D Y PATIL INTERNATIONAL UNIVERSITY
Sector 29, Pradhikaran, Akurdi, Pune - Maharashtra, INDIA 411044
(Establishment by Maharashtra Act No. LXIII of 2017)
School of Computer Science, Engineering & Applications

Course Name	Quantum Computing for Artificial Intelligence
Course Code	AIM3001
Credits	5
Prerequisites	Linear Algebra, Matrix Theory, Basic of Quantum Mechanics and Computing
L-T-P-C	3-1-2-5

COURSE OBJECTIVES

1. Understand the foundational principles of quantum computing including qubits, quantum gates, quantum circuits, and block encoding.
2. Apply quantum kernel methods and compare them with classical approaches for classification tasks such as image recognition.
3. Design and implement quantum neural network models including quantum perceptrons and generative adversarial networks using appropriate quantum frameworks.
4. Analyze and simulate quantum transformer architectures, including quantum self-attention, residual connections, and feedforward layers.
5. Integrate Python-based quantum programming tools (Qiskit, PennyLane) to build and evaluate hybrid classical-quantum AI models for real-world datasets.

COURSE SYLLABUS

Modules	No. of Lectures
Module I: Basics of Quantum Computing : Classical bits, Quantum bits (Qubits), Density matrix, Classical digital logical circuit, Quantum circuit, Quantum read-in protocols, Quantum read-out protocols, Block encoding, Basic arithmetic for block encodings, Quantum singular value transformation, Read-in implementations and Block encoding.	8
Module II: Quantum Kernel Methods: Classical Kernel Machines, Dual representation, Kernel construction, Quantum Kernel Machines, Quantum feature maps and quantum kernel machines, Relation between quantum and classical kernel machines, Expressivity of quantum kernel machines, Generalization of quantum kernel machines and Classification on MNIST dataset.	9

Module III: Quantum Neural Networks: Classical Neural Networks, Perceptron, Multilayer perceptron, Fault-tolerant Quantum Perceptron, Grover search, Online quantum perceptron with quadratic speedups Near-term Quantum Neural Networks, Discriminative learning with QNNs, Generative learning with QNNs, Theoretical Foundations of Quantum Neural Networks, Expressivity and generalization of QNN's, Quantum classifier and Quantum patch GAN.	8
Module IV: Quantum Transformer: Classical Transformer, Tokenization and embedding, Self-attention, Residual connection, Feed-forward network, Optimization and inference, Fault-tolerant Quantum Transformer, Quantum self-attention, Quantum residual connection and layer normalization, Quantum feedforward neural network, Overview of runtime Analysis with Quadratic Speedups and Numerical evidence.	12
Total Lectures	37

LABORATORY	
Sr. No.	**Content**
1	Create quantum circuits for —0⟩ and —1⟩, apply Hadamard gate to show superposition.
2	Simulate logical operations using quantum circuits and observe state vector evolution.
3	Implement SVM on MNIST using scikit-learn and Quantum Kernel Classifier using Qiskit Machine Learning.
4	Use Qiskit to encode classical data and plot the mapped quantum states.
5	Simulate Grover's search-based perceptron for binary classification.
6	Use PennyLane or Qiskit to integrate quantum circuits within a PyTorch/Keras model.
7	Build a minimal transformer with quantum self-attention using Qiskit/PennyLane.
8	Simulate a quantum network layer-wise and analyze forward propagation.

COURSE OUTCOMES At the end of the course the student will be able to:	
CO1	Understand the foundational principles of quantum computing including qubits, quantum gates, quantum circuits, and block encoding.
CO2	Apply quantum kernel methods and compare them with classical approaches for classification tasks such as image recognition.
CO3	Design and implement quantum neural network models including quantum perceptrons and generative adversarial networks using appropriate quantum frameworks.
CO4	Analyze and simulate quantum transformer architectures, including quantum self-attention, residual connections, and feedforward layers.
CO5	Integrate Python-based quantum programming tools (Qiskit, PennyLane) to build and evaluate hybrid classical-quantum AI models for real-world datasets.

CO-PO Mapping:			3: Substantial				2: Moderate				1: Slight			
COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	-	-	2	-	-	-	-	-	-	-	3	2
CO2	3	3	2	2	3	-	-	-	-	-	-	-	3	3
CO3	3	3	3	2	3	-	-	-	-	1	-	-	3	3
CO4	3	3	3	3	3	-	-	-	2	2	-	-	3	3
CO5	3	2	3	2	3	-	-	-	1	2	-	-	3	3

TEXTBOOKS

1. ”Quantum Computation and Quantum Information” by Michael A. Nielsen and Isaac L. Chuang.
2. ”Quantum Machine Learning: What Quantum Computing Means to Data Mining” by Peter Wittek.
3. ”Neural Networks and Learning Machines” (3rd Edition) by Simon Haykin.

EVALUATION SCHEME

Theory: (70%)			
Continuous Assessment	**Mid-term**	**End-term**	**Total**
25	25	50	100

Practical: 30%				
Continuous Assessment			**End-term Practical**	**Total**
Lab Manual	**Lab Assessment**	**Internal Viva-voce**		
10	10	30	50	100

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