

SREENIVASAINSTITUTE OF TECHNOLOGY AND MANAGEMENT STUDIES
(Autonomous)

Minor - QUANTUM COMPUTING - Offered by OPEN / CSE

S.No	Course Code	Course Title	Scheme of Instructions Hours per Week				Scheme of Examination Maximum Marks		
			L	T	P	C	I	E	Total
1	23MRQMC1	Introduction to Quantum Computing	3	-	-	3	30	70	100
2	23MRQMC2	Mathematical Foundations for Quantum Computing	3	-	-	3	30	70	100
3	23MRQMC3	Quantum Algorithms	3	-	-	3	30	70	100
4	23MRQMC4	Quantum Information and	3	-	-	3	30	70	100
5	23MRQMC5	Quantum Machine Learning (QML)	3	-	-	3	30	70	100
6	23MRQMC6	Quantum Algorithms Lab	-	-	3	1.5	30	70	100
7	23MRQMC7	Quantum Programming and Simulation	-	-	3	1.5	30	70	100

QUANTUM COMPUTING

23MRQMC1	Introduction to Quantum Computing	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL OBJECTIVES:

- Understand quantum mechanics principles in computing.
- Explore qubits, quantum gates, and circuits.
- Analyze the advantages of quantum algorithms.
- Study entanglement, superposition, and interference.
- Investigate real-world applications and platforms.

UNIT –1: Qubits and Quantum Foundations (9)

Classical Bits vs Qubits, Postulates of Quantum Mechanics, Superposition and Probability Amplitudes, Dirac Notation (Bra-Ket), Bloch Sphere Representation, Measurement in Quantum Systems, Quantum State Collapse

UNIT –2: Quantum Gates and Circuits (9)

Quantum Logic Gates: Pauli-X, Y, Z; Hadamard (H); Phase (S, T), Controlled Gates: CNOT, Toffoli, Unitary and Reversible Operations, Quantum Circuit Representation, Building Basic Quantum Circuits, Quantum Parallelism and Interference, No-Cloning Theorem and Quantum Gate Simulation

UNIT –3: Quantum Algorithms (9)

Need for Quantum Algorithms, Deutsch and Deutsch-Jozsa Algorithm, Grover's Search Algorithm (Quadratic Speed-up), Shor's Factoring Algorithm (Exponential Speed-up), Simon's Algorithm (Overview), Complexity Comparison: Classical vs Quantum

UNIT –4: Entanglement and Quantum Communication (9)

Quantum Entanglement and Bell States, Quantum Teleportation Protocol, Superdense Coding, Quantum Key Distribution: BB84, E91 Protocols, Decoherence and Quantum Noise, Quantum Error Correction Codes (Bit Flip, Phase Flip, Shor Code)

UNIT –5: Quantum Platforms and Applications (9)

Overview of Quantum Programming Platforms: IBM Qiskit, Microsoft Q#, Google Cirq, Quantum Circuit Simulation using Qiskit, Executing Code on Real Quantum Hardware (IBM Q). Quantum Applications in: Cryptography, Machine Learning, Optimization, Chemistry, Building and Testing a Sample Quantum Program

Total Hours: 45

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COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
CO1	Explain concepts of quantum mechanics	Understand(L1)
CO2	Illustrate quantum gates/circuits	Apply(L3)
CO3	Analyze algorithms (e.g., Shor, Grover)	Analyze(L4)
CO4	Evaluate communication protocols	Evaluate(L5)
CO5	Develop quantum programs on IBM Q	Create(L6)

TEXT BOOKS:

1. **Michael A. Nielsen & Isaac L. Chuang** – *Quantum Computation and Quantum Information*, Cambridge University Press, 10th Anniversary Edition.
2. **David McMahon** – *Quantum Computing Explained*, Wiley.
3. **Bernhardt, Chris** – *Quantum Computing for Everyone*, MIT Press.

REFERENCE BOOKS:

1. **Mermin, N. David** – *Quantum Computer Science: An Introduction*, Cambridge University Press.
2. **William H. Press et al.** – *Numerical Recipes in C: The Art of Scientific Computing* (for simulation background)
3. **Rieffel&Polak** – *Quantum Computing: A Gentle Introduction*, MIT Press.

REFERENCE WEBSITE:

Platform	Course Name	Link
IBM Qiskit	<u>IBM Qiskit Textbook</u>	Hands-on, beginner-friendly curriculum for quantum programming
Coursera	<i>Quantum Mechanics for Scientists and Engineers</i> by Stanford (Leonard Susskind)	<u>Link</u>

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23MRQMC2	Mathematical Foundations for Quantum Computing	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL OBJECTIVES:

- Cover linear algebra & complex vector spaces.
- Model quantum states mathematically.
- Apply probability theory to measurements.
- Study eigenvalues and transformations.
- Prepare for algorithm analysis with rigor.

UNIT –1: Foundations of Complex Vector Spaces

(9)

Complex Numbers: Polar form, Euler's formula, Vectors in $\mathbb{C}^n$, Inner Product Spaces, Dirac Notation (Bra-Ket), Hilbert Space: Definitions and Properties, Orthogonality and Completeness, Norms, Metrics, and Distance in Complex Spaces

UNIT –2: Matrix Algebra and Operators

(9)

Matrix Multiplication and Linear Transformations, Special Matrices: Identity, Diagonal, Unitary, Tensor Products of Matrices and Vectors, Kronecker Product Applications, Unitary and Invertible Operators, Quantum Gates as Linear Operators

UNIT –3: Eigen Concepts and Quantum Observables

(9)

Eigenvalues and Eigenvectors, Hermitian Operators and Spectral Theorem, Quantum Observables and Expectation Values, Commutators and Compatibility, Measurement Operators and Matrix Diagonalization, Applications in Quantum Gate Analysis

UNIT –4: Quantum Measurement & Probability`

(9)

Basics of Probability Theory in Quantum Systems, Born's Rule and Measurement Probabilities, Projection Postulate, Density Matrix Formalism, Mixed States and Pure States, Trace, Partial Trace, and Operator Sums

UNIT –5: Advanced Structures in Quantum Math (CO5 – Create)

(9)

Group Theory Basics: Symmetry, Permutations, Pauli Group, Clifford Group, and their roles, Fourier Transform in Quantum Context, Gram-Schmidt Orthogonalization, Lie Groups and Lie Algebras, Use of Lie Algebra in Hamiltonian Formulation

Total Hours: 45

COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
CO1	Understand complex numbers & linear algebra	Understand
CO2	Apply vector space & Dirac notation	Apply
CO3	Analyze unitary & Hermitian operators	Analyze
CO4	Evaluate eigen decomposition in quantum ops	Evaluate
CO5	Create models using probability theory	Create

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TEXT BOOKS:

1. **Nielsen & Chuang** – *Quantum Computation and Quantum Information*, Cambridge University Press
2. **Brian C. Hall** – *Quantum Theory for Mathematicians*, Springer
3. **T.S. Blyth & E.F. Robertson** – *Basic Linear Algebra*, Springer

REFERENCE BOOKS:

1. **Roman S.** – *Advanced Linear Algebra*, Springer
2. **Axler, Sheldon** – *Linear Algebra Done Right*, Springer
3. **Shankar, R.** – *Principles of Quantum Mechanics*, Springer
4. **W. Greiner** – *Quantum Mechanics: An Introduction*, Springer

REFERENCE WEBSITE:

Platform	Course Name	Link
MIT OpenCourseWare	<i>Linear Algebra (Gilbert Strang)</i>	<u>Link</u>
edX	<i>Mathematics for Quantum Computing by TUDelft</i>	<u>Link</u>
Khan Academy	<i>Linear Algebra, Probability & Statistics</i>	<u>Link</u>
Quantum Country	<i>Spaced Repetition & Essays on Quantum Math</i>	<u>Link</u>

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23MRQMC3	Quantum Algorithms	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL OBJECTIVES:

- Understand algorithm design principles in the quantum domain.
- Use mathematical tools such as linear algebra and probability in algorithm analysis.
- Implement quantum algorithms and compare them with classical equivalents.
- Study key applications in cryptography, database search, and optimization.

UNIT –1: Mathematical Tools for Quantum Algorithms (9)

Review of Complex Numbers & Linear Algebra for Quantum Computing, Inner Product Spaces, Hilbert Spaces, Dirac Notation and Interpretations, Quantum State Vectors and Superposition, Overview of Quantum Gates and Operators, Building Block Concepts for Algorithmic Design

UNIT –2: Quantum Circuits and Operations (9)

Quantum Gates: X, H, Z, CNOT, Toffoli, Quantum Circuits: Representation and Simulation, Quantum Teleportation Protocol, Circuit-based Measurement and State Collapse, Reversible Computing and Unitary Evolution, Applying Circuits to Small-scale Problems

UNIT –3: Search and Oracle-Based Algorithms (9)

Deutsch's Algorithm: Problem and Solution Strategy, Simon's Algorithm: Period-finding and Speed-up Over Classical, Grover's Search Algorithm: Amplitude Amplification, Oracle Construction in Grover's Algorithm, Circuit Analysis and Complexity Comparison, Limitations and Applications in Database Search

UNIT –4: Fourier-Based & Cryptographic Algorithms (CO4 – Evaluate) (9)

Quantum Fourier Transform (QFT): Theory and Circuit, Phase Estimation Algorithm: Foundations and Usage, Shor's Algorithm: Integer Factorization and Discrete Logarithms, Modular Arithmetic and Period Finding, Cryptographic Implications of Quantum Algorithms, Efficiency Analysis vs Classical RSA Factorization

UNIT –5: Advanced & Hybrid Quantum Algorithms (CO5 – Create) (9)

Variational Quantum Eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), Quantum Machine Learning (QML): Classification & Clustering, Hybrid Quantum-Classical Models, IBM Qiskit&Cirq for Implementation, Building Custom Quantum Algorithms for NISQ Devices

Total Hours: 45

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COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
CO1	Understand quantum algorithm building blocks	Understand
CO2	Analyze well-known quantum algorithms	Analyze
CO3	Apply quantum algorithms to application domains	Apply
CO4	Evaluate efficiency and complexity of algorithms	Evaluate
CO5	Create and simulate quantum algorithms	Create

TEXT BOOKS:

1. **Michael A. Nielsen & Isaac L. Chuang** – *Quantum Computation and Quantum Information*, Cambridge University Press
2. **Cristopher Moore & Stephan Mertens** – *The Nature of Computation*, Oxford University Press
3. **Eleanor G. Rieffel & Wolfgang Polak** – *Quantum Computing: A Gentle Introduction*, MIT Press

REFERENCE BOOKS:

1. **Gideon Amir** – *Quantum Algorithms via Linear Algebra*, MIT Press
2. **S. Jordan** – *Quantum Algorithm Zoo*, [Online repository]
3. **T. G. Wong** – *Quantum Algorithm Design Techniques*
4. **Roland, Cerf** – *Quantum Search Algorithms*, Springer

REFERENCE WEBSITE:

Platform	Course Name	Link
edX (MIT)	<i>Quantum Algorithms for Cybersecurity</i>	Link
Coursera	<i>Quantum Computing</i> by University of London	Link
Qiskit Textbook	<i>Algorithms & Quantum Machine Learning Modules</i>	Link
Braket (AWS)	<i>Quantum Computing Developer Tools & Tutorials</i>	Link

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23MRQMC4	Quantum Information and Communication	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL OBJECTIVES:

- Understand the principles of quantum information theory.
- Explore quantum entropy, fidelity, and mutual information.
- Study quantum communication protocols and networks.
- Analyze quantum key distribution and cryptographic security.
- Implement protocols like teleportation and superdense coding

Unit I: Quantum Information Basics (9)

Classical vs Quantum Information, Density matrices and mixed states, Quantum entropy and Shannon entropy, Von Neumann entropy, Quantum data compression,

Unit II: Quantum Communication Protocols (9)

Quantum teleportation, Superdense coding, Quantum repeaters and communication channels, No-cloning theorem, Quantum channel capacity

Unit III: Fidelity, Distance & Information Theory (9)

Fidelity and trace distance, Quantum mutual information, Holevo bound, Information trade-offs in communication, Channel noise and error modeling

Unit IV: Quantum Cryptography (9)

Principles of quantum cryptography, BB84 and B92 key distribution protocols, Eavesdropping and security analysis, Quantum bit commitment, Post-quantum cryptography relevance

Unit V: Applications & Tools (9)

Quantum internet: architecture and challenges, Networked quantum systems, Simulation using Qiskit, NetSquid, QuTiP, IBM Q Network and cloud-based setups, Practical implementation of QKD in simulation

Total Hours: 45

COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
CO1	Understand quantum information concepts	Understand
CO2	Apply quantum communication protocols	Apply
CO3	Analyze fidelity, entropy, and data transfer limits	Analyze
CO4	Evaluate quantum cryptographic techniques	Evaluate
CO5	Create and simulate quantum communication models	Create

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TEXT BOOKS:

1. Michael A. Nielsen & Isaac L. Chuang – *Quantum Computation and Quantum Information*, Cambridge University Press
2. Mark M. Wilde – *Quantum Information Theory*, Cambridge University Press
3. John Watrous – *The Theory of Quantum Information*, Cambridge University Press

REFERENCE BOOKS:

1. Peter W. Shor – *Foundations of Quantum Computing* (Lecture notes)
2. Charles H. Bennett & Gilles Brassard – *Original Papers on QKD (BB84)*
3. Stephanie Wehner – *Quantum Communication Networks*, arXiv

REFERENCE WEBSITE:

Platform	Course Name	Link
Coursera	<i>Quantum Cryptography</i> by University of Geneva	<u>Coursera Link</u>
edX	<i>Quantum Information Science I</i> (Harvard/MIT)	<u>edX Course</u>
Qiskit	<i>Quantum Information Applications in Qiskit Textbook</i>	Qiskit Info
QuTech	<i>Quantum Internet Tutorials & Tools</i>	QuTech

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23MRQMC5	Quantum Machine Learning (QML)	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL OBJECTIVES:

- Introduce the fundamentals of quantum-enhanced machine learning.
- Understand quantum data encoding and kernel methods.
- Explore quantum algorithms for supervised and unsupervised learning.
- Analyze hybrid quantum-classical architectures.
- Implement QML models using frameworks like Qiskit and PennyLane.

Unit I: Introduction to QML

(9)

Need for QML: Why quantum for ML?, Classical vs quantum machine learning, Quantum states as information carriers, Data encoding: amplitude, angle, basis encoding, Introduction to quantum feature space.

Unit II: QML Algorithms – Supervised Learning

(9)

Quantum classifiers (quantum SVMs, qNN), Quantum perceptron, Variational quantum classifiers (VQC), Quantum kernels, Cost functions in quantum models

Unit III: QML Algorithms – Unsupervised Learning

(9)

Quantum k-means and clustering, Quantum PCA, Quantum generative models (QGANs), Dimensionality reduction and similarity metrics, Performance analysis and limitations

Unit IV: Hybrid Models & Optimization (CO4 – Evaluate)

(9)

Variational Quantum Circuits (VQCs), Hybrid quantum-classical training loops, Barren plateaus and optimization issues, Quantum gradient descent and parameter shift rule, Comparative study of classical and QML models

Unit V: QML Tools and Case Studies (CO5 – Create)

(9)

Implementing QML with Qiskit Machine Learning, PennyLane and TensorFlow Quantum integration, Case studies: quantum-enhanced fraud detection, NLP, Quantum datasets and benchmark models, Project: design a small QML application

Total Hours: 45

COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
CO1	Understand foundations of quantum machine learning	Understand
CO2	Apply QML algorithms to datasets	Apply
CO3	Analyze quantum kernels, data encoding, and models	Analyze
CO4	Evaluate hybrid quantum-classical models	Evaluate
CO5	Create and simulate QML models using frameworks	Create

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TEXT BOOKS:

1. Maria Schuld, Francesco Petruccione – *Machine Learning with Quantum Computers*, Springer
2. Peter Wittek – *Quantum Machine Learning: What Quantum Computing Means to Data Mining*, Academic Press

REFERENCE BOOKS:

1. Jacob Biamonte – *Quantum Machine Learning*, Nature, 2017
2. Seth Lloyd – *Quantum algorithms for supervised/unsupervised learning* (Research papers)
3. Vojtěch Havlíček – *Supervised Learning with Quantum-Enhanced Feature Spaces*, Nature, 2019

REFERENCE WEBSITE:

Platform	Course Name	Link
edX	<i>Quantum Machine Learning</i> by UTS	edX Course
Qiskit	<i>Qiskit Machine Learning Module</i>	Qiskit ML
Xanadu	<i>QML with PennyLane (Free online textbook)</i>	PennyLane QML Book
Coursera	<i>Quantum Machine Learning</i> by University of Toronto	<u>Coursera</u>

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23MRQMC6	Quantum Algorithms Lab	L	T	P	C
		-	-	3	1.5

PRE-REQUISITES: Nil.

COURSE EDUCATIONAL OBJECTIVES:

Experiments(12):

1. Deutsch Algorithm
2. Deutsch-Jozsa
3. Grover's Algorithm
4. QFT Visualization
5. Shor's Algorithm
6. QRNG Implementation
7. Bell State Entanglement
8. Bernstein-Vazirani Algorithm
9. Quantum Teleportation
10. Phase Estimation
11. Circuit Simulation
12. Mini-Project: RSA Key Breaking

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23MRQMC7	Quantum Programming and Simulation Lab	L	T	P	C
		-	-	3	1.5

Experiments (12)

1. State Vector Simulation (Qiskit)
2. Bell State Implementation
3. Deutsch-Jozsa Circuit
4. Grover's Search in Qiskit
5. QFT Circuit in Python
6. Shor Algorithm Simulation
7. Quantum Teleportation in Code
8. VQE (Hybrid Circuit)
9. QAOA Simulation
10. Quantum Random Number Generator
11. Comparison: Real vs Simulated Runs
12. Mini-Project: Quantum Password Cracker

Textbooks & References

- Michael Nielsen & Isaac Chuang – *Quantum Computation and Quantum Information*
- Eric R. Johnston et al. – *Programming Quantum Computers*
- David McMahon – *Quantum Computing Explained*
- Gilbert Strang – *Introduction to Linear Algebra*
- Sarah Kaiser & Chris Granade – *Learn Quantum Computing with Python and Q#*

Online Resources

- IBM Qiskit Textbook: <https://qiskit.org/learn>
- Microsoft Q# Documentation: <https://learn.microsoft.com/en-us/azure/quantum/>
- Coursera: *Introduction to Quantum Computing*
- edX: *Quantum Computing Fundamentals, Quantum Algorithms*