THE PRESENT CRISIS IN THEORETICAL PHYSICS

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We are living in a period of great physical discoveries, which follow each other in rapid succession. After the discovery of radioactivity, the electron, and Roentgen rays, toward the end of the last century, there followed the discovery of the diffraction of Roentgen rays, the Stern-Gerlach experiment, the Compton and Raman effects, the diffraction of electrons and hydrogen atoms, the discoveries of heavy hydrogen, of positrons, neutrons, induced radioactivity and the transmutation of the chemical elements.

This rapid progress in experimental physics is accompanied by a bold speculation in theoretical physics, aiming to coordinate all the wonderful phenomena discovered in experimental physics. The present mathematical researches in theoretical physics are dominated by two theories, the theory of relativity and the quantum theory. The special and the general theory of relativity rest on definite principles from which very definite conclusions can be drawn and which are in agreement with experiments. But unfortunately the logically perfect special theory of relativity, abandoning the ether as seat of the electromagnetic phenomena, becomes a purely mathematical-analytical theory rejecting all intuitive understanding of physical phenomena without mathematical formulae. It does not give a physical world picture, but only a formula. The mathematical apparatus of the general theory of relativity is much more complicated than that of the special relativity, and it coordinates besides the phenomena of Newtonian mechanics as a special case, three microscopic phenomena. The world appears as a four dimensional non-Euclidean, nonuniform finite continuum. While it is mathematically easy to construct such worlds, the space-time continuum of Minkowski and of general relativity are for me purely formal mathematical expressions or constructions. I do not live and make experiences in a non-Euclidean world of four dimensions. A four or two dimensional being is for me only a mathematical abstraction without contact with sense experience.

The quantum theory.—In the 18th century light was considered as made up of particles; in the 19th century as a wave in a medium called ether; and now since 1900 after Planck's ideas of radiation either as a wave or as particles called photons, or quanta of energy $E = h\nu$, which are emitted or absorbed in a discontinuous process, ruled by statistics. In 1905 Einstein materialized this idea concerning light to consist of particles of energy $h\nu$. In the photoelectric effect this energy is transformed into kinetic energy of moving electrons. The Compton effect also consists in a transformation of light energy of Roentgen rays into kinetic energy of electrons. But here an individual elementary collision between a photon and an electron is assumed with conservation of energy and of momentum. If the momentum is equal to $E/c = mc = h\nu\ /c = h/\lambda$, and if we assume for the momentum of an electron $g = mv = h/\lambda$, then $\lambda = h/mv$; i. e., the relation of deBroglie, i. e., with a moving particle is associated a wave of wavelength λ. But before the discovery of the Compton effect and the diffraction of electrons N, Bohr had made great progress in the theory of the structure of the atom, giving a rational explanation of the Balmer, Lyman and Paschen series of the hydrogen atom. This theory of Bohr was extended by Somerfeld, who introduced relativity into Bohr's theory. The theory was successful in many respects and gave rise to a classification of the line spectra by means of quantum numbers. But the theory was unable to explain the spectrum of helium, the next simple element after hydrogen. This theory was replaced by wave mechanics, quantum mechanics or probability mechanics, whose principles are difficult to enumerate separately, but which is largely based on Schrödinger's wave equation and the uncertainty principle. According to this principle it is impossible to measure in one experiment alone both the position and the momentum of one electron. If we determine the position, then we alter the momentum and vice-versa. Knowledge of position and velocity of a subatomic system is not obtainable, scientific causality breaks down, the future remains uncertain and open. We can determine only the probability of an atomic event, not the event itself. But if in the laboratory we look at the experiments on atomic structure, for instance the line spectra of the elements, they are just as well or better defined as other phenomena treated in classical physics. Hence either scientific causality has to be given up altogether, or it rules the atomic phenomena as well as the microscopic phenomena. The uncertainty may be only a subjective indeterminancy. Compton's experiments may be explained in different ways. That even in bulk experiments we disturb the quantities to be measured by means of our measuring instruments, is often a bitter experience of the experimental physicist. In the Schrödinger equation we have to know the kinetic and potential energy of the atomic or molecular system simultaneously, i.e., position and velocity, and here we introduce classical values. Herein I see a violation of the uncertainty principle itself. The question arises, if there are waves of electrons, what is the wave made of? It seems to me that the wave is taken in two different senses; a wave of an electron is considered either as a material wave (—for diffraction) or as probability wave (—in atomic structure.) The Schrödinger function for an atom with two electrons represents a wave in a six-dimensional space, for an atom with three electrons a wave in a nine-dimensions, in an atom with 92 electrons a wave in $92 \cdot 3 = 276$ dimensions! I doubt if any theoretical physicist believes in these dimensions in atomic systems, i. e., the Schrödinger equation again is a purely formal mathematical construction. Efforts to imagine such spaces, must forever fail. There are other difficulties connected with this function which I must omit here. Difficulties arise also with the mass and size of the photon. In the photoelectric and Compton effect, the photon is considered as of very small size, but in the formation of the image of a star, whose light is reflected from a 100-inch reflector, the photon must be of the size of the reflector. Moreover the energy E of a photon is equal to $h\nu$, its mass $m = h\nu/c^2$. But according to relativity the mass of a particle depends on the velocity v

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

and if $v = c$, then the mass becomes infinite. To assume the rest mass m_0 equal to zero, destroys the conception of mass, as an empirical quantity altogether. Finally, if light from a source is emitted as particles, how can the velocity of light be independent of the velocity of the source, an assumption which is fundamental in special relativity. Both the wave theory and the corpuscular theory of light are true, but both together cannot be true.