American Research Journal of Physics

Volume 10, Issue 1, 9-12 Pages
Research Article | Open Access
ISSN (Online)- 2380-5714
DOI : 10.21694/2380-5714.24002

AMERICAN RESEARCH JOURNALS
An Academic Publishing House

Philosophy of Quantum Physics

Aiden Hyun
Bergen County Technical School, Teterboro.

ABSTRACT

This abstract provides an overview of key topics central to the interpretation of quantum mechanics, exploring various theories and their unique perspectives. It delves into the concept of "quantum superposition" and its physical implications, exemplified by the Schrödinger's cat thought experiment. The "measurement problem" is addressed, questioning the nature of "measurement," the application of Schrödinger's equation, and the interaction between measurement devices and wave functions in determining probabilities. Additionally, the study examines the relationship between quantum mechanics and determinism. Finally, it considers potential conflicts between quantum mechanics and other established physical theories, such as special relativity, highlighted by the EPR paradox.

IS THE FUTURE PREDETERMINED?

Before quantum theory, the motion of objects was explained by Newtonian mechanics, established by Isaac Newton. This framework describes the movement of objects under the influence of forces. For example, when you throw a ball, Newtonian mechanics can predict where it will land based on its initial speed, direction, and height. Essentially, the ball's landing position is determined the moment it leaves your hand. French scientist Pierre-Simon Laplace expanded on Newton's ideas, proposing a hypothesis known as "Laplace's Demon."For much of the 19th century, physicists believed in Laplace's idea that if someone could know the state of all matter in the universe, they could predict the future. This belief was based on the assumption that the future is predetermined and that any inability to predict it was due to human limitations.

However, the advent of quantum theory significantly changed this perspective. Quantum theory challenges Laplace's Demon, asserting that even with complete information, predicting the future is fundamentally impossible. Thus, the future is not predetermined as previously thought. Quantum theory, which emerged in response to discoveries about atoms and subatomic particles, differs significantly from Newtonian mechanics. In the microscopic world, behaviors are distinct from what we observe in everyday life. Quantum theory introduces concepts like the "electron cloud," which describes electrons surrounding a nucleus, not in fixed orbits but in a cloud-like region.One of the intriguing revelations of quantum theory is the phenomenon that matter can appear and disappear in a vacuum—an empty space where such occurrences defy previous conceptions. Additionally, quantum theory describes the "tunnel effect," where microscopic particles like electrons can pass through barriers. Unlike a baseball that bounces back when thrown against a wall, electrons can, under certain conditions, move through the wall, demonstrating the unique and counterintuitive nature of the quantum world.

QUANTUM SUPERPOSITION - COEXISTENCE OF STATES

Quantum theory introduces an enigmatic idea: an object like an electron can exist in more than one place at the same time. This concept is hard to grasp because it is so different from our daily experiences. Imagine a small ball in a box. If you shake the box and then divide it in half, you would expect the ball to end up on one side. But in quantum mechanics, it is as if the ball is on both sides simultaneously!This scenario changes once you look to find the ball's position. The moment you observe it, the ball seems to be in only one spot. This is known as "coexistence of states," a principle where something can be in two places at once until it is observed. When you check, it appears to settle on one side. This phenomenon, unique to the microscopic world of atoms and electrons, challenges our usual understanding of existence.In quantum terms, observing an electron changes its state. For instance, if an electron appears on the left side of a box upon observation, it is not correct to say the electron was always there. Before observation, it existed in a "coexisting" state, being both left and right. Observing it forces the electron into a definite location, a process called "collapse" of its superposition. This underlines a key aspect of quantum mechanics: the act of observation influences an electron's state, making the observer an active participant in defining reality.

Hans Reichenbach introduced the concepts of "observational language" and "quantum mechanics language," exploring how we discuss and understand scientific phenomena.

Reichenbach also proposed two distinct logic systems: binary truth value logic and three-value logic. Binary truth value logic is either true or false. This straightforward approach suits many everyday scenarios. However, the three-value logic adds a third category, representing states that are "undecided" or "unknown."This addition of a third value provides a more nuanced way to handle the complexities of quantum physics, where certain phenomena cannot be neatly labeled as true or false.

THE WAVE-LIKE PROPERTIES OF ELECTRONS

Electrons, much like light, display interference patterns in a double-slit experiment. This experiment involves a plate with two slits positioned in front of an electron gun, which emits electrons one at a time. Behind the slits is a screen that captures the impact points of the electrons.

In theory, if electrons were merely particles, they should travel in straight lines and produce two distinct impact areas aligned with the slits. Contrary to this expectation, when a single electron is emitted, it leaves a single point-like trace on the screen. But as more electrons are emitted, a pattern emerges that is not aligned with the straight paths one would expect from particles. Instead, an interference pattern, characteristic of waves, becomes visible. This pattern is a clear indication of the wave-like nature of electrons, a phenomenon that cannot be explained if electrons are considered solely as particles. The experiment reveals that with each emission, the cumulative effect of multiple electrons demonstrates their wave properties.

The wave associated with an electron corresponds to the likelihood of locating the electron. It is important to clarify that the term "wave" in this context does not imply any physical vibration of material. This interpretation, known as the "probability interpretation," was initially put forth by the German physicist Max Born in 1926. By observing where these electrons appear, physicists can calculate the likelihood of finding an electron at any specific point. This concept is referred to as the "probability distribution of electron positions." Between observations, an electron does not have a definite location. Physicists describe this "superposition" of positions. To illustrate, when we observe an object, the image transmitted to our retina appears continuous, and even in the case of an animation consisting of 24 frames per second, it creates the illusion of continuous motion. Each frame, when broken down into 1/24th of a second, represents a discrete still image, but our perception integrates them seamlessly. In quantum physics, superposition works in a similar way. Different possible states of an electron (like state 1 and state 2) overlap, creating a continuum of possibilities. This is the essence of quantum superposition: a state where multiple possibilities exist simultaneously and thephenomenon underpinningthe fundamental aspect of how particles behave like electrons.

SCHRÖDINGER'S CAT AND QUANTUM SUPERPOSITION

The idea of quantum superposition is largely derived from the Copenhagen interpretation, developed by Niels Bohr and Werner Heisenberg. This interpretation suggests a division between the macro-world (our everyday world) and the micro-world (the world of quantum particles). According to this view, the state of a quantum system becomes determined only when it is observed or measured. However, the Copenhagen interpretation does not clearly define the boundary between the quantum and classical realms. This ambiguity gives rise to intriguing thought experiments like "Schrödinger's Cat." The experiment highlights the uncertainty surrounding the collapse of the state function during measurement, leading to questions about the very nature of measurement itself.Schrödinger, a physicist, conceived an experiment to illustrate a complex aspect of quantum physics. Imagine placing a cat insidea box with an atom, and neither cat nor atom can be observed while inside. This atom can be in two states: A (like a particle) or B (like a wave). If the atom is in state A, nothing happens. But if it is in state B, a machine breaks a poison bottle, thereby killing the cat. The twist is that the atom can be in both states at once, a so-called "superposition," until someone checks. So, the question is: is the cat alive or dead before you open the box?The paradox surrounding the cat's life and death serves as a compelling illustration of the concepts of quantum probability and superposition within the macroscopic realm. The paradox of Schrödinger's Cat, mixing the microscopic and macroscopic worlds, remains unresolved. This paradox also relates to Heisenberg's uncertainty principle, which states that it is impossible to precisely know both the position and momentum of a particle at the same time. In quantum mechanics, an electron or particle's precise state is actually many possible mixed states, highlighting the fundamentally uncertain nature of the quantum world.

QUANTUM MECHANICS AND MEASUREMENT

Niels Bohr is renowned for his Copenhagen interpretation of quantum mechanics, which centers on how we understand the connections between observable quantities in the world. A key aspect of this interpretation is Bohr's complementary principle, highlighting the wave-particle duality in quantum mechanics. This principle asserts that in the quantum level, particles can simultaneously exhibit both wave-like and particle-like attributes. Bohr's principle becomes particularly significant when it comes to observing and experimenting in quantum mechanics. The nature of the observation or measurement determines whether a particle's wave-like or particle-like characteristics are revealed. For instance, under the Heisenberg' Uncertainty Principle, it is impossible to precisely measure both the position and momentum of a particle at the same time. This principle underlines the fundamental limitations in observing quantum systems.

Bohr's principle of complementarity in quantum mechanics opens up philosophical discussions about the nature of reality and the observer's role. This theory suggests that the act of measuring or observing can influence the outcome in the quantum realm. This idea introduces deep epistemological questions regarding reality, indicating that an observer's intervention might alter a quantum system's properties. Bohr's emphasis on "what is observed" and "how it is observed" underlines the crucial interplay between observation and reality in quantum mechanics interpretation. From this perspective, the principle of complementarity offers insightful views on quantum mechanics, profoundly impacting debates in both physics and philosophy. It highlights the unique aspects of quantum mechanics and reshapes our understanding of the observer's influence on the observed phenomena.

John von Neumann, building on the work of Schrödinger and Heisenberg, developed a theory about how quantum systems transition into classical states during measurements. He explained this using wave functions in quantum mechanics, dividing the process into two stages. The first stage is the natural evolution of the wave function, which is predictable and follows set rules. The second stage happens during measurement, where the wave function suddenly "collapses" into a specific state. This collapse is unpredictable and based on probabilities.In essence, von Neumann distinguished between "physical processes without measurement" and "physical processes with measurement" in quantum mechanics. He argued that before measurement, the wave function changes in a predictable way. However, during measurement, it collapses into a specific state, introducing elements of unpredictability. This view contrasts slightly with the Copenhagen interpretation, which states that a wave function represents many possibilities at once until measured. Upon measurement, it collapses into a single outcome, highlighting the inherently unpredictable nature of the quantum world.The question of when and how the wave function collapses in quantum mechanics has led to various theories. In the 1960s, Eugene Wigner redefined the "Schrödinger's cat" thought experiment and suggested that an observer's consciousness acts as a critical boundary, leading to the collapse of the wave function. Wigner introduced a distinction between the "purely physical" and the "conscious."However, the problem was that Wigner himself did not provide a sufficient answer as to what constitutes a "conscious system."Wigner's ideas remain a subject of ongoing discussion and exploration in the area of quantum philosophy and the nature of consciousness.

Can we formulate a theory that elucidates the collapse while preserving a macroscopic concept of position? One approach to this problem is to consider that when a particle's wave function collapses, it interacts with the eigenfunction of the position operator. This hypothesis led to the formulation of the GRW theory, named after its developers: Ghirardi, Rimini, and Weber. This theory attempts to provide a more concrete explanation of the wave function collapse in quantum mechanics.The GRW theory presents a solution to the measurement problem in quantum mechanics. While the conventional Copenhagen interpretation emphasizes the observer's role, the GRW theory interprets the 'wave function collapse' as an intrinsic physical process. In the GRW theory, it postulates that the wave function spontaneously collapses with a defined probability. This collapse probability scales with the size of the object, resulting in macroscopic objects displaying classical behavior. This distinction is crucial for establishing a clear boundary between the realms of quantum mechanics and classical mechanics. The GRW theory has not yet received direct experimental confirmation. Nonetheless, it possesses significant potential in explaining various quantum mechanical phenomena, with hopes for experimental corroboration in the future. In the context of the observer's role in quantum mechanics, all three prominent theories - the Copenhagen interpretation, John von Neumann's approach, and the GRW theory - acknowledge the importance of the wave function. However, the Copenhagen interpretation places emphasis on the observer's role, John von Neumann emphasizes mathematical rigor, and the GRW theory posits the spontaneous collapse of the wave function, thereby reducing the observer's influence.

EPR PARADOX

The EPR thought experiment involves two particles with opposite spins, totaling zero, and placed far apart. Measuring one particle's spin "up" instantly tells us the other's "down." This raises a question: does measuring the first particle instantly affect the second? Einstein favored a hidden variables explanation, suggesting the second particle's spin was predetermined, not influenced by the first.

The EPR paradox introduces the concept of "entanglement" in quantum mechanics. This means when two particles are entangled, measuring one can instantly affect the other, no matter the distance between them. This challenges classical ideas of separate, independent systems. Einstein, who preferred a deterministic view of the universe, argued that quantum mechanics was incomplete because it relied on probabilities. He famously questioned the Copenhagen interpretation, asking, "Does the moon exist only when someone is looking at it?" (Realism, Namuwiki) and stating that "God does not play dice" to express his discomfort with the inherent randomness in quantum mechanics. On the other hand, Niels Bohr believed in the probabilistic nature of quantum mechanics. He compared the wave function's relativity to the measurement process to the relativity of length in Einstein's theory of special relativity.

Physicist John Stewart Bell (1928-1990) turned Einstein's EPR theory into a paradox. Bell proposed "Bell's inequality," which provided a way to test the predictions of quantum mechanics against Einstein's hidden variable theories. Bell's inequality highlights the difference between the predictions of quantum mechanics and the expectations based on local realism, the idea that physical processes occurring at one location cannot instantly influence another distant location. Bell suggested hidden variables might exist in entangled particles, challenging local realism's ability to fully explain quantum phenomena. As a consequence, Bell's experiments demonstrated that neither local realism nor hidden variable theories can align with quantum mechanics' predictions. This establishes that certain aspects of quantum mechanics contradict conventional physical assumptions, particularly the concept of locality. These results have fueled philosophical debates about the relationship between quantum mechanics and our understanding of reality, inspiring a deeper exploration of physics' philosophical dimensions. Regarding the nature of quantum properties, Bell's theorem deals with indeterminacy, not determinism. Even if certain properties of a system are indeterminate, it does not mean they do not exist. Quantum systems still have deterministic properties like charge, spin magnitude, and mass. Despite some properties being relative, it is incorrect to say that objects with these properties are non-existent.

Following Bell's theorem, Dieter Zeh's Decoherence theory emerged as a significant topic. Quantum systems inherently harbor minuscule uncertainties, which manifest as superposition states of quantum states. However, when quantum systems interact with their surrounding environment, the superposition of quantum states diminishes, and the quantum system converges into specific states. This process is referred to as decoherence. The decoherence theory provides a mathematical explanation for this transition from quantum ambiguity to classical certainty. It differs from the Copenhagen interpretation, which focuses on the mathematical description of quantum mechanics and introduces the "collapse of the wave function" concept. The Copenhagen interpretation suggests that a quantum system's state becomes definite only upon measurement. In contrast, Decoherence theory argues that quantum systems become "classical" due to environmental interactions, not because of wave function collapse.

CONCLUSION

"It is safe to say that nobody understands quantum mechanics."

— Richard Feynman

"The theory agrees amazingly well with experiment and at the same time possesses a profound mathematical beauty, yet it makes absolutely no sense."

— Roger Penrose

Every time a new interpretation of quantum mechanics emerges, the words of these two scientists come to mind. While some dismiss the philosophical approach to quantum mechanics as pseudoscience, others claim it is a process of breaking conventional wisdom, often based on a lack of understanding of quantum mechanics and bolstered by various delusions. Most pseudosciences and other superstitions base their claims on inaccurate experiments, arbitrary interpretations of observed phenomena, or on phenomena that are, in fact, unobservable. Lisa Randal,a Harvard physicist, points out that quantum mechanics is not a discipline for explaining human cognition, but one that deals with the sub-atomic scale. She asserts that even if a new theory requires fundamentally different premises from existing ones, as quantum mechanics certainly did, the validity of such a theory ultimately rests only upon well-founded scientific discourse and experimentation.

The reason for interpreting quantum mechanics philosophically is because experiments show results that are very different from our intuitive understanding, causing many philosophical debates. In conclusion, quantum mechanics breaks down the boundary between scientific discovery and philosophical inquiry, deeply influencing the way we understand the universe. For these reasons, many scholars are still interpreting and exploring quantum mechanics from a philosophical perspective.

REFERENCE

1. Capra, F. (2010). *The tao of physics: An exploration of the parallels between modern physics and Eastern mysticism*. Shambhala; Boulder.
2. Kosso, P. (1998). *Appearance and reality: A introduction to the philosophy of physics*. Oxford University Press; New York.
3. Laszlo, E. (2003). *The connectivity hypothesis: Foundations of an integral science of quantum, cosmos, life & consciousness.* State University Of New York Press; Albany.
4. Primas, H. and Esfeld, M. A critical review of Wigner's work on the conceptual foundationsquantum theory, *The collected works of Eugene Paul Wigner. Historical, philosophical, and socio-political papers.* (Vol. VI). Springer-Verlag; Berlin.
5. Reichenbach, H. (2011). *Philosophic foundations of quantum mechanics.* Dover; London.
6. Reichenbach, H. (1957). *The philosophy of space & time*. (M. Reichenbach & J. Freund Trans.). Dover; London.
7. Sklar, L. (2018). *Philosophy of physics*.(Dimensions of philosophy series). CRC Press; Boca Raton.

Citation: Aiden Hyun, "Philosophy of Quantum Physics", American Research Journal of Physics, Vol 10, no. 1, 2024, pp. 9-12.