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THE SPACE PROBLEM IN THE NEW QUANTUM MECHANICS*

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The difficulties that have arisen with respect to a successful integration of Bohr's model of the atom into mechanics and electrodynamics have recently led to speculations that a failure of all of our space-time conceptions is involved rather than a mere inadequacy of physics. It seems highly doubtful that it might be possible to represent inner-atomic occurrences in the form of space-time models. Comments of this kind have been made by Bohr\(^1\) as well as Born, Jordan and Heisenberg\(^2\) in connection with their matrix mechanics. Schrödinger's wave mechanics should be seen as the decisive step towards a solution of the problem of matter. His views on wave mechanics have given a profound new turn to the problem of the atom. Accordingly, it seems justified to investigate once and for all the epistemological aspects of the problem of the atom.

The indeterminateness in the characterization of the spatial structure of the atom was reflected in the use of the concept of a model. From the outset this concept was supposed to indicate not merely a new physical hypothesis, but an uncertainty of a much more important kind. A model is something that is not the same as the real thing which it describes; if the scientist speaks of atomic models he expresses a limitation. Initially this restriction is not very far-reaching. If we construct a model out of wooden balls and wire, we must not say that this structure made of wire and wood is in every respect similar to the atom. It does not only transcend it in size, but also in some specific macroscopic properties such as color, sharp borders of the wooden balls, existence of rigid connections, etc. For this reason the wire frame is only a model, only a macroscopic analogue; yet it is relatively easy to disregard the irrelevant properties and to concentrate upon the spatial structure alone. This structure – this was the original significance of the Bohr-Rutherford atomic model – was intended to represent the essential properties. The spatial arrangement of nucleus and orbiting

electrons was supposed to be similar to the spatial arrangement of the wooden balls of the model. Therefore, this model, in its essential features, was meant to be a faithful structural enlargement rather than a mere analogue. The atomic model was just as good a model as, say, the plaster model of a building in which window openings, door knobs, etc., have not been executed in detail, but where the spatial structure is strictly to scale. It is a model in the same sense as a planetarium is a model of the astronomical planetary system.

The hesitation to consider the atomic model true to nature was due to the fact that inferences from this model to the observed quantities were strained. It was necessary to disregard the contradiction with Maxwell's theory. In a strict interpretation of the model radiation occurs during the revolution of the electron while according to Bohr, this was to happen only during a jump from one orbit to another. Whereas this contradiction was overcome for the time being by the assumption that Maxwell's theory was not applicable to the microcosm, another fundamental principle of Bohr led to very puzzling statements. The correspondence principle asserted that the emitted radiation was after all determined in every respect by the form of the orbital curve: the harmonic oscillations of the orbit furnished by Fourier analysis were said to occur in the emitted radiation with a certain systematic deviation of the frequency and in exactly the same amplitudinal relation. Interpreted as physical causation the processes became unintelligible because then the revolution of the electron in its orbit would have an effect upon an event that is not released by this revolution. The correspondence principle, therefore, was to be understood only as a rule that supplied the correct result but did not justify a direct physical interpretation.

There seemed to be two possibilities to avoid this difficulty. First, one might try to change the atomic model in such a way that the electrons do no longer occur as material balls in revolutions. It would then be necessary to construct an essentially different model, one in which the electron may lose its individual existence and the negative charge is distributed continuously through the whole space. Its space-time electric mechanism would lead to the very laws of the emitted radiation asserted in the correspondence principle. It would be a model that yields results of the correspondence principle without using electronic orbits as premises. Since this program promised little success, a second way seemed to be needed: it was assumed that no space-time