FROM THE OUTSIDE LOOKING IN AT QUANTUM THEORY, ITS DICHOTOMIES AND TAUTOLOGIES

SOSALE CHANDRASEKHAR

Department of Organic Chemistry, Indian Institute of Science, Bangalore 560 012, India (E-mail: sosale@iisc.ac.in; sosalechandra@hotmail.com)

Abstract – It is argued that the key concepts of quantum theory—Planck's quantum proposal, de Broglie's wave–particle dualism and Schrödinger's wave function idea—are neither incontestable nor integrated seamlessly into the fabric of quantum theory. In fact, it is doubtful whether classical wave treatments can serve as the basis for analysing (purported) matter waves at all. Also, an element of circular reasoning apparently surrounds the wave function concept, as the Hamiltonian-based Schrödinger equation is constrained to lead to the discrete solutions that represent quantization. These ambiguities appear particularly damning against the backdrop of the dubious Rayleigh–Jeans–Planck analysis of black body radiation, and the discredited evidence for the wave theory of radiation (based on purported diffraction phenomena). These considerations raise intriguing questions about the role of mathematical modelling in the study of natural phenomena (not to mention certain pedagogical quandaries). Thus, quantum theory—cloaked though it is in forbidding mathematical rigor—must submit to a dispassionate analysis of its extent and compass, particularly in view of its ostensible subversion of common-sense notions of reality.

INTRODUCTION

Quantum theory arose from early studies on the nature of heat and electromagnetic radiation, which led to the Rayleigh-Jeans model of black body radiation that was subsequently modified by Planck (1900) to one based on quantized oscillators. The Planck proposal of the quantization of energy was bolstered by studies on atomic spectra, which apparently inspired further experimental and theoretical studies on atomic structure and the fundamental nature of matter itself. In particular, the wave–corpuscular duality of light originally proposed by Einstein was generalized into wave–particle dualism of matter by de Broglie (1924), which served as the basis of a mathematical model of quantization developed by Schrödinger (1925). These proposals were apparently emboldened by a body of experimental studies that purportedly evidenced the occurrence of waves—whether of light or of electrons—via various 'diffraction' phenomena.

However, as has been argued previously [1], the Rayleigh–Jeans model is manifestly dubious because it assumes that the inner surface of the black body cavity can be defined to the same level of accuracy as the wavelength of electromagnetic radiation. In fact, a similar limitation (inter alia) invalidates the various diffraction phenomena that are believed to evidence the occurrence of waves. The validity of the de Broglie proposal is also questionable as it implies wave properties even to macroscopic objects as they approach resting velocities (although this does not apply to ordinary objects possessing normal velocities) [1].

Therefore, in light of the dubious assumptions that form the early foundations of quantum theory, its general validity needs to be reassessed. In particular, the idea of wave–particle duality was key to the efflorescence of quantum theory, and forms the basis of the wave function idea as enshrined in the Schrödinger equation. Yet, despite its elegance and majesty, the Schrödinger equation apparently cannot avoid the skein of ambiguities surrounding quantum theory as a whole, as elaborated below.

DISCUSSION

The wave function and the basis of the Schrödinger equation

The wave function: ambiguities and possible tautology

It is indeed sobering to ponder the fact that the Schrödinger equation was installed on foundations that now stand discredited [1]. Furthermore, a particularly intriguing concept that is at the heart of the Schrödinger equation is that of the wave function. The allure of the Schrödinger equation essentially lies in its leading to a justification of Planck's quantum proposal, via the discrete solutions that are obtained by employing the Hamiltonian operator upon the wave function. It is noteworthy, however, that this result is inevitable, given the nature of the Hamiltonian operator, thus raising the possibility that the exercise is imbued with an element of circular reasoning (hence tautological).

To be sure, the Schrödinger equation does flesh out the quantum state with mathematical detail that is interesting and perhaps useful. Thus, in the harmonic oscillator example, the quantized energy levels are shown to be dependent on the force constant and the (atomic) masses in a certain manner. However, it is noteworthy that not only are these carried over from the classical model upon which the Schrödinger methodology is imposed, but also, there is apparently no independent verification of the derived relationship possible.

Operator based equations for wave propagation, and indeed leading to discrete solutions, were known prior to the advent of quantum theory. Extending these equations to model (purported) quantization phenomena was, of course, an attractive intellectual challenge and quite a quantum leap (sic)! All said and done, however, what the Schrödinger equation does not accomplish is create quantization out of thin air (so to speak)! This is intriguing, considering that the Schrödinger equation is generally believed to be a mathematical justification for quantization.

Derivation of the Schrödinger equation from classical wave equations — more ambiguities

The Schrödinger equation was originally derived from the classical equations of wave propagation. However, 'classical' waves need an elastic medium for their propagation, which implies a continuum of matter that is intimately involved in the ebb and flow of the 'wave train'. The de Broglie idea, on the other hand, is based in the idea of waves associated with discrete particles, which implies an absence of the continuum that characterizes the classical wave concept. This raises the question whether the classical wave equations can be applied to the case of particle-waves at all!

Of course, electromagnetic waves—proposed well before the advent of quantum theory—are believed not to require a medium for their propagation. However, the wave equations were applied to electromagnetic waves in an analogical sense, although an oscillating source that serves as 'output force' was assumed. A particle-wave would thus be a 'burst' of an electromagnetic wave that is isolated from its source, by virtue of its discreteness (in contrast to a continuous ray).

Thus, wave-particle dualism is predicated on the validity of both the electromagnetic wave equations and their applicability to the case of 'discrete bursts', with the Schrödinger equation being hostage to these suppositions. (These acquire particular significance in light of the discredited diffraction evidence for the wave theory of radiation.)

Indeed, to reiterate, the classical wave equations are derived by assuming a force—whether pressure (on a medium) or shear (on a string)—a scalar measure of the said force being the basis of the wave function. Wave motion effects a transfer of energy along a spatial dimension without moving the medium itself (along that dimension). This is impossible without the action of a sustaining force that would maintain the wave train.

The equations for wave propagation have thus been derived by assuming a constant oscillatory force that sustains the wave train in an elastic medium. Therefore, it is doubtful that the resulting equations can be applied to a purported particle-wave for which neither a generating oscillatory force nor an elastic medium exists.

In fact, a particle moving at constant velocity is not being acted upon by any force, so the particle-wave is merely an associated wave, hence different from a conventional wave which is propelled by a force acting on a medium supporting the wave. This implies that the classical wave equations have been taken out of context in deriving the Schrödinger equation.

It is interesting that the Schrödinger equation ends up eliminating the wavelength of the wave—a consequence of applying both the de Broglie and Planck equations—and replacing it with the mass of the particle. Again, this is the mass of a discrete particle, thus restating with mathematical exactitude the absence of a continuum for the propagation of the purported wave. (Indeed, the contradictory ideas represented by the wave function and the mass, coexist in the same equation, in a kinetic extension of the earlier de Broglie equation.)

These ambiguities acquire renewed significance in light of the above revelations concerning the founding assumptions of quantum theory, particularly the dubious basis for the Planck quantum proposal and the de Broglie equation itself.

The quantum–duality–wave function triad: a tenuous interrelatedness

As argued previously [1], Planck's quantum proposal served as the dubious backdrop to the development of quantum theory, being the inspiration for its final consummation in the Schrödinger equation. However, this needed the intermediate de Broglie proposal of wave–particle duality, although this was hardly of any relevance to Planck's quantum idea. Wave–particle duality, however, is critical to the derivation of the Schrödinger equation, although with the caveats argued above. Thus, the three key ideas that form the basis of quantum theory are apparently only tenuously interrelated, so quantum theory is hardly a seamlessly integrated and coherent whole.

Broader implications concerning science and pedagogy

On the nature of scientific knowledge

The above arguments constitute a comprehensive critique of various facets of quantum theory, both experimental and theoretical. In fact, they lead to disturbing questions about the nature of scientific knowledge, not to mention its pedagogical manifestation. The history of quantum theory represents a fascinating case study of intellectual exploration, in which observations of natural phenomena have led to hypotheses that are both mathematically rich and complex. If observation be the final arbiter of truth, however, mathematics can only serve as handmaiden: And in the case of quantum theory, intriguingly, the roles may well have been reversed!

Hypotheses that now seem manifestly flawed, such as the Rayleigh–Jeans–Planck proposal, and those involving purported diffraction phenomena, inspired mathematical models that apparently sustained prevailing views and beliefs. Subtly introduced extensions, particularly the wave function idea, led to the dominance of mathematical approaches thenceforth, which clearly continue to prevail. Yet, the fact remains that most of the early models and hypotheses now seem deeply flawed, thus raising troubling questions about the role of mathematical methods in the advance of science.

Quantum theory has also spawned a considerable philosophical sub-culture, which apparently claims to reformulate our understanding of the nature of reality. In light of the above ambiguities concerning the core theory itself, however, the philosophical claims appear of dubious significance. (It is interesting to speculate whether quantum theory can be derived from said philosophical speculation itself!)

Pedagogical issues

Another intriguing question that arises from the above considerations concerns the role of quantum theory in science education and the training of young minds. In light of the fact that quantum theory is shot through with ambiguities, it is likely to promote rigmarole learning to the detriment of critical inquiry and scholarship. Thus, quantum theory may not be suitable for even intermediate level courses at college levels, as a certain degree of maturity would be required to deal with the mass of inconsistent observational and mathematical content, with far too many unstated assumptions and contradictions. Thus, quantum theory would possibly instil a false notion of science as intellectually convenient, with mathematics being commandeered to justify the unjustifiable. Generally, quantum theory as a body of knowledge, appears neither cohesive nor cogent.

CONCLUSIONS

The place of quantum theory in science—both historically and in its final manifestation—is intriguing. Quantum theory is generally regarded as representing a triumph of mathematical science in modelling observational phenomena. A dispassionate analysis of both the historical evolution of quantum theory, as also the fundamental concepts that are the basis of its consummate manifestation, however unearth disturbing questions of a both topical and general nature.

Several of the early observations and hypotheses that constitute the foundations of quantum theory now appear dubious. These include the Rayleigh–Jeans–Planck theory of black body radiation that led to the quantum proposal, but most intriguingly, also the various purported diffraction phenomena that are believed to evidence the clutch of wave–corpuscular theories. This apparently invalidates the de Broglie proposal of particle-waves, and by implication the Schrödinger equation itself. It is also unclear whether the classical wave equations can serve as the basis for describing the behaviour of purported matter waves, as assumed in deriving the Schrödinger equation.

These may appear sweeping claims, yet they have been made with due regard to the available factual evidence, which is merely being examined afresh thus leading to a reassessment. In fact, the inherent ambiguities of quantum theory raise intriguing didactic and pedagogical questions. Thus, quantum theory may be appropriate only for advanced college level courses, as it calls for considerable maturity, in both teacher and student alike, in order to deal with its apparently contradictory content. (The philosophical claims of quantum theory, relating to our perception of reality, likewise elicit scepticism.)

REFERENCES

[1] S. Chandrasekhar. False formalisms and ends justifying means: The case of quantum theory. *viXra e-print archive* (2019), available at: viXra:1904.0079 (and references therein).