One of the postulates is that all measurable quantities in a quantum system are represented mathematically by so-called observables. An observable is thus a mathematical object, more specifically a real linear operator whose 'eigenstates' form a complete set. This essentially means that any quantum state can be expressed as a linear combination of these eigenstates of the observable.

A simple example of an observable is the spin operator. If we apply the postulate to this case it simply means that any spin state can be expressed as a combination of the eigenstates of the spin operator. If we are talking about the spin of an electron, for example, the eigenstates are 'spin up' and 'spin down' (naively one could think of an electron spinning counterclockwise or clockwise, respectively). So any spin state can be seen as a linear combination of these spin up and spin down states.

Now, when we do a measurement of the spin of a particular electron, we find out what the spin of the electron is at that moment. Another postulate states that the only possible outcomes of such a measurement is an eigenstate. So the only possible results of measuring the spin of an electron is either spin up, or spin down. After this measurement we thus know that the electron has one of these spins, it's previous spin state has 'collapsed' onto one of these states.

Now there are other postulates which explicitly tell us exactly how the state of a quantum system evolves with time. So if we wait a while after we measured the spin state of the electron, it's spin state might have changed if for example it interacts with some other particle. Using the laws of quantum mechanics, we can thus calculate the probabilities of measuring spin up or spin down at a later time. So quantum mechanics really does not state anything about quantum states being constantly observed, or about observation apart from measurement at all for that matter. It is only concerned with measurements of states and evolution of states over time.

Say that we have a complex quantum system consisting of many parts (particles, fields, etc). We can measure some properties of this system at the outset, providing us with a specific initial state of the system. These different parts of the system then might go on to interact with each other and evolve by the laws of quantum mechanics into some new state (i.e. by the Schrödinger equation). After this, we can do new measurements, and we can in principle calculate, exactly, the probabilities of the different possible outcomes of each of these measurements. When we do these new measurements, the probabilities stop being probabilities however and we get a new definite state, the previous 'probabilistic state' has 'collapsed' (the probabilistic state being a linear combination of eigenstates, and the collapsed state a specific eigenstate).

Quantum mechanics really does not state anything about quantum states being constantly observed, or about observation apart from measurement at all for that matter. It is only concerned with measurements of states and evolution of states over time.

How to Collapse the Wavefunction

From the wavefunction, one can determine the probability that a measurement performed on the system will yield a particular result. For instance, if we know the wavefunction of an electron in a hydrogen atom, we can find the probability that a measurement of the electron's position will find it at 1 angstrom away from the nucleus. We can also find the probability that the electron will be found 1 meter away from the nucleus (it's very low), or half an angstrom away from the nucleus (probably higher).
A counter-intuitive property of quantum systems is that each state can be expressed as a linear combination of other eigenstates (this is known as a "superposition"). Given a sufficiently large number of states, every other state can be expressed as a superposition of the original states. When a measurement of a property is carried out, the wavefunction "collapses" to one of the state with a defined value for that property, and the measurement corresponding to that particular state is observed. A system in a superposition of states 1, 3, 5, and 6 might collapse to state 3. The probability of collapsing to a given state is determined by the wavefunction of the system before the collapse.

Example \(\PageIndex{1}\): A Three-state Wavefunction

Suppose that we have a hypothetical quantum system with several eigenstates with well-defined momentum represented by \(|1\rangle\), \(|2\rangle\), \(|3\rangle\), \(|4\rangle\), .... Now suppose that the wavefunction of the system \(|\Psi\rangle\) is in a superposition of states \(|1\rangle\), \(|2\rangle\), and \(|6\rangle\), i.e.,

\[
|\Psi\rangle = c_{1}|1\rangle + c_{2}|2\rangle + c_{6}|6\rangle
\]

Now, say that we want to measure the momentum of the system, which involves applying the momentum operator on the wavefunction. The instant we make the measurement, the wavefunction collapses to one of the three basis eigenstates. If it collapses to \(|1\rangle\), then the value for momentum associated with the state is measured. If it collapses to \(|2\rangle\) instead, we measure a value for momentum associated with that state and the same is true if the system collapses to state \(|6\rangle\).

Note that a superposition of states is never actually observed, since the system collapses to a single state at the instant that a measurement takes place. The superposition can be interpreted as the description of potential measurement outcomes, while the state of the system after the collapse takes place is the actual realized outcome. The collapse can thus be defined as the transition between the potential and the actual. However, the situation is a bit more complicated than that, since whether something is a "superposition" of states, or a "pure" state, depends on the property being measured. A state with a well-defined position will be a superposition of states with well-defined momentum, and a state with well-defined momentum will be a superposition of states with well-defined position (the fact that no state is both well-defined is related to the Heisenberg uncertainty principle).

Example \(\PageIndex{2}\): Schrödinger's Cat

A cat, a flask of poison, and a radioactive source are placed in a sealed box. If an internal monitor detects radioactivity (i.e., a single atom decaying), the flask is shattered, releasing the poison that kills the cat. The Copenhagen interpretation of quantum mechanics implies that after a while, the cat is simultaneously alive and dead. Yet, when one looks in the box, one sees the cat either alive or dead, not both alive and dead. This poses the question of when exactly quantum superposition ends and reality collapses into one possibility or the other.
Schrödinger's cat poses the question, "when does a quantum system stop existing as a superposition of states and become one or the other?" (More technically, when does the actual quantum state stop being a linear combination of states, each of which resembles different classical states, and instead begin to have a unique classical description?)

*Collapse* is fancy terminology for *measurement*

### Five Interpretations of Collapsing Wavefunctions

So far, the discussion of quantum mechanics has focused on the numerics and mathematics, but there exists a rich effort in discussing the nature of the quantum mechanical world which often more philosophical than mathematical. Below are the five most popular interpretations of quantum mechanics, which the definition of "measurement" differ and hence the interpretation of the wavefunction collapse also differ.

1. **The Copenhagen/von Neuman interpretations** argues the collapse of the wave function is triggered by the observer. This person has the special property which no other object in universe is capable of. In the Copenhagen interpretation, the collapse can be triggered by any system which is connected to the observer, including the measurement apparatus and external medium (if the observer is not isolated from it). The Copenhagen interpretation is the most popular interpretation of quantum mechanics.

2. **The von Neuman interpretation** argues the collapse of the wave function happens when the observer feels any feeling depended on the measured value.

3. **The Bohm interpretation** argues collapse of the wavefunction happens when the observer introduces into the measured system some perturbation, which is inevitable when performing the measurement. The difference between the measurement and any other interaction is in that the perturbation introduced by measurement is unknown beforehand.

4. **The Relational interpretation** argue the collapse happens when the interaction affects the ultimate measurement performed by ultimate observer on the universal wavefunction at infinite future. As such, for the collapse to happen, the result of interaction should somehow affect the external medium, the stars, etc, either now or in the future, rather than being lost.

5. **The Many-worlds interpretation** argues the wavefunction collapse never happens. Instead what the observer perceives as the collapse is just the event of entanglement of the observer with the observed system.
Figure (PageIndex(2)): The quantum-mechanical "Schrödinger's cat" paradox according to the many-worlds interpretation. In this interpretation, every event is a branch point. The cat is both alive and dead—regardless of whether the box is opened—but the "alive" and "dead" cats are in different branches of the universe that are equally real but cannot interact with each other. Image used with permission from Wikipedia.

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