

Quantum
superposition
& Schrödinger's
cat





Quantum superposition and Schrodinger's cat

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Abstract

A glass will shatter to the ground if it is dropped. A wagon rolls when you push it. You cannot pass through a wall if you approach it. We comprehend several fundamental physical principles that exist all around us, such as how gravity causes objects to fall to the earth, how pushing an object causes it to move, and how two objects cannot occupy the same space at the same time. At first, scientists believed that all of nature's fundamental laws should hold for everything but after that, they started studying the microscopic world. Atoms, electrons, and light waves all exhibited abnormal behavior. As they studied particles, physicists such as Niels Bohr and Albert Einstein found different physics principles that were uncommon. These were the rules of quantum mechanics. Quantum superposition is from the core concepts in the field of quantum mechanics. What is quantum mechanics? What is the meaning of quantum superposition? What is the story behind Schrödinger's cat? All these questions will be answered in this paper.

Keywords: cat, mechanics, quantum, Schrödinger, superposition, and waves.

1. Introduction

Quantum mechanics deals with the study of matter and how it interacts with energy at the level of atomic and subatomic particles. Classical physics, in contrast, can only describe matter and energy on a scale recognizable to human experience, including how celestial things like the moon behave. In a lot of contemporary research and technology, classical physics is still applied. However, as the 19th century ended, researchers found phenomena that classical physics could not explain in both the great (macro) and small (micro) worlds. [1] The theory of relativity and the development of quantum mechanics were two significant revolutions in physics that caused a change in the original scientific paradigm in response to the need to explain inconsistencies between observed phenomena and classical theory. In quantum mechanics, objects have properties of both particles and waves (wave-particle duality); and there are

limitations to how well the value of a physical quantity can be anticipated before measurement, given a complete set of initial conditions. As a result, quantum mechanics makes use of probability to foretell how particles will interact and behave, as particles can exist simultaneously in multiple states. The particles can be in various positions, speeds, and energies, and they travel in the form of overlapping waves. This phenomenon is known as quantum superposition. Schrödinger's cat in quantum mechanics, which will be discussed later in the paper, is a thought experiment that demonstrates the paradox of quantum superposition. In the theoretical model, a fictional cat that is unnoticed in a confined box could be perceived to be both living and dead at the same time.

2. Quantum mechanics

Quantum mechanics is a fundamental physics theory that describes the physical aspects of nature at the atomic and subatomic particle scales. [2] It serves as the theoretical cornerstone for all branches of quantum physics, including quantum information science, quantum technology, quantum field theory, and quantum chemistry. Regarding energy, momentum, angular momentum, and other quantities of a bound system, quantum mechanics differs from classical physics in that these quantities are constrained to discrete values (quantization); objects have properties of both particles and waves (wave-particle duality); and there are restrictions on how precisely a physical quantity can be predicted before being measured, given a complete initial set of circumstances (the uncertainty principle).

Progressively, ideas to explain facts that could not be described by classical physics, such as Max Planck's solution to the black-body radiation problem in 1900 and Albert Einstein's 1905 paper explaining the photoelectric phenomenon, led to the development of quantum mechanics. These early investigations into microscopic phenomena—now referred to as the "old quantum theory"—led to the complete development of quantum mechanics by Niels Bohr, Erwin Schrödinger, Werner Heisenberg, Max Born, Paul Dirac, and others in the middle of the 1920s. The modern theory is expressed in several numbers of newly created mathematical formalisms.

One of them describes what measurements of a particle's energy, momentum, and other physical properties may reveal in terms of probability amplitudes. This mathematical entity is known as the wave function. As shown in figure (1), the wave functions of an electron in a hydrogen atom at various energy levels. The precise location of a particle in space cannot be predicted by quantum mechanics; only its

probability to be found at various locations can. A higher chance of locating the electron is represented by the brighter spots.

➤ *Applications of quantum mechanics:*

Modern technology acts in many ways at a scale where quantum effects influence. Quantum chemistry, quantum optics, quantum computing, superconducting magnets, light-emitting diodes, optical amplifiers, lasers, transistors and semiconductors, magnetic resonance imaging, electron microscopy, and other medical and research imaging techniques are a few examples of important quantum theory applications.

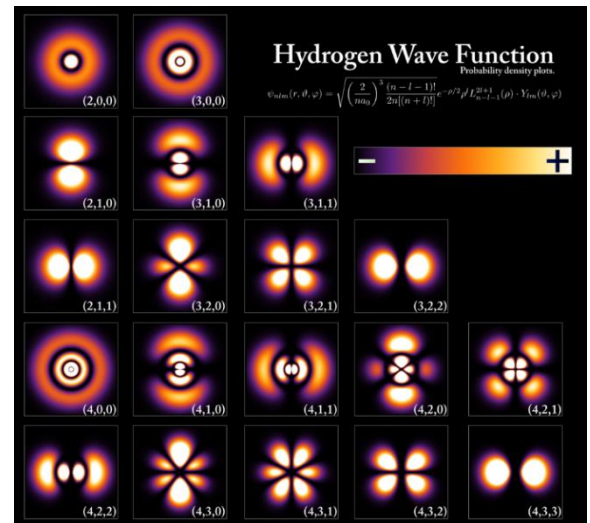


Figure (1) Hydrogen wave function

3. *Quantum Superposition*

The basis of quantum mechanics is the concept of quantum superposition. It asserts that any two (or more) quantum states can be combined to create another acceptable quantum state (much like waves in classical physics), and vice versa. Every quantum state can also be represented as the sum of two or more other distinct states. In mathematics, it refers to a characteristic of Schrödinger equation solutions; given that the Schrödinger equation is linear, every linear combination of solutions will also be a solution (s). The interference peaks from an electron beam in a double-slit experiment are one illustration of a physically observable manifestation of the wave nature of quantum systems. The pattern strongly matches the one produced by the diffraction of classical waves.

Simply said, superposition refers to a quantum system's ability to be in numerous states at the same moment until it is measured. Superposition is defined mathematically as an equation with several solutions. X can either be 2 or -2 when we solve $X^2=4$. Both responses are appropriate. Although superposed wave functions will be harder to solve, they can still be treated in the same way. Visualizing the idea of quantum superposition might be challenging. Traditional explanations have compared it to a coin that has both a head and a tail at once, or to the famous Schrödinger's cat thought experiment, which will be discussed in the next section.

For a very long time, the Copenhagen's interpretation, which was initially put forth by physicist Niels Bohr in 1920, served as the standard explanation for why a quantum particle might act in so many distinct ways. According to this theory, a quantum

particle is capable of coherent superposition, the simultaneous existence of all conceivable configurations. The total of these potential states is an object's wave function. The superposition collapses when the system is observed and can only be in one of the wave function's states. The particle can act in such a wide variety of ways because it can be made to enter distinct states each time. This is still a common belief, although Schrödinger disapproved.

4. Schrödinger's cat thought experiment

Schrödinger was a physicist from Vienna who was born in 1887 and won the Physics Nobel Prize in 1933. Schrödinger intended his thought experiment as a discussion of the EPR article—named after its authors Einstein, Podolsky, and Rosen—in 1935. [3] The EPR article emphasized how quantum superpositions, in which a quantum system like an atom or photon can exist as a composite of numerous states corresponding to different conceivable outcomes, are counterintuitive.

A quantum system, according to Copenhagen interpretation, is said to remain in superposition up until it interacts with or is observed by the outside world. When this occurs, one of the potential definite states—or both—collapses into the superposition. The EPR experiment demonstrates that such a superposition can exist in a system of many particles that are far apart from one another. In their correspondence over Einstein's EPR essay, Schrödinger and Einstein discussed Einstein's observation that the state of an unstable keg of gunpowder will eventually contain a superposition of both exploded and unexploded states. [4] Schrödinger went on to explain how one could theoretically induce a superposition in a large-scale system by making that system dependent on a quantum particle that was in a superposition.

In his hypothetical scenario, Schrödinger placed a cat in a box with a Geiger counter, a machine that measures radiation, and a minor quantity of radioactive material. A flask of hydrocyanic acid would be broken by a hammer when this apparatus sensed the radioactive material decay, which would kill the cat. To retain uncertainty, the experiment was conducted inside a precise time window of one hour; while some radioactive material may theoretically decay during that window, it was also short enough that none might. A 50/50 chance existed.

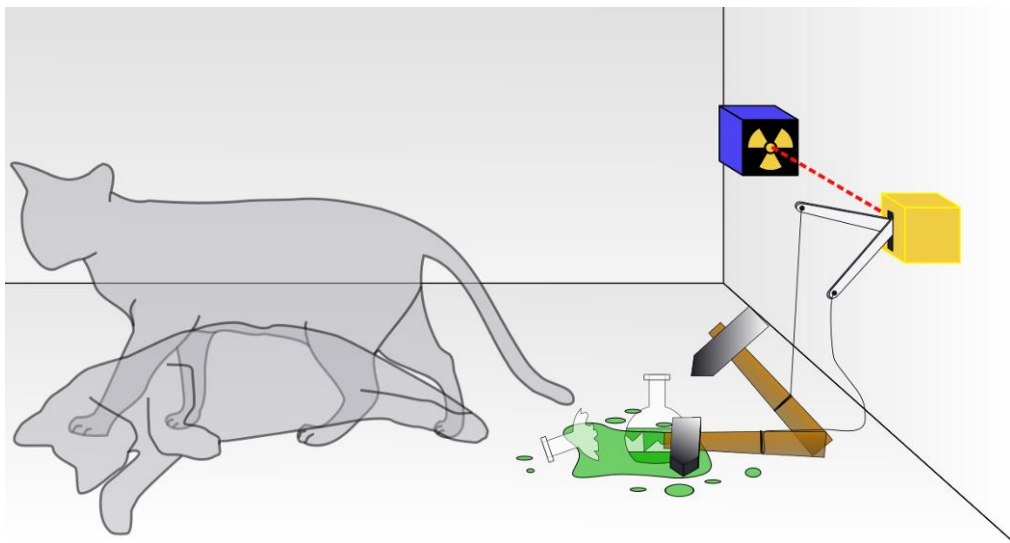


Figure (2) An illustration to Schrödinger's cat thought experiment.

Since no one could see the cat within the box, it was in an undetermined state. It was in a superposition of decaying and not decaying since it could be either living or dead. As a result, it might be in either a condition of life or death. The cat's end couldn't be predicted until this box was opened, at which point the system certainly fell into one form. Schrödinger deduced from this that since it is essentially impossible for an animal to be both living and dead, quantum superposition could not be applied to such huge (macroscopic) objects or organisms as cats. This experiment was carried out to demonstrate how absurd the Copenhagen theory would be if it were true.

This test wasn't an actual experiment; rather, it served as an educational tool to expose the absurdity of the quantum theory that some people are trying to spread. It highlighted a paradox of quantum superposition.

5. Conclusion

The conclusion drawn from this paper is that quantum mechanics, which explores the physical properties of particles at the atomic and subatomic scales, is the foundation of quantum physics. It examines how atomic things exhibit both wave and particle qualities simultaneously. Numerous fields, including quantum computing, have utilized quantum mechanics. In accordance with Copenhagen's interpretation, quantum superposition examines the possibility of the quantum object existing in several states prior to observation. This interpretation is impossible for macroscopic species like cats, as demonstrated by the theoretical model by the Irish physicist Erwin Schrödinger, known as Schrödinger's cat.

6. References

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