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The Dilemma in Quantum Mechanics

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ABSTRACT

This study possesses the ambition to further investigate and indulge in the world of quantum mechanics and its complexities and possibly ascertain a solution for one major issue attributed to it: the measurement problem, which refers to, in layman's words, the issue of how and why a wave function collapses. According to papers published during the late 1930s, the measurement problem was an issue that could be partially resolved by utilizing the loosely shaped ideas of the Copenhagen Interpretation, which was later coined by Werner Heisenberg during the 1950s, as well as the newborn Pilot-Wave theory, which was further developed and brought to prominence by David Bohm's work during the 1950s. However, due to the deficiency of new information from modernised research modalities and experiments, these papers lack the new approaches proposed by various physicists, which places a circumscription on the aptitude possessed on this topic. Hence, through this paper, I possess the ambition to utilise the theories of Many Worlds (MWI), QBism, and the further developed Pilot Wave Theory (PWT) to hopefully solve this issue. Contrary to what has customarily been believed, the measurement problem can be partially solved by twisting the functioning of quantum mechanics according to certain theories, which would then act as a base for them and substantiate their claims regarding the measurement issue, such as the MWI theory going against traditional quantum theory and claiming that particles possess definite properties, with many other theories doing something similar, which I will be articulating upon in this paper. To deduce this prolonged abstract, I hope to provide you with a higher magnitude of perception on this infamous issue and probably resolve some of your pertaining doubts on quantum physics.

Keywords: Quantum Mechanics, Copenhagen Interpretation, Pilot-Wave Theory, Many Worlds Interpretation (MWI), and QBism

INTRODUCTION

The phrase "quantum mechanics" (or Quantenmechanik in German) was created by a team of physicists, which incorporated famous scientific figures, such as Max Born, Werner Heisenberg, and Wolfgang Pauli, in the early 1920s at the University of Gottingen. The antiquity of quantum mechanics has been proven to be an indispensable component of the history of modern physics. The history of this bemusing topic, interfacing with the history of quantum chemistry, essentially began with many distinctive scientific discoveries as many other sections of science do: Michael Faraday's discovery of cathode rays in 1836; the 1859-1860 winter statement of Gustav Kirchoff's black radiation problem; the suggestion made by Ludwig Eduard Boltzmann that the energy states of a physical system could be discrete; and more.

However, notwithstanding the efforts of, great discoveries made by, and spectacular additions to our aptitude on this topic by these scientists, there is one issue modern physicists and the great Erwin Schrodinger could not solve: the issue that the manner wherein wave functions change with time is governed by Schrondinger's equation, which does not account for probabilities.

In other words, despite quantum mechanics being an area of highly accurate studies, it is not able to predict the precise location of a particle in space but rather only the probability of identifying it at distinctive locations. Being aware of the location of an electron is quite significant in the field of quantum mechanics. In this field, electrons are portrayed by wave functions that provide us with the probability of them being in a specific location. By possessing an aptitude for its location, scientists can calculate the energy of an electron, the reactivity of an atom, and the conductivity of a material, all of which help them deduce the fundamental nature of matter and energy, helping us progress our civilization and work towards a more advanced world. This research/review paper aims to explore the methods utilised by scientists to resolve this issue and see how effective they are in doing so.

THEORETICAL BACKGROUND

During the period before the late 19th and early 20th century, the world's physicists took the fact that physical objects possess definite properties, which could be substantiated by scrutinising suitable observations, as a privilege. However, concerning the principles of quantum mechanics, the measurement of an aberrant property, for example, a particle's momentum, can possess a variety of plausible results with varying probabilities of its state. According to the Copenhagen perception of quantum mechanics, which was led by Niels Bohr, the reputed Danish physicist of the Institution of Theoretical Physics in Copenhagen, lest a measurement has been recorded, the properties of quantum particles possess no definite value: they are/become variables. Furthermore, this was substantiated by Werner Hiesenberg's famous uncertainty principle of 1927, which stated that the measurement of a particle's position limits the ability to measure its momentum and vice-versa; it is impossible to measure both position and speed accurately. This principle governs many other pairs of observable quantities. Popular physicists of the early 20th century, such as Albert Einstein, Boris Podolsky, and Nathen Rosen, stated that such a manner of thinking leads to inconsistency. According to them, a pair of particles speeding away from each other possessed co-related properties; a position or speed measurement would promptly provide data on the position or speed of the latter. They implied that the first particle always had definite values of both properties, as either property could be precisely examined where no physical action has been performed on that particle. On the contrary, the Copenhagen interpretation seemed to imply that the properties of the second particle would only become definite once the first particle had been measured though they were no longer related/in contact.

The introduction of probabilities into physics disturbed a few physicists, but quantum mechanics incorporating probabilities wasn't the issue; the issue is that the manner wave functions, which is a mathematical description of the quantum state of a particle as a function of position, momentum, time, and spin, alter with time is governed by an equation, the Schrodinger equation, which doesn't take account of probabilities. This means that at any given moment, concerning the wave function, the equation can predict the wave function at any time in the future. Eminently, this will lead to many problems, as the probability of chaos is absent, the extreme sensitivity to initial conditions that is possible in Newtonian mechanics. After scrutinising this issue, Heisenberg realised a particle can't possess both a definite position or velocity in the same period; the measuring of one would make the measuring of the other impossible, as its velocity and position would be changing together. These shortcomings are partially averted in the realist - as opposed to the instrumentalist - approach to quantum mechanics, where the wave function and its evolution is gravely deemed the description of reality. However, again, this leads to other issues. What then? One reasonable answer is incorporated in the advice provided to inquiring students: "Shut up and calculate!" No disputes are present in describing how to utilise quantum mechanics, only in describing what it means and aims to imply, so it may be that the issue is only in words. In this paper, I will be endeavouring to ascertain modalities to fix this dilemma.

LITERATURE REVIEW

Quantum physics is a sorely aberrant, albeit captivating, perplexing genre of classical physics. From possessing a lumpy surface, permitting a particle to be in two places at once, being the reason the sun shines, and instigating the evaporation of black holes to elucidating the enormous, vast structure of the universe, this subtopic is the base for chemistry and biology or everything in the world. In other words, it informs us of the functioning of the universe due to it elucidating the functioning of atoms. As with everything, quantum physics also possesses issues that hinder our perception of it as well as other topics that rely upon it. However, there is one major issue that many physicists are endeavouring to resolve, which is the problem of not incorporating probabilities in Schrödinger's equation. In this literature review, I will be analysing the modalities utilised by contemporary physicists to overcome this issue by scrutinising three sources, which will provide us with a greater understanding of the issue and its solutions.

According to the Stanford Encyclopedia of Philosophy (SEOP), "If quantum state evolution proceeds via the Schrödinger equation or some other linear equation, typical experiments will lead to quantum states that are superpositions of terms corresponding to distinct experimental outcomes." This means that until measured, the quantum state of a particle is variable; it could be present in multiple states and at distinctive positions. If the quantum state is deemed to be a complete description of the quantum system, one would ascertain that, surprisingly, the state does not correspond to a unique/particular, definite outcome. Due to this phenomenon, an interpretational issue is precipitated, which is customarily referred to as the 'measurement problem'. "Either the wavefunction, as given by the Schrödinger equation, is not everything, or it is not right." (Bell, J.S., 1987: 41, 2004, 201). Based on J.S. Bell, we can categorise the approaches to this issue into three categories:

a) There are approaches that incorporate a denial that a quantum wave function, or any other manner of representing a quantum state, possesses a complete description of a physical system.
b) There are approaches that modify dynamics to create a collapse of the quantum state under appropriate conditions.
c) There are approaches that deny Bell's dilemma and state, "Quantum states undergo unitary revolution at all times and that a quantum state-description is, in principle, complete."

The First approach: "Many-Worlds Interpretation (MWI) Theory," -
The M.W.I. was first developed by Hugh Everett III. Throughout his scientific career, he possessed the ambition to perceive what the equations of quantum mechanics portrayed in reality by having the mathematics of the theory itself portray how these equations functioned instead of 'by appending interpretational hypotheses to the maths'. Whilst endeavouring to do so, Hugh came across the notorious "measurement problem" that had baffled scientists of the early 20th century. To overcome this hindrance, he addressed the issue by combining the microscopic and macroscopic worlds and introducing a universal wave function that establishes a connection between the observers and objects as a part of a single quantum system. In other words, he questioned whether the continuous evolution of a wave function is not interrupted by the acts of measurement: what if the quantum state of an object possessed a definite value before measuring it? After more research, Everett ascertained that according to his assumption, at each interaction of an observer with a superimposed object, the wave function of the observer would, in effect, bifurcate; the function would incorporate unique branches for every alternative creating the superposition of the object. Consequently, each branch independently embarks on a distinctive future. The idea of multiple universes was created as a repercussion of his assumption. In his thesis, Hugh stated, "From the viewpoint of the theory, all elements of a superposition (all 'branches') are 'actual', none any more 'real' than the rest." This theory has been disputed by many physicists who stated that it possessed many issues, but it remains one of the most valid approaches to resolving the measurement problem.

The Second approach: "The Pilot-Wave Theory," -
The Pilot-Wave theory was devised by Louis de Broglie, a reputed French physicist of the 20th century. Louis' theory states, "Particles don't exist as probabilistic waves, but that there are both real particles - which always have definable properties - and real waves influencing how the particles move." (Popular Mechanics, 2016). It claims that in addition to particles, physical waves pertain and make somewhat tracks for the particles to follow; with the aptitude of all the properties of the particle (its direction, momentum, velocity, position, etcetera), it is possible to predict where it is ultimately going to land. In other words, it states that regarding the measurement problem, the particle already possessed definite values of its properties before being measured, implying that the wave function has already collapsed for some time. This conjecture goes contrary to the general idea of quantum mechanics, which claims that the journey of a sole particle is fundamentally arbitrary, not probabilistic. Again, this theory is quite controversial but provides a viable solution to the issue being worked upon, as it implies that the properties of any particle are always definite, permitting scientists to accurately predict or locate the particle/utilise the properties of it for mathematical purposes.

The Third approach: "Quantum Bayesianism (QBism)," -
'QBism' was devised in the early 21st century by profound physicists, such as Christopher Fuchs, Carlton Caves, and Rüdiger Schack to endeavour to provide an utter, consistent framework description to our perception of quantum

mechanics as well as to resolve the infamous measurement problem. This approach is derived from the Bayesian interpretation of probabilities, which refers to a framework of reasoning regarding dubitable events by deeming probabilities as degrees of belief, which are reformed with the publication of new information. According to Qbism, wave functions and their probabilities represent an observer's subjective aptitude regarding a quantum system rather than an objective description of reality (Medium, 2023). In other words, the observer's beliefs and degrees of belief play an imperative role in perceiving quantum mechanics/physics. By taking the above definition into account, this theory resolves some of the conceptual problems of other theories endeavouring to solve the measurement problem, as well, such as the collapse of wave functions and the role of an observer. With the utilisation of this approach, an observer's (personal) degrees of belief about the possible outcome of a quantum measurement will contradict the measurement problem, as the wave function does not need to collapse, which all depends on the observer's aptitude on the quantum system, making the role of the observer a crucial one, and solving (attempting to solve) the measurement problem. As with every theory endeavouring to ascertain a solution to this issue, it is quite controversial, as it disregards other factors, such as not substantiating the pertinence of an underlying ontic state of a quantum as well as realism, undermines the objectivity of science, and raises doubts about an 'independent, physical reality', but it is logical and a part of a scarce number of solutions to this problem.

To deduce this literature review, I have ascertained that solving the measurement problem present in quantum physics/mechanics is a solely arduous task incorporating a lot of research and diligence. According to my findings, there are numerous controversial approaches to the issue researched with some of them being logical and illogical. For example, the MWI theory refers to the pertinence of infinite parallel universes, which hasn't been substantiated yet. Furthermore, the Pilot-Wave theory claims that the properties of a particle (spin, momentum, direction, etcetera) were, are, and will always remain definite, which according to many physicists, doesn't incorporate much logic. However, according to me, if provided with more time, mankind will be able to generate an accurate, valid approach that will put every physicist's mind to rest and provide us with a greater perception of our vast, bemusing universe, even perhaps, time travel.

CONCLUSION

The testimonies that have been stated are quite eminent: the measurement problem is an issue that is open to numerous, distinctive interpretations, with all of its solutions being quite controversial and contradictory to each other and each of them utilizing their personalized schools of thought, which they have inherited from their creator. The measurement problem is an issue to which a solution will be ascertained only when additional information is found, which would elongate our aptitude for pertinent mathematical and scientific topics and support us in discerning this issue in more detail. In other words, it will be a few decades before one finds a solution that does not go against any rules and is accepted by all physicists. Albeit many valid, logical approaches currently pertain in the scientific realm, most of them take a reference or incorporate topics/ideas/statements in their beliefs/claims that haven't been substantiated yet, making them solely ambitious and not facts.

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