Fundamental Problems of Quantum Physics

The present special issue of Apeiron fulfills a wish expressed by Franco Selleri when he joined the editorial board just over a year ago. The plan was to solicit short essays from a number of leading theorists of quantum physics on the problem—past, present and future—of achieving a consistent, rational understanding of the microworld, and in particular, to present, in very general terms, thoughtful alternatives to the tortured vision bequeathed to physics by the Copenhagen school.

The response to our survey was not as voluminous as we had hoped, though the quality of the essays we received is quite respectable. We placed before our respondents a series of four questions touching on the very essence of the debate over the foundations of quantum mechanics: the prospects of a hidden variable model, the basic problem in quantum theory, the origins and early history of the debate and, finally, possible avenues of development. The questions read as follows:

1. *Do you think that the confrontation between existing quantum theory and the hidden variable model has been resolved once and for all by the experiments performed in the 70's and early 80's on Bell's theorem and the recent two-photon interference experiments?*
2. *What is the most important unresolved issue in quantum physics today? Please explain your choice.*
3. *Do you think that the debate currently underway concerning the nature of quantum physics has points in common with the discussions that took place at the 1927 Solvay conference or at other times in the early history of quantum theory (before 1939)?*
4. *What, in your opinion, are the most likely developments to be expected in the near future concerning the foundations of quantum physics?*

There is an important difference between people active in the foundations of quantum mechanics and those active in relativity. The latter are basically united and almost invariably convinced of the conventionality of the postulate of invariant light velocity, and of the factual existence of a privileged frame, while entertaining different ideas about the best way of develop such a point of view. The former, however, are also divided on the most fundamental issues.

First of all one should distinguish physicists who are basically pro- from physicists who are basically anti-Copenhagen. The former believe that the consistent development of the Bohr-Heisenberg point of view can still lead to important discoveries, some concluding in favour of the existence of spiritual entities, others in favour of retroaction of the future on the past. The latter (usually called "realists") believe instead that the Copenhagen philosophy was an historical mistake and that a reinterpretation/reformulation of quantum theory is needed, based on the ideas of objective reality, causality, and comprehensibility of nature to man.

The realists' outlook is far from unified, however. First of all one must distinguish local realists from nonlocal ones, the latter being convinced that existing quantum theory is fundamentally correct, and that a consistently causal but nonlocal interpretation of the theory needs only to be given in order to solve all the basic questions that have bothered physicists since the quantum paradigm was formulated in 1927. Adherents of the nonlocal view do not admit the possibility of action at a distance, which some consider implicit in the quantum mechanical violation of Bell's inequality. Rather, they believe that all physical phenomena take place through the local action of particles, waves, and fields. Some of them think that the quantum mechanical predictions for correlated particles are probably not correct and point out that they deal with a novel situation, never investigated experimentally before, that of microscopic objects separated by large macroscopic distances. There are, however, also local realists who entertain hopes of a final reconciliation of existing quantum theory with locality by means of minor modifications of the detection process.

Almost all tendencies of this varied panorama are represented in the responses we received to our questions. Yet there is a final point to keep in mind when reading them: the problem of "wave-particle duality." For realists, it is correct to make conjectures about the real nature of the quantum objects, and on this they all agree, even though the hypothesised pictures are sometimes quite different. Some believe that all quantum objects have a dual nature (particle + wave), both aspects being objectively present in every photon, electron, neutron. Others tend to accept a

classical picture in which the electromagnetic field is basically an extended structure ("wave"), while the electron and the other massive systems are only localized particles. Still others work with the Schrödinger picture, accepting only waves (but no particles) in their description of all atomic systems. Finally, there are different ideas about the role played by the physical vacuum, which is sometimes considered to actively interact with every quantum system, pushing it in a kind of endless Brownian motion. This physical vacuum is certainly a realistic conjecture, philosophically speaking, but there are still people who believe that not all existing empirical evidence is compatible with this particular type of physical action.

From the responses to our questionnaire, it would appear that there is widespread support for hidden variables, most respondents opting for the "local" flavour, as an escape from the pragmatist and positive view of the Copenhagen interpretation to a terrain upon which fundamental physical processes might possibly be understood and visualized, rather than merely predicted. While progress toward this goal may prove slow and tedious, it should open the way to detailed models of the fundamental particles, first and foremost the electron, and to a unification of quantum theory and general relativity, the two solitudes of the physical world, whose reconciliation has become something of an obsession with many practitioners.

One observation is perhaps in order: given its fundamental role in so many of the problems that beset modern physicists—the nature of vacuum fluctuations, the "noise" that contaminates the Bell inequalities, the site of the underlying stochastic processes, the source of zero-point radiation, the medium of wave transmission and, in the perspective of a unification with general relativity, the content of "space-time" itself (which should really be assimilated with the vacuum)—the notion of a plenum would appear to merit renewed consideration. Some may prefer to designate this plenum the "ether"; yet since time immemorial, in the tradition of natural philosophy, it has travelled under the name apeiron.

We regret to inform our readers of the death of Asim Barut earlier this year. His passing marks the loss of a fearless crusader for the cause of a deterministic quantum theory.

The Editors