**Introduction:**

Quantum Computing has been the latest hype in the tech market recently majorly due to its perceived extra-ordinary capabilities compared to classical computers. When I say ‘extra-ordinary’, you immediately tend to think about exponential enhancements in calculations or computation power. Trust me this is much beyond that! So let’s unveil the pandora’s box to explore the extra-ordinary.

**Fundamentals:**

The basic fundamental building block of a quantum computer is a Quantum bit or Qubit similar to a binary bit in classical computers. The term “classical” implies that these computers follow the Newtonian Mechanics and do not defy the laws of nature. The term “quantum” however, implies that the computers follow Quantum Mechanics and defy all possible laws of nature!

**What is a qubit?**

To answer this, lets first know what is a bit (*short for binary digit*). It can be in to states, either 0 or 1. A classical computer only understands the language of bits hence it translates all the data into bits before performing any task. A qubit is kind of a bit but with 0 & 1 and many more possible states.

**Notation:** A qubit in 0 state is represented by

|0> in Braket notation. [1] in matrix notation

[0]

A qubit in 1 state is represented by

|1> in Braket notation. [0] in matrix notation

[1]

The a general form of a Quantum bit(qubit) is c1\*|0> + c2\*|1> where c1^2 , c2^2 represents probabilities of attaining |0> & |1> respectively when the system is measured. Hence c1^2+c2^2 = 1 should be satisfied to ensure that the system will definitely collapse to some state.

So c1 and c2 can take any values and hence, a single qubit can be a linear combination of |0> and |1> states also. Now you know how can a qubit exist in multiple states. This is the first “extra-ordinary” capability of the qubit that differentiates the operation of quantum computer from classical computer.

**Measurement**:

What does it mean when I say, measure the system? To answer this question, I would like to recollect Schrodinger’s famous cat in the box experiment which paved the way for Quantum Mechanics. He placed a cat in a box with a radio-active material. As the radio-active material starts to decay, it releases poison and the cat would die inhaling it. But we do not know when the material would release poison. So, without opening the box, we could not tell the state of the cat.

If you put the cat in the box, and if there's no way of saying what the cat is doing, you have to treat it as if it's doing all of the possible things—being living and dead—at the same time," explains [Eric Martell](http://www.millikin.edu/academics/cas/physicsastronomy/Pages/Faculty.aspx), an associate professor of physics and astronomy at Millikin University. "If you try to make predictions and you assume you know the status of the cat, you're [probably] going to be wrong. If, on the other hand, you assume it's in a combination of all of the possible states that it can be, you'll be correct.

So in quantum computers the qubits can exist in any of the state at any time. Only when we try to measure the system, will we come to know the current state of the system. So, when we measure the system, the state with maximum probability will be seen after measuring.

**Quantum Superposition:**

If you take 2 classical bits together, the total possible states will be 2^2 i.e. Each bit can be either 0 or 1. Therefore total possible states are 00,01,10,11 and only one of these cases will exist at one time instance.

In case of 2 qubits, we know that each qubit can exist as c1|0>+c2|1>. Therefore, if we take both the qubits together, a generalized system would be created as shown below.

(c1\*|0>+c2\*|1>) (c3\*|0>+c4\*|1>) = c1’\*|00> + c2’\*|01> +c3’\*|10>+c4’\*|11>

The above result on the right-hand side says that, the system of 2 qubits will exist as a ‘superposition’ of these 4 states i.e. |00>, |01>, |10>, |11> at any time. Can we say which state is this system currently in? Not until we measure the system.

The two qubits are said to ‘superimpose’ with each other to create this state. There isn’t really a concept of which qubit goes first or when does this qubit enter the system. This is the real crux of the quantum computing theory. The operations are done on the entire set of states in a parallel manner, a concept called Quantum Parallelism. This is the second “extra-ordinary” capability of the qubits that differentiates the operation of quantum computer from classical computer.

**Quantum Entanglement**: