A brief discussion on the connection between classical theory and quantum mechanics

Wang Qiang[1, a*], Zhou Jianguo[2, b],

[1]Anhui University of Science and Technology, Huainan Main Campus, No. 168 Tai feng Street, Huainan City, Anhui Province, 232001, China
[2]North China University of Science and Technology, Caofeidian Main Campus, No. 21 Bohai Avenue, Caofeidian New Town, Tangshan City, Hebei Province, 063210, China
a.wangqiang_46fhj8@163.com,b.jianguo_6597_zhou@gmail.com
***Corresponding Author**

Abstract: This paper first reviews several issues in the history of quantum mechanics development, briefly explaining the main contents of the "EPR paradox" and "Schrödinger's cat." It then introduces the efforts scientists have made in recent years in studying the relationship between classical and quantum theory through the "ghost imaging" experiment. Furthermore, by introducing "Ohm's law in the quantum world" and "the connection between photosynthesis and quantum mechanics," it illustrates the relevance of quantum mechanics to our daily lives. Finally, the paper analyzes and summarizes the problems that still exist in quantum mechanics today, concluding that quantum mechanics urgently needs further development.

Keywords: classical theory, quantum mechanics, connection

1. Introduction

Since its establishment in the early 20th century, quantum mechanics has undergone rapid development and gradually become an integral part of modern physics. As the core of modern quantum theory, its development concerns not only human material civilization but also has brought revolutionary advances in our understanding of the quantum world [1].

However, quantum mechanics is not a complete theory, and many problems remain within its framework, particularly regarding the connection between the microscopic and macroscopic worlds—that is, the relationship between classical theory and quantum mechanics. To resolve these puzzles, scientists throughout history have proposed numerous experiments and theories. This paper aims to take several experiments proposed in the history of quantum mechanics development as examples, analyze them briefly, and thereby demonstrate the connection between classical theory and quantum mechanics.

2. Problem statement

In March 1935, Einstein and his colleagues introduced the concept of "quantum entangled state" in their EPR paper. The so-called "quantum entangled state" takes two or more particles as its object. In a sense, the "quantum entangled state" can be understood as applying the superposition state to two or more particles. If two particles exist in a "quantum entangled state," these two particles must be correlated with each other. From the perspective of quantum mechanics, as long as people do not observe them, the state of each particle cannot be determined. However, if both particles are simultaneously maintained in a fixed state at a certain moment that is, if the superposition states of both particles collapse instantaneously particle 1 will then remain in one state without further change. According to the conservation law, particle 2 will be in a state corresponding to that of particle 1. If the two particles are separated by a very great distance and there is no action at a distance, it would be impossible for the two particles to communicate with each other instantaneously. Yet action at a distance contradicts many contemporary theories; thus, a paradox arises here, namely the "EPR paradox."

In the same year, Schrödinger proposed an experiment later known as "Schrödinger's cat." Imagine a cat confined in a box containing a device that does not directly interfere with the cat. This device is triggered by

https://doi.org/10.62852/csa/2026/262

the decay of an atom within it: if the atom decays, the device is activated and the cat dies immediately. Thus, the decay of the atomic nucleus in quantum mechanics indirectly determines the life or death of the cat in classical theory. According to quantum mechanics, the atomic nucleus should be in a superposition state formed by two states: "decayed" and "not decayed." Consequently, the cat should also be in a superposition state formed by two states: "dead" and "alive." The cat's life or death is no longer an objective existence but depends on the observer's measurement. Clearly, this contradicts common sense [2].

The roots of these two paradoxes are identical: both concern the relationship between classical theory and quantum theory.

3. Recent research progress

3.1. Verification of the existence of quantum entanglement

Chinese-American physicist Yanhua Shih [3] once conducted an experiment known as "ghost imaging." The experimental process and phenomena can be roughly described as follows: Suppose there exists an entangled light source that can emit two mutually entangled photons. A polarizer is used to separate the two photons, allowing the first photon beam to pass through a slit while leaving the second beam untreated. Then, the projections of both beams are observed. The results show that the projection shape of the second beam is exactly identical to the slit shape through which the first beam passed.

People found that if only classical theory is employed, the experimental phenomena cannot be explained. Quantum theory must be applied to account for the phenomenon of "ghost imaging." This experiment also precisely verifies the existence of "quantum entanglement."

3.2. Ohm's law in the quantum world

Ohm's law was proposed by the German physicist Ohm in the early 19th century. It is an empirical law based on the observed electrical transport properties of materials, stating that in the same circuit, the current in a conductor is directly proportional to the voltage applied across its ends and inversely proportional to the conductor's own resistance, namely $I = U/R$ (where U denotes the voltage across the conductor; R denotes the resistance of the conductor; and I denotes the current passing through the conductor).

In the 1920s and 1930s, people believed that classical methods were valid in the macroscopic domain but would break down in the microscopic domain. The Landauer formula provides a method for calculating the resistance of nanowires, namely $R = h/2e^2N$ (where h is the Planck constant; e is the electron charge; and N is the number of transverse modes). In the macroscopic domain, however, $R = \rho\ l/s$ (where ρ is the resistivity of the material; l is the length of the sample; and s is the cross-sectional area of the sample). From this, it is found that in the macroscopic domain, the resistance of a sample increases with its length, whereas in the microscopic domain, the resistance of a sample has no relation to its length.

Weber [4] and others prepared atomic-scale nanowires and conducted observations. The experiments revealed that Ohm's law is also satisfied in the microscopic domain. Ferry [5] argued that the resistance of a sample arises from multiple mechanisms, and his final result was precisely due to the superposition of these various mechanisms. Upon analysis, he concluded that when Ohm's law begins to take effect depends on the strength of electron dissipation in the nanowires the greater the dissipation strength, the smaller the scale at which it begins to take effect. However, this simultaneously raises another question for consideration: under low-temperature conditions, Ohm's law still holds, meaning that classical theory remains valid. Yet it is often precisely under low temperatures that researchers hope to study relatively pure quantum effects. The validity of Ohm's law under low-temperature conditions demands that experimental studies must devote greater effort to separating classical theory from quantum theory.

3.3. Quantum mechanics in photosynthesis

Scholes et al. [6] extracted a chemical substance called the light-harvesting pigment-protein complex from two different types of algae, and under its normal living conditions, analyzed and studied its mechanism of action using two-dimensional electronic spectroscopy. They first used femtosecond laser pulses to simulate sunlight to excite these proteins, and discovered quantum states that persist for a long time. That is, the light energy absorbed by these proteins can exist at different locations simultaneously, which is

https://doi.org/10.62852/csa/2026/262

in fact a quantum superposition state. Thus, it can be seen that quantum mechanics is closely related to photosynthesis.

4. Decoherence theory and the quantum-to-classical transition

The paradoxes posed by the EPR thought experiment and Schrödinger's cat both point to a fundamental question: how does the deterministic classical world emerge from the probabilistic quantum realm? In the 1970s and 1980s, physicists H. Dieter Zeh and Wojciech Zurek independently developed the theory of quantum decoherence, which provides a crucial bridge between quantum superposition and classical definiteness. Decoherence theory posits that quantum systems are never truly isolated; they continuously interact with their surrounding environment, causing the delicate phase relationships (coherences) between superposed states to dissipate rapidly into the environment.

Consider Schrödinger's cat once more: while the atom may indeed exist in a superposition of decayed and undecayed states, the cat as a macroscopic object comprises approximately 10^{26} atoms. Each of these atoms interacts continuously with ambient photons, air molecules, and thermal radiation. These environmental interactions effectively "measure" the cat's state trillions of times per second, causing the quantum superposition to collapse into either "dead" or "alive" long before a human observer opens the box. Experimental verification of decoherence has been achieved through cavity quantum electrodynamics experiments, where researchers observed that the decoherence rate of a superposition state increases exponentially with the size of the system [7]. This explains why we do not observe macroscopic superpositions in daily life: it is not that quantum mechanics ceases to apply at large scales, but rather that decoherence occurs too rapidly for quantum effects to remain observable. Thus, classical theory emerges not as a separate framework replacing quantum mechanics, but as the effective description of quantum systems that have lost their coherence through environmental interaction.

5. Quantum computing: engineering the classical-quantum boundary

The ongoing effort to build practical quantum computers has forced scientists to confront the classical-quantum boundary with unprecedented precision. Quantum bits (qubits) must maintain coherent superposition states long enough to perform computations, yet they must also be measured to extract classical information—a process that inherently collapses the quantum state. This tension has led to the development of quantum error correction and dynamical decoupling techniques, which actively suppress decoherence by manipulating the qubit-environment interaction.

Recent advances have demonstrated remarkable control over this boundary. In 2019, Google's quantum supremacy experiment utilized a 53-qubit processor to perform a specific calculation in 200 seconds that would require approximately 10,000 years on the most powerful classical supercomputer [8]. However, the result itself—a specific bit string—had to be read out through classical measurement. More intriguingly, researchers have begun exploring mesoscopic systems that sit at the intermediate scale between microscopic quantum behavior and macroscopic classical physics. Superconducting quantum interference devices (SQUIDs) and micromechanical resonators have been cooled to their quantum ground states and placed in superposition, demonstrating quantum behavior in systems containing billions of atoms [9]. These experiments suggest that the boundary between classical and quantum is not a fixed threshold but rather a controllable transition zone. As physicist Anthony Leggett noted, the question is no longer "where does the quantum world end?" but rather "how can we maintain quantum coherence at ever-larger scales?" This engineering perspective transforms the philosophical puzzle of the classical-quantum relationship into a practical challenge of isolation, control, and measurement precision.

6. Conclusion

From the fundamental problems of quantum mechanics and related experimental research in recent years, it can be seen that although the connection between classical theory and quantum theory remains an open question, contemporary scientists have already been able to gradually resolve the mysteries left by history through various ingenious experiments, making the measurement and control of individual quanta in the microscopic domain possible. Moreover, they are actively investigating the microscopic nature of

https://doi.org/10.62852/csa/2026/262

macroscopic phenomena, gradually bridging the gap between daily life and quantum mechanics. Continuous research on this topic of "the connection between classical theory and quantum mechanics" is still needed, so that quantum mechanics can be further refined and developed.

7. References

[1] Sun C P. New progress in the study of several fundamental problems of quantum mechanics [J]. Physics, 2001, 30(5): 310-316.
[2] Sun C P. "Schrödinger's cat" at the boundary between classical and quantum [J]. Science, 2001(3): 2, 7-11.
[3] Shih Y. The Physics of Ghost Imaging [J]. 2008.
[4] Weber B, Mahapatra S, Ryu H, et al. Ohm's law survives to the atomic scale [J]. Science, 2012, 335(6064): 64-67.
[5] Ferry D K. Ohm's law in a quantum world [J]. Science, 2012, 335(6064): 45-46.
[6] Collini E, Wong C Y, Wilk K E, et al. Coherently wired light-harvesting in photosynthetic marine algae at ambient temperature [J]. Nature, 2010, 463(7281): 644-647.

https://doi.org/10.62852/csa/2026/262