The Future of Physics ?

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As we approach the end of the twentieth century, I believe it is healthy for physics for us to sit back and take stock as to our future directions, based on our present understanding in the field. It is the purpose of this note, then, to attempt to initiate a discussion in the physics community on these questions.

It is, of course, well known to scientists that in order to increase our comprehension of the material world, it is necessary to ask significant questions and then to try to answer them, as completely and rigorously as possible - no matter how hard this may seem to be at the outset. A *significant question*, to me, is one whose answer could possibly increase our understanding. Of course, there is no guarantee at the outset that any question might turn out to be significant in the final analysis. On the other hand, it is often clear, objectively speaking, when a question, that a great deal of attention may have been given to, is not significant ! Let me start out, then, with some questions that I believe are significant, and then try to answer them, in my view, at least as a starting point.

1) What do we presently believe are the most fundamental assertions of the laws of physics ? My answer is : The bases of the quantum theory and the theory of relativity. I am not referring here to the mathematical expressions of these theories ; I refer to the basic concepts that underlie these mathematical expressions. If you do not agree with this answer, or those to the questions below, please respond with your own views.

2) Are the quantum and relativity theories compatible with each other, in terms of their respective assertions and the ensuing mathematical expressions ? My answer is : No ! A close examination of the irreducible premises of each of these theories reveals that they are indeed both logically and mathematically incompatible, when they are ex-

pressed in their most general forms. A long treatise, or possibly a Ph.D. thesis in the philosophy of physics could be written on this subject.[1]

Briefly, examples of these logical and mathematical incompatibilities are as follows, for the "quantum theory" *versus* "the theory of relativity" :

A) The principle of complementarity *versus* the principle of relativity, implying a philosophy of pluralism *versus* monism, in their respective epistemologies.

B) Atomism, elementarity and separability of particles of matter, and a model in terms of an "open system", *versus* the continuous field concept and a model in terms of a "closed system" at the outset, holistically, i.e. in terms of the basic inseparability of the material components of a system of matter.

C) In our approach to what it is that we can truly "know" about a material system, we have the conflict of logical positivism *versus* realism - the former asserting that all that we can possibly know is what we can directly verify in measurements, the latter asserting that there is a real world, independent of whatever we may do to find out about it, and that indeed we may acquire new knowledge about the material world that is not directly verifiable in measurements, though it may be inferrable from the logical structures of our theories, if the latter also predict correctly the empirical facts.

D) Irreducible subjectivity in the role of the measuring apparatus as a fundamental ingredient in our understanding of matter *versus* full objectivity, in which the "subject" and the "object" of an interacting system are truly interchangeable in the overall description of the system, without losing its objective truths.

E) Indeterminism (all variables of matter are not "predetermined") *versus* determinism (where all variables of matter are predetermined, irrespective of what measurements may or may not be carried out).

F) Linear mathematics *versus* nonlinear mathematics, in the general, unapproximated forms of the theories.

G) A fundamental role in the laws of nature of probabilities and their calculus, *versus* the role of probabilities only as a calculational tool for the observer, but playing no fundamental role in the laws of physics.

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[1] I have discussed these incompatibilities in my recent book, *Einstein versus Bohr* (Open Court, 1988).

H) Special reference frame of the measuring apparatus *versus* no special frame of reference for any component of a closed system, whether or not one of these components is a large macroobserver and another a small bit of micromatter.

3) Has there been any real success in unifying the quantum theory and the theory of relativity (in its most general form), ever since the discovery of quantum mechanics in the 1920s ? My answer is : There has been no substantial success in this direction, essentially because of the fundamental incompatibilities discussed above. In my view, to try to fully unifly these two theories, both logically and mathematically, would be like trying to force a square peg into a round hole !

4) Is it then possible to re-express the formalism of the quantum theory with the relativity requirements fully removed ? My answer is : No. This is because the basic elements of the quantum theory, according to the underpinnings of the Copenhagen school, are *unbreakable* triads of the measurement process : emitter-signal-absorber. The problem is the following : while the emitter and absorber components of this unbreakable triad have a nonrelativistic limit in their mathematical description, i.e. one can always find a reference frame that is at rest with respect to them, the signal component of the triad does not have such a limit in its mathematical representation. This is well known in the case of the electrodynamic signal, the "photon", representing the virtual coupling in the electrodynamic interaction. But even in other types of interaction, such as the nuclear interaction, one must still be able to describe the "signal" (the virtual pions) relativistically, because of their fundamental high energy coupling with other matter. It then follows that the emitter-signal-absorber units of measurement, according to the quantum theory itself, must necessarily be represented in terms of the quantum theory subject to the symmetry requirements of the theory of relativity. When the case of special relativity is evoked (it should also be subject to the rules of general relativity, in principle) we have quantum electrodynamics, when the interaction is electromagnetic. Generally, the theory is called "Relativistic Quantum Field Theory" (RQFF) for any type of interaction.

The well known trouble with RQFT is that when the formal expression of this theory is examined for its solutions, it is found that it does not have any ! This is because of infinities that are automatically generated in this formulation. After this failure of the quantum theory was discovered, renormalization computational techniques were invented that provide a recipe for subtracting away the infinities, thereby generating finite predictions - some which had amazing empirical success. But the trouble is that a) such a scheme is not demonstrably mathematically consistent (implying that, in principle, any number of predictions could come from the same physical situations, even though one of them is empirically correct) and b) there remains the problem that there is still no closed form for the theory and no demonstrable finite solutions. Thus, if nonrelativistic quantum mechanics is supposed to be not more than an approximation for RQFT, and if the latter does not exist as a mathematically or logically consistent theory, then we still do not have the right to claim the scientific truth of the bases of nonrelativistic quantum mechanics - fundamental uncertainty, probability in the laws of matter, linearity, "open system", mathematical representation with a Hilbert space, etc. **It is important to know that the empirical agreement with the predictions of a scientific theory, while being necessary for the truth of that theory, is not sufficient to establish its truth**. To be a scientifically true theory, its expression must also be both logically and mathematically consistent. Unfortunately, RQFT is neither, at the present stage of physics. On this subject, one of the founders of RQFT, Paul Dirac, made the following remarks, toward the end of his life : [2]

It seems clear that the present quantum mechanics is not in its final form. Some further changes will be needed, just about as drastic as the changes made in passing from Bohr's orbit theory to quantum mechanics. Some day, a new quantum mechanics, a relativistic one, will be discovered, in which we will not have these infinities occurring at all. It might very well be that the new quantum mechanics will have determinism in the way that Einstein wanted. This determinism will be introduced only at the expense of abandoning some other preconceptions that physicists now hold. So, under these conditions I think it is very likely, or at any rate quite possible, that in the long run Einstein will turn out to be correct, even though for the time being physicists have to accept the Bohr probability interpretation, especially if they have examinations in front of them.

An obvious alternative approach that might get us out of this dilemma, possibly alluded to in Dirac's remarks above, is the following : Start at the outset with a theory based fully on the premises and

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[2] P.A.M. Dirac, "The Early Years of Relativity", in G. Holton and Y. Elkana, editors, Albert Einstein - Historical and Cultural Perspectives (Princeton, 1982), p. 85.

the ensuing mathematical expression of the theory of general relativity (i.e. curved spacetime, field concept, determinism, closed system, etc. - implying a nonlocal, nonlinear field theory), yet a theory in which a part of the generally covariant formalism reduces to the formal probability calculus of quantum mechanics, as a linear approximation for a nonlinear, nonlocal field theory of matter, according to general relativity. If this could be shown, rigorously, it would mean that we must abandon the assertions of the Copenhagen school approach to quantum mechanics (as well as various other off-shoots, such as the hidden variable theories). In this case, the linear, nonrelativistic *approximation* for this relativistic, nonlocal, nonlinear, deterministic (non-hidden variable) field theory of matter would be, precisely, the formal probability calculus that is the Hilbert space expression of nonrelativistic quantum mechanics. This would be entirely analogous to what happened to the paradigm change in going from Newton's theory of gravity to Einstein's theory of general relativity. Newton's theory became an approximation for an entirely different theory, conceptually, yet it remains useful in this role.

I have spent the past 35 years in pursuing this field approach in general relativity on the way that quantum mechanics emerges as a mathematical approximation for an entirely different field theory of matter - a theory rooted in Einstein's theory of general relativity - both mathematically and conceptually. I have found, in this research program, that the generally covariant field theory of matter, that quantum mechanics emerges from, as a linear approximation, is a field theory of the inertia of matter. I have found that this is an essential ingredient in a unified theory because not only does general relativity imply that there must be a field unification of all of the forces of nature, representing the actions of matter on other matter, it also implies that we must include the reaction of the latter to the former, in a truly closed system. (This is consistent with the spirit of Newton's third law of motion). The incorporation of the inertia of matter in a unified field theory, as one of the field components, is a feature that Einstein and Schroedinger did not yet consider in rigorous terms, yet an ingredient that I believe is essential to complete the theory.[3]

I strongly believe that it is essential to resolve this problem of the dichotomy between the quantum and relativity theories before we can

[3] I have written two monographs that summarize my research program (until 1986) :*General Relativity and Matter* (Reidel, 1982) and *Quantum Mechanics from General Relativity* (Reidel, 1986).

make any genuine progress in physics. I believe that, if I haven't made any major mistakes, I have taken several positive steps toward this goal in my research program. Other approaches to resolve the problem, equally rigorous (both logically and mathematically) should also be considered seriously. But pretending that the problem does not exist does not help us to make real progress in physics. I believe that this is a part of Paul Dirac's legacy.

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