QUANTUM THEORY AND REALITY

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Albert Einstein ends his book The Evolution of Physics with a section entitled "Physics and Reality." In it he speaks of the "new realities" created by the advance of physics, and he states that "physical theories try to form a picture of reality." His constant use of the concept of "reality" is interesting in light of his participation in the controversy over the interpretation of quantum theory that continues to this day.

The controversy began with Werner Heisenberg's formulation of the Uncertainty Principle in 1927. Heisenberg realized the implications of his theory, and saw that it could be interpreted in two ways. The uncertainty in the measurement of an observable, for instance position, could be seen as being of either an ontological or epistemological nature. In other words, either an exact value for the position of a particle simply doesn't exist, or else it does, but the nature of human knowledge and perception is such that this exact position cannot be known to us. As quantum theory developed, these two interpretations of the Uncertainty Principle evolved into two divergent streams of thought as to the meaning of quantum theory. The first, which saw the uncertainty as ontological in nature, was followed by Neils Bohr and his co-workers and has come to be known as the Copenhagen Interpretation. The second interpretation,

which conceived of the uncertainty as being solely epistemological in nature, was espoused by Einstein and others.

Both interpretations begin with the same mathematical framework, a framework whose validity has been proven time and time again by its usefulness in predicting the results of experiments. In quantum theory, an abstract mathematical entity called a state function is set up for each situation occurring in nature. This state function can then be operated on in such a way as to produce a value for any quantity that we can observe. However, because of the nature of the mathematics involved, this value is only good as a prediction of the statistical average of many measurements. For any one measurement of one property of a single particle, the Uncertainty Principle holds, and the value of the measurement cannot be accurately predicted.

The Copenhagen Interpretation of quantum theory has its origins in the 19th century philosophy of positivism. This was the philosophy that claimed, among other things, that a tree falling in a forest, if it could not be heard, made no sound. This philosophy, as further developed by Bohr, says that it is meaningless to talk about and event or object unless it is observed. The mathematical state function describes the limits to what can be known about a particle, and when a measurement is made this state function is "collapsed", producing a definite value for

the property of the particle that is being measured.

Einstein's interpretation evolved from a so-called "realist" philosophical position. This position is characterized by the contention that physical reality would exist even if no observer existed. A positivist such as Bohr would deny that this statement has any meaning at all, saying that speaking of a physical object without also talking about the observer is impossible. Our intuition makes us want to side with Einstein, since we tend to believe that reality is independent of our experience. The realist interpretation, at least in its most common form, claims that there are "hidden variables" associated with physical systems that predetermine what the observer will measure. Unfortunately, all attempts so far to devise a workable hidden variables theory have been unsuccessful.

use a bit like "ether" theories

Thus, today we are faced with a serious dilemma when trying to interpret quantum theory. Either we throw away some of our most basic ideas about the nature of the world and accept the Copenhagen Interpretation, or else we can take the realist viewpoint with the full knowledge that no one has yet been able to come up with a complete, valid theory of this type that works. Attempts have been made to develop alternate interpretations, such as that of Prof. Hilary Putnam of Harvard who has suggested solving the problem by tinkering with the laws of logic. For instance, it may be possible to develop a self-consistent system of

logic where statements, instead of being simply true or false, can be true, false, or indeterminate.

While there still exist some problems with the Copenhagen Interpretation, during the past fifty years Einstein's realist position has become increasingly untenable. His attempt to hold on to some certainty, to maintain objective reality, seems to have been doomed to failure. Einstein expressed his feelings in his well-known quotation "God does not play dice with the world." It now appears that he was wrong.

Thoughtful and intelligent, another fine essay of the quality I have come to expect from you Peter.

Mour essay, like a good piece of writing and thinking, makes me brim with ideas. What you have to say points in two directions for me, right away. You could extend the positivist bias you detect in Einstein to suggest the motivation behind his basically "aesthetic" explanation of how he has come to understand the "evolution" of physcis, and the motive for doing scientific research. He says as much on the last two pages of the book; also in his essay Motiv des Forschens.

Had you done that the end of your essay could well have returned to E and I's book, rounding out the essay so that it stands more distinctly as a "review".

Finally, all of what you treat here is fascinating to pursue and I have done a little in that direction on my own. Gerald Holton's book Thematic Origins of Scientific Thought, Kepler to Einstein, (H.U.Press, 1973) is a good place to begin, especially ~~xkkk~~ for a man with your background. I mention it because I am convinced after reading your essay that you would find it engaging reading.

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