
🔹 **UNIT – III : QUANTUM COMPUTING**

Advanced Engineering Physics (R25 – JNTUH)

Below are **important 10-MARK answers**, written with **paragraphs + points**, easy English, and last-minute revision friendly.

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1. Qubit and Quantum States (10 Marks)

Introduction

Classical computers use **bits** that exist only in two states: 0 or 1. Quantum computers use **quantum bits (qubits)**, which are based on the principles of quantum mechanics. The concept of a qubit is the foundation of quantum computing.

Qubit

A **qubit** is the basic unit of quantum information. Unlike a classical bit, a qubit can exist in **both 0 and 1 states simultaneously**, due to the property of **superposition**.

Mathematically, a qubit is represented as:

$$
|\psi\rangle = \alpha|0\rangle + \beta|1\rangle
$$

Where:

- $|0\rangle$ and $|1\rangle$ are basis states
- α and β are probability amplitudes
- $|\alpha|^2 + |\beta|^2 = 1$

Quantum States

- **Pure state:** Exact quantum state
- **Superposition state:** Combination of multiple states
- **Measured state:** Collapses to either 0 or 1

Significance

- Enables parallel computation
- Increases computational power exponentially

Conclusion

Qubits form the backbone of quantum computing and enable complex computations beyond classical limits.

Keywords: qubit, superposition, probability amplitude, quantum state

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2. Superposition and Entanglement (10 Marks)

Introduction

Superposition and entanglement are two unique properties of quantum mechanics that give quantum computers their extraordinary power.

Superposition

A quantum system can exist in multiple states at the same time until measured.

Example:

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

Entanglement

Entanglement is a phenomenon in which two or more qubits become **correlated**, such that the state of one qubit instantly affects the other, regardless of distance.

Example:

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

Importance

- Enables faster information processing
- Used in quantum teleportation
- Improves computational efficiency

Conclusion

Superposition and entanglement are key resources that make quantum computing powerful and unique.

Keywords: superposition, entanglement, quantum correlation

3. Quantum Gates and Quantum Circuits (10 Marks)

Introduction

Quantum gates are the building blocks of quantum circuits, similar to logic gates in classical computing.

Quantum Gates

Common quantum gates include:

- **Hadamard (H):** Creates superposition
- **Pauli-X:** Quantum NOT gate
- **Pauli-Y, Pauli-Z:** Phase and spin operations
- **CNOT gate:** Two-qubit gate used for entanglement

Quantum Circuit

A quantum circuit consists of:

1. Qubits
2. Quantum gates
3. Measurement devices

Diagram (Text Explanation)

Input Qubits → Quantum Gates → Measurement → Output

Conclusion

Quantum gates manipulate qubits and form the basis of quantum algorithms.

Keywords: quantum gate, Hadamard, CNOT, quantum circuit

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4. Quantum Algorithms (10 Marks)

Introduction

Quantum algorithms are designed to run on quantum computers and solve certain problems much faster than classical algorithms.

Important Quantum Algorithms

1. Deutsch–Jozsa Algorithm

- Determines whether a function is constant or balanced
- Demonstrates quantum speedup

2. Shor's Algorithm

- Factors large numbers efficiently
- Threatens classical cryptography

3. Grover's Algorithm

- Searches unsorted databases
- Faster than classical search algorithms

Advantages

- Exponential or quadratic speedup
- Solves complex problems

Conclusion

Quantum algorithms highlight the superiority of quantum computation over classical methods.

Keywords: Shor's algorithm, Grover's algorithm, quantum speedup

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5. Applications and Challenges of Quantum Computing (10 Marks)

Applications

- Cryptography
- Drug discovery
- Artificial intelligence
- Optimization problems

Challenges

- Decoherence

- Error correction
- Hardware complexity
- Cost and scalability

Conclusion

Although quantum computing is still developing, it has immense potential to revolutionize future technology.

Keywords: decoherence, quantum supremacy, error correction

✅ UNIT–III FINAL CONCLUSION

Unit–III introduces the principles of quantum computing, including qubits, quantum gates, and algorithms, which promise revolutionary advancements in computation.