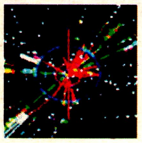
Can We Really Understand Matter?



By EUGENE LINDEN

Few tasks are more daunting than standing in the path of a charging theoretical physicist who is hell-bent on getting funding for the next particle accelerator. As practitioners of the hardest of the hard sciences, physicists do little to discourage their aura of intellectual supremacy, particularly when suggesting to Congress that a grand synthesis of all the forces of nature is at hand if the Government will only cough up a few billion dollars more. But what if this confidence is misplaced? What if the barriers to knowledge are higher than many physicists like to admit?

ILLUSTRATION FOR TIME BY PETER SIS

For much of this century, scientists have known that the comfortable solidity of things begins to break down at the subatomic level. Like the Hindu veil of Maya, the palette from which nature paints atoms proves illusory when approached. From afar, this world appears neatly separated into waves and particles, but close scrutiny reveals indescribable objects that have characteristics of both.

Physicists have prospered in this quirky realm, but neither physics nor the rest of science has fully digested its implications. Inside the atom is a world of perpetual uncertainty in which particle behavior can be expressed only as a set of probabilities, and reality exists only in the eyes of the observer. Though the recognition of this uncertainty grew in part out of Albert Einstein's work, the idea bothered him immensely. "God does not play dice with the universe," he remarked.

The set of mathematical tools developed to explore the subatomic world is called quantum mechanics. The theory works amazingly well in predicting the behavior of quarks, leptons and the like, but it defies common sense, and its equations imply the existence of phenomena that seem impossible. For instance, under special circumstances, quantum theory predicts that a change in an object in one place can instantly produce a change in a related object somewhere else—even on the other side of the universe.

Over the years, this seeming paradox has been stated in various ways, but its most familiar form involves the behavior of photons, the basic units of light. When two photons are emitted by a particular light source and given a certain polarization (which can be thought of as a type of orientation), quantum theory holds that the two photons will always share that orientation. But what if an observer altered the polarization of one photon once it was in flight? In theory, that event would also instantaneously change the polarization of the other photon, even if it was light-years away. The very idea violates ordinary logic and strains the traditional laws of physics.

The two-photon puzzle was nothing more than a matter of speculation until 1964, when an Irish theoretical physicist named John Stewart Bell restated the problem as a simple mathematical proposition. A young physicist named John Clauser came upon Bell's theorem and realized that it opened the door to testing the two-photon problem in an experiment. Like Einstein, Clauser was bothered by the seemingly absurd implications of quantum mechanics. Says Clauser, now a research physicist at the University of California, Berkeley: "I had an opportunity to devise a test and see whether nature would choose quantum mechanics or reality as we know it." In his experiment, Clauser, assisted by Stuart Freedman, found a way of firing photons in opposite directions and selectively changing their polarization.

The outcome was clear: a change in one photon did alter the polarization of the other. In other words, nature chose quantum mechanics, showing that the two related photons could not be considered separate objects, but rather remained connected in some mysterious way. This experiment, argues physicist Henry Stapp of Lawrence Berkeley Laboratories, imposes new limits on what can be established about the nature of matter by proving that experiments can be influenced by events elsewhere in the universe.

Clauser's work pointed out once again that the rules of quantum mechanics do not mesh well with the laws of Newton and Einstein. But most physicists do not see the apparent disparity to be a major practical problem. Classical laws work perfectly well in explaining phenomena in the visible world—the motion of a planet or the trajectory of a curveball—and quantum theory does just as well when restricted to describing subatomic events like the flight of an electron.

Yet a small band of physicists, including Clauser and Stapp, are disturbed by their profession's priorities, believing that the anomalies of quantum theory deserve much more investigation. Instead of chasing ever smaller particles with ever larger accelerators, some of these critics assert, physics should be moving in the opposite direction. Specifically, science needs to find out whether the elusiveness of the quantum world applies to objects larger than subatomic particles.

No one worries about the relevance of quantum mechanics to the momentum of a charging elephant. But there are events on the border between the visible and the invisible in which quantum effects could conceivably come into play. Possible examples: biochemical reactions and the firing of neurons in the brain. Stapp, Clauser and others believe that a better understanding of how quantum theory applies to atoms and molecules might help in everything from artificial-intelligence research to building improved gyroscopes. For now, though, this boundary area is a theoretical no-man's-land. Certainly physicists are a lot further from understanding how the world works than some would have Congress believe. ■