COMMUNICATION

Marxism and Quantum Mechanics

THE ARTICLE by K K Theckedath in *Social Scientist 25*(August 1974)has been useful in drawing attention to the idealist interpretation especially of the Copenhagen school of quantum phenomena. The author has rightly suggested that it amounts essentially to the denial of objective reality and the knowability thereof.

In the Marxist-Leninist analysis of a scientific theory such as the quantum theory, which brought about a qualitative change in our understanding of physics and about objective reality, it is clearly insufficient to indicate the idealist distortions and to make a general affirmation of the dialectical materialist philosophical position. The Marxist stand, viewpoint and method must be applied in a detailed examination of the scientific theory from every angle, in order to separate its rational core from its idealist philosophical trappings.

From this standpoint arise two substantive criticisms of Theckedath's presentation of the question of Marxism and quantum mechanics. First, Theckedath has not clearly brought out the revolutionary core of the quantum theory, the core that forms the basis for further theoretical advances in contemporary physics. Secondly, he does not really show how the Marxist stand, viewpoint and method can be (and has been) applied to the solution of the contradictions that have arisen between the existing quantum theory and the most recent scientific data. Theckedath's presentation is characterized by a one-sided emphasis on the work of David Bohm. Prematurely, and quite unconvincingly, it elevates the tentative views of Bohm into the Marxist-Leninist standpoint on quantum mechanics.

With the quantum theory, the first revolutionary step was that of Planck and Einstein who boldly postulated that energy is transmitted in a discontinuous fashion through quanta. This was a sharp break with the established ideas of 'continuity' in classical physics and was confirmed immediately in the photo-electric effect. The second revolutionary step was the de Broglie hypothesis on the complicated form of matter. The concept of 'wave-particle duality' was a great step forward; and the various atomic spectra, the several spectroscopic effects, the theory of absorption and emission of radiation were some of the areas where quantum mechanics was found essentially correct by experimental verification. Hence the 'wave-particle duality' must be accepted as part of the rational core of the theory. The probability interpretation of Ψ marks a sharp break with the mechanistic determinism of classical physics and is a concrete expression of the statistical nature of quantum phenomena. This interpretation, though not directly verifiable, has not run counter to experimental work and data, and, in fact, has been upheld by the work on spectra. This must also be considered a part of the rational core of quantum theory.

The idealist interpretation of quantum mechanics is based on the acceptance of two main principles, the Heisenberg Uncertainty Principle and the Complementarity Principle. The two cannot be considered in isolation, since, as will be shown later, in essence the latter is only a stronger and more explicit denial of objective reality than the former. The Uncertainty Principle states that a simultaneously precise specification of both position and momentum is not possible. This is expressed quantitatively as $\triangle x. \triangle p > \frac{h}{4\pi}$, where $\triangle x$, $\triangle p$ are the uncertainties in position x and momentum p and h is Planck's constant. In other words, the product of the uncertainties in co-ordinate and momentum is greater than or equal to $\frac{\lambda}{4\pi}$. Two points must be clarified about the role of the uncertainty relation.

Foibles on Both Sides

First, a relation expressing the coarseness of measurement cannot be elevated into a principle denying the possibility of the existence of specific values of position and momentum. To deny the existence of such specific values for position and momentum means that we are not permitted to talk of a trajectory and this leads to a denial of objective reality. There is also the implicit statement that there do not exist precise values of position and momentum without measurement. This is an idealist position denying the existence of objectively real values of position, momentum and other quantities. The Heisenberg Uncertainty Principle must be understood merely as a relation expressing the coarseness of the microscope method of measurement (from a study of which the Uncertainty Principle is derived) and not as a rigid 'law of nature'. Fock, a Soviet physicist, is one of the scientists who accept this understanding of the uncertainty relation.[1]

Secondly, one cannot say that the microscope method of measurement is the only possible method of measurement and hence the uncertainty holds for all time. In fact, the Soviet physicist, A A Sokolov, has pointed out a method where "the electron reveals itself without the intervention of an observer using instruments possessing microstructure to detect it."[2] The electron, moving with high energy in a synchrotron, emits light quanta which in turn react with the electron itself producing a peculiar quantum 'macro-atom', which is easily detectable with great precision. Thus the electron reveals itself without any microscopic method of detection.

To understand the physical implications of the Uncertainty Principle, Bohr formulated the Complementarity Principle which states that the wave and particle aspects are mutually exclusive and only that which is being measured is capable of existence at a particular moment. In this understanding of 'wave-particle duality', the dialectical unity and conflict of opposites are not understood. The unity of the corpuscular and wave properties is objective in the fact that the laws of quantum mechanics do not change for both wave and corpuscle aspects. It is also an inherent property as seen by the fact that the discontinuous (Planck's constant) and the continuous (frequency) are connected concretely. The contradiction is objective and concrete[3]. Instead, in the Copenhagen Interpretation, the wave and particle aspects are understood as external to each other and unrelated in a quantum object. Hence follows the statement that only that aspect exists which is being measured at a particular moment, which leads to a denial of objective reality. Thus what is only implied by Heisenberg in his Uncertainty Principle is stated strongly and more explicitly by Bohr in his Complementarity Principle. Though Theckadath has examined generally the idealist position arising from the Uncertainty Principle and the proposed 'unanalysability' of subject and object, he has neglected the Complementarity Principle in his attack on the idealist interpretation of quantum theory. The Complementarity Principle, as much as the Uncertainty Principle, is incapable of experimental verification. It is mainly a question of the philosophical interpretation of microphenomena, as J D Bernal was quick to recognize: .. "ideas which were consciously or unconsciously in the minds of the experimenters who made the new discoveries and opened the new fields to scientific thought."[4]

Formalism to Understanding

The lack of clarity about the exact nature of 'wave-particle duality' and the mathematical structure of the quantum theory have led to further idealist distortions. The mechanical picture of a particle being made up of the superposition of a number of waves with very close frequencies (that is, a wave packet) is very insufficient. This picture breaks down when the case of the interference of the single particle is considered. Only a single spot is formed on the screen, and this is said to be due to a 'reduction' of the wave packet, but this explanation does not say anything about what really happens. Further information about the particle in the course of reaching the screen is, according to the Copenhagen Interpretation, impossible. But having rejected the Copenhagen Interpretation, a more meaningful picture of 'wave-particle duality' must be worked out. It is possible that individually they have particle properties whereas the wave aspect is manifest in the statistical behaviour of these particles.

But as Theckedath has rightly noted, instead of working out these details there is a tendency among quantum physicists to give up physical concepts altogether and to speak merely in terms of the equations and the various operators involved in these equations. In the question of 'wave-particle duality,' this attitude is seen in the abandoning of scientific attempts to find a more meaningful physical explanation and in the mere extension of formal mathematical methods to various problems. The identical results of Heisenberg's matrix method (which, being a method of treating discontinuous assemblages, is suitable to a particle description) and Schrödinger's differential equation method (which is suited to the wave description) indicate the objective nature of 'wave-particle duality'. But not to go beyond this to the physical meaning of these equations, is to substitute formalism for the concrete study of objective reality.

Bohm's work on a causal interpretation of quantum mechanics represents an initial effort to combat the idealist interpretation of quantum mechanics and to carry forward the scientific understanding of physical phenomena. However, in no way can it be assumed that Bohm's work provides a definite, scientifically verifiable solution to the main problems of quantum mechanics.

Bohm himself considers his theory only as an attempt to move forward, to show that alternatives do exist at a deeper level to the present theory, and that the Copenhagen Interpretation's claim that it is final and absolute is untrue.[5] Bohm's theory makes numerous assumptions about the exact nature of the sub-quantum level. The only definite statement is about the random fluctuations at that level. These assumptions, though not classifiable as unphysical, are still a long way from scientific proof and verification. It is possible that further developments may occur through the resolution of the inner contradictions of the quantum field theory without the immediate introduction of a further sub-quantum level but through the introduction of concepts like quantization of mass, space and time.

Scientific Practice under Socialism

The development of any scientific theory is only possible by its application in practice. The scientific practice of the socialist countries, especially the two largest, the Soviet Union and China, would be highly relevant to the discussion of Marxism and quantum mechanics. It is surprising that this important experience has been entirely omitted in Theckedath's analysis. A large body of scientific literature, specialized as well as popular, is available from the USSR on quantum mechanics. Scientists like Landau, Fock, Blokhintsev and philosophers like Omelianovsky have written extensively and contributed to the debate on various aspects of quantum mechanics.

The two popular Soviet books on quantum mechanics available in English which purport to provide a historical approach to the subject fail to make a clear distinction between the rational core of quantum theory and its idealist trappings. L Ponomarev in his book, *In Quest of the Quantum,* [6] fails to approach the Uncertainty Principle from a critical Marxist standpoint. He accepts the Uncertainty Principle as a rigorous 'law of nature' and concurs, without the slightest inhibition, with the idealist conclusion of Heisenberg that the state does not exist independent of observation. Ponomarev omits from his popular presentation any account of the viewpoints of Soviet scientists on the interpretation and the limits of the uncertainty relation. He also accepts the Principle of Complementarity, ignoring its idealist essence which led Bohr to deny the existence of objective reality in quantum phenomena. The 'wave-particle duality' is the rational core of quantum theory but its idealist distortions arise in the Complementarity Principle, as shown earlier. This understanding is totally absent from Ponomarev's account.

V Rydnik in *ABC's of Quantum Mechanics*[7] does make certain observations on how dialectical materialism can be used as a guide to the solution of some problems of quantum mechanics, such as the interrelation of matter and field. Rydnik also points out the significance of the two main advances in quantum physics—the quantum and the de Broglie hypothesis. But he fails to apply the Marxist stand, viewpoint and method in the analysis of the Uncertainty Principle. Mentioning both the understanding of the uncertainty relation as a rigorous law of nature and the understanding of the uncertainty relation as an existing limit to the purity of observation, Rydnik attempts a compromise, asserting that the electron and the instrument are "both to blame, half and half". [8]

Reality of the Ensemble

Among Soviet scientists and philosophers in the field of quantum mechanics, three main trends have been identified. The first is represented by D I Blokhintsev. The key point of his interpretation is the representation of the wave-function Ψ as giving a statistical description of micro-particles(not statistical information of the observer as the Copenhagen Interpretation has it) in their totality, called an ensemble. [9] He maintains that Ψ cannot be applied to a single micro-object but only to an ensemble of such micro-objects. It is the ensemble which has objective reality. Blokhintsev did not accept the Copenhagen Interpretation and the Principle of Complementarity, regarding them as the source for the denial of causality and the liquidation of objective reality. He maintained that causality is not violated in quantum mechanics, but expresses itself in the causal nature of the statistical laws of the ensemble. To him, one of the great achievements of quantum mechanics is its negation of classical determinism by the introduction of probability. In 1966, however, Blokhintsev accepted the formulation that "the wave-function is simply a routine record of the observer's information on the state of the ensemble of microsystems."[10] Although this, in his opinion, is "convenient as a formulation against which it is difficult to raise objection,"[11] it is unsuitable from a philosophic standpoint because of the choice of words which give a subjective taint to the theory.

Serious objection has been raised to Blockhintsev's concept of ensembles, especially by V A Fock who found it "self-contradictory."[12] Fock pointed out that the essentials of the ensemble interpretation are (a) that the ensemble is a collection of particles which, independent of one another, are in such a state that the ensemble can be characterized by Ψ, (b) hence the state of the particle should be understood as its association with an ensemble, so that (c) the wave-function does not concern an individual particle. According to Fock, in assertion (a) the state of the particle is defined by its wave-function but this stands in conflict with assertion (c). Again, by assertion (a) the ensemble is defined by the wave-function whereas by assertion (b) the wave-function is defined through the ensemble. This is a vicious circle.

V A Fock himself was representative of another major trend. His interpretation is presented in his article, "On the Interpretation of Quantum Mechanics", written in 1958.[13] Fock asserted that quantum mechanics does give a fully obective account of microscopic reality. He blamed Bohr's inexact use of terminology for much of the confusion created. One such example, he identified in the contention of the Copenhagen Interpretation that the Principle of Complementarity contradicted the Principle of Causality. According to the Copenhagen Interpretation, since the individual properties of a body exist only at the time of measurement there can be no causality at the quantum level. Fock insisted that this problem could be removed by a redefinition of causality. Along with Blokhintsev, he maintained that causality had been preserved in the behaviour of statistical ensembles. However, he differed from Blokhintsev in that he maintained that the wave-function Ψ referred to a single micro-object.

Physical State and Measuring Devices

The essential point where the quantum system differs from the classical system, according to Fock, is that the physical state of the quantum system depends explicitly on measuring devices. He considered that this dependence on an instrumental device was in no way a denial of objective reality "because all the properties of a micro-object, including the specifically quantum ones(those which classical mechanics cannot describe) are disclosed through the influence of a micro-object on a classically describable measuring instrument."[14] This view of the physical state not being independent of measuring devices has not been generally accepted by Soviet physicists. Omelianovsky, for instance, has pointed out that the physical state is non-relative to measuring instruments. To deny this would be to assert that the physical state is determined by the instrument, which would be denying objective reality.[15]

Omelianovsky's position represents the third trend. It is more or less identical with Fock's except that Omelianovsky rejects Fock's interpretation of the state being dependent on the instrument, as we discussed above. Although Omelianovsky in 1956 opposed the Principle of Complementarity as a mechanistic understanding of 'duality', in 1963 at the thirteenth World Philosophical Congress he accepted it as a dialectical statement of 'wave-particle duality' with some reservations on the way in which it was applied.[16]

We may note the points of agreement among the three major trends: (1) They agree that causality can be retained in quantum theory, and (2) they reject Bohm's approach as an attempt to return to classical concepts and classical determinism. In fact, Blokhintsev compares Bohm's attempt to "seeking unwettable gunpowder."[17]

There are other views among Soviet scientists. A A Tiapkin has suggested[18] that an approach could be made in terms of creating a newer and more complete theory, which, while not differing from the present theory in its predictions, would provide a more complete description of physical phenomena and deal especially with the gaps left by the Complementarity Principle between the moments of measurement. As a beginning, he has pointed out that even existing work by Feynman has shown that it is possible to specify the trajectory of a quantum object.[19]

Chinese material on this subject is not easily accessible, because of the censorship imposed by the Government of India and our libraries on this material. But discussions in *Red Flag*[20] indicate that Chinese physicists and philosophers are doing serious work on these problems.

Towards New Physics

The further development of quantum physics, and the solution of its fundamental problems, is possible only by a comprehensive scientific investigation of all available facts and theories on the firm foundation of dialectical materialist philosophy. The scientist will be led astray in his field if idealist philosophy is allowed to intrude and distort scientific truth. Though science is instinctively materialist, idealist bourgeois philosophy tends to take cover behind scientific development. Those physicists who are not firmly grounded in dialectical materialist philosophy are led into what Lenin called "physical idealism",[21] idealism in the field of physics.

This invariably leads to a crisis in physics. The essence of the crisis, in Lenin's words, "consists in the breakdown of the old laws and basic principles, in the rejection of an objective reality existing outside the mind, i.e. in the replacement of materialism by idealism and agnosticism."[22] The contention of the Copenhagen physicists that objective reality had disappeared reveals only their ignorance of dialectics; their ignorance that science, as it advances, does not disprove objective reality, but discovers new forms and deepens our knowledge of objective reality. Lenin noted that

> one school of natural scientists in one branch of natural science has slid into a reactionary philosophy, being unable to rise directly and at once from metaphysical materialism to dialectical materialism. This step is being made, and will be made, by modern physics; but

> it is advancing towards the only true method and the only true philosophy of natural science, not directly, but by zigzags, not consciously, but instinctively, not clearly perceiving its 'final goal,' but drawing closer to it gropingly, unsteadily, and sometimes even with its back turned to it. Modern physics is in travail; it is giving birth to dialectical materialism. The process of child-birth is painful. And in addition to a living healthy being, there are bound to be produced certain dead products, refuse fit only for the garbage heap. And physical idealism...must be regarded as such refuse.[24]

This, the Marxist-Leninist presentation of the question of true scientific method and philosophy, applies as much to the 'new physics' of today, as it did to the 'new physics' of the late nineteenth and early twentieth century.

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1 Loren R Graham, *Science and Philosophy in the Soviet Union*, Allen Lane, 1973, Ch III, p 99.
2 A A Sokolov in *Philosophical Problems of Elementary-Particle Physics*, Progress Publishers Moscow 1968, p 263.
3 See E I Bitsakis, "Symmetry and Contradiction", *Science and Society*, Fall 1974, Vol 38 No 3, pp 326-346.
4 J D Bernal, *Science in History*, Watts & Co, London 1954, p 532.
5 D Bohm, *Causality and Chance in Modern Physics*, Routlede and Kegan Paul, 1957, p 75.
6 L Ponomarev, *In Quest of the Quantum*, MIR Pub lishers, Moscow 1973.
7 V Rydnik, *ABC's of Quantum Mechanics*, MIR Publishers, Moscow 1958.
8 V Rydnik, *op. cit.*, p 114.
9 D Blokhintsev cited in Graham, *op. eit.*, p 84.
10 D Blokhintsev cited in Graham, *op. cit.*, p 92.
11 *Ibid.*
12 V A Fock cited in Graham, *op.cit.*, p 87.
13 V A Fock, cited in Patrick A Heelan, "Quantum Mechanics", *Marxism, Communism, and Western Society*, Vol 7, Herder & Herder, 1973, p 131.
14 *Ibid.*,
15 Omelianovsky, cited in Patrick A Heelan, *op. cit.*, p 131.
16 Omelianovsky, cited in Graham, *op. cit.*, p 106.
17 D Blokhintsev, cited in Graham, *op. cit.*, p 93.
18 A A Tiapkin in *Philosophical Problems of Quantum Mechanics*, Mosow 1970, cited in Loren Graham, *op. cit.*, p 108-109.
19 A A Tiapkin in *Philosophical Problems of Elementary-Particle Physics*, Progress Publishers, Moscow 1968, p 338.
20 "Natural Science and Dialectical Materialism: Looking at the Bankruptcy of Idealism and Metaphysics from the Development of Modern Physics", *Hong Qi* No 9, 1965, p 31.
21 V I Lenin, "Empirio-Criticism", *Collected Works*, Vol 14, Progress Publishers, Moscow 1968, p 314,
22 *Ibid.*, p 258,
23 *Ibid.*, pp 312-313.