthur Stanley Eddington's book, "The Nature of the Physical Universe:"

"The mind-stuff is not spread in space and time; these are part of the cyclic scheme ultimately derived out of it. But we must presume that in some other way or aspect it can be differentiated into parts. Only here and there does it rise to the level of consciousness, but from such islands proceeds all knowledge."

Below are my reactions to Professor Hobson's reply to my letter.
(For ease of following just who is speaking, I have put his reply in italics.)

1) It is remarkable what interpretive extremes physicists will go to in order to make sense of quantum physics. But, as Van Kampen and I argue in our letters, quantum physics needs no interpretation. Once one views electrons, photons, and so forth as fields rather than particles, the pieces fall into place. Those quantum pieces include some surprising and nonintuitive concepts such as uncertainty, nonlocality, and cats that can in idealized thought experiments be simultaneously alive and dead, but these are not inconsistencies that need to be rectified by a Copenhagen, many worlds, hidden variables, mental, or mystical interpretation; they are simply phenomena that physicists need to get used to.

The above paragraph has nothing to do with anything that is in my letter. Indeed, the "surprising and nonintuitive concepts" need no rectification from an interpretation, and I did not suggest that they did, nor did I suggest that the universe (i.e., the observations) being mental does "rectify" that. But the weirdness is not rectified by viewing electrons as fields, it is rectified by discovering that if observations have the character of numbers, and if simple symmetries (time translation, for example) apply, then quantum mechanics emerges immediately, weirdness and all. See, for example, my paper "Quantum Mechanics Made Transparent," AJP 58, 1087, 1990, or see M. Shapiro, 2008, J. Phys. A: Math. Theor. 41: 175303. Quantum mechanics is not even slightly mysterious—it is our existence that is mysterious, as is the fact that we find ourselves making observations.

2) If, as Henry asserts, observations and everything else are "purely mental" and "not real," then this desk I am sitting at is not real. Henry apparently takes David Mermin's question "Is the moon there when nobody looks?" quite seriously, and answers, "No, and furthermore it is not there even when you do look." Such a view reduces to its ultimate absurdity the notion that quantum physics needs an interpretation.

The question is not absurdity, it is correctness. Unless quantum mechanics is wrong (as, for example, Anthony Leggett believes to be the case), my claim is correct.

3) Eugene Wigner's interpretation of quantum physics invokes mental phenomena in a way that is similar to, but less extreme than, Henry's interpretation. Wigner argued 50 years ago that the consistency of quantum physics requires human consciousness to ultimately "collapse the wave packet," i.e., to select one from the many possible outcomes of an unpredictable microscopic experiment. A recent book by Rosenblum and Kuttner touts this view. But do wave packets then not collapse on planetary systems where there are no humans? Can a low-IQ human collapse a wave packet? Can a monkey, or a cat, do it? Decoherence theory explains perfectly well how wave packets are collapsed by the interaction of quantum fields (wave functions) with macroscopic systems.

I am pleased to be in the company of Wigner, and I am pleased to endorse the book by Rosenblum and Kuttner who at least are moving gingerly in the right direction! As for the second half of the paragraph, the answer of physics is there are no real monkeys or cats or other humans—the entire universe exists only in YOUR mind. If you choose not to believe that (and I so choose) a leap of faith is required, that other people's minds (not bodies) really exist, as your own mind unquestionably exists. (It is one more simple step to belief in God, a step which to my astonishment I took in 2004). As for so-called decoherence theory, it explains nothing at all (and in particular, cannot even pretend to explain Renninger-type experiments, in which the wave function is collapsed simply by a human mind seeing nothing).

4) With great confidence but no stated justification, Henry makes assertions such as "quantized fields have no meaning at all, ... the wave function is merely an intellectual tool used by physicists... we know for a fact that the universe is not made of anything." And "observations are not real" but "are purely mental."

I am pleased that I had available Marburger's "underlying stuff" to partner with Hobson's (and Weinberg's) "quantized fields." The latter does sound so *scientific*! But "fields" is simply recognition of four dimensionality in the observations, and "quantized" is simply recognition that quantum mechanics prevails (which is hardly saying anything at all—see my response, above, to Art's first paragraph). And yet this is what the universe "is made of?" Please!

5) *As Faraday, Maxwell, Einstein, and most physicists who have thought about it, knew, spatially continuous fields such as the electromagnetic field are physically real. If not, then electromagnetic radiation violates conservation of energy. Furthermore, the quantized electromagnetic field is an elementary variation on the classical field: the energy of the quantized field does not vary over a continuous range but must instead be a whole-number multiple of hf plus the vacuum energy. Thus a quantized electromagnetic field is continuous in space and time but comes in discrete bundles having energy hf , $2hf$, etc. Such a bundle is called a “field quantum.” It is not a difficult concept. For an authoritative nontechnical discussion of photons and material particles as field quanta, see Robert Mills’ Space, Time and Quanta.*

It is risible to see the views of Faraday and Maxwell invoked ex cathedra on fundamental questions so long after the complete transformation of all of physics caused by the discovery of quantum mechanics. As for Einstein, J. Robert Oppenheimer said, after discussing these things with Einstein, “Einstein is cuckoo!”

6) *Henry asserts that “the wavefunction is merely an intellectual tool used by physicists.” But the wavefunction for an electron is the nonrelativistic limit of a real physical entity, the quantized electron-positron field. As stated by Weinberg and quoted in my previous letter, such “quantum fields are the basic ingredients of the universe.” The views of Weinberg and Mills surely deserve more than Henry’s quick brushoff.*

The basic ingredients going into the writing of modern papers on theoretical physics are quantum fields. The basic ingredients of the universe are mind and observations. Theoretical physics is a purely mental phenomenon. Papers on theoretical physics are observations that we call “papers.” (Click on “further reading,” below).

7) *Henry quotes the paper of Groeblacher et al., and Aspect’s response to it, as though this ended all discussion and proved the nonreality of every thing. But the paper of Groeblacher et al. is full of reservations and claims to only “suggest” that “giving up the concept of locality is not sufficient...unless certain intuitive features of realism are abandoned.” And Aspect’s comment on the paper of Groeblacher et al. is that “they conclude by questioning realism rather than locality.... Interesting as this conclusion is, it remains a matter of personal preference not of logical deduction.”*

Persons such as Aspect and Zeilinger are folks who (like Einstein), cannot believe that quantum mechanics can possibly be true, or, at least, cannot be complete. And they know (correctly) that there is a Nobel in *demonstrating* that. So, they do very difficult experiments. When they don’t get the result they want, they punt.

8) *I agree with Henry that the universe is not made of things. But that does not mean it is mental; in fact, it is made of real quantum fields. In an argument similar to Henry’s point about spin, Redhead used the physical reality of vacuum fields to make precisely this point, namely, that any consistent view of quantum physics must be a field, not a particle, view. Fields are not things and fields are not made of things. It is the other way ’round: things are made of fields.*

I have restored Art’s use of ’round instead of around (a change that the Editor, it seems, required)—I like Art’s version much better!

Further reading:

Alice in Physics Land