COMMENTARY

A Complete Quantum Mechanics

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Abstract

We hypothesize that quantum mechanics is incomplete because it does not take into consideration the absorption of energy by quantum systems as described by matrix mechanics. To be complete quantum mechanics must include both matrix and wave mechanics, and due to the conservation of energy the first (absorption) must be carried out to completion before the second one (emission) can begin. The combined model of matrix and wave mechanics integrates naturally with Einstein's use of independent coordinate systems K and K' to describe the absorption and emission of radiation. All subsequent mathematical models are versions of this physical model.

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1. Introduction

Quantum mechanics is formulated in many different ways, with matrices, wave equations, transformations, and path integrals to name the more familiar. We will unify the different mathematical pictures by visualizing them as part of a single physical model. As an example of how visualization can assist in understanding the behavior of natural phenomena we refer to Einstein's many successes. He imagined riding a light beam and the relative motion of magnets and conductors to derive special relativity theory. The possibility of formulating general relativity occurred to him by picturing experiments performed in free fall or in an accelerating laboratory. He anticipated the invention of lasers by visualizing the effect photon momentum has on the emission and absorption of radiation. We wish to continue in the spirit of his methods by visualizing the radiation processes that lead to the present day theory of quantum mechanics.

When quantum mechanics originated its purpose was to make sense of the spectral properties of black body radiation, the radiation emitted by a body that is based only upon temperature. To visualize how black body radiation is generated we imagine the molecular-kinetic effect of heat on an iron rod. When heat is applied to the rod the iron molecules vibrate more and more rapidly and begin to emit radiation, first in the infrared spectrum and then in higher and higher electromagnetic frequencies. The curve formed by plotting black body radiation was reproduced mathematically in 1901 and it is known as Planck's radiation law. In 1905 Einstein interpreted Planck's mathematical derivation as the result of discrete and continuous contributions to radiation; discrete contributions due to "energy quanta" and continuous contributions due to thermal energy[1]. The relative contribution of energy quanta to spectral radiance (intensity) increases dramatically with temperature, but all emissions of the iron rod include both forms of contribution irrespective of the temperature. We visualize black body radiation as the continuous transformation of thermal energy to radiation. In other words, as the iron rod is heated it initially emits infrared radiation and later radiation in the visible spectrum.

2. Visualizing matrix mechanics

Quantum mechanics developed in order to explain the spectral properties of the black body radiation emitted by hydrogen. The first attempt, matrix mechanics, is based on the assumption that matrices describe the observables of a quantum system, frequencies and intensities. There are an infinite number of observables with each one indexed by a matrix element with two distinct energy levels. Matrix elements representing transitions that cannot be observed are assigned a value of zero since Heisenberg believed that quantum mechanics should be "founded exclusively upon relationships between quantities which in principle are observable"[2]. He defended that idea, vehemently opposing Schrodinger's wave mechanical model which appeared shortly after[3]. No evidence, theoretical or physical, has ever been presented to substantiate his claim. To believe it requires absolute faith in the importance of the observable. It led Heisenberg to think that matrices describe the complete atom for they include all possible observables related to its spectroscopic properties. However, there are no matrices describing single atoms. The only matrices that are actually used in radiation processes describe spin, a quantum mechanical variable with no thermal input.

The spectroscopic properties of hydrogen studied by Heisenberg are produced by heating hydrogen gas to create an emission spectrum. The transfer of heat to a gas has been extensively studied and occurs from both classical and quantum mechanical perspectives. It initiates with classical exchanges of energy by the temperature dependent motion of particles. Gradual increases of absorption occur according to the electron quantum Hamiltonian describing the transition energy between states. Infinitesimal thermal exchanges correspond to matrix elements that describe infinitesimal changes in state. We describe the heat absorption of a hydrogen gas molecule initially with matrix elements far from the diagonal, gradually proceeding closer to the diagonal as the temperature increases. Electron transitions can be either emissions or absorptions so the complete matrix of an atom requires a two-fold infinite number of elements to describe all possible energy exchanges, with energy emission occurring when atoms have net positive transition energies. The continued influx of heat leads to spectral emissions and the existence of line structure. No one has ever used matrix mechanics to study the function of an atomic oscillator, for if the off-diagonal matrix elements corresponding to unobservable heat transfers are equal to zero it is immersed in a "thermal bath" equal to absolute zero and cannot radiate at all.

3. The complete quantum mechanics

When quantum mechanics first appeared in 1926 it was questioned why two formulations, matrix mechanics and wave mechanics, were necessary. Mathematical equivalence was demonstrated by showing that the matrix mechanically determined energy states of the Bohr atom and the eigenvalues of wave mechanics define the same physical endpoint[4]. However, every other aspect of the models; their experiments, mathematical formalisms, and physical interpretations; is different. The two theories both describe the same *invariant* physical observables that characterize the steady states, but they do not explain why they follow different paths to arrive there. Einstein's unfinished theory answers that question by showing that radiation processes occur in two physically independent steps, absorption in K and emission in K'[5]. We adopt Einstein's mathematical convention describing the foundations of quantum theory in the remainder of this paper.

There are two coordinate systems and two distinct mathematical formulations, matrix mechanics originating in K and ending with the eigenvalues. Wave mechanics which originates in K' and produces the eigenvalues. Both formulations are needed for a complete quantum mechanics. To be complete quantum mechanics must describe the time evolution of two physical processes, and due to the conservation of energy the first (absorption) must be carried out to completion before the second one (emission) can begin. Incomplete theories, such as many worlds, are typically concerned with emissions alone thereby violating the conservation of energy.

4. Discussion

We propose a unified quantum mechanics by visualizing heat transfer to the hydrogen gas that causes it to radiate. It begins classically with particle motions described by statistical mechanics using four degrees of freedom in Einstein's coordinate system K. The transition from classical to quantum occurs seamlessly with continuous heat meshing with far from diagonal matrix elements. We next assign four degrees of freedom to the wave function with coordinates in K', at rest with respect to the atom. Combining both mathematical formulations requires eight degrees of freedom to describe the complete radiation process, absorption and emission. Einstein's system of coordinates, K and K', developed in his unfinished quantum theory, may now be used to visualize the impact of external influence on an atomic system.

Consider the atomic process of parametric down conversion where the impact of a photon on a non-linear crystal produces two photons with perpendicular polarization. The photons are created in the coordinate system K', at rest with respect to atomic structure. They separate and follow different trajectories in K in accordance with the conservation of energy and momentum. There is nothing unusual about the entanglement that exists between the two photons because it originated in K' and propagated in K. Wave function collapse, when the polarization of both photons becomes known, is the sudden recuperation of the four classical dimensions in K that were suppressed when the wave function was formulated in K'. The wave function is incomplete, not for reasons given in the EPR paper, but because it is formulated without taking into consideration the principles of matrix mechanics. Due to the conservation of energy neither model is complete without the other.

References

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4. ^*See for example, B. L. van der Waerden "From Matrix Mechanics and Wave Mechanics to Unified Quantum Mechanics" (Kluwer, 1973).*
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