tained answers from 56 participants and believe these answers are representative of physicists working on the foundations of quantum mechanics.

Our poll began with these instructions:

> This conference has shown that there is a great disagreement concerning the interpretation of quantum mechanics and the significance of recent experiments. The only way out of this confusion seems to be a statistical one; therefore we would like to ask you for a *sincere* answer to the questions below. If you think that you are a really existing individual please put your name and signature; if you think that you are just a member of a statistical sample you do not have to.

▶ Do you believe in Einstein locality? 54% answered yes, 39% answered no and 7% had no opinion.

▶ Do you believe that recent experiments have falsified Einstein locality? 30% said yes, 57% said no and 13% were undecided.

▶ Do you believe that recent experiments have shown that there are signals faster than light? Only 5% believe this, 89% do not and 6% are undecided.

Because signals faster than light would imply closed time loops we asked the next question:

▶ If yes, do you think it will be possible to kill your grandfather? Only a few (extremists) replied "yes" to this question.

Some physicists, though not believing in action faster than light, do claim that the experiments have shown some "influence" faster than light. Let us call it "passion faster than light." Therefore we asked the following question:

▶ Do you believe that the recent experiments prove that there is an influence (passion) faster than light? 21% answered yes, 52% answered no and 27% were without a firm opinion.

We obviously were eager to know whether some of the 21% had some opinion about the nature of this passion. Hence:

▶ If yes, do you think that it will be possible to fall in love with your great-grandmother? This question (11% yes, 50% no) aimed also to create a good mood for the more serious one:

▶ Do you believe that there will ever be an interpretation of quantum mechanics as firmly established as the one we now have for classical mechanics? Here optimists prevail: 71% answered yes and only 18% answered no (despite the fact that 60 years have passed and opinions differ more than ever).

▶ Are you a realist? It is remarkable that except for one person everyone considered himself to be a realist (86%), although some found this question too ambiguous to answer (12%).

▶ Are you a solipsist (one never knows)? 80% answered firmly no, while 5%, evidently unaware how rude it is to *be* a solipsist, answered yes.

▶ Do you believe in a world outside still existing after your death? This time only one true solipsist answered no.

▶ If no, will you leave some money for your children?

▶ Is glass transparent in the dark? This was a tricky question. 64% answered yes, 9% answered no (all considering themselves to be realists) and 27% could not decide.

▶ Do you believe in some form of parapsychological phenomena or magic? It turned out that only 18% do (much below most national averages), while 27% still hesitate and 55% say no.

Only one person decided not to sign the questionnaire.

In concluding, we would like to point out that if disagreement on the fundamental issues of quantum mechanics is so large, one should be very careful in formulating opinions about various aspects of the newer theories like quantum electrodynamics or quantum chromodynamics.

* * *

One of us (Duch) would like to thank the Humboldt Foundation for sponsoring his stay in Urbino.

References

1. A. Einstein, B. Podolsky, N. Rosen, Phys. Rev. **47**, 777 (1935).
2. A. Aspect, J. Dalibard, G. Roger, Phys. Rev. Lett. **49**, 1804 (1982).

Włodzisław Duch
Max-Planck-Institut für Astrophysik
Garching, West Germany
Diederik Aerts
Vrije Universiteit Brussel
Brussels, Belgium

1/86

Quousque tandem, EPR?

Cats are said to have nine lives. The alleged "paradox" or "conundrum" of Einstein, Podolsky and Rosen seems to have still more. In its latest resurgence (PHYSICS TODAY, April 1985, page 38) there is not even any indication that it was reverentially pronounced[1,2] dead and disposable quite some time ago. What a hardy monster—or are there several?

All the EPR experiments that have been done or discussed[1–3] are based on conservation laws, a fact most writers fail to mention. For example, when a deuteron is photodisintegrated, on account of charge conservation the detection of a proton implies that a neutron

continued on page 116

continued from page 15

has been ejected, and the velocity of the latter could similarly be inferred from momentum conservation if the proton momentum had been measured too. Thus the nature and the motion of one particle are deducible[1] from measurements made on another particle. There is nothing paradoxical about such proceedings.

When the existence of conservation theorems is inadvertently or mischievously concealed, however, the way toward solipsist aberrations opens, for conservation is[4] the very root of identity. Then it becomes possible to obfuscate the permanent identity of the neutron in the above example, and to state that when the proton is detected "a spooky interaction at a distance" takes place that somehow creates the neutron at that very instant. To some, it will come as no surprise that military planners have seriously considered such delusions as being usable for the purpose of safe and superluminal communication between the Boss of Naval Enterprises and his minions under the ocean (see PHYSICS TODAY, April 1985, page 46). How a paradox industry can continue to flourish among seasoned physicists appears less hilarious to contemplate.

As a boon for true aficionados, another kind of fodder is available to keep the beast alive if solipsism should fail, namely the EPR fallacy. This is purely logical and has nothing to do with quantum physics; it consists[2] in the substitution of an "and" for an "or." By sleight of hand it can result in self-contradictory statements about noncommuting observables, but those are easily avoided by the adoption of a commonsense postulate (see D3 of reference 2).

Once the logic is straightened out in this (or an equivalent) manner, it remains[2] entirely legitimate to join Einstein, Podolsky and Rosen in their original quest for a specific meaning of the term "reality," or to discuss the topic from alternative points of view. Still, whenever in such discussions EPR inferences are envisaged for handy armchair experimenting, relentless attention must be paid to conserved quantities. They are the alpha and the omega of identification. In particular, and to return to the starting point of this letter, awareness of conservation allows one easily to see through the mystifications surrounding Bell's inequality, which in its essence states only that in a system with mutating identities more randomness will be observed than in a system subject to strict conservation.

Shall we see further, costly experiments done whose outcomes were never in doubt? Perhaps some sprightly nuclear and particle experimentalists can be found to rally in healthy protest and tell the profession in no uncertain terms that a fair lot of modern physics would be abject nonsense if there were anything paradoxical about the many, many counter techniques in common use for the identification of particles by means of conserved quantities.

References

1. E. Breitenberger, Nuovo Cimento **38**, 356 (1965). (Owing to a proofreading oversight, which I deeply regret, this reference attributes a near-solipsism to Bohr; the intended target of the remark was reference 6 of this paper.)
2. E. Breitenberger, Nucl. Phys. A **211**, 623 (1973).
3. J. F. Clauser, A. Shimony, Rep. Prog. Phys. **41**, 1881 (1978). A. Aspect, J. Dalibard, G. Roger, Phys. Rev. Lett. **49**, 1804 (1982), and references therein.
4. See also E. Breitenberger, "Identity and indistinguishability," submitted to Found. of Phys.

ERNST BREITENBERGER
Ohio University
Athens, Ohio

5/85

Heisenberg and nuclear physics

In his article "Werner Heisenberg and the beginning of nuclear physics" (November, page 60), Arthur I. Miller points out quite correctly that "the roots of Heisenberg's nuclear charge-exchange force are found in his June 1926 discovery of the exchange energy in atomic processes." He discusses these roots, the exchange force itself and "two early ramifications" of the latter: Enrico Fermi's beta-decay theory and Hideki Yukawa's meson theory. The discussions in Miller's article, as in his recent book *Imagery in Scientific Thought*, on which the article is based, are meant to support the thesis that many physicists (such as Heisenberg) were more sensitive to conceptual problems than to empirical data.

My own view on some of the matters discussed by Miller differs sharply from his. For example, I believe that the empirical discovery of the neutron was as critical to the nuclear theories of Heisenberg, Fermi and Yukawa as anything purely conceptual, just as the nonobservation of the neutrino was the main reason that Heisenberg in 1932 preferred an energy-nonconserving picture of beta decay. Similarly, it is hard to see Fermi's totally different approach to beta decay as a ramification of Heisenberg's exchange force or to imagine its acceptance on grounds other than its agreement with a large amount of empirical data. The real connections of the three theories are a little different: Yukawa's theory stemmed directly out of Fermi's and Heisenberg's, while Heisenberg tried to modify his exchange force in 1934 on the basis of Fermi's theory.

It is hardly surprising to find that two historians differ in their interpretations. However, my main point here is to draw attention to what I regard as flaws in Miller's *method*. Because of limitations of space, I will consider only the interpretation of one of Heisenberg's paragraphs, that with which Miller claims "modern nuclear physics begins." (In his book, he adds elementary-particle physics as well.)

The quotation in question is the third paragraph (except for its noncontroversial introductory sentence) of part I of Heisenberg's important three-part article "On the structure of atomic nuclei," received by the *Zeitschrift für Physik* on 7 June 1932, shortly after James Chadwick announced the discovery of the neutron. Since the matter of translation is crucial to my argument, I will quote the German version and then Miller's translation as it appears in the PHYSICS TODAY article. (The translation in Miller's book is different and it contains additional problems.) The paragraph reads:

> Bringt man Neutron und Proton in einen mit Kerndimensionen vergleichbaren Abstand, so wird—in Analogie zum H_2^+ Ion—ein Platzwechsel der negativen Ladung eintreten, dessen Frequenz durch eine Funktion $J(r)/h$ des Abstandes r der beiden Teilchen gegeben ist. Die Grösse $J(r)$ entspricht dem Austausch- oder richtiger Platzwechselintegral der Molekültheorie. Diesen Platzwechsel kann man wieder durch das Bild der Elektronen, die keinen Spin haben und den Regeln der Bosestatistik folgen, anschaulich machen. Es ist aber wohl richtiger, das Platzwechselintegral $J(r)$ als eine fundamentale Eigenschaft des Paares Neutron und Proton anzusehen, ohne es auf Elektronenbewegung reduzieren zu wollen.

This is Miller's translation:

> Suppose we bring the neutron and proton to a separation comparable to nuclear dimensions; then in analogy to the H_2^+ ion, the negative charge will undergo a migration [*Platzwechsel*], whose frequency is given by a function $J(r)/h$ of the separation r between the two particles. The quantity $J(r)$ corresponds to the exchange [*Austausch*], or more correctly, migration integral [*Platzwechselintegral*], of molecular theory. The migration can again be made more intuitive by the picture of electrons that have no spin and follow the rules of Bose statistics. But it is surely more correct to regard the migration integral $J(r)$ as a funda-