QUANTUM MECHANICS

The Principles of Quantum Mechanics

By Prof. P. A. M. Dirac. (International Series of Monographs on Physics.) Third edition. Pp. xii+312. (Oxford: Clarendon Press; London: Oxford University Press, 1947.) 25*s*. net.

IT is now twenty years since the theory of quantum mechanics was founded, and not much less since the first edition of Dirac's book was published. Ever since, it has been a classic of scientific literature.

The importance of the development which has taken place in these twenty years can scarcely be fully gauged at present. The whole of the atomic world has been opened up for exact treatment and understanding in a way which can only be compared with the development of mechanics since Newton; and so rapid has the progress been that already large-scale practical applications of quantum mechanics have been made. Moreover, and more important still, there is no doubt that quantum mechanics implies a profound departure from the way of thinking which is characteristic of classical physics. This feature, the philosophical consequences of which are up to now scarcely fully realized, will have consequences which will perhaps make themselves felt only after a considerable time, just as the impact of exact science on European thought and life became noticeable only a long time after Newton.

The text-book literature on quantum mechanics is still in an unsatisfactory state. The much-wanted text-book, of some 1,000 pages, giving a balanced account of all the important aspects of the theory and a selection of the most typical applications, has not yet appeared. Dirac's book certainly does not profess to occupy this place. It is not a book for the student who wants to learn quantum mechanics; but no one who wishes to have a thorough insight into the subject, provided he has gained a first knowledge of it, can afford not to study Dirac's book very carefully. The condensed and crystal-clear style, characteristic of the author, makes delightful and satisfactory reading, especially for someone who (like the reviewer) thinks that this, rather than the descriptive style, is more appropriate for subjects of this kind.

The author has chosen a straight, one-line approach to the subject, and this is the more formal axiomatic approach. It is very satisfying from the logical point of view, but not, of course, the best pedagogical way to introduce a student to quantum mechanics. As in the previous editions, the first 100 pages or so are devoted to the 'framework' of quantum mechanics, that is, the general principles and properties of all those mathematical entities which occur in quantum mechanics: the eigenvectors (the word eigenfunction or wave-function does not occur until much later), linear operators, observables, etc. So, for example, the book begins with the superposition principle of states, and continues by explaining (and postulating) how the 'observables' are represented by linear operators. The principle of indeterminacy is introduced from the start. Nothing so far about dynamics and the equations of motion, which will fill the framework with physical content. All this is much in the same style as in the previous editions, except for a notable change in the notation. The author uses the 'bracket notation' (rather 'bra-c-ket' notation) which he has invented for the purpose. The well-known type of quantity $(\psi_a^* Q \psi_b)$ occurring so frequently in quantum mechanics, where ψ_a, ψ_b are the wave-functions of eigenstates a, b, and Q a linear operator, are denoted by $<a|Q|b>$. The author rightly lays emphasis on the fact that all that matters here is not what function ψ_a is, but what states a and b are and what Q is. It is also emphasized that ψ and ψ^* are never mixed up in quantum mechanics; they occur *always* after and before the operator Q, respectively, whereas the fact that ψ^* is the complex conjugate to ψ is less fundamental. This is brought out by the notation $<$ and $>$. The vectors $<a$ and $b>$ are called 'bra' and 'ket' from the word 'bracket', which describes the notation used in print. Its two syllables, one of them mutilated (for symmetry reasons, obviously) by the loss of the letter 'c', are promoted to the full rank of nouns and important mathematical and physical content is conferred upon them.

In the second third of the book the laws of quantum dynamics are developed. After an exposition of the equations of motion, the angular momentum and the spin are introduced, and a few applications to the hydrogen atom, perturbation theory and the general theory of collisions (with the important representation in momentum space) follow. Also here the main difference compared with previous editions is the notation.

In the last part of the book the many-body problem, the relativistic wave equation and the theory of radiation are treated. Here important alterations and additions are made. In the treatment of an assembly of 'bosons' ('bosons' and 'fermions' are particles obeying Bose and Fermi statistics), the elegant and powerful method of Fock is used which the author has himself applied and developed in his work since 1940. This is applied to the radiation field, that is, an assembly of photons. The author treats a photon on exactly the same footing as any other type of particle obeying Bose-statistics, which is justified in quantum theory. On the other hand, one might perhaps also mention the difference that exists between charged and neutral particles when talking of them as particles in the classical sense. In particular, it seems that photons cannot in the classical limit be considered as particles at all in the sense that a charged particle can.

The last few sections of the book contain somewhat controversial matter. In the treatment of the interaction of radiation with electrons, the author uses the λ-limiting process which was originated by Wentzel, in order to remove the infinite self-energy of a classical point-electron, and was later extended to quantum theory by the author. In reading these sections of the book, one gets the impression that the author firmly believes in this procedure as a remedy for part of the difficulties of quantum electrodynamics; whereas it is mentioned at the end of the book that, nevertheless, fundamental difficulties occur here. It might be mentioned that not all who work on this subject share the author's opinion about the physical correctness of the λ-procedure, although this is, of course, a most interesting and stimulating theory.

In the new version, as in the old ones, Dirac's book will play the part it has played before: it is the standard work in the fundamental principles of quantum mechanics, indispensable both to the advanced student and the mature research worker, who will always find it a fresh source of knowledge and stimulation.

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