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Hypothesis:

The difference between classical vector superposition and quantum vector superposition lies in the difference between how they are represented.

Reason:

In classical mechanics, vectors are a quantity that have both magnitude and direction. The concept of vector superposition in classical mechanics explains that the net effect or response created by two or more vectors is the sum of the individual effect or response of each vector. This means that the properties (magnitude and/or direction) of the final vector will be different from the properties of the individual vectors (assuming all vectors are non-zero). For example, take two non-zero vectors $a_1 = x\hat{i}$ and $a_2 = y\hat{j}$. Using some simple vector algebra, we find that the resultant vector is $x\hat{i} + y\hat{j}$.

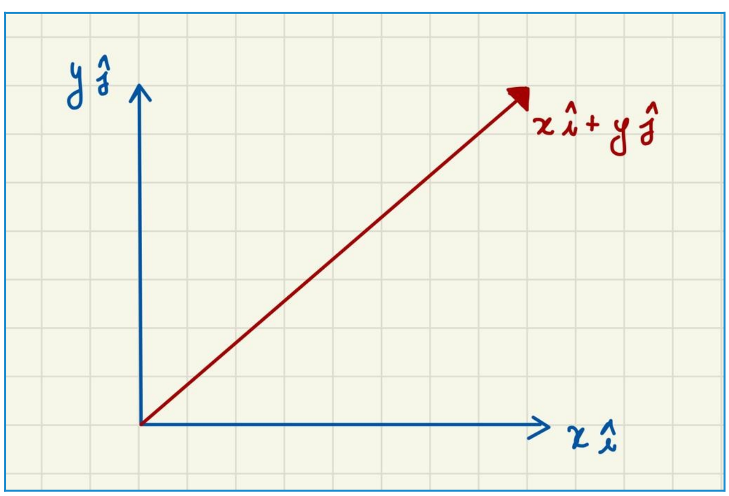

Fig:1 – Superposition of two non-zero vectors

We can see that the resultant vector is different from either x_i or y_j alone. We can represent every vector in a given state as a linear combination of the basis vectors in that state. The resultant vector is not identical to either basis vector.

In quantum physics, a quantum state is a two-dimensional vector that represents the state of a qubit. A qubit is the quantum version of a computer bit. The quantum state vector has all the information needed to describe a qubit. Just like bits have two different states, 0 and 1, qubits are represented using two quantum basis states which are |0> and |1>. This notation is known as ket notation. |0> and |1> both represent two different vectors.

$$|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$|1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Fig:2 - Ket Representation of Quantum State Vectors

Quantum vectors are the combination of both 0 and 1 states. However, unlike classical vector superposition, in quantum superposition the coefficients of the basis quantum vectors represent the probability of finding the qubit in that state.

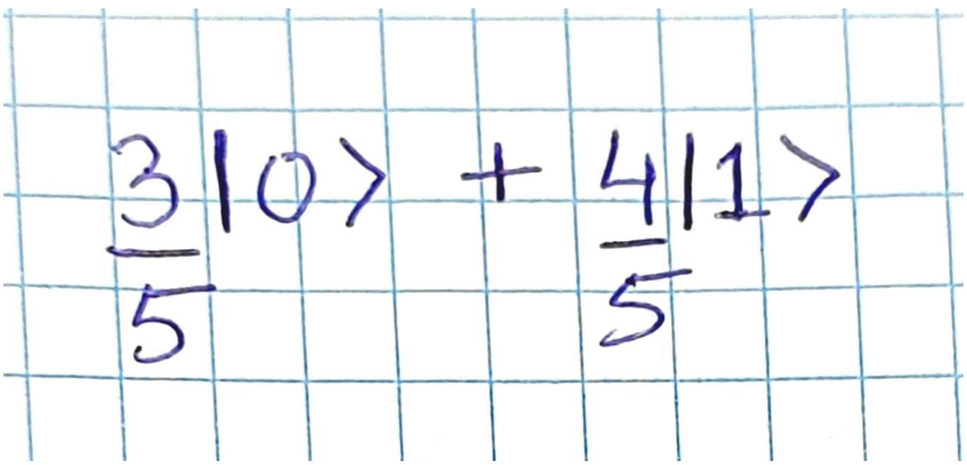

Fig:3 – An example quantum vector

We find the probability of the states by squaring the coefficients of the given basis states. The example vector in Fig: 3 represents a quantum vector using the basis states |0> and |1>. It shows that the probability of finding the qubit in |0> state is 9/25 and finding it in the |1> state is 16/25.

Conclusion:

In conclusion, the difference between classical vector superposition and quantum vector superposition is that classical vector superposition results in the sum of two or more vectors with respect to the basis vectors while quantum vector superposition is used to show the probabilistic description of the states in which the resultant vector is present.

Citations:

- https://en.wikipedia.org/wiki/Superposition_principle
- https://en.wikipedia.org/wiki/Quantum_superposition
- https://quantum.country/
- https://learn.microsoft.com/en-us/azure/quantum/concepts-the-qubit
- https://www.futurelearn.com/courses/intro-to-quantum-computing