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## CHALLENGES OF QUANTUM COMPUTING

**Significance for Prelims:** Quantum Computing
**Significance for Mains:** Limitations and Benefits of Quantum Computing.
**News:** Quantum computers (QC) use quantum physics to solve complex problems not solved by conventional computers that use classical physics. Even Nobel Prize for physics in 2022 was awarded for work that rigorously tested quantum 'experience'.

**Government Initiatives in developing quantum-computing systems:**

- Institutes, companies and governments have invested in developing quantum-computing softwares to solve various problems to electromagnetic and materials science.
- Government of India launched National Mission to study quantum technologies in 2021 with an allocation of ₹8,000 crore.
- A quantum research facility was opened by the Indian Army in Madhya Pradesh.
- The Department of Science and Technology co-launched another quantum research facility in Pune.

**Use of Quantum Physics or superposition in Computer:**

- In Quantum physics, reality is described at the subatomic scale at the electrons, protons and neutrons.
- In the realm of subatomic particles, one cannot pinpoint the location of these particles.
- Knowing these particles' presence in any place can be known only by their presence in a given volume of space. These subatomic particles have probability attached to each point in the volume like 10% at point A and 5% at point B meaning there is probability that electron is at point B 5% of the time.
- The fundamental unit of a Qunatum Computer is qubit, like an electron. Google and IBM have used transmons and in transmons pairs of bound electrons oscillate between two designated states or superconductors.
- There is some information that is directly encoded on the qubit, meaning if the spin of an electron is up, it means 1; when the spin is down, it means . Hence, the information is encoded in

a superposition instead of being either 1 or 0 that is third kind of state unlike the two separate states of 0 and 1.
- Collapsed state of qubits is the computer's final output: The qubits work together due to entanglement. The calculation performed on the qubit revealed the state of the qubits.
- Calculation of Quantum states: A computer with N qubits can encode 2N states while N transistors computer can only encode 2 × N states.

**Interpretations of the laws of quantum physics:**
- **'Copenhagen interpretation':** This thought-experiment was popularised by Erwin Schrödinger in 1935. In this cat is put in a closed box with a bowl of poison.Hence, without opening the box one cannot know whether the cat is alive or dead.So, cat is said to exist in a superposition of two states i.e. alive and dead in this case. After opening the box, superposition is forced to collapse to a single state. Now, the probability of each state decides the state to which cat collapses.
- Similarly, after probing the volume of the space the superposition of the electrons' states forced to collapse to one depending on the probability of each state.
- **Concept of entanglement:** When two particles are entangled and even it is separated by an arbitrary distance i.e. more than 1,000 km it will cause the superposition of one particle to collapse. Hence, superposition of the other particle will collapse as well. Quantum Entanglement phenomenon violate the notion that the speed of light is the universe's ultimate speed limit.

**Limitations of Quantum Computers:**
- Challenges in finding the shape of an undiscovered drug and autonomously exploring space or factoring large numbers.
- **Engineering-related problems associated with quantum computers:** A practical and reliable QC needs at least 1,000 qubits. There are no theoretical limits on larger processors, but The current biggest quantum processor has 433 qubits.
- **Disturbances in quantum computing systems with a few dozen qubits:** States of the qubit sitting on the table could simply collapse by just tapping finger on the table as in specific conditions Qubits exist in superposition including very low temperature (~0.01 K), with radiation-shielding and protection against physical shock.
- **Tricky Error-correction:** Due to no-cloning theorem, engineers can't create a copy of a qubit's sates in a classical system.
- **Chances of increase in informational noise:** It is nearly impossible for researchers to create QCs that don't amplify errors when additional qubits are added.

**Benefits of qubit-based computers:**
- These computers can access more states than a transistor-based computer, and hence have access more computational pathways and can solve more complex problems.
- QCs are used to model the binding energy of hydrogen bonds and simulate a wormhole model.

**Prelims:**
**Q. Consider the following statements:**
1. Basis of calculations in Conventional computers are 'bits' or ones and zeroes.
2. Quantum computing use property of sub-atomic particles that simultaneously exist in different states.

**Select the correct answer using the code given below:**
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

**Source:** The Hindu

**Article:** Explained | The challenges of quantum computing

**Sharad**