



CURRENT AFFAIRS



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QUANTUM COMPUTER

This article covers "Daily Current Affairs" and the topic details "Quantum Computer". The topic "Quantum Computer" has relevance in the Science and Technology section of the UPSC CSE exam.

Relevance:

For Prelims:

What is a Quantum Computer?

Facts about Quantum Computers?

For Mains:

GS 3: Science and Technology

Applications of Quantum Computing?

Challenges in Quantum Computing?

India and Quantum Computing?

Why in the news?

Recently, IBM published a paper in which it claimed to have demonstrated that a quantum computer could solve a useful problem that today's conventional computers can't.

What is a Quantum Computer?

A quantum computer is a type of computing device that leverages the principles of quantum mechanics to perform computations. Unlike classical computers, which use bits to represent and process information as binary digits (0s and 1s), quantum computers use quantum bits, or qubits, which can exist in multiple states simultaneously thanks to a property called superposition.

Facts about Quantum Computers?

- **Quantum Supremacy:** In 2019, Google claimed to have achieved "quantum supremacy," demonstrating that a quantum computer could perform a specific calculation faster than the world's most powerful supercomputers. This milestone showcased the potential of quantum computers to outperform classical computers in certain tasks.
- **Quantum Bits (Qubits):** Qubits are the fundamental units of information in quantum computing. Unlike classical bits that can represent only 0 or 1, qubits can exist in a superposition of states, allowing for exponentially larger computational possibilities.
- **Entanglement:** Entanglement is a property unique to quantum systems where two or more qubits become linked, regardless of their physical distance. This phenomenon enables the creation of highly correlated quantum states and is crucial for performing complex computations and achieving quantum speedup.
- **Quantum Parallelism:** Quantum computers can perform calculations on multiple inputs simultaneously, thanks to superposition. This inherent parallelism holds the potential to solve certain problems significantly faster than classical computers, leading to exponential speedup.

- **Quantum Error Correction:** Quantum error correction techniques are essential for preserving the integrity of qubits and protecting quantum information from errors caused by decoherence and noise. These techniques involve encoding qubits redundantly and applying error correction codes.
- **No-Cloning Theorem:** Unlike classical bits, it is impossible to make an exact copy of an unknown quantum state due to the no-cloning theorem. This theorem underpins the security of quantum cryptography protocols, where the transmission of quantum information can be performed securely.
- **Quantum Algorithms:** Several quantum algorithms have been developed that exploit the unique properties of quantum computers. Examples include Shor's algorithm for factoring large numbers and Grover's algorithm for database searching, which offer significant speedup compared to classical algorithms in their respective domains.

Applications of Quantum Computing?

- **Cryptography:** Quantum computing can impact cryptography by breaking current encryption algorithms, such as RSA and ECC, which rely on the difficulty of factoring large numbers. Quantum algorithms, like Shor's algorithm, can factor large numbers exponentially faster, posing a threat to traditional cryptographic systems. However, quantum cryptography can also provide enhanced security through techniques like quantum key distribution.
- **Optimization and Simulation:** Quantum computers can be utilized to solve optimization problems, such as finding the best routes for logistics or minimizing energy consumption. Quantum algorithms, like the Quantum Approximate Optimization Algorithm (QAOA), can provide more efficient solutions compared to classical optimization algorithms. Additionally, quantum simulation allows for the study of complex physical and chemical systems that are difficult to model classically, leading to advancements in material science and drug discovery.
- **Machine Learning and AI:** Quantum computing can enhance machine learning algorithms by accelerating tasks like pattern recognition and optimization of large datasets. Quantum machine learning algorithms, such as quantum support vector machines and quantum neural networks, have the potential to achieve better performance than classical counterparts in certain applications.
- **Financial Modeling:** Quantum computing can enable more accurate and sophisticated financial modeling by efficiently analyzing vast amounts of data and complex mathematical models. This can aid in risk analysis, portfolio optimization, option pricing, and simulations for financial decision-making.
- **Weather Forecasting and Climate Modeling:** Quantum computers have the potential to improve weather forecasting and climate modeling by simulating complex atmospheric and oceanic processes more accurately. This can lead to better predictions of weather patterns, extreme events, and long-term climate trends, aiding in disaster management and climate change mitigation.
- **Drug Discovery and Molecular Modeling:** Quantum computers can accelerate the process of drug discovery by simulating molecular interactions and predicting the behavior of complex chemical systems. This can help in designing more effective drugs and understanding the mechanisms of diseases.
- **Supply Chain and Logistics:** Quantum computing can optimize supply chain and logistics operations, enabling more efficient routing, inventory management, and resource allocation. This can lead to cost savings, reduced transportation times, and improved overall efficiency in logistics networks.
- **Artificial Intelligence (AI) and Natural Language Processing:** Quantum computing can enhance AI algorithms by providing faster data processing, enabling more sophisticated pattern recognition, and enhancing natural language processing tasks like sentiment analysis and language translation.

Challenges in Quantum Computing?

- **Quantum Decoherence:** Quantum systems are extremely sensitive to environmental noise and interference, leading to decoherence and the loss of quantum states. Maintaining the fragile quantum states for a sufficiently long time is crucial for performing reliable computations. Developing error correction techniques and reducing decoherence rates are ongoing challenges in quantum computing.
- **Scalability:** Building large-scale, fault-tolerant quantum computers is a significant challenge. The number of qubits and the level of control required increases exponentially as the system size grows. Overcoming technical barriers and engineering challenges to scale up quantum systems while maintaining the integrity of qubits is a major hurdle.

- **Qubit Reliability and Error Correction:** Qubits are prone to errors due to decoherence, control imperfections, and noise from the environment. Developing error correction codes and fault-tolerant quantum gates is necessary to protect the quantum states and ensure accurate computations. Increasing qubit reliability and minimizing errors are critical for practical quantum computing.
- **Physical Implementation:** Various physical platforms are being explored for implementing quantum computers, including superconducting qubits, trapped ions, topological qubits, and others. Each platform has its own set of challenges in terms of stability, scalability, and coherence. Determining the most viable and scalable approach for building quantum computers is an active area of research.
- **Quantum Software and Algorithms:** Developing quantum algorithms that can effectively leverage the power of quantum computers and outperform classical algorithms is a significant challenge. Designing efficient quantum software tools, programming languages, and quantum simulators to facilitate algorithm development and testing is also an ongoing effort.
- **Access to Quantum Resources:** Quantum computing requires specialized resources and expertise that are currently limited. Access to quantum computers and adequate training for researchers and developers is essential to drive innovation and practical applications. Ensuring wider accessibility and fostering collaborations among academia, industry, and governments is crucial.
- **Quantum Security and Ethical Implications:** The advent of quantum computers poses security risks to traditional encryption systems, raising concerns about data privacy and cybersecurity. Developing quantum-resistant encryption methods and addressing ethical implications related to privacy, data protection, and potential misuse of quantum technology are important considerations.
- **Cost and Infrastructure:** Quantum computing technologies are still expensive and require sophisticated infrastructure, making them inaccessible to many organizations. Reducing the cost of hardware, improving infrastructure, and enabling cloud-based access to quantum resources can help overcome this challenge.

India and Quantum Computing?

- **National Mission on Quantum Technologies and Applications (NMQTA):** In 2020, the Government of India launched the NMQTA with a budget allocation of INR 8,000 crore (approximately USD 1.1 billion). The mission aims to accelerate the development and adoption of quantum technologies in India, including quantum computing, quantum communication, and quantum cryptography.
- **Quantum Computing Initiatives:** Under the NMQTA, several initiatives have been launched to support quantum computing research and development. Institutes like the Indian Institute of Science (IISc) and the Indian Institutes of Technology (IITs) are actively engaged in quantum computing research.
- **Collaboration and Partnerships:** India has been fostering collaborations and partnerships with leading international organizations and institutions in the field of quantum computing. For instance, the Indian Institute of Science Education and Research (IISER) has collaborated with IBM to establish the IBM-IISER Quantum Computing Lab in Mohali. Such collaborations provide access to resources, expertise, and collaborative research opportunities.
- **Quantum Computing Research and Talent Development:** India has been investing in quantum computing research to develop indigenous capabilities. Efforts are being made to train and develop a skilled workforce in quantum technologies through specialized programs, workshops, and training initiatives. This helps in nurturing talent and building expertise in quantum computing within the country.
- **Quantum Communication and Cryptography:** India is also exploring the development of quantum communication and quantum cryptography technologies. These areas are crucial for secure communication and data transmission in the quantum era. Initiatives are underway to develop quantum communication networks and explore quantum-safe cryptographic solutions.
- **Startup Ecosystem:** India has a growing quantum computing startup ecosystem, with several startups working on quantum software, algorithms, and applications. The government has also launched programs to support and incubate quantum technology startups, fostering innovation and entrepreneurship in the field.
- **International Collaborations:** India actively participates in international collaborations and initiatives related to quantum computing. For example, India is a member of the Quantum Flagship Program of the European Union, which aims to accelerate the development and commercialization of quantum technologies.

Source:

<https://www.thehindu.com/sci-tech/science/phonons-quantum-computer-acoustic-beam-splitter/article66984735.ece>

Q.1 Which of the following statements is true regarding quantum computing?

- (a) Quantum computing uses classical bits to process information.
- (b) Quantum computing relies on superposition and entanglement of qubits.
- (c) Quantum computing has no applications beyond cryptography.
- (d) Quantum computing is primarily focused on enhancing classical computing speed.

Answer: (b)

Q.2 Which of the following is a major challenge in the field of quantum computing?

- A. Quantum entanglement
- B. Quantum algorithms
- C. Quantum error correction
- D. Quantum decoherence

Select the correct option:

- (a) A, B
- (b) B, C
- (c) C, D
- (d) A, D

Answer: (d)

Q.3 Assess the potential impact of quantum computing on various sectors, including cybersecurity, scientific research, and economic growth. Highlight the steps that India should take to harness the full potential of quantum computing and establish itself as a global leader in this field.

Rishabh

