THE PARTICLE MENACE PART 2

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THE WAVE MODEL OF THE ATOM

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Shrodinger's Wave Model of the Atom

Schrödinger believed that atomic activity could best be expressed by a wave model of the atom. For example, he argued that it was more intuitive to view the 'movement' or changes in energy of electrons as the changes in frequency of a standing wave. That is why he maintained that his famous wave equation described real physical activity. The mathematics in the solution to his wave equation forced him to use the imaginary number *i* and so the resulting wave function was complex: it had a real part and an imaginary part. There is nothing 'imaginary' about *i*. It is a mathematical method of avoiding tedious trigonometry [1]. At the conclusion of his 6th paper Schrödinger writes of his wave equation:

'Meantime, there is no doubt a certain crudeness in the use of a *complex* wave function. If it were unavoidable *in principle*, and not merely a facilitation of the calculation, this would mean that there are in principle *two* wave functions, which must be used *together* in order to obtain information on the state of the system. This somewhat unacceptable inference admits, I believe, of the very much more congenial interpretation that the state of the system is given by a real function and its time-derivative.' [*Collected papers on Wave Mechanics*, Minkowski Press 2020 p 194]

Einstein had told Schrödinger; 'Of course every theory is true, provided you suitably associate its symbols with observed quantities.' [Max Jammer, *The Philosophy of Quantum Mechanics,* John Wiley & Sons 1974, p23]

As Max Jammer points out, the formalism of wave mechanics had preceded its interpretation but an interpretation could be arrived at

' . . . by showing that the formalism F of Schrodinger's wave mechanics could be regarded as being part of, or at least isomorphic with the formalism F* of another theory T* which was fully interpreted.' *[ibid*, p24]

Schrödinger looked for parallels in the well developed classical physics of electromechanics and hydrodynamics. In this he was following the traditions of the physicist-philosophers of the nineteenth century, particularly Maxwell.

Maxwell was not content with using terms such as 'attraction', 'repulsion', 'lines of force' and 'charge' without understanding the mechanism under which they operated, and in arriving at his *Dynamical Theory* he drew upon analogous phenomena such as light, fluid and heat. He defended his appeal to these other areas of scientific enquiry in his paper *Analogies of Nature* :

'Whenever [scientists] see a relation between two things they know well, and think they see there must be a similar relation between things less known, they reason from one to the other. This supposes that, although pairs of things may differ widely from each other, the relation in the one pair may be the same as that in the other. Now, as in a scientific point of view the relation is the most important thing to know, a knowledge of the one thing leads us a long way towards a knowledge of the other. ' [1856, *The Scientific Letters and Papers of James Clerk Maxwell*, p381-382]

and

'In order to obtain physical ideas without adopting a physical theory we must make ourselves familiar with the existence of physical analogies. By a physical analogy I mean that partial similarity between the laws of one science and those of another which makes each of them illustrate the other.' [*On Faraday's lines of Force* Papers Vol 1 p155]

By following past masters, a certain amount of opprobrium was cast on Schrödinger as being behind the times and clinging to the out-dated classical idea that physics describes reality. It was argued this no longer held true and Schrödinger had to be left behind in the new age of indeterminacy and counter-intuitive phenomena such as entanglement and superposition of particles and so on.

Notwithstanding the success of the Copenhagen interpretation at predicting results, I believe it was a blunder which has led physics down a rabbit hole. The classic wave function describes the displacement of the wave at a point in time, and Schrödinger's function should do much the same thing but because of the determination to construe the structure of the atom in terms of particles, virtual or real, the equation was hi-jacked and basically the maximum displacement of the wave (the amplitude) was identified not as 'stimulating the appearance of a particle' but as the *probability* of locating a particle.

I believe Schrödinger accepted that a wave packet could be mathematically construed as a particle without relinquishing his belief in the ontological priority of waves. It should be clear that the 'particle' is redundant from an ontological point of view. For the proponents of the Copenhagen interpretation the characteristics of each phenomena have been conflated, hence the ridiculous conclusions reached about the phenomenal world.
Schrödinger tried to clarify his position in his acceptance speech for the Noble prize in physics. His essays on wave mechanics had included a description of the hydrogen atom and demonstrated the equivalence of Heisenberg's Matrix Mechanics and his Wave Mechanics. He was awarded the Nobel Prize in physics in 1933. His acceptance speech, *The Fundamental Idea of Wave Mechanics* analyses the intellectual trajectory of both wave and particle proponents to arrive at conflicting views of the internal structure of the atom. He begins by pointing out the similarities between Fermat's Principle relating to a light ray and Hamilton's Principle relating to point masses and declaring both to be fictitious. I take this to mean that they were mathematical abstractions.

'Now, it is very difficult, without further going into details, to convey a proper conception of the success or failure of these classical-mechanical images of the atom. On the one hand, Hamilton's principle in particular proved to be the most faithful and reliable guide, which was simply indispensable; on the other hand one had to suffer, to do justice to the facts, the rough interference of entirely new incomprehensible postulates, of the so-called quantum conditions and quantum postulates. Strident disharmony in the symphony of classical mechanics - yet strangely familiar - played as it were on the same instrument. In mathematical terms we can formulate this as follows: whereas the Hamilton principle merely postulates that a given integral must be a minimum, without the numerical value of the minimum being established by this postulate, it is now demanded that the numerical value of the minimum should be restricted to integral multiples of a universal natural constant, Planck's quantum of action. This incidentally. The situation was fairly desperate. Had the old mechanics failed completely, it would not have been so bad. The way would then have been free to the development of a new system of mechanics. As it was, one was faced with the difficult task of saving the soul of the old system, whose inspiration clearly held sway in this microcosm, while at the same time flattering it as it were into accepting the quantum conditions not as gross interference but as issuing from its own innermost essence.

The way out lay just in the possibility, already indicated above, of attributing to the Hamilton principle, also, the operation of a wave mechanism on which the point-mechanical processes are essentially based, just as one had long become accustomed to doing in the case of phenomena relating to light and of the Fermat principle which governs them. Admittedly, the individual path of a mass point loses its proper physical significance and becomes as fictitious as the individual isolated ray of light. The essence of the theory, the minimum principle, however, remains not only intact, but reveals its true and simple meaning only under the wave-like aspect, as already explained. Strictly speaking, the new theory is in fact not new, it is a completely organic development, one might almost be tempted to say a more elaborate exposition, of the old theory.'

He goes on to argue that diffraction phenomena which may not play a huge role in mechanics may entirely dominate interactions at subatomic level and will

' . . . entirely dominate the mechanical process, and will face the old system with insoluble riddles, *if the entire mechanical system is comparable in extent with the wavelengths of the "waves of matter"* which play the same part in mechanical processes as that played by the light waves in optical processes.

He describes how the particle model of the structure of the atom, though fine for macroscopic interactions, is inadequate at these minute scales, and how the wave-mechanical description is more natural and appropriate.

'This is the reason why in these minute systems, the atoms, the old view was bound to fail, which though remaining intact as a close approximation for gross mechanical processes, but is no longer adequate for the delicate interplay in areas of the order of magnitude of one or a few wavelengths. It was astounding to observe the manner in which all those strange additional requirements developed spontaneously from the new undulatory view, whereas they had to be forced upon the old view to adapt them to the inner life of the atom and to provide some explanation of the observed facts.

[I believe he is referring to inter alia the quantum numbers of the electron]

Thus, the salient point of the whole matter is that the diameters of the atoms and the wavelength of the hypothetical material waves are of approximately the same order of magnitude. And now you are bound to ask whether it must be considered mere chance that in our continued analysis of the structure of matter we should come upon the order of magnitude of the wavelength at this of all points, or whether this is to some extent comprehensible. Further, you may ask, how we know that this is so, since the material waves are an entirely new requirement of this theory, unknown anywhere else. Or is it simply that this is an assumption which had to be made?

The agreement between the orders of magnitude is no mere chance, nor is any special assumption about it necessary; it follows automatically from the theory in the following remarkable manner. That the heavy nucleus of the atom is very much smaller than the atom and may therefore be considered as a point centre of attraction in the argument which follows may be considered as experimentally established by the experiments on the scattering of alpha rays done by Rutherford and Chadwick. Instead of the electrons we introduce hypothetical waves, whose wavelengths are left entirely open, because we know nothing about them yet. This leaves a letter, say a, in dictating a still unknown figure, in our calculation. We are, however, used to this in such calculations and it does not prevent us from calculating that the nucleus of the atom must produce a kind of diffraction phenomenon in these waves, similarly as a minute dust particle does in light waves. Analogously, it follows that there is a close relationship between the extent of the area of interference with which the nucleus surrounds itself and the wave-length, and that the two are of the same order of magnitude. What this is, we have had to leave open; but the most important step now follows: we identify the area of interference, the diffraction halo, with the atom; we assert that the atom in reality is merely the diffraction phenomenon of an electron wave captured as it were by the nucleus of the atom. It is no longer a matter of chance that the size of the atom and the wavelength are of the same order of magnitude: it is a matter of course.'

I have underlined a phrase above because I believe the theory of matter waves was not that new as it can be extracted from Einstein's equation $E=mc^2$ and that Faraday had intuited something along these lines when he described the world as consisting of one type of thing which varied only in concentration and motion. Newton also stated in Definition 1 in his *Mathematical Principles of Natural Philosophy*:

'The quantity of matter is the measure of the same arising from its density and bulk conjointly.'

But if mass and energy are equivalent, with the mass variable simply providing a shape to contain electromagnetic waves, then what better way to explain this than mass being the density of a system of bound waves rather than the accumulation of matter or particles.

A more fundamental hurdle for the particle physicists is the realisation that all H atoms are identical (i.e. they all have identical spectral lines as do all other elements). This is viewed as a mystery! Leibniz demonstrated that if the only factor distinguishing two objects was spatio-temporal location, then they were identical.

'A consideration that is of the greatest importance in all philosophy . . . is this: that there are no purely extrinsic denominations, because of the interconnexion of things, and that it is not possible for two things to differ from one another in respect of place and time alone, but that it is always necessary that there shall be some other internal difference. So there cannot be two atoms which are at the same time similar in shape and equal in magnitude to each other; for example two equal cubes. Such notions are mathematical, that is, they are abstract and not real. For all things that are different must be distinguished in some way, and in the case of real things, position alone is not a sufficient means of distinction. This overthrows the whole of corpuscularian philosophy.' [Leibniz *On the Identity of Indiscernibles* (c 1696) Dent 1973 p133]

Waves, unlike a particle, can continue indefinitely. The wave theory of the phenomena avoids these criticisms: a system of interacting transverse, standing and travelling waves with all the features of linearity, reflection, refraction, defraction, interference, resonance, frequency, amplitude, direction or orientation, harmonics etc arising naturally, would provide a more elegant, rich and rewarding description of the phenomena at all scales. It also ties in with Faraday's pronouncement that in a sense the electron is everywhere.

Sticking obstinately to the particle model reverses progress and a return is made to a solar system of orbits and forces. 'Forces' along with 'charges' are as occult as the Greek god Zeus, but in modern imagination stripped of a personality. Reformulating these as motion and direction of waves, I believe would go some way in providing a clearer ontological picture and bring together classical and quantum physics. By this I mean a scalable ontology. The next essay looks at how to replace some primitive concepts associated with particle physics that may be blocking the route to that vision.

The most telling criticism against the wave model of the atom was that its structure would not endure. Lorentz who preferred the wave model nevertheless pointed out that

' . . . a wave packet which when moving with the group velocity should represent a "particle" "can never stay together and remain confined to a small volume in the long run. The slightest dispersion of the medium will pull it apart in the direction of propagation, and even without that dispersion it will always spread more and more in the transverse direction. Because of this unavoidable blurring a wave packet does not seem to me to be very suitable for representing things to which we want to ascribe a rather permanent individual existence."' [quoted by Max Jammer in *The Philosophy of Quantum Mechanics* p31]

This flaw in the wave model is addressed in the fifth essay on The Space Theory of Matter and the Vortex Atom.

For those who eschewed models of any type and believed mathematical formalism was the correct approach, following Dirac was considered the best course, despite all the logical anomalies his relativistic wave equation encountered. There is a critique of Dirac and Quantum Field Theory in the Additional Material section of the website.

Note1 There is an explanation of how to arrive at √-1 using trigonometry in the Additional Material section of The Quantum Cat Meets the Quantum Computer.