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On Schrodinger’s Cat

A gap between classical and quantum physics

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Abstract

Sir Isaac Newton and his colleagues enjoyed studying and expanding the supposedly unequivocal laws of physics, such as Newton’s three laws of motion. During the twentieth century, theories such as Einstein’s relativity and those in quantum mechanics turned Newton’s world upside down. Today, a lot more is known about quantum mechanics. However, there is a still an unknown world between Newton’s and Feynman’s. One example of this gap is Schrodinger’s infamous cat.

Two Vast Worlds

Isaac Newton was born in 1642. Some of his most prominent work included discovering the nature of gravity and light diffraction, calculating planetary orbits, establishing his well-known laws of motion and inventing calculus. The field of knowledge which stems from Newton’s work is often called classical or Newtonian mechanics.[1] Many other physicists prevailed, such as Edmund Halley and Michael Faraday, discovering further astronomical theories and the nature of electricity and magnetism respectively. Until the early 1900’s, the study of physics was very clear and predictable.

At the beginning of the twentieth century, some physicists inverted the simplicity of Newtonian mechanics. An early example was Albert Einstein’s theory of general and special relativity, in which he theorised that space and time can be woven together in a metaphorical fabric, that the speed of light is constant, and that the measurements of different quantities are relative to the velocities of their observers.[2] Later, physicists began to study another realm of knowledge called quantum mechanics, consisting of theories such as the uncertainty principle, wave-particle duality, and superposition, among others.

According to Princeton University, “quantum superposition refers to the quantum mechanical property of a particle to occupy all of its possible quantum states simultaneously.”[3] A common example of quantum superposition is quantum tunneling.[4] Imagine an electron moving towards an electric field. By definition of Newtonian physics, as long as the electron’s energy is less than the energy of the field, the electron will repel from the field. Counter-intuitively, the theory of wave-particle duality of quantum mechanics says the electron wave has a possibility of traveling through the field. This is a quantum superposition because the electron is occupying both its quantum states as a particle and wave before it is observed.

When scientists go to look and see how the particle behaved towards the field, the superposition collapses and an actual result occurs. In other words, the act of measuring the superposition, whether that is its position, charge, mass or other quality, forces nature to select which of the two possible outcomes actually occur. This collapse is often referred to as a quantum collapse.[3] Scientists are not certain why the phenomena occurs, but they are reasonable to think it pertains to the physical qualities of observation. This is only one of a series of quantum theories that are both fantastically complicated and exciting for those who study them.

This idea certainly keeps physicists awake at night. One reason is because particles become extraordinarily hard to define once quantum superposition is considered. The reason for this challenge is that to define a particle, scientists must define its quantum superposition; therefore, they must define all possible and theoretical quantum states.[4] Moreover, the need for the definitions of quantum states calls for more rigorous, tedious, and seemingly impossible analyses of hypotheses in quantum mechanics. These analyses require observations; however, observing a superposition leads to a quantum collapse, which complicates the experiments.

There is one particular problem regarding quantum superposition that has bothered physicists for decades. Initiated by Erwin Schrodinger, an Austrian physicist, it is one of the greatest unanswered questions of modern science. It is a thought experiment, meaning no one has physically tested it; it has only been hypothesised. It involves a tanker, a cat, some poisonous gas, a hammer, a radioactive isotope, and a Geiger counter.

Imagine there is a huge iron tanker. Inside the tanker is the average house cat, a sealed glass bottle of poisonous gas, a Geiger counter with an attached hammer, and a radioactive isotope. If an atom of the isotope decays, the Geiger counter will detect it and subsequently drop the hammer, which will destroy the container of gas. If the glass is broken, the gas diffuses through the air, thus killing the cat.

Now assume there is a 1-in-2 chance that the isotope will decay a particle. After having completed the experiment a number of times, the mathematics will show that 50 percent of the time the cat was found alive, while it was found dead for the other 50 percent.

Recall that the decayed particle is a quantum particle. Contrarily, recall that a cat is not a quantum particle. This means that while everything is still inside the tank, the particle is both decayed and not decayed, which means that the cat is both dead and alive. It is true that the particle is in a superposition, but a cat cannot be in a superposition, because it is not a quantum particle. Eighty years after it was initially devised, no physicist has yet been able to scientifically theorise a solution to this paradox.

A sketch of the quantum states inside of the tanker.[5]

To make this situation even more complicated, recall that the observation of a quantum superposition causes its collapse and ultimate outcome. Since the cat is inside the tank, it must be observing the superposition, which forces nature to “select” the outcome. The cat is not a quantum object, so it must observe the bottle break, or it must observe the bottle sit in the tanker safety. More simply stated, because the cat is in the tank, its observation becomes involved with its own outcome from a superposition.

This problem serves to demonstrate several conclusions about quantum and Newtonian physics. The most obvious conclusion is that Newtonian mechanics and quantum physics are two vast worlds. Given the clock-like nature of the cat’s motion and the unpredictable nature of the quantum particle, there seems to be no way to connect the two worlds. To this day, no one has been able to fully link quantum physics and classical mechanics. Some scientists hypothesise that the connection is in the methods of observing nature, while others hypothesise it is related to light and the places in space-time where either set of laws collapse, such as a singularity or black hole. Some scientists argue that the two worlds cannot be drawn together.

It also shows that both Newtonian physics and quantum mechanics are incredibly useful. The cat is not a quantum object, so it cannot be both dead and alive; thus, it follows the laws of classical physics. The quantum particle is in a superposition before we observe it, so it follows quantum physics. This serves to demonstrate several things to physicists. First, it shows there is no single correct interpretation of physics. Second, it shows physicists must study both classical and quantum physics to achieve a greater understanding of science, since both worlds have value, depending on the problem at hand.

The thought experiment also demonstrated that the act of observing a superposition causes a quantum collapse. This suggests that other observations on the quantum level can cause other ramifications besides collapses. A tested example of an observation causing an unexpected implication is the uncertainty principle, the theory shown to give the universe free-will. When one goes to look for an electron, he or she cannot know its exact position and its exact velocity, and the more exact we know about one, the less exact we know about the other quality. In other words, the act of looking to find the electron causes the electron to change in position and velocity.

Humans are also a part of nature. This means that something is forcing us to either observe or not observe the cat – so who is observing us? If this is true, then something must be observing that something, and someone or something must be observing them, too. This chain of events is starting to create some quantum confusion. Luckily, some people have some ideas about how this can all work.

A common idea pertains to the hypothetical idea of the multiverse. This theory suggests that the quantum superposition is tied to two new alternate universes, one in which we find the cat alive, and the other in which we find the cat dead. The idea that new universes spontaneously appear based on different theoretical and possible quantum states is actually common in modern physics.[6] The only problem with this hypothesis is that science is too technologically underdeveloped to physically test it. Even though it is implied by the mathematics, it requires more evidence to pass the scientific method.

Another hypothesis is objective collapse. Objective collapse theory states that a superposition can be randomly destroyed based on some objective physical quality. This would mean the cat would have already settled into a state before the tank was opened, that it settled before the quantum interpretation of nature would have “made its decision.”[7] Again, the problem is that this theory cannot be observed, neither directly or indirectly, so there is no evident reason to theorise this hypothesis.

It is quite clear that our current scientific and mathematical knowledge is not yet developed enough to find the answers to these problems. Each day, scientists are absorbing more and more information about black holes, singularities, alternate universes, quantum entanglement, and much more. It is therefore possible that in the coming decades, scientists may be able to test these ideas with technologies such as quantum computers.

The scientific community cannot say with certainty that it will know within the coming decades, or that it will ever know. The best scientists and students can do is to continue to research and develop classical and quantum physics. They already have some ideas, but continuing to learn will be the best chance we have at finally reaching the “eureka!” moment for Schrodinger’s cat.

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