SARVAJANIK UNIVERSITY
Sarvajanik College of Engineering and Technology
Master of Technology

Year: M. Tech. I (Semester – II)

Subject Name: Quantum Computing **Subject Code:** MTCO24203
Type of course: Professional Elective-IV
Prerequisite (if any): linear algebra

List of Courses where this course will be prerequisite: --

Rationale:
Quantum computing is based on the principles of quantum mechanics, a branch of physics that deals with the behavior of particles at the smallest scales. Unlike classical computing, which uses bits as the fundamental unit of information (either 0 or 1), quantum computing employs quantum bits, or qubits.

Teaching and Examination Scheme:

Teaching Scheme				Theory Marks			Practical Marks		Total
L	T	P	C	TEE	CA1	CA2	TEP	CA3	
3	0	2	4	60	25	15	30	20	150

CA1: Continuous Assessment (assignments/projects/open book tests/closed book tests. CA2: Sincerity in attending classes/class tests/ timely submissions of assignments/self-learning attitude/solving advanced problems TEE: Term End Examination TEP: Term End Practical Exam (Performance and viva on practical skills learned in course) CA3: Regular submission of Lab work/Quality of work submitted/Active participation in lab sessions/viva on practical skills learned in course

Content:

Sr. No.	Content	Total Hrs
1	Introduction of Quantum Computing, Applications Qubit & Quantum States: The Qubit, Vector Spaces. Linear Combination Of Vectors, Uniqueness of a spanning set, basis & dimensions, inner Products, orthonormality, gram-schmidt ortho gonalization, bra-ket formalism, the Cauchy-schwarez and triangle Inequalities.	6
2	Matrices & Operators: Observables, The Pauli Operators, Outer Products, The Closure Relation, Representation of operators using matrices, outer products & matrix representation, matrix representation of operators in two dimensional spaces, Pauli Matrix, Hermitian unitary and normal operator, Eigen values & Eigen Vectors, Spectral Decompostion, Trace of an operator, important properties of Trace, Expectation Value of Operator, Projection	12

	Operator, Positive Operators, Commutator Algebra, Heisenberg uncertainty principle, polar decomposition & singular values, Postulates of Quantum Mechanics.	
3	Tensor Products: Representing Composite States in Quantum Mechanics, Computing inner products, Tensor products of column vectors, operators and tensor products of Matrices.	5
4	Density Operator: Density Operator of Pure & Mix state, Key Properties, Characterizing Mixed State, Practical Trace & Reduce Density Operator, Density Operator & Bloch Vector.	6
5	Quantum Algorithms:Quantum-Circuit-Based Algorithms, The Deutsch Oracle, The Deutsch-Josza Oracle, The Simon Oracle, Shor's Algorithm,Grover's Algorithm	6
5	Quantum Measurement Theory : Distinguishing Quantum states & Measures, Projective Measurements, Measurement on Composite systems, Generalized Measurements, Positive Operator- Valued Measures.	5
6	Quantum programming languages, Probabilistic and Quantum computations, introduction to quantum cryptography and quantum information theory. Case Study: Programming a quantum computer:(IBMQ)	5

Reference Books:

Sr no	**Title of book /article**	**Author(s)**	**Publisher and details like ISBN**	**Year of publication**	**Publication Edition**
1	Quantum Computing without Magic	Zdzis_law Meglicki			
2	Quantum Computing Explained	DAVID McMAHON			
3	Quantum Computer Science	Marco Lanzagorta, Jeffrey Uhlmann			

4	An Introduction to Quantum Computing	Phillip Kaye, Raymond Laflamme, Michele Mosca			

Course Outcomes:

Sr. No.	CO statement	Marks % weightage
CO-1	Understand the fundamental principles of quantum computing, including qubits, quantum states, and their mathematical representation in vector spaces.	15
CO-2	Analyze quantum systems and operators by applying mathematical concepts and quantum mechanics.	30
CO-3	Analyze composite quantum systems using tensor products and understand their implications in quantum algorithms and information processing.	15
CO-4	Examine various quantum algorithms and measurement theory in quantum computing, and their role in quantum information processing.	25
CO-5	Evaluate density operators to characterize pure and mixed quantum states.	15

List of Open learning website:

List of Open Source Software:

FOR LAB SESSIONS:

List of Experiments:

Sr. No	Practical
1	Implement a simple qubit using a quantum simulator or a real quantum computer. Observe its quantum states (e.g., $|0\rangle$ and $|1\rangle$) and perform basic quantum gates (Hadamard, Pauli-X, etc.).
2	Explore vector spaces in quantum mechanics. Construct linear combinations of quantum states and verify their properties.

3	Apply Gram-Schmidt orthogonalization to create an orthonormal basis for a given set of vectors.
4	Represent Pauli operators (Pauli-X, Pauli-Y, Pauli-Z) using matrices. Verify their properties (Hermitian, unitary, etc.).
5	Compute the spectral decomposition of a Hermitian operator (e.g., a quantum observable). Find its eigenvalues and eigenvectors.
6	Calculate the trace of an operator and explore its significance in quantum mechanics.
7	Compute the tensor product of two quantum states (e.g., qubits). Understand how composite states are represented using tensor products.
8	Apply tensor products to operators (e.g., constructing controlled gates).
9	Create density operators for pure and mixed quantum states. Investigate their properties (e.g., purity, entropy).
10	Use the Bloch vector representation to visualize quantum states on the Bloch sphere.

Major Equipment Needed: