

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
Minor in QUANTUM COMPUTING
Course Structure & Syllabus (R-25 Regulations)
Applicable from AY 2025-2026 Batch

Semester	Theory (# Credits) <i>(Which is not studied in regular course):</i>	Total Credits
II Year II Sem.	Introduction to Quantum Computing	3
II Year II Sem.	Quantum Programming Lab	1
III Year I Sem.	Quantum Communication and Cryptography	3
III Year II Sem.	Quantum Computing Applications and Project	3
III Year II Sem.	Quantum Simulation Lab	1
IV Year I Sem.	Quantum Information and Algorithms	3
IV Year I Sem.	Project/ Experiential Learning	4
Total Credits		18

INTRODUCTION TO QUANTUM COMPUTING

B.Tech. II Year II Sem.

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Course Learning Outcomes

1. Understand the fundamental principles of quantum mechanics relevant to quantum computing.
2. Explain the concepts of qubits, quantum gates, and quantum circuits.
3. Analyze and implement basic quantum algorithms.
4. Apply quantum computing frameworks such as Qiskit or Cirq for simple quantum programs.
5. Identify emerging applications of quantum computing in optimization, machine learning, and cryptography.

UNIT – I: Fundamentals of Quantum Mechanics for Computing

- Limitations of classical computing
- Classical vs quantum computation
- Mathematical foundations: vectors, matrices, complex numbers
- Linear algebra concepts for quantum systems
- Postulates of quantum mechanics
- Representation of quantum states
- Dirac notation
- Measurement postulate
- Superposition principle

UNIT – II: Qubits and Quantum Gates

- Qubit representation
- Bloch sphere representation
- Multi-qubit systems
- Tensor product and composite systems
- Quantum gates: Pauli gates (X, Y, Z), Hadamard gate, Phase gate, T gate
- Multi-qubit gates: Controlled-NOT (CNOT), SWAP gate
- Universal quantum gates
- Quantum circuit representation

UNIT – III: Quantum Algorithms

- Introduction to quantum algorithms
- Quantum parallelism
- Deutsch and Deutsch–Jozsa algorithms
- Grover’s search algorithm
- Quantum Fourier Transform
- Shor’s factoring algorithm (overview)
- Quantum Phase Estimation
- Variational Quantum Eigensolver (VQE)
- Quantum Approximate Optimization Algorithm (QAOA)

UNIT – IV: Quantum Programming and Simulation

- Introduction to quantum programming platforms
- Quantum circuit design using Qiskit / Cirq
- Quantum simulators
- Execution on cloud quantum computers
- Implementation of basic quantum algorithms
- Noise in quantum systems
- NISQ (Noisy Intermediate Scale Quantum) devices

UNIT – V: Applications of Quantum Computing

- Quantum cryptography and quantum key distribution
- Quantum communication and teleportation
- Quantum machine learning concepts
- Quantum chemistry simulations
- Optimization problems using quantum computing
- Emerging quantum technologies and future directions

Suggested Textbooks

1. Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press.
2. Eleanor Rieffel and Wolfgang Polak, Quantum Computing: A Gentle Introduction, MIT Press.
3. Jack D. Hidary, Quantum Computing: An Applied Approach, Springer.
4. N. David Mermin, Quantum Computer Science: An Introduction, Cambridge University Press.

Reference Books

5. Phillip Kaye, Raymond Laflamme, and Michele Mosca, An Introduction to Quantum Computing, Oxford University Press.
6. Chris Bernhardt, Quantum Computing for Everyone, MIT Press.
7. Eric R. Johnston, Nic Harrigan, and Mercedes Gimeno-Segovia, Programming Quantum Computers, O'Reilly.
8. Scott Aaronson, Quantum Computing Since Democritus, Cambridge University Press.

QUANTUM PROGRAMMING AND SIMULATION LAB

B.Tech. II Year II Sem.

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Course Learning Outcomes

1. Understand the fundamental principles of the course area.
2. Explain theoretical foundations and related models.
3. Analyze and implement algorithms or techniques related to the subject.
4. Use appropriate software tools or frameworks where applicable.
5. Identify practical applications and future research directions.

UNIT – I

- Introduction to Qiskit environment
- Installing and configuring Qiskit
- Creating simple quantum circuits

UNIT – II

- Single qubit gate implementation
- Multi-qubit circuits
- Measurement operations

UNIT – III

- Simulation of quantum circuits
- Statevector simulator
- Quantum assembly language basics

UNIT – IV

- Implementation of Deutsch algorithm
- Implementation of Grover search algorithm
- Visualization of results

UNIT – V

- Running circuits on IBM Quantum hardware
- Noise analysis
- Report preparation and experiment documentation

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QUANTUM COMMUNICATION AND CRYPTOGRAPHY

B.Tech. III Year I Sem.

L T P C
3 0 0 3

Course Learning Outcomes

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2. Explain theoretical foundations and related models.
3. Analyze and implement algorithms or techniques related to the subject.
4. Use appropriate software tools or frameworks where applicable.
5. Identify practical applications and future research directions.

UNIT – I

- Basics of quantum communication
- Quantum states transmission
- Quantum channels
- Noise in quantum communication

UNIT – II

- Quantum teleportation
- Superdense coding
- Quantum repeaters

UNIT – III

- Quantum key distribution fundamentals
- BB84 protocol
- B92 protocol
- E91 protocol

UNIT – IV

- Eavesdropping strategies
- Security proofs for QKD
- Quantum cryptographic protocols

UNIT – V

- Post-quantum cryptography overview
- Lattice-based cryptography
- Hash-based signatures
- Future quantum communication networks

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QUANTUM COMPUTING APPLICATIONS AND PROJECT

B.Tech. III Year II Sem.

L T P C
3 0 0 3

Course Learning Outcomes

1. Understand the fundamental principles of the course area.
2. Explain theoretical foundations and related models.
3. Analyze and implement algorithms or techniques related to the subject.
4. Use appropriate software tools or frameworks where applicable.
5. Identify practical applications and future research directions.

UNIT – I

- Applications in optimization
- Combinatorial optimization problems
- Quantum annealing overview

UNIT – II

- Quantum chemistry simulations
- Molecular energy calculations
- Variational Quantum Eigensolver applications

UNIT – III

- Quantum machine learning
- Quantum feature spaces
- Variational quantum classifiers

UNIT – IV

- Quantum sensing and metrology
- Quantum imaging
- Precision measurements

UNIT – V

- Mini project work
- Problem formulation
- Quantum algorithm implementation
- Project presentation and evaluation

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QUANTUM PROGRAMMING AND SIMULATION LAB

B.Tech. III Year II Sem.

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3. Analyze and implement algorithms or techniques related to the subject.
4. Use appropriate software tools or frameworks where applicable.
5. Identify practical applications and future research directions.

UNIT – I

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- Creating simple quantum circuits

UNIT – II

- Single qubit gate implementation
- Multi-qubit circuits
- Measurement operations

UNIT – III

- Simulation of quantum circuits
- Statevector simulator
- Quantum assembly language basics

UNIT – IV

- Implementation of Deutsch algorithm
- Implementation of Grover search algorithm
- Visualization of results

UNIT – V

- Running circuits on IBM Quantum hardware
- Noise analysis
- Report preparation and experiment documentation

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16. Scott Aaronson, Quantum Computing Since Democritus, Cambridge University Press.

QUANTUM INFORMATION AND ALGORITHMS

B.Tech. IV Year I Sem.

L T P C
3 0 0 3

Course Learning Outcomes

1. Understand the fundamental principles of the course area.
2. Explain theoretical foundations and related models.
3. Analyze and implement algorithms or techniques related to the subject.
4. Use appropriate software tools or frameworks where applicable.
5. Identify practical applications and future research directions.

UNIT – I

- Classical information vs quantum information
- Shannon entropy
- Quantum entropy and von Neumann entropy
- Quantum information measures

UNIT – II

- Quantum circuits
- Reversible computing
- Universal gate sets
- Quantum circuit complexity

UNIT – III

- Deutsch and Deutsch–Jozsa algorithms
- Bernstein–Vazirani algorithm
- Simon's algorithm

UNIT – IV

- Quantum Fourier Transform
- Phase estimation algorithm
- Applications of phase estimation

UNIT – V

- Shor's factoring algorithm (overview)
- Grover's search algorithm
- Amplitude amplification
- Complexity advantages of quantum algorithms

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