K K Wagh Institute of Engineering Education & Research

Department of Computer Engineering

B. Tech with Honors degree with Multidisciplinary Minor (2023)

Honors in Quantum Computing

Sem	Course Code	Couse Type	Title of Course	Teaching Scheme			Evaluation Scheme and Marks							Credits			
				TH	TU	PR	INSEM	ENDSEM	CCE	TUT	TW	PR	TOTAL	TH	TU	PR	TOTAL
V	2301381	PCC	Foundation of Quantum Computing	04	-	-	20	60	20	-	-	-	100	04	-	-	04
	2301382	PCC	Quantum Programming Fundamentals	-	-	02	-	-	-	-	25	50	75	-	-	01	01
	2301383	AEC	Seminar	-	-	02	-	-	-	-	50	-	50	-	-	01	01
VI	2301384	PCC	Advanced Quantum Computing	04	-	-	20	60	20	-	-	-	100	04	-	-	04
	2301385	PCC	Advanced Quantum Algorithm Programming	-	-	02	-	-	-	-	25	50	75	-	-	01	01
	2301386	PROJ	Mini Project	-	-	02	-	-	-	-	50	-	50	-	-	01	01
VII	2301481	PCC	Advanced Quantum Computing Concepts	04	-	-	20	60	20	-	-	-	100	04	-	-	04
	2301482	PCC	Specialized Applications of Quantum Comp uting	02	-	-	-	-	50	-	-	-	50	02	-	-	02
	Total			**14**	**-**	**08**	**60**	**180**	**110**	**-**	**150**	100	**600**	**14**	**-**	**04**	**18**

T. Y. B. Tech. Computer Engineering Pattern 2023 Semester: V 2301381: Foundation of Quantum Computing		
Teaching Scheme:	**Credit Scheme:**	**Examination Scheme:**
Theory :04hrs/week	**04**	**Continuous Comprehensive Evaluation: 20 Marks** **InSem Exam: 20 Marks** **EndSem Exam: 60 Marks**

Course Outcomes:

	Course Outcomes	Bloom's Level
CO1	Explain the fundamental differences between classical and quantum computing, including key concepts like superposition, entanglement, and quantum parallelism.	2-Understand
CO2	Explain the working principles of foundational quantum algorithms, such as Deutsch's Algorithm, and understand their computational advantages.	2-Understand
CO3	Interpret quantum circuits using single- and multi-qubit gates, understanding their effects on quantum computations.	2-Understand
CO4	Identify the impact of quantum noise and decoherence and explore basic quantum error-correcting techniques to improve quantum computation reliability.	2-Understand
CO5	Make use of linear algebra, complex numbers, and probability theory to represent and manipulate quantum states using Dirac notation.	3-Apply

COURSE CONTENTS

Unit I	**Introduction to Quantum Computing**	**(04hrs)**	**Cos Mapped** **CO1, CO2, CO4, CO5**
History and Motivation, Differences between Classical and Quantum Computing Applications of Quantum Computing			
Unit II	**Mathematical Foundations**	**(8hrs)**	**Cos Mapped** **CO1, CO3, CO4, CO5**
Linear Algebra (Vectors, Matrices, Tensor Products), Complex Numbers and Probability, Dirac Notation (Bra-Ket Notation)			
Unit III	**Quantum Mechanics Basics**	**(8hrs)**	**Cos Mapped** **CO1, CO3, CO4, CO5**
Postulates of Quantum Mechanics, Quantum States and Qubits, Superposition and Entanglemen			
Unit IV	**Quantum Gates and Circuits**	**(12hrs)**	**Cos Mapped** **CO1, CO3, CO4, CO5**
Single-Qubit Gates (X, Y, Z, H, S, T), Multi-Qubit Gates (CNOT, Toffoli, SWAP), Quantum Circuit Representation			
Unit V	**Quantum Algorithms (Introduction)**	**(6hrs)**	**Cos Mapped** **CO1, CO2, CO4, CO5**
Deutsch's Algorithm, Quantum Parallelism			

Unit VI	Quantum Error and Noise	(8 hrs)	Cos Mapped CO1, CO2, CO4, CO5
Quantum Decoherence, Quantum Error-Correcting Codes			

Text Books

1. "Introduction to the Theory of Computation" by Michael Sipser
2. "Principles of Quantum Mechanics" by R. Shankar
3. "Quantum Computation and Quantum Information" by Michael A. Nielsen and Isaac L. Chuang
4. "Quantum Mechanics: The Theoretical Minimum" by Leonard Susskind and Art Friedman
5. "Learn Quantum Computing with Python and Qiskit" by Robert Loredo
6. "Quantum Algorithms via Linear Algebra" by Richard J. Lipton and Kenneth W. Regan
7. "Quantum Computing: A Gentle Introduction" by Eleanor Rieffel and Wolfgang Polak

Reference Books

1. "An Introduction to Quantum Computing" by Phillip Kaye, Raymond Laflamme, and Michele Mosca
2. Quantum Computation" by N. David Mermin

F. Y. B. Tech. Computer Engineering **Pattern 2023 Semester: V** **2301214: Quantum Programming Fundamentals Lab**		
Teaching Scheme:	**Credit Scheme:**	**Examination Scheme:**
Practical: 02 hrs/week	**01**	**Termwork: Marks** **Practical Exam : Marks**
Course Outcomes: On completion of the course, students will be able to–		

	Course Outcomes	**Bloom's Level**
CO1	Configure the Qiskit environment, utilize the Quantum Composer, and perform basic qubit operations	3-Apply
CO2	Initialize and measure qubits, apply single- and multi-qubit gates, and construct basic quantum logic circuit	3-Apply
CO3	Build quantum circuits using Qiskit, implement digital logic gates, and simulate their functionality.	3-Apply
CO4	Implement simple quantum algorithms like Deutsch's Algorithm, visualize circuit outputs, and debug quantum programs for practical applications.	3-Apply

List of Laboratory Experiments / Assignments

Sr. No.	**Laboratory Experiments / Assignments**	**CO Mapped**
1.	Introduction to Quantum Programming Tools (4 hours, 1 week) Setting up Qiskit Environment Understanding Quantum Composer	
2.	Basic Operations with Qubits (12 hours, 3 weeks) Initializing and Measuring Qubits Implementing Quantum Gates (X, Y, Z, H, S, T, CNOT, Toffoli, SWAP)	
3.	Building and Running Quantum Circuits (12 hours, 3 weeks) Designing Circuits using Qiskit Digital gates implementation using Quantum gates (AND, NOT, OR, XOR, Half Adder, Full Adder) Simulating Circuits	
4.	Programming Simple Algorithms (12 hours, 3 weeks) Deutsch's Algorithm Implementation Visualizing Circuit Outputs	
5.	Review and Practical Assessment (8 hours, 2 weeks) Debugging Quantum Programs Project Implementation and Presentation	
Additional programming Problems		

1		
2		
3		

Guidelines for Laboratory Conduction

Guidelines for Student's Lab Journal

Guidelines for Termwork Assessment

Strength of CO-PO/PSO Mapping														
	PO												PSO	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3	3	3	-	2	-	-	-	-	-	-	3	3	2
CO2	3	3	3	-	2	-	-	-	-	-	-	3	3	2
CO3	3	3	3	3	2	-	-	-	-	-	-	3	3	2
CO4	3	3	3	3	2	-	-	-	-	-	-	3	3	2
Average	**3**	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**2**

T. Y. B. Tech. Computer Engineering **Pattern 2023 Semester: V** **2301383: Seminar**		
Teaching Scheme:	**Credit Scheme:**	**Examination Scheme:**
Practical:02hrs/week	**01**	**Termwork: 50 Marks**

COURSE CONTENTS

Students should focus on following suggested key points

Fundamentals of Quantum Computing – Core principles, key concepts, and distinctions from classical computing.

Quantum Algorithms and Applications – Notable algorithms, real-world use cases, and industry impact.

Quantum Hardware and Implementation – Overview of quantum processors, programming frameworks, and simulations.

Challenges and Future Directions – Current limitations, error correction, and future advancements in quantum technology.

T. Y. B. Tech. Computer Engineering Pattern 2023 Semester: VI 2301384: Advanced Quantum Computing		
Teaching Scheme:	**Credit Scheme:**	**Examination Scheme:**
Theory :04hrs/week	**04**	**Continuous Comprehensive Evaluation: 20 Marks InSem Exam: 20 Marks EndSem Exam: 60 Marks**

Course Outcomes:

	Course Outcomes	**Bloom's Level**
CO1	Explain the principles, implementation, and computational advantages of Grover's Search Algorithm, Shor's Factoring Algorithm, and the Quantum Fourier Transform (QFT).	2-Understand
CO2	Explain the principles and applications of Quantum Teleportation, Superdense Coding, and Quantum Key Distribution (QKD) in secure quantum communication.	2-Understand
CO3	Explain the concept of Bounded Quantum Polynomial Time (BQP), its relationship with classical complexity classes, and the computational advantages of quantum algorithms.	2-Understand
CO4	Describe different quantum hardware platforms, including superconducting qubits and ion traps, and analyze the challenges of noise, decoherence, and scalability in quantum computing.	2-Understand
CO5	Analyze and implement quantum algorithms for real-world problems	3-Apply

COURSE CONTENTS

Unit I	**Quantum Algorithms**	**(12 hrs)**	**Cos Mapped CO1**
Grover's Search Algorithm, Shor's Factoring Algorithm, Quantum Fourier Transform (QFT)			
Unit II	**Quantum Communication**	**(8hrs)**	**Cos Mapped CO2**
Quantum Teleportation, Superdense Coding, Quantum Key Distribution (QKD)			
Unit III	**Quantum Complexity Theory**	**(8hrs)**	**Cos Mapped CO3**
BQP and Complexity Classes, Comparisons with Classical Complexity Classes			
Unit IV	**Quantum Hardware**	**(12hrs)**	**Cos Mapped CO4**
Overview of Quantum Hardware Platforms, Superconducting Qubits and Ion Traps, Noise and Scalability Challenges			
Unit V	**Hybrid Quantum-Classical Computing**	**(8hrs)**	**Cos Mapped CO5**

Variational Quantum Eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA)
Text Books
1. Introduction to the Theory of Computation" by Michael Sipser 2. "Principles of Quantum Mechanics" by R. Shankar 3. "Quantum Computation and Quantum Information" by Michael A. Nielsen and Isaac L. Chuang 4. "Quantum Mechanics: The Theoretical Minimum" by Leonard Susskind and Art Friedman 5. "Learn Quantum Computing with Python and Qiskit" by Robert Loredo 6. "Quantum Algorithms via Linear Algebra" by Richard J. Lipton and Kenneth W. Regan 7. "Quantum Computing: A Gentle Introduction" by Eleanor Rieffel and Wolfgang Polak 8. "Quantum Error Correction" by Daniel A. Lidar and Todd A. Brun 9. "Introduction to Quantum Mechanics" by David J. Griffiths 10. "Programming Quantum Computers" by Eric R. Johnston, Nic Harrigan, and Mercedes Gimeno-Segovia
Reference Books
1. "An Introduction to Quantum Computing" by Phillip Kaye, Raymond Laflamme, and Michele Mosca 2. Quantum Computation" by N. David Mermin 3. **Qiskit Documentation and Tutorials** (https://qiskit.org)

K.K.Wagh Institute of Engineering Education and Research, Nashik
(Autonomous from Academic Year 2022-23)

T. Y. B. Tech. Computer Engineering Pattern 2023 Semester: VI 2301385: Advanced Quantum Algorithm Programming		
Teaching Scheme:	**Credit Scheme:**	**Examination Scheme:**
Practical: 02 hrs/week	**01**	**Termwork: 25 Marks** **Practical Exam :50 Marks**

Course Outcomes: On completion of the course, students will be able to–

	Course Outcomes	Bloom's Level
CO1	Design and execute Grover's Search Algorithm using quantum programming frameworks, analyzing its efficiency in searching an unsorted database.	3-Apply
CO2	Implement and simulate Shor's Factoring Algorithm, demonstrating its ability to factor large numbers and its implications for cryptography.	3-Apply
CO3	Develop and test simulations of Quantum Teleportation and Quantum Key Distribution	3-Apply
CO4	Utilize Qiskit's Aqua library to implement the Variational Quantum Eigensolver (VQE) and analyze its applications in solving optimization and chemistry problems.	3-Apply

Sr. No.	Laboratory Experiments / Assignments
1.	**Implementation of Grover's Algorithm** (8 hours, 2 weeks)
2.	**Shor's Algorithm Simulation** (8 hours, 2 weeks)
3.	**Quantum Teleportation and QKD Simulation** (8 hours, 2 weeks)
4.	**Exploration of Qiskit's Aqua Library for VQE** (8 hours, 2 weeks)
5.	**Noise Analysis and Error Mitigation** (8 hours, 2 weeks)
6.	**Building Hybrid Quantum-Classical Models** (8 hours, 2 weeks)

T. Y. B. Tech. Computer Engineering Pattern 2023 Semester: VI 2301386: Mini Project		
Teaching Scheme:	**Credit Scheme:**	**Examination Scheme:**
Practical:02hrs/week	**01**	**Termwork: 50 Marks**

COURSE CONTENTS

Mini Project should be based on the concepts learn in semester V and VI

T. Y. B. Tech. Computer Engineering Pattern 2023 Semester: VII 2301481: Advanced Quantum Computing Concepts		
Teaching Scheme:	**Credit Scheme:**	**Examination Scheme:**
Theory :04hrs/week	**04**	**Continuous Comprehensive Evaluation: 20 Marks InSem Exam: 20 Marks EndSem Exam: 60 Marks**

Course Outcomes:

	Course Outcomes	**Bloom's Level**
CO1	Explain the principles of hybrid quantum-classical computing, including variational algorithms such as the Variational Quantum Eigensolver (VQE) and the Quantum Approximate Optimization Algorithm (QAOA).	2-Understand
CO2	Explain how classical computation supports hybrid quantum algorithms through pre- and post-processing,	2-Understand
CO3	Explain the principles of quantum cryptography, including Quantum Key Distribution (QKD) protocols	2-Understand
CO4	Explain the fundamental concepts of distributed quantum systems and their potential applications in quantum networking and computation.	2-Understand
CO5	Explain the principles of quantum teleportation and entanglement distribution	2-Understand

COURSE CONTENTS

Unit I	**Hybrid Quantum-Classical Computing I**	**(8 hrs)**	**Cos Mapped CO1**

Overview of hybrid models, Variational algorithms: Variational Quantum Eigensolver (VQE) and Quantum Approximate Optimization Algorithm (QAOA).

Unit II	**Hybrid Quantum-Classical Computing II**	**(8hrs)**	**Cos Mapped CO2**

Role of classical computation in hybrid systems (e.g., pre- and post-processing), Case studies: Quantum chemistry and optimization problems.

Unit III	**Quantum Cryptography**	**(12hrs)**	**Cos Mapped CO3**

Principles of quantum cryptography, Quantum key distribution (QKD): BB84 and E91 protocols, Quantum-resistant cryptographic algorithms (post-quantum cryptography).

Unit IV	**Distributed Quantum Computing I**	**(4hrs)**	**Cos Mapped CO4**

Introduction to distributed quantum systems.

Unit V	Distributed Quantum Computing II	(8hrs)	Cos Mapped CO5
Quantum teleportation and entanglement distribution, Applications in secure communication and optimization.			

Text Books

1. Introduction to the Theory of Computation" by Michael Sipser
2. "Principles of Quantum Mechanics" by R. Shankar
3. "Quantum Computation and Quantum Information" by Michael A. Nielsen and Isaac L. Chuang
4. "Quantum Mechanics: The Theoretical Minimum" by Leonard Susskind and Art Friedman
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Reference Books

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T. Y. B. Tech. Computer Engineering
Pattern 2023 Semester: VII
2301482: Specialized Applications of Quantum Computing

Teaching Scheme:	Credit Scheme:	Examination Scheme:
Theory :02hrs/week	02	Continuous Comprehensive Evaluation: 50 Marks

Course Outcomes:

	Course Outcomes	Bloom's Level
CO1	Explain quantum data encoding techniques, feature maps, and the principles of Quantum Support Vector Machines (QSVM)	2-Understand
CO2	Analyze the application of quantum algorithms in Principal Component Analysis (PCA), addressing challenges in scalability	3- Apply
CO3	Investigate hybrid and quantum-only approaches for portfolio optimization	3- Apply
CO4	Explore quantum Monte Carlo techniques for risk analysis and their applications	3- Apply
CO5	Examine the challenges of the NISQ era, quantum benchmarking methodologies, and performance metrics for evaluating quantum systems.	3- Apply

COURSE CONTENTS

Unit I	Quantum Machine Learning I	(6 hrs)	Cos Mapped CO1

Quantum data encoding and feature maps, Quantum Support Vector Machines (QSVM).

Unit II	Quantum Machine Learning II	(6hrs)	Cos Mapped CO2

Quantum-enhanced unsupervised learning: Principal Component Analysis (PCA), Challenges in scalability and data loading.

Unit III	Applications	(4hrs)	Cos Mapped CO3

Portfolio optimization: Hybrid and quantum-only approaches.

Unit IV	Applications in Quantum Finance	(4hrs)	Cos Mapped CO4

Quantum Monte Carlo methods for risk analysis, Applications in pricing derivatives and fraud detection.

Unit V	Emerging Trends and Future Research	(4hrs)	Cos Mapped CO5

- NISQ (Noisy Intermediate-Scale Quantum) era challenges.

- Quantum benchmarking and performance metrics.

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