Quantum Experiences

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Quantum Mechanics forms one of the modern theories in theoretical physics. Generally, it addresses the atomic and subatomic systems in nature. In its way to interpret nature, quantum mechanics produces multiple paradoxes and questions on how we perceive the universe and on our epistemological system. In this paper, I will begin by explaining some basic but important experiment in quantum mechanics to get a feeling about the strangeness of quantum mechanics. Later, I will explain the mathematical modeling for these experiments. Furthermore, I will discuss the relationship between the eigenvector (state) and eigenvalue. Moreover, I will present the measurement problem and the contradiction that occurs between the dynamic (the linear equation of motion) and the collapse postulate. After, I will examine the many-worlds interpretation which is proposed as a solution for the measurement problem. Finally, I will dispute the many-worlds interpretation.

In the beginning, I will explain experiments related to quantum mechanics. First of all, it is important to mention that the following experiments are done on electrons, and the experiments look to two properties of an electron, Hardness, and Color. These properties are not the properties that we experience, but rather it is just theoretical properties, and we choose Hardness and Color for simplicity. In addition, the Hardness property has two values: hard and soft, and the Color property has two values: white and black. Moreover, we assume that we have boxes that are capable to test the Hardness property and color property upon feeding these boxes by electrons, and it has two outputs: black and white if the box measures the color property, hard and soft if the box measures the hardness property. Now, I will start explaining interesting experiments related to these two properties. First, we fed the hardness box a white electron, we found that fifty percent of the time this electron is hard and fifty percent is soft. However, feeding a white electron to a color box will give us hundred percent white, the same thing is applicable we fed a hard electron for a hardness box, it will give hundred percent hard (similarly for black and soft). Furthermore, a more advanced experiment is having a hardness box that has two output gates, one for hard and one for soft electron. Moreover, two mirrors are located at a distance d from these two gates that reflect the coming electron to the direction that is perpendicular to the direction of the electron. After the electrons get reflected, they meet at the same point where a color measurement takes place. The experiment starts by feeding white electrons to the hardness box, this box will out 50% of the electron as hard and fifty percent of them as soft, and the last measuring of the color of the electron after they get reflected will lead to 100% white electrons. However, the interesting part is taking any measurement of the color between the hardness box and the mirrors or between the mirror and the color box will give 50% of the electrons are white and 50% of the electron are black. Further, having a wall on one of the paths between the hardness box and the mirror will lead us to have at the last color measurement 50% percent of the electrons are white and 50% of the electrons are black in contrast with the previous experiment which gave us 100% percent white electrons. Therefore, as we can see strange observations happen while experimenting at the quantum level.

In this paragraph, I will explain the mathematical modeling for some of the experiments described in the previous paragraph to have a deeper understanding of what is going on during the experiment. First, the mathematical modeling of quantum mechanics is based on linear algebra where we have the concept of a vector and vector spaces. In quantum mechanics, we have states which are equivalent to vectors and they can be represented as vectors, but rather each vector describes a state not a location or position in space, and we usually denotes state S as $|S\rangle$. Further, a vector space is the collection of vectors, states in our case. An important fact about this structure, vector space, is any vector (state) can be written in terms of some chosen vectors (state) that we call basis. For instance, a white electron has the state $|White\rangle$, a black electron has the state $|Black\rangle$, Hard electron has the state $|Hard\rangle$, and a soft electron has the state $|Soft\rangle$. Moreover, all these states can be written as a linear combination of other states. Now let suppose that the vector (1, 0) is associated with that $|Hard\rangle$ state, the vector (0, 1) is associated with $|Soft\rangle$ state, the vector $(\frac{1}{2}^{\frac{1}{2}}, \frac{1}{2}^{\frac{1}{2}})$ is associated with black, and the vector $(\frac{1}{2}^{\frac{1}{2}}, -\frac{1}{2}^{\frac{1}{2}})$ is associated with white. An important observation is that: $|Black\rangle = \frac{1}{2}^{\frac{1}{2}}|Hard\rangle + \frac{1}{2}^{\frac{1}{2}}|Soft\rangle, |White\rangle = \frac{1}{2}^{\frac{1}{2}}|Hard\rangle - \frac{1}{2}^{\frac{1}{2}}|Soft\rangle, |Hard\rangle = \frac{1}{2}^{\frac{1}{2}}|Black\rangle + \frac{1}{2}^{\frac{1}{2}}|White\rangle, \quad and \quad |Soft\rangle = \frac{1}{2}^{\frac{1}{2}}|Black\rangle - \frac{1}{2}^{\frac{1}{2}}|White\rangle$. Therefore, any white state is a combination of hard and soft state this explains while we are getting hard and soft electron after making the hardness measurement, and that lead us to discover that there is no relation between the color and the hardness of an electron; knowing that the color of an electron is white does not allow us to determine with certainty the hardness of the electron (the converse is true also). However, explaining the 50% results will involve more mathematics, but the basic idea can be reframed, if we have a normalized state (that is its norm equal to one), the square of the coefficient of the basis (chosen orthogonal), in our case the $|Black\rangle$ and the $|White\rangle$ (which are orthogonal if we did the mathematical test), we get the right probability which is $\frac{1}{2}$ for white and $\frac{1}{2}$ for black. Therefore, doing a measurement for a hard or soft electron will give us the same corresponding probability of whiteness and blackness. In sum, we have properties that can be written as a combination of other properties and doing the necessary measurement results probabilistically one of these combinations.

Now, I will discuss the link between eigenvector eigenvalue. In mathematics, we have operators that operate over vector and transform them from vector space to another vector space, basically this operator just like a map from some domain to some codomain. In addition, some of these operators have the property of linearity. For instance, suppose we have a linear operator O and two vectors $|A\rangle$ and $|B\rangle$, the linearity property implies that $O(|A\rangle + |B\rangle) = O|A\rangle + O|B\rangle \quad and \quad O(c|A\rangle) = c(O|A\rangle)$, and these operators are called linear operators (linear transformations or linear maps). It turns out that this kind of operators is very useful in quantum mechanics. For example, every observable in nature can be represented as an operator, and after applying this operator over special states or vectors it gives as useful information about the observable. Moreover, some vector happened to be special. Hitting these vector with some operator gives us the same vector up to a constant. This vector is called eigenvector (or eigenstate), and the constant is called eigenvalue. It is important to mention that these eigenvectors are depending on the operator. In other words, it is operator-vector relation, some vector is eigenvector for an operator but not to the others. Furthermore, The eigenvector, eigenvalue pop-ups in the collapse postulate of quantum mechanics as follow; Caring out a measurement of an observable O over a state vector of S whatever the state of S was before measurement, the state vector of S just after the measurement must necessary be an eigenvector of O with some eigenvalue (Page 36).

In the following paragraphs, I will address the measurement problem and the responses against it. However, before continuing I shall introduce the dynamic postulates. The Dynamics is about how the state of a system evolves in general (Page 73). That is, given the state of a physical system at an initial time in addition to the forces and constraints to which that system is subject, the dynamic predict deterministically what is the state of the system at any later time (Page 34). To illustrate the problem, I will explain the following experiment. Suppose we have a device that we feed it an electron from one side and the electron goes out from the second side. In addition, this device has a pointer that point to one of the three states, ready, hard, or soft. The device is initially pointing to ready, and assuming the dynamic is always true. The dynamic equation of motion implies the following:

$$|Ready\rangle_m |Hard\rangle_e \longrightarrow |Hard\rangle_m |Hard\rangle_e \tag{1}$$

$$|Ready\rangle_m |Soft\rangle_e \longrightarrow |Soft\rangle_m |Soft\rangle_e \tag{2}$$

Where the state which is labeled by m refers to the state of the machine, and the state which labeled by e refers to the electron. So feeding this machine a hard electron it will leave it at the hard sate, and similarly for soft electron. Now suppose that the machine was also at the ready state, and we fed the machine a black electron. Therefore, according to the dynamic, the electron will evolve in the following manner:

$$|Ready\rangle_m |Black > e \rightarrow |Ready\rangle_m \Big(\frac{1}{2}^{\frac{1}{2}} |Hard\rangle_e + \frac{1}{2}^{\frac{1}{2}} |Soft\rangle_e\Big) = \frac{1}{2}^{\frac{1}{2}} |Ready\rangle_m |Hard\rangle_e + \frac{1}{2}^{\frac{1}{2}} |Ready\rangle_m |Soft\rangle_e \tag{3}$$

And using (1) and (2), (3) will become equal to:

$$\frac{1}{2}^{\frac{1}{2}} |Hard\rangle_m |Hard\rangle_e + \frac{1}{2}^{\frac{1}{2}} |Soft\rangle_m |Soft\rangle_e$$

But according to the collapse postulate doing a measurement for the given electron, it will result in either $|Hard\rangle_m |Hard\rangle_e$ or $|Soft\rangle_m |Soft\rangle_e$ with 50% percent chance for each one (Page 75). Here the problem arises, the dynamics tell us that the system is in a superposition of hard and soft state, however doing a measurement will lead to either one of the states, so the state of the system collapse. In other words, our system without introducing any measurement device or observer is in a superposition of different states. But, while the measurer or the observer is introduced to the experiment the system decides in somehow with a probability one of the superposing states. In sum, the dynamic provides a completely right discerption while there is no measurement and wrong description if we are performing measurement (Page 79). And on the other hand, the collapse postulate provides the wrong description when there is no measurement and right description if there is (Page 79). In conclusion, these two postulates seem to be contradictory.

After introducing the measurement problem, I would like to present the many worlds' interpretation that tries to solve or explain the contradiction between the dynamic and the collapse theory. First, the many-worlds theory stands beside the dynamic or the linear equation of motion, and it considers this equation the true and the complete equation of motion of the whole world (Page 113). The main idea behind this theory is the linear equation of motion which described in quantum mechanics represents literally multiple physical worlds (Page 113). For instance, take the superposition of the color of a hard electron, the hard electron has 50% chances to be white and 50% chances to be black. However, the many-worlds theory interprets this observation as we have two physical worlds on one of these worlds the electron has the black color and in the other one the electron has the white color. Furthermore, the many-worlds theory states that upon experimenting the universe branches into multiple possible universes, and one of these universes is our physical world. In other words, whenever we do measurement what the linear equation of motion states are the branches that will be at the moment and only one of these will exist in our universe. Therefore, many universe theory approaches realities from different perspectives. It states that reality is not just one but it is multiple realities, and we are stocked in one of them. Under this theory, the measurement problem is not a problem at all, but the linear equation of motion acquired a higher place and the collapse postulate becomes unnecessary.

Finally, I will discuss my argument against the many worlds' interpretation. First of all, we are not able to verify that this interpretation is true. For instance, if other universes or realities literary exists and we stocked on one of these universes, how we can ensure that these other universes exist. The point is this interpretation proposes the existence of something without being able to locate or identify it. This proposal of the existence of something that we cannot verify is much more like a metaphysical argument. So, it cannot be taken seriously Second of all, this interpretation is motivated by the modeling of the state of a system as a linear combination of different states. So, it is appearing to us that the mathematical modeling of quantum mechanics affects the interpretation of the reality, or more precisely it tells us how the realty is. However, mathematical modeling should not give us interpretation about how reality should be, but it should help us in giving an effective description of the universe. In addition, it is important to note that in any major scientific work, the scientific theory comes first, then we try to model it using mathematics, and later on, we verify our mathematical prediction. However, many worlds interpretation seems more like an ad-hoc rather than a complete scientific theory. It comes at the end of quantum mechanics to solve the measurement problem. For instance, Isaac Newton thought first about his mechanical theory and gravity through contemplation and observing nature. Then, he came out with his great mathematical discovery, calculus, to create a supportive framework for his theory to prove later results. Finally, looking to the origin of many worlds idea, the dynamic equation describes the many universes that will exist upon measurement. However, this linear equation, the dynamic, is written in terms of the basis that represents the candidate universes. But by construction, we choose conventionally this basis. So, we are imposing the multiple universes that the quantum system will branch on it. By consequence, changing the basis will change the possible universe. Therefore, the problem is how we can as human determine how the universe could be (or branch). So, many worlds theory seems imposing the way that the universe will split according to a conventionally chosen basis. That is the branches of the universe are conventionally chosen which is illogical.

In conclusion, through this paper, I addressed quantum mechanics and the basic experiments that introduce us to the strange world of quantum mechanics. After introducing these experiments, I explained the mathematical modeling for these experiments in order of having a mathematical interpretation of what is going on in these experiments. Furthermore, I explained the link between eigenvector (state) and eigenvalue. Later on, I presented the measurement problem and what it entails from contradiction and uncertainty. In these last paragraphs, I discussed the proposal of many-worlds interpretation to solve the measurement problem. In the end, I argued against this proposal trying to show that it is not applicable or verifiable and that many worlds' interpretation states indirectly that the universe is branches according to a convention we agree on it.

References

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