

QUANTUM COMPUTING

❖ INTRODUCTION

- Quantum computing is an emergent field of computer science and engineering that harnesses the unique qualities of quantum mechanics to solve problems beyond the ability of even the most powerful classical computers.
- The field of quantum computing includes a range of disciplines, including quantum hardware and quantum algorithms. While still in development, quantum technology will soon be able to solve complex problems that classical super computers can't solve (or can't solve fast enough).
- By taking advantage of quantum physics, large-scale quantum computers would be able to tackle certain complex problems many times faster than modern classical machines. With a quantum computer, some problems that might take a classical computer thousands of years to solve might be solved in a matter of minutes or hours.
- Quantum mechanics, the study of physics at very small scales, reveals surprising fundamental natural principles. Quantum computers specifically harness these phenomena to access mathematical methods of solving problems not available with classical computing alone.

❖ History of quantum computing

- The history of quantum computers starts in the early 1900s when scientists, including Max Planck, Niels Bohr and Werner Heisenberg, laid the theoretical foundations of quantum mechanics, a new science for explaining the behavior of matter and light at the atomic and subatomic levels.

Computer applications of quantum mechanics didn't arrive until the early 1980s, when physicist Richard Feynman asserted that only computers based on quantum principles could simulate quantum mechanics and that they could also handle calculations not possible on classical computers.

In 1985, physicist David Deutsch published a paper outlining a universal quantum computer, but it took nearly two decades for researchers to build a basic quantum system. In 2011, D-Wave introduced what it claimed was the first commercial quantum computer. In the decade that followed, major

names such as Google, NASA, IBM, Microsoft and AWS released key components, such as quantum processors and cloud services, Meanwhile, work continued on thorny practical problems, such as quantum error correction and scalability, which have yet to be solved. A key milestone was reached in 2018 when theoretical physicist John Preskill defined NISQ.

❖ **What is a qubit?**

- Quantum computing uses the qubit as the basic unit of information rather than the conventional bit. The main characteristic of this alternative system is that it permits the coherent superposition of ones and zeros, the digits of the binary system around which all computing revolves. Bits, on the other hand, can only have one value at a time — either one or zero —.
- This aspect of quantum technology means that a qubit can be both zero and one at the same time, and in different proportions. This multiplicity of states makes it possible for a quantum computer with just 30 qubits, for example, to perform 10 billion floating-point operations per second, which is about 5.8 billion more than the most powerful PlayStation video game console on the market.

❖ **Main uses of quantum computing**

- **Finance:-**
Companies would further optimise their investment portfolios and improve fraud detection and simulation systems.
- **Healthcare:-**
This sector would benefit from the development of new drugs and genetically customised treatments, as well as DNA research.
- **Cybersecurity:-**
Quantum programming involves risks, but also advances in data encryption, such as the new Quantum Key Distribution (QKD) system. This is a new technique for sending sensitive information that uses light signals to detect intruders in the system.
- **Mobility and transport:-**

Companies like Airbus use quantum computing to design more efficient aircraft. Qubits will also enable significant progress in traffic planning systems and route optimisation.

❖ **Advantages of Quantum Computers**

- **Speed:** Quantum computers can perform certain calculations much faster than classical computers, making them well-suited for tasks that involve a large amount of data or complex mathematical calculations.
- **Parallelism:** Quantum computing allows for the parallel processing of information, which means that multiple computations can be performed simultaneously. This can significantly speed up certain tasks, such as searching large databases.
- **Cryptography:** Quantum computing has the potential to break many of the encryption methods currently used to secure data. However, it also has the potential to develop new and more secure encryption methods, which could be more resistant to attacks by hackers.
- **Chemistry:** Quantum computing can simulate the behavior of molecules at a level of detail that is not possible with classical computing. This could lead to new discoveries in drug design, materials science, and other areas.

❖ **Disadvantages of Quantum Computer**

- **Noise and decoherence:** One of the biggest challenges in building a quantum computer is the problem of noise and decoherence. Quantum systems are extremely sensitive to their environment, and any noise or disturbance can cause errors in the computation. This makes it difficult to maintain the delicate quantum state of the qubits and to perform accurate and reliable computations.
- **Scalability:** Another major challenge is scalability. Building a large-scale quantum computer with a large number of qubits is extremely difficult, as it requires the precise control of a large number of quantum systems. Currently, the number of qubits that can be controlled and manipulated in

a laboratory setting is still quite small, which limits the potential of quantum computing.

- **Error correction:** Error correction is another major challenge in quantum computing. In classical computing, errors can be corrected using error-correcting codes, but in quantum computing, the errors are much more difficult to detect and correct, due to the nature of quantum systems.
- **Lack of robust quantum algorithms:** Even though some quantum algorithms have been developed, their number is still limited, and many problems that can be solved using classical computers have no known quantum algorithm.
- **High cost:** Building and maintaining a quantum computer is extremely expensive, due to the need for specialized equipment and highly trained personnel. The cost of building a large-scale quantum computer is also likely to be quite high, which could limit the availability of quantum computing to certain groups or organizations.
- **Power consumption:** Quantum computers are extremely power-hungry, due to the need to maintain the delicate quantum state of the qubits. This makes it difficult to scale up quantum computing to larger systems, as the power requirements become prohibitively high.

❖ **Why is it important?**

- **Solving complex problems:** Quantum computers have the potential to solve problems that are currently intractable for even the most powerful supercomputers, such as those in drug discovery, materials science, and financial modelling.
- **Revolutionizing industries:** Quantum computing could revolutionize various industries by enabling breakthroughs in drug development, materials science, artificial intelligence, and more.
- **Breaking encryption:** Quantum computers, with algorithms like Shor's algorithm, could potentially break current encryption methods, necessitating the development of new, quantum-resistant cryptographic techniques.

❖ **Challenges and Future:**

- **Building and scaling:** Building stable and scalable quantum computers is a significant engineering challenge.
- **Controlling qubits:** Maintaining the delicate quantum states of qubits and preventing decoherence (loss of quantum information) is crucial.
- **Developing quantum algorithms:** Designing and optimizing quantum algorithms for specific problems is an ongoing area of research.