PHYSICS DEMYSTIFIED

BY JAMES TREFIL

Years ago, the public misunderstood relativity. Are we making the same mistake about quantum theory?

The twentieth century has not been kind to our mental equilibrium. First relativity and then quantum mechanics shook the very foundations of our thought, and it's not at all obvious that we've recovered from the shock even today. Popular understanding of physics has been corrupted by distorted ideas about relativity and by fads such as Eastern mysticism.

The twin surprises in physics came close together—Albert Einstein published his first paper on relativity in 1905, and the Danish Nobel laureate Niels Bohr gave the first quantum-mechanical description of the atom in 1912. But it was several decades before the public came to grips with relativity theory and another six decades before quantum theory made itself felt outside the scientific community.

The fact of quantum's lag in "arriving" is puzzling. But there is one tremendous advantage: We can now look back at the reception accorded relativity in the 1920s and 1930s and learn from the mistakes that were made. If we're smart, we will avoid repeating with quantum mechanics today the awful blunders we earlier committed before finally coming to terms with relativity.

The experimental confirmation of general relativity in 1919 was announced in the *New York Times*. The news catapulted Einstein into the role of an international celebrity. Quantum mechanics, on the other hand, developed far from the public eye. Even though quantum mechanics is responsible for the transistor and the microchip, which have had such a profound influence on our lives, it is only in the past decade that the full philosophical impact of quantum theory has begun to dawn on us. Unfortunately, quantum's advent has brought with it misunderstandings of a sort strongly reminiscent of those that surrounded relativity when it emerged. Most of those misapprehensions sprang from the public's mistaken notions of what the term "relativity" meant. It is still little known that Einstein fought a long and unsuccessful battle against this name for his theory. He preferred the term "theory of invariants," because he felt that it more accurately described his work. Einstein's theory may get rid of absolute Newtonian space and time, but—contrary to popular misunderstanding—relativity replaces these fixed points with another, infinitely more powerful one: the idea that the great principles of physics do not depend in any way on the state of motion of a person observing them.

Einstein's insistence that his theory was based on this firm and unmoving bedrock could not, however, prevail against the buzz words already making the intellectual circuit. In no time, the rich logic of the theory was reduced to a phrase that could be easily repeated: "Everything is relative." Commentators who understood this phrase and failed to understand that it had nothing to do with relativity vied with one another to blame everything from modern art to the prose of William Faulkner on the new ideas emanating from physics. As time went by, however, and the actual content of the theory of relativity began to be more widely understood and appreciated, this sort of thinking faded away.

Nowadays, the buzz words in quantum mechanics that seem to be attracting the same kind of attention are "uncertainty principle" and "role of the conscious observer." Both of these phrases have to do with properties of the subatomic world—properties that, while surprising at first glance, are quite reasonable once you think a little about them. In our everyday world, we are used to observing things without having our observations interfere

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Illustration by Frances Jetter

with what's going on. The fact that light bounces off a car and comes to our eyes does not affect the speed of the car in any appreciable way. This is because the energy imparted to the car by its collisions with light-waves is negligible compared with the energy of the car itself. The situation would be quite different if the only way we could detect the presence of one car was by bouncing another car off it. In this case, the act of detection would certainly affect the thing being detected.

When we shift our attention from the everyday world to the atomic world, this second situation is exactly what we find. To detect an electron we have to bounce off of it what scientists call a probe—another electron or some other particle of comparable energy. The interaction of this probe with the object being probed changes that object and this, in turn, limits the kind of knowledge we can obtain from quantum systems. We can, for example, find out exactly where the electron is, but in so doing we change the system and give up any chance of finding out how fast it is moving. This phenomenon is known as the Heisenberg uncertainty principle.

Conditions within the atomic world thus force us to describe events in ways that are different from those we are used to. Normally, if we knew that a car was in Chicago and heading east at 55 mph, we would predict that five hours or so later it would be in Pittsburgh. But if the car were an electron, all we would be able to find out was that it was in Chicago. We'd have no idea how fast or in what direction the car was moving. We would therefore have to describe its subsequent location in terms of probabilities ("It could be in Pittsburgh, it could be in Des Moines . . ."). Some locations would be more probable than others, of course—the car would be unlikely to show up in Hong Kong the next day—but the best we could do is list the probabilities for each possible final location. Such a listing of probabilities is what physicists call a wave-function description of a particle's position.

SNEAKING A PEEK

In the example of the car starting in Chicago, our ignorance about the speed of the car doesn't bother us too much, because we assume the car is *somewhere* within a given area, even if we don't know exactly where. We can always imagine, in our mind's eye, sneaking a peek to see just where the car is, and this peek would not disturb the car's motion.

With a speeding electron, however, this comforting thought isn't there. We can describe the electron in terms of probabilities, but we can't sneak a look at it *without changing the system*. Thus, the fact that we can't observe an electron without changing it necessarily leads us to a probabilistic description of events on the atomic scale. It was this situation that led Einstein to make his famous comment: "I shall never believe that God plays at dice with the world." I only wish Niels Bohr's rejoinder—"Albert, stop telling God what to do!"—was as widely known.

The important point about the introduction of probability into quantum mechanics is that it arises because of the *interactions* of particles at the atomic level. Physicists understand that it is necessary that such interactions take place in order for us to measure, or observe, the behavior of a particle. Hence, they tend to use the words *interaction* and *observation* interchangeably.

This usage, while understandable, has had the same sort of negative consequences that the term *relativity* had in the earlier part of this century. The problem is that the word *observe* implies the presence of an observer, and this in turn implies the presence of consciousness. From the simple fact that interactions at the atomic level change the interacting systems, then, the leap is made to the idea that the existence of the elementary particles somehow depends on the complementary existence of a consciousness responsible for the observations. This conclusion no more follows from the argument than "everything is relative" follows from Einstein's work.

> Is there any validity to the notion that Western science, to succeed, is being forced to turn to Eastern mystics for help?

The result of the misunderstanding is that a new sort of mysticism is making the rounds today, claiming to be based on quantum mechanics. It takes its extreme form in the argument that the kind of linear, rational, right-brain sort of thought that brought Western science to its present eminence is no longer possible and that we must now turn to Eastern mystics for guidance. Instead of viewing the world in the traditional way, we should see it as a sort of interconnected web. Fritjof Capra's *The Tao of Physics* is a good example of this point of view, and its popularity is testimony to the appeal the idea has.

Unfortunately, like the popular ideas surrounding relativity in the 1920s, the new mysticism is wrong and for roughly the same reasons. The spectacular recent advances in the development of unified field theories show unequivocally that rationality has not yet reached its limits in modern science.

SUBATOMIC LAWS

We have no trouble using the science of quantum mechanics to predict the behavior of subatomic particles with extremely high precision, nor do we have difficulty using it to develop new products, which are in the process of reshaping our society. Physicists have learned to deal with the atomic world on its own terms—to recognize that whenever a measurement is made, the system will be changed. They have, in other words, learned that quantum systems are unlike those in our everyday experience. But they have also learned that this property has to do with the subatomic particles themselves, not with the consciousness of the people doing the experiment.

I hasten to add that I am not arguing that there are no philosophical problems associated with quantum mechanics. The theory presents us, in fact, with the very old problem of whether knowledge can exist without a consciousness that does the knowing. The most famous version of this problem is the old "If-a-tree-fell-in-the-forest-when-no-one-was-there-would-there-be-a-sound?" dilemma so dear to first-year philosophy students. This problem has existed since the Greeks without, as far as I can tell, any appreciable progress being made toward a solution.

In quantum mechanics we are presented with the problem in a particularly difficult form: What the uncertainty principle tells us is that the falling trees are located in a forest where we cannot go, even in theory. But this is a difference in degree, not in kind, from the traditional problem. The advent of quantum mechanics sheds no new light on this old problem, but it doesn't make the difficulty any worse.

This does not mean that there is nothing whatsoever new or revolutionary in quantum mechanics. Certainly there is a profound difference between describing a car in terms of easily visualized quantities like position and velocity and describing an electron in terms of a wave function. Understanding the reason that this is so doesn't affect the strangeness of the new science. But our reaction to this description tells us more about ourselves than it tells us about the atomic world. What we are really saying is that it's hard to visualize what an electron must be like because there is nothing in our experience to give us any guidance. What quantum mechanics is telling us, then, is nothing more or less profound than this: An electron isn't like a car. ■